

Design and Application of Customized Personalized Prostheses

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Abstract: The article introduces the advantages and characteristics of customized personalized prostheses, as well as their applications in orthopedic surgery, dental treatment, cranial reconstruction, and cosmetic surgery. It elaborates on the process of designing and applying customized personalized prostheses, using customized acetabular revision prostheses as an example. The article discusses in detail the process of designing customized personalized prostheses based on the Paprosky or AAOS classification, combined with clinical demand. The personalized prostheses are ultimately manufactured using advanced technologies such as 3D printing. Finally, the article looks towards the future development prospects of customized personalized prostheses.

Keywords: customized individualized prostheses; revision prosthesis; acetabular defect classification; 3D printing; prosthesis design

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Introduction

The development of prosthetic design and manufacturing technology has made great progress, however, traditional prosthetic design still has some limitations, such as the inability to meet personalized needs for prosthetic shape, size, and material. With the continuous advancement of science and technology, the design and application of customized personalized prostheses has become a new research hot spot. In clinical applications, due to differences in body structure and morphology, conventional prostheses are difficult to fully meet the personalized needs of patients^[1], which is particularly prominent in some complex surgical cases. To better meet the needs of patients, the design of customized personalized prostheses has emerged.

This article will explore the advantages and characteristics of customized personalized prostheses from clinical needs and prosthetic applications, and discuss the application process of customized personalized prosthetic design, and look forward to future development.

1 Customized Individualized Prosthetic Structure Features and Advantages

Compared with traditional prosthetic design, customized individualized prosthetic design has the following features and advantages:

1.1 Features of Customized Individualized Prosthetic

(1) Personalized customization: Customized individualized prosthetic design can be customized

according to the specific needs of the patient, such as the shape, size, material of the prosthesis can be adjusted according to the patient's needs to better adapt to the patient's body structure. (2) High precision: Customized individualized prosthetic design uses digital technology, which can accurately measure and simulate the patient, thereby achieving precise positioning and adjustment of the prosthesis. (3) Better function: Compared with traditional prostheses, customized individualized prostheses can better restore the patient's function. For example, in joint replacement surgery, customized individualized prostheses can better restore the patient's joint mobility and improve surgical outcomes. (4) Reduced surgical risk: Due to the better adaptation of customized individualized prostheses to the patient's body structure, surgical risks can be reduced. In addition, due to the high accuracy, surgical time can be greatly reduced. (5) Improved patient experience: Customized individualized prostheses can improve the patient's surgical experience by better adapting to the patient's body structure, reducing postoperative discomfort and pain, and so on. In summary, customized individualized prosthetic design has a high degree of personalization and precision, can improve surgical outcomes and patient experience, reduce surgical risks, and is an important technology that traditional prosthetic design cannot replace.

1.2 Advantages of Customized Individualized Prostheses

(1) Improving surgical outcomes and patient quality of life: Since customized individualized prostheses are designed and manufactured based on the patient's body structure and needs, they can better adapt to the patient's actual situation, improve surgical outcomes, and enhance the patient's quality of life. For example, in artificial joint replacement surgery, the use of customized individualized

prostheses can better restore the patient's original joint structure and function, avoiding problems such as inappropriate size or shape of traditional standard prostheses, thereby reducing the incidence of adverse consequences such as prosthetic loosening, dislocation, and pain.

(2) Reducing surgical risks and complications: The design and manufacture of customized individualized prostheses use digital technology and 3D printing technology, avoiding problems such as size deviations and shape mismatches that may occur in manual production, thereby reducing the incidence of surgical risks and complications. For example, the use of customized individualized prostheses in cranial repair surgery can better adapt to the complex shape and size of the patient's skull, reducing the risk of skull damage during surgery, and better repairing skull defects, improving surgical outcomes.

(3) Improving treatment efficiency: The manufacture of customized individualized prostheses using digital technology and 3D printing technology is faster and more accurate than traditional manual production, which can improve surgical efficiency and treatment outcomes. For example, the use of customized individualized prostheses in dental implant surgery can better adapt to the patient's oral structure and tooth shape, reducing surgery time and shortening the recovery period.

(4) Reducing the total cost of treatment: Although the manufacturing process of customized individualized prostheses is more complex, it can reduce the risk of postoperative complications and patient reoperation compared to traditional standardized prostheses, which can reduce the total cost of treatment in the long run.

