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Research on the Development and Application of 3D Technology

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Abstract: 3D printing, also known as additive manufacturing, is a manufacturing technique that creates three-dimensional objects by adding materials layer by layer. Unlike traditional reduction manufacturing such as cutting and grinding, 3D printing does not require the removal of material from large pieces of material to form the desired shape but rather builds the object by adding material. Although the concept of 3D printing dates back to the 19th century, it began to commercialize in the 21st century, though the technology is still evolving. With its advancements, 3D printing technology has become relatively mature and is now used to produce various models and applications, including those in aviation, medicine, and other fields. This paper explores its applications, benefits, and potential challenges in 3 paragraphs. This study adopts the method of literature reading and analysis. 3D printing has revolutionized the medical field by enabling the creation of custom prosthetics implants, and even bio-printed organs. It allows personalized devices that fit patient perfectly, reducing the need for adjustment and increasing comfort. In the aerospace sector, 3D printing is used to create complex and lightweight components for aircraft and spacecraft. This can lead to reduced fuel consumption, lower emissions, and improved performance. Additionally, 3D printing facilitates the production of parts that are challenging to manufacture using conventional methods.

Keywords: 3D printing, bionic stent, 3D print heart, aerospace engine metal stent, Mechanical manufacturing.

1. Introduction

This paper mainly enumerates three examples to discuss the application of 3D printing technology in various fields, including 3D-printed hearts, 3D-printed bionic stents, and its application in mechanical manufacturing. Despite significant advances in 3D printing technology, there are still some challenges and gaps. These include a lack of high-volume manufacturing cases, relatively high costs, the absence of intelligent design methods, and limited integration with other technologies. In addition, certain specific 3D printing technologies remain underdeveloped in China, such as the binder jet metal 3D printing system, post-processing techniques, unsupported metal 3D printing systems like VELO3D, and high-speed cold spray metal 3D printing technology. The commercial application of these technologies faces difficulties and involves many cross-disciplinary challenges, such as those

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related to metal materials, binders, and degreasing sintering processes. This paper provides case support and technical analysis for the research of 3D printing.

2. Analysis of Application

2.1. 3D Technology in Medical Applications

This chapter aims to describe two aspects of 3D printing in the medical field—3D-printed hearts and bio-3D-printed bionic stents.

2.1.1.3D Printing Heart

3D printing technology currently can be used to print hearts, such as the atrial structure of human ventricles.

Using 3D printing technology, a model of non-restrictive perimembranous ventricular septal defect (VSD) can be made. The model was based on a sample of an 8-month-old child weighing 9 kg, with data obtained from a cardiac enhanced CT scan and imported into 3D printing software (MimicsV 21.0 and 3-MaticV 13.0), provided by a Belgian company in DICOM format for 3D reconstruction. In the software, the appropriate volume rendering conversion function was selected, and 3D filling technology was applied to ensure the integrity and clarity of the heart structure. By adjusting the imaging threshold, the heart region was precisely separated from the CT data and converted into a 3D digital model in STL format. The model was then printed using the J750 digital anatomy printer, which employed melt deposition technology to secure the model onto a designed platform with a bracket for maintaining its anatomical position. In terms of material selection, a mixture of gel matrix resin, tissue mucosa resin and Argillus type 30 rubber was used to print the heart model, while a solid material of polystyrene resin was used to make the platform and scaffold. In addition, the ring part was printed using a mixture of the two materials, while the lobe was printed using a flexible transparent material (UV-curable resin, model FLX910T), in order to closer the texture and appearance of the model to the real heart tissue.

