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# Research on the Application of 3D Printing Technology in Custom Denture Manufacturing

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***Abstract:*** *Custom dentures, as an important oral rehabilitation device, are of great significance to the comfort and quality of life of patients. There are many inconveniences in the traditional denture manufacturing process, such as long production cycles, poor adaptability, and high production costs. This paper aims to investigate the application of 3D printing technology in custom denture manufacturing, and explore its significance and prospects in patient personalized needs, manufacturing processes, and future development. By analyzing the technical characteristics of patient oral data acquisition, digital processing, design optimization, and manufacturing processes, the advantages, challenges, and prospects of 3D printing technology in custom denture manufacturing are revealed. Through this research, it is hoped to provide more insights and support for technological innovation in the medical device industry and patient personalized needs.*

***Keywords:*** *3D printing technology, custom dentures, medical applications, manufacturing processes, patient personalized*

## 1. Introduction

Custom dentures, as an important oral rehabilitation device, are of great significance to the comfort and quality of life of patients. There are many inconveniences in the traditional denture manufacturing process, such as long production cycles, poor adaptability, and high production costs. In recent years, 3D printing technology has been rapidly developed in various industries due to its fast forming speed and high manufacturing accuracy, especially in the medical field, bringing revolutionary changes to traditional medical equipment manufacturing and medical device customization. If 3D printing technology is introduced into the manufacturing industry of custom dentures, it will bring new development to the denture industry. This article mainly discusses the application of 3D printing technology in the custom denture industry, from the perspective of patient personalized needs, manufacturing processes, acquisition of patient oral data, digital processing, design optimization, and manufacturing processes.

## 2. Current Status of Custom Denture Manufacturing Technology

Dentures, also known as false teeth, are oral rehabilitation devices made for partial or complete tooth loss in the upper or lower jaw, which are of great significance for the comfort and quality of life of patients. In the 1990s, they were typically fabricated by dental technicians in medical institutions and gradually moved from medical institutions to society, leading to the concept of denture processing plants and custom dentures. Currently, custom dentures mainly include custom fixed dentures, custom removable partial dentures, and custom full dentures.

Currently, most of the denture manufacturing industry still uses relatively traditional manual fabrication processes for various types of denture processing. Firstly, dental doctors clinically examine the patient's condition and obtain an accurate impression of the patient to obtain data information about

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the dental arch and jawbone. Secondly, using the patient's oral impression to make a plaster model and make the base according to the doctor's recommended oral material; then, the technician molds the teeth shape according to the patient's dental arch and simulates the dental arch; finally, through firing, grinding, glazing, and other processes, the finished denture is produced.

Traditional denture processes are prone to errors in the impression and duplication processes, and defects such as sand sticking, shrinkage holes, cracks, and cold barriers are prone to occur during casting. The expansion, contraction, and casting process of materials can affect the precision of restorations; the match between embedding material and alloy; and the casting performance of the alloy will all have an important impact on the suitability of dentures, which can easily lead to adverse events in medical devices due to process errors. [1]. In the past two years, the Anhui Provincial Drug Administration conducted a flight inspection of 16 denture manufacturers and found 138 defect items. Among them, 3 companies voluntarily stopped production for rectification, 2 cases were transferred, and 3 risk warning letters were issued [2]. The generation of these defects and risks is mainly due to the serious dependence of traditional denture manufacturing on the experience and skills of processing technicians, leading to errors in the production process of dentures, and the product consistency is difficult to effectively guarantee; at the same time, it has also led to uneven production management and quality management of enterprises, as well as serious problems such as poor quality events.

## 3. Principle and Classification Research of 3D Printing Technology

3D printing technology, also known as additive manufacturing (AM), is considered a revolutionary technology in the manufacturing industry due to its special layer-by-layer deposition molding principle, which can quickly and integrally form complex structural parts. Compared with traditional subtractive processes, 3D printing technology can quickly integrate molding and has the characteristics of processing multiple or multiple batches at the same time; compared with traditional casting, it is suitable for rapid prototyping, personalized customization, small batch production, and complex structure manufacturing. When 3D printing technology is used for small-batch and customized production, it reduces material waste, saves mold opening time, and reduces production and manufacturing costs, so it is widely used in medical, aerospace, fashion, and other fields, especially in complex and customized processing fields.[3]

Usually, the principle of 3D printing technology mainly includes modeling, slicing, and printing three steps. First, 3D printing technology converts the three-dimensional model of an object into a digital file (such as Autodesk Fusion 360, SolidWorks, Tinkercad, etc.) through computer-aided design (CAD) software; then, this digital file undergoes a process called "slicing," and the slicing software cuts the 3D model into layers. These cross-sections will guide the 3D printer to deposit material layer by layer, thereby constructing the final object. The slicing software allows users to make detailed adjustments to the printing process, such as adjusting layer thickness, fill density, support structures, and printing speed, to adapt to different printing needs and material characteristics; finally, the 3D printer constructs a three-dimensional object based on the instructions generated by the slicing software.[4]

Currently, 3D printing in the medical field is roughly divided into melting deposition molding, stereolithography molding, digital light processing molding, and laser sintering molding according to different clinical purposes, materials used, and slicing methods, as shown in Table 1.