(5) Promoting technological progress: With the development of digital technology and 3D printing technology, the manufacturing technology of customized individualized prostheses is constantly innovating and developing, promoting the application and development of digital technology and 3D printing technology in the medical field. With the continuous maturity and progress of technology, the application scope of customized individualized prostheses is also constantly expanding, covering multiple fields such as artificial joint replacement, cranial repair, dental implantation, etc. At the same time, it also promotes the development and innovation of the medical industry and provides better treatment options and outcomes for patients.

Customized individualized prostheses have many advantages, such as improving surgical outcomes and patient quality of life, reducing surgical risks and complications, improving treatment efficiency, reducing the total cost of treatment, promoting technological progress, etc. With the continuous development and improvement of technology, customized individualized prostheses will be more widely used and promoted in the future, bringing more benefits and convenience to patients ^[2-5].

2 Current status of customized personalized prosthetics application

Customized personalized prosthetics is an important advancement in modern medical technology. It can tailor prosthetics to the specific needs, body shape, and condition of patients, thereby improving the effectiveness and success rate of surgical treatments, reducing surgical risks and complications. Currently, customized personalized prosthetics have been widely used in various fields such as orthopedic surgery, dental treatment, cranioplasty, and plastic surgery.

Firstly, orthopedic surgery is one of the most widely used fields for customized personalized prosthetics. In orthopedic surgery, customized personalized prosthetics are used to treat diseases such as fractures, joint replacement, spinal surgery, and hip replacement based on the patient's bone morphology, pathological condition, age, and gender ^[6-9]. Customized personalized prosthetics can improve the accuracy and effectiveness of surgical treatment. For example, in joint replacement surgery, doctors can use computer-aided design software to make prosthetics that are perfectly matched to the patient's joint size and shape, resulting in more accurate and stable surgical outcomes.

Secondly, dental treatment is also an important field for customized personalized prosthetics. In dental treatment, customized personalized prosthetics are mainly used for dental implantation, teeth correction, and repair of dental defects ^[10-11]. By using customized personalized prosthetics, dentists can make prosthetics that are most suitable for the patient's oral cavity based on the patient's tooth size, shape, and location, thereby improving treatment effectiveness and patient comfort.

Thirdly, cranioplasty is another important field for the application of customized personalized prosthetics. In cranioplasty, customized personalized prosthetics are mainly used to treat diseases such as skull defects and fractures ^[12]. By using customized personalized prosthetics, doctors can make prosthetics that are most suitable for the patient's skull size, shape, and bone quality, thereby improving the success rate of surgical treatment and patient's quality of life.

Finally, plastic surgery is another important field for the application of customized personalized prosthetics. In plastic surgery, customized personalized prosthetics are mainly used to repair and improve the face and body. By using customized personalized prosthetics, doctors can make prosthetics that are most suitable for the patient's facial and body shape, contours, and other factors, thereby improving the effectiveness of plastic surgery and patient satisfaction ^[13-15].

Customized personalized prosthetics is an important advancement in modern medical technology and has been widely used in various fields such as orthopedic surgery, dental treatment, cranioplasty, organ transplantation, and plastic surgery. By using customized personalized prosthetics, doctors can make prosthetics that are most suitable for the patient's specific condition, thereby

improving the effectiveness and success rate of surgical treatments, reducing surgical risks and complications. With the continuous development and improvement of technology, the application prospects of customized personalized prosthetics will become broader, bringing more innovation and progress to the medical industry.

3 Customized Individualized Prosthesis Design Process

The process of customized individualized prosthesis design typically includes the following stages:

(1) Clinical needs assessment: The doctor evaluates the patient to understand their specific condition, physical condition, and special needs to determine whether customized prosthesis design is needed. At the same time, the doctor also needs to ask detailed questions and understand the patient's medical history, allergies, etc. (2) Imaging examination: The doctor selects appropriate imaging examination methods, such as X-rays, CT scans, MRI, etc., to conduct a comprehensive imaging examination of the patient to obtain relevant anatomical structure information. (3) Image data processing: After the imaging examination, the doctor processes the obtained image data and converts it into a three-dimensional data model. (4) Design stage: Based on the image data model, the engineer designs the individualized prosthesis, develops a prosthesis plan that meets the patient's special needs. (5) Manufacturing: After the design stage is completed, the engineer manufactures the customized individualized prosthesis based on the design plan. (6) Surgical implementation: After manufacturing is completed, the doctor implants the customized individualized prosthesis into the patient during surgery. (7) Postoperative follow-up: The doctor needs to follow up with the patient after surgery, observe whether the prosthesis meets the design requirements, and promptly handle any postoperative complications that may occur. The focus of the customized individualized prosthesis design process is on the design stage, which is the most critical link in the entire process. In the design stage, the engineer needs to develop an individualized prosthesis design plan based on imaging examination data and the patient's specific condition. This process requires accurate and rigorous design to ensure that the prosthesis can perfectly integrate with the patient's body structure.