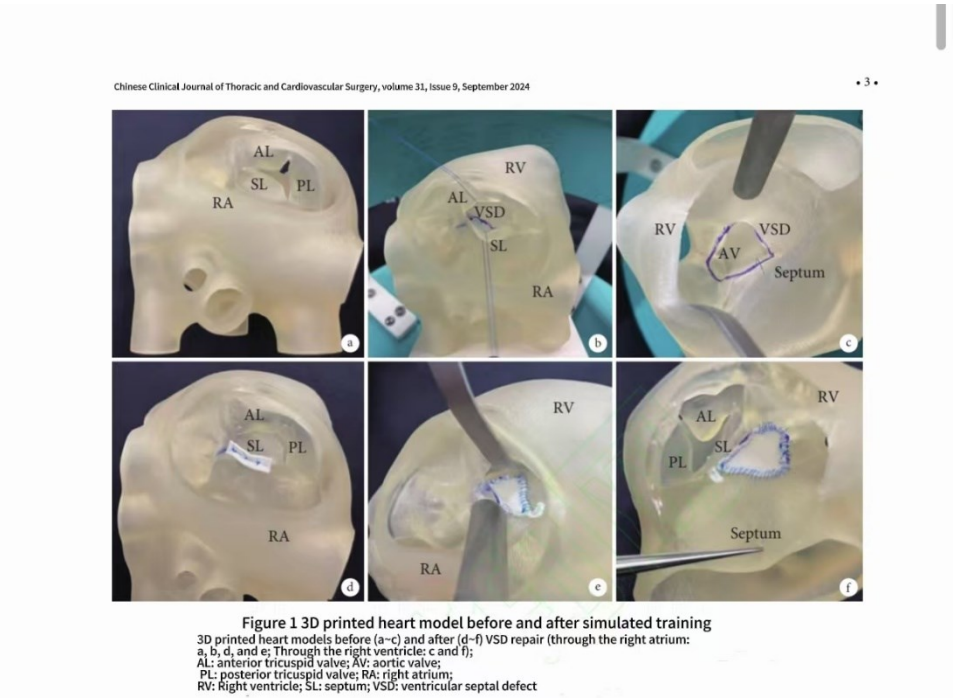

Figure 1: 3D printed heart model before and after simulated training

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Figure 1 illustrates a 3D-printed heart model. Its production process includes sample source, data acquisition, 3D reconstruction, editing and conversion, 3D model production, layering and printing, material selection, lobe printing, and model fixation. Through this process, a highly simulated heart model can be made, which provide a powerful auxiliary tool for the research and teaching of heart disease.

2.1.2. Bionic Scaffold

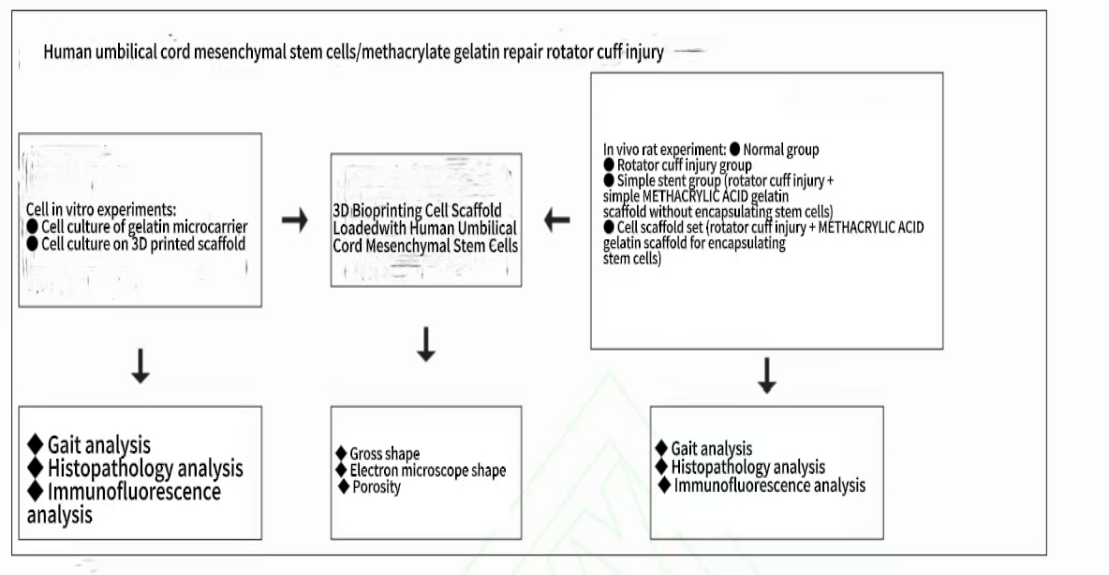

Figure 2: Human umbilical cord mesenchymal stem cells/methacrylate gelatin repair rotator cuff injury

Figure 2 shows the brief steps of 3D bio-printed bionic scaffold. Most rotator cuff injuries are concentrated in the supraspinatus tendon region, which is mainly due to the insufficient supply of blood vessels to this tendon, coupled with the complex anatomy of the rotator cuff itself, so that clinical results are often unsatisfactory. However, with the rapid development of the field of cell biology, new opportunities have emerged to improve tendon repair.