*Table 1: Classification and Characteristics of 3D Printing Technology*

| 3D Printing Process | 3D Printing Classification | Printing Materials | Printing Characteristics |
|---|---|---|---|
| Fused Deposition Modeling | FDM | Thermoplastics like PCL, PEEK | Slow printing speed, easy to use, cost-effective. |
| Stereolithography | SLA | Resin, ceramics | Moderate printing speed, low resolution, printed objects prone to shrinkage. |
| Digital Light Processing | DLP | Resin, ceramics | Fast printing speed, high accuracy; high purity requirement for liquid photopolymers; high cost; low mechanical strength. |
| Selective Laser Sintering | SLS | Resin, metal powder, ceramics | Moderate printing speed; printed objects prone to shrinkage. |

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## 4. Key Processes in Denture Manufacturing and 3D Printing Technology

Denture manufacturing is a complex and intricate process involving multiple steps and the application of various technologies to ensure that the final denture meets the patient's oral health and aesthetic needs. The main processing steps of traditional manual denture fabrication are shown in Figure 1. In the traditional manual denture manufacturing process, impression, wax pattern, casting, and other links are the most important production processes, which have a crucial impact on the effectiveness, safety, and durability of denture products. If the key links such as impression, wax pattern, and casting are replaced by 3D printing technology, it will have a profound impact on the denture processing and manufacturing industry.[5]

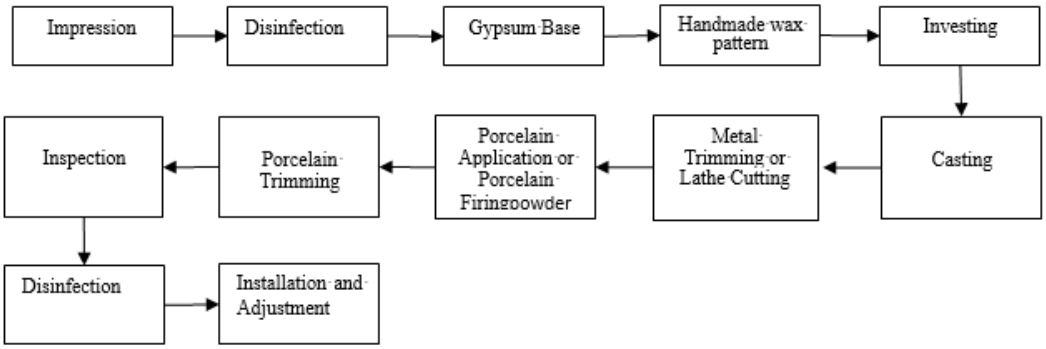


*Figure 1: Manual processing process for dentures*

### *4.1 Impression*

Impression is the first step in denture manufacturing and a fundamental link in oral restoration treatment. It is crucial for ensuring the precision of the restoration, as it aims to obtain accurate three-dimensional information of the patient's oral cavity, providing a foundation for subsequent denture fabrication.

In the traditional impression method, dentists use special impression materials to simulate the teeth and alveolar structures in the patient's oral cavity, subsequently creating a gypsum model. The accuracy of the impression is influenced by numerous factors, including the strength, size, and type of the tray, the type of impression material used, the roughness of the prepared body, the effect of gingival retraction, the disinfection process of the impression, and the method and technique employed in taking the impression. The concavity of the oral soft and hard tissues is a significant factor contributing to the deformation of the impression. Although this traditional method is simple and cost-effective, it is time-consuming, and the model's accuracy is constrained by the impression material and the operator's technique [6].

With the rapid development and extensive application of digital technology in dentistry, digital diagnosis and treatment have become a new treatment mode. This modern method employs optical or laser scanners to scan the patient's oral cavity, capturing the morphological data of the oral soft and hard tissues. The scanned data is then quickly converted into digital models. This approach is fast, accurate, and supports the storage and sharing of digital data.

In 2016, Haddadi et al. conducted a study on the internal fit of restorations made by different impression methods. Their findings revealed that restorations created using digital methods had better internal fit and were more precise. The digital impression technique minimizes errors associated with traditional methods, such as material shrinkage and operator variability. Additionally, it enhances patient comfort by eliminating the need for physical impression trays and materials, which can sometimes cause discomfort or gagging.