4 Design process of custom individualized acetabular revision prosthesis using the example of customized individualized acetabular revision prosthesis design

4.1 Theoretical basis for designing custom individualized acetabular revision prosthesis

The principle of designing acetabular revision

prosthesis is based on the classification and analysis of acetabular defects. Currently, the commonly used classification systems are Paprosky classification and AAOS classification system^[18].

The Paprosky classification divides acetabular defects into three levels based on the degree and location of the defect. Level 1 defect refers to an acetabular wall defect of less than 50%, level 2 defect refers to an acetabular wall defect greater than 50% but less than or equal to 50% of the circumference, and level 3 defect refers to an acetabular wall defect greater than 50% of the circumference. In addition, defects can also be classified into different types based on their location, such as anterior superior defect, posterior superior defect, and posterior inferior defect. Different repair methods and prosthesis designs need to be used for different types of acetabular defects.

The AAOS classification system, on the other hand, divides defects into three categories, A, B, and C, based on the location, degree, and type of acetabular defect. Type A refers to anterior superior edge defects, type B refers to acetabular wall defects, and type C refers to posterior edge defects. In the actual design process, different repair methods and prosthesis designs need to be selected based on different types of defects.

4.2 Customization of Individualized Acetabular Revision Implant Design Process

The goal of acetabular revision implant design is to restore the function of the acetabulum and address any defects while maintaining its stability. The process involves the following steps: (1) obtaining the patient's imaging data: doctors use imaging techniques such as CT and MRI to obtain three-dimensional data of the patient's body. This data serves as the basis for designing a customized implant and provides detailed structural information of the patient's body part^[19]. (2) Three-dimensional modeling: based on the patient's imaging data, designers use computer software to create a three-dimensional model that simulates the patient's actual structure and design an implant based on the doctor's requirements. (3) Optimizing the design: designers evaluate and optimize the initial design. During this process, they consider aspects such as structure, material, and production processes to ensure that the design meets the patient's needs and medical standards^[20]. (4) Generating the implant's CAD drawings: based on the final design, designers generate the implant's CAD drawings, which are used in the subsequent production process. (5) Manufacturing the implant prototype: technical personnel from the production company use 3D printing or other manufacturing techniques to produce a prototype of the implant based on the CAD drawings. These prototypes are used for quality inspection and testing. (6) Conducting quality inspection of the implant: the production company conducts rigorous quality inspection and testing of the implant prototype. During

this process, they check for issues related to the implant's size, structure, material, production process, etc., to ensure that the implant's quality meets medical standards and the patient's needs ^[21]. (7) Manufacturing the customized implant: based on the prototype's test results, the production company begins to manufacture the customized implant. During this process, they use high-precision machine equipment to produce the implant's structure according to the CAD drawings. (8) Conducting quality control of the implant: the production company performs quality control on the manufactured implant. During this process, they conduct multiple tests and monitoring to ensure that the implant meets medical standards and the patient's needs ^[22]. (9) Delivery to the doctor and patient: the production company delivers the customized implant to the doctor and patient. Under the guidance of the doctor, the implant is installed inside the patient's body to ensure its stability. This process involves multiple links and requires support and cooperation from various professional and technical aspects to ensure the quality and effectiveness of the customized implant.

5 Outlook

Overall, customized individualized prostheses have broad prospects in the medical field. In the future, with the continuous advancement of technology and deepening research, we believe that customized individualized prostheses will continue to improve and develop in the following aspects: (1) materials: Currently, most customized individualized prostheses use biologically inert materials. In the future, more biocompatible and mechanically performing materials will be explored to achieve more perfect biological composite effects. (2) Technology: Currently, the design of customized individualized prostheses mainly relies on computer-aided design and 3D printing technology. In the future, more advanced digital technology, simulation technology, etc. will be developed to further improve design accuracy and realism. (3) Applications: Currently, customized individualized prostheses are mainly used in the orthopedic field. In the future, it will involve more extensive medical fields, such as dentistry, cardiovascular, and other fields. (4) Clinical aspects: Future customized individualized prostheses will be closer to clinical needs. For example, combining individualized prostheses with stem cell technology to accelerate bone formation and biological repair, etc.

As a typical representative of personalized medicine, customized individualized prostheses will play an increasingly important role in the future medical field, bringing better medical services and treatment effects to more patients.

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