Moreover, digital impressions can be easily archived, allowing for efficient long-term storage and easy retrieval for future reference or adjustments. The digital files can be shared instantly with dental laboratories, expediting the overall process and improving collaboration between the dentist and the technician. This technological advancement not only improves the accuracy and efficiency of denture manufacturing but also paves the way for more customized and patient-specific dental care.

In summary, the transition from traditional to digital impression methods represents a significant leap forward in denture manufacturing. The precision, efficiency, and patient comfort offered by digital

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impressions highlight the importance of embracing advanced technologies in modern dentistry.

### *4.2 Denture Model Making*

Denture model making is a critical process that follows the impression preparation. It involves creating a complete and accurate model of the patient's teeth, which serves as the foundation for the subsequent design and manufacturing of the denture. In traditional methods, technicians use materials such as gypsum and wax to craft tooth models manually. This process requires shaping and trimming the models to match the patient's oral cavity conditions precisely. The manual approach relies heavily on the skill and experience of the technician, making it time-consuming and prone to significant variations in accuracy. These variations can lead to substantial deviations in the final denture, impacting the patient's comfort, aesthetic outcome, and potentially causing oral health issues like inflammation.

With the advent of 3D printing technology, the process of denture model making has undergone a significant transformation. Using scanned data from the patient's oral cavity, computer-aided design (CAD) and computer-aided manufacturing (CAM) technologies can process and analyze this information to create highly accurate three-dimensional images of the tooth model. These digital models can be quickly adjusted based on precise measurements and then automatically produced by 3D printers according to the design specifications. This method is not only faster and more accurate but also allows for easy replication and modification of the models.

In 2017, Zhang Jiangtao et al. conducted an experimental comparative study on the size accuracy of gypsum tooth models and 3D printed tooth models. The study's findings indicated that the size change rate of gypsum tooth models ranged from 0.002% to 0.005%, with a maximum size deviation of +0.506 to -0.506 mm. In contrast, the size change rate for 3D printed tooth models was between 0.007% and 0.020%, with a maximum size deviation of +0.204 to -0.204 mm. This data demonstrated that 3D printed tooth models are superior to traditional gypsum models in terms of manufacturing accuracy. The precision of 3D printed models ensures a better fit and function of the final denture, reducing the likelihood of patient discomfort and enhancing overall oral health outcomes.

Furthermore, 3D printing technology in denture manufacturing offers several additional advantages. The digital workflow streamlines the production process, reducing the time required from initial impression to final denture fitting. This efficiency benefits both dental practitioners and patients by shortening appointment times and minimizing the number of necessary visits. The digital models can also be stored indefinitely, allowing for easy future adjustments or replacements without the need for new impressions.

In conclusion, the integration of 3D printing technology in denture model making represents a significant advancement over traditional methods. The enhanced accuracy, efficiency, and flexibility of 3D printed models contribute to improved patient outcomes, making it a valuable tool in modern dentistry. As the technology continues to evolve, it is expected to play an increasingly vital role in the customization and optimization of dental prosthetics.[7]

### *4.3 Denture Casting*

Denture casting is a highly specialized process that demands stringent quality control to ensure the final product meets the required standards of comfort, stability, and longevity. Defects arising during the casting process can significantly compromise the quality and effectiveness of the denture. Common issues encountered include internal porosity, incomplete casting, and surface roughness, all of which must be meticulously managed through scientific process design and rigorous quality inspection.

In a study conducted by Liu Yalin et al. (2016), it was found that incomplete casting, internal porosity, and surface roughness are prevalent defects in the casting of titanium dentures. The design of the casting channel was identified as a critical factor in preventing these defects. Proper channel design ensures that the molten material flows smoothly and uniformly, filling the mold completely and minimizing the risk of voids and imperfections.

Similarly, Xiao Yanping et al. (2018) highlighted the challenges in using the casting method to produce pure titanium frameworks for dentures. Their research revealed a high rate of unqualified production, primarily due to internal porosity, which underscores the necessity of stringent quality control measures. Detecting and addressing internal porosity is vital for ensuring the structural integrity and functional performance of the dentures.

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In contrast, 3D printing technology offers substantial advantages over traditional lost wax casting, particularly in terms of dimensional accuracy and product stability. In denture manufacturing, 3D printing technology excels by providing higher precision and consistency. This technology allows for the creation of highly accurate and customized dentures, which significantly improves the quality and fit for patients. By leveraging digital design and precision molding techniques, 3D printing can produce dentures that are tailored to the unique anatomical features of each patient.

One of the key benefits of 3D printing in denture casting is its ability to enhance production efficiency. Traditional casting methods are time-consuming and labor-intensive, often requiring multiple adjustments and refinements to achieve the desired outcome. In contrast, 3D printing streamlines the production process, reducing the time required from design to final product. This efficiency not only benefits dental laboratories by increasing throughput but also enhances patient satisfaction by shortening the overall treatment timeline.

Furthermore, 3D printing technology facilitates greater personalization and refinement in denture production. With digital models, dentists and technicians can easily make precise adjustments to ensure an optimal fit, improving the comfort and functionality of the dentures. The accuracy of 3D printing also reduces the likelihood of post-production modifications, which can further improve patient outcomes.

In summary, the integration of 3D printing technology into denture casting represents a significant advancement over traditional methods. The enhanced accuracy, efficiency, and personalization capabilities of 3D printing contribute to higher quality dentures that better meet the needs of patients. This technological innovation not only improves the production process but also plays a crucial role in advancing oral health and patient comfort. As 3D printing technology continues to evolve, it is expected to further revolutionize the field of prosthodontics, offering even more sophisticated and customized dental solutions.

### *4.4 Basic Process of Denture Manufacturing Based on 3D Printing*

In the production of customized dentures, the application of 3D printing technology has significantly revolutionized the workflow. This advanced technology shortens the production cycle, enhances production efficiency and accuracy, and elevates the level of personalization, thus providing superior denture solutions for patients and promoting the continuous advancement of dental medical technology. When compared with traditional manual denture manufacturing, it is evident that key stages such as impression taking, wax pattern creation, and casting can be entirely replaced by 3D printing technology, establishing a novel and more efficient production process, as illustrated in Figure 1.

The integration of 3D printing in denture manufacturing begins with capturing a highly accurate digital impression of the patient's oral cavity. This is achieved using optical or laser scanners, which provide detailed three-dimensional information about the oral tissues. This digital impression eliminates the need for physical impression materials and trays, thus enhancing patient comfort and providing a more precise foundation for the subsequent stages.

Following the digital impression, the next step involves processing the scanned data using computer-aided design (CAD) software to create a detailed digital model of the denture. This model can be easily adjusted to account for the unique anatomical features of the patient's mouth, ensuring an optimal fit and functionality. The digital design phase allows for meticulous planning and customization, addressing specific patient needs and preferences.

Once the digital model is finalized, it is sent to a 3D printer, which constructs the denture layer by layer using biocompatible materials. This additive manufacturing process allows for the creation of complex geometries and fine details that are difficult to achieve with traditional techniques. The precision of 3D printing ensures that the final denture closely matches the digital model, resulting in a product that offers superior fit and comfort.

After the printing process, the denture undergoes several post-processing steps to enhance its properties. These steps may include cleaning, polishing, and curing, which help to improve the strength, aesthetics, and overall quality of the denture. The post-processing phase ensures that the denture meets the high standards required for patient use.

The final stage involves fitting the denture to the patient and making any necessary adjustments to ensure optimal comfort and functionality. The precision of the digital and 3D printing processes often

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means that only minor adjustments are needed, if any. This efficiency not only reduces the time and effort required but also enhances patient satisfaction with the final product.

In summary, the basic process of denture manufacturing based on 3D printing represents a significant improvement over traditional methods. The use of digital impressions and 3D printing technology ensures greater accuracy, efficiency, and customization in denture production. This modern approach provides dental professionals with the tools to deliver high-quality, personalized dentures that enhance patient comfort and oral health. The streamlined process, from digital impression to final fitting, sets a new standard in the field of prosthodontics, illustrating the transformative potential of 3D printing technology in dental care.

## 5. Discussion

3D printing technology has brought a more efficient, precise, and personalized manufacturing method to traditional denture manufacturing, which can effectively improve production efficiency and product quality, and promote the rapid development of the denture industry. First, it can effectively improve production efficiency. The use of 3D printing technology can digitize the entire manufacturing process, improve product quality and meet personalized needs. It replaces the traditional denture manufacturing process that requires multiple steps and manual operations, reduces manual intervention, greatly shortens the production cycle, and improves production efficiency. Second, it can effectively achieve customized denture production. 3D printing technology can personalize design and manufacture according to the patient's oral data, producing customized dentures that better meet the patient's needs, improving user comfort and effectiveness. Third, it improves resource utilization. 3D printing technology can accurately control the amount of material used, reduce waste, improve material utilization, energy consumption, and environmental resource utilization, reduce the waste of materials and energy consumption that may occur in traditional denture production, and lower manufacturing costs.

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