2.2. Aerospace Area

3D printing technology has also been fully used in the aerospace field, such as printing aerospace engine metal brackets.

3D technology can print metal support parts on solid motor composite shells. The main function of this part is to address the issue of preparing threaded holes at the connection points of composite structural parts, while simultaneously strengthening the tensile strength of these structures and buffering the mechanical differences between the connected components. The material of this part is TC4 titanium alloy, which is used in groups on the same product, and needs to meet the characteristics of quality stability, connection transition, stress buffer, lightweight and so on. Overall, this part plays an important role in the composite shell of the solid motor, and through the application of 3D printing technology, the precise manufacturing of this complex component can be achieved to meet the above requirements. Not only does 3D printing ensure the performance of the molded parts, but it also allows for the optimization of structural design and weight reduction. This technology opens up a new development path for the design and manufacture of high-performance solid rocket engines.

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2.3. Machinery Manufacturing Field

3D printing technology offers numerous advantages in the field of mechanical manufacturing, such as:

* Rapid prototyping: 3D printing technology can quickly create prototypes, assisting designers in testing and validating before full-scale production, which significantly reduces the product development cycle.

* Complex structure manufacturing: 3D printing technology is capable of producing complex geometric shapes that are difficult or impossible to achieve with traditional manufacturing methods, bringing flexibility in design and manufacturing to the mechanical manufacturing sector.

* Customized production: 3D printing technology enables on-demand production, meeting the needs for personalized and small-batch production, thereby increasing production efficiency and reducing inventory costs.

* High material utilization: Compared to traditional subtractive manufacturing, 3D printing uses an additive process, making more efficient use of materials and minimizing waste.

* Precision and dimensional accuracy: As the technology evolves, the precision of 3D printing is continuously improving, approaching from the micrometer level to the nanometer level, allowing 3D printed products to meet the high precision standards required in the mechanical manufacturing field.

* Cost-effectiveness: With lower setup costs, 3D printing is ideal for producing small batches of parts at reduced costs, making it especially suitable for responding quickly to market changes and customer demands.

* Innovation and flexibility: 3D printing technology fosters innovation as it allows for rapid design iteration and provides the possibility of manufacturing designs that are difficult to achieve with traditional methods.

* Enhanced printing efficiency: 3D printing technology, which combines computer technology, mechanical and electrical technology, and optical technology, not only significantly reduces the time consumed by mechanical molding but also helps to comprehensively improve printing efficiency.

Stereolithography 3D printers are manufacturing machines that use photopolymerization technology for three-dimensional printing. They belong to additive manufacturing techniques and are also known as a type of 3D printing technology. At the start of printing, the surface of the resin vat is covered with a thin layer of resin. Then, a computer-controlled laser scans the resin surface according to the cross-sectional contour of the three-dimensional model, and the resin exposed to the laser immediately solidifies. Subsequently, the build platform descends by one layer, and new liquid resin is covered over the solidified resin. This process repeats, with the laser scanning and solidifying each new layer, until the entire model is constructed.

3. Disadvantages of 3D Printing

As stated in Chapter 2, 3D printing technology has been fully utilized in various fields. However, this printing technology also has its drawbacks:

Cost issues: 3D printers and their materials can be relatively expensive, especially for new technologies and professional-grade equipment.

Material limitations: The available printing materials are limited, and not all metals or plastics are suitable for 3D printing, which may restrict its use in certain fields.

Size limitations: The size of the printing chamber of 3D printers restricts the size of the printed components; large components may need to be printed in multiple parts and assembled afterward.

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4. Conclusion

This article primarily analyzes 3D printing through case studies in the medical, mechanical manufacturing, and aerospace sectors. By analyzing these cases, the article identifies the advantages of 3D printing as well as some remaining shortcomings. As a representative of additive manufacturing, 3D printing technology is continuously driving innovation in the manufacturing industry. Despite the significant progress made in 3D printing technology, there are still some research gaps and challenges, such as binder jetting metal 3D printing systems, support-free 3D printing systems like VELO D, and "regional 3D printing" technology with 2 million laser points for metals. These gaps and challenges represent areas for future research. In terms of cost, the high cost of 3D printing limits its application in mass production; in terms of the industry chain, the connections between upstream material suppliers, midstream equipment manufacturers, and downstream application service providers in 3D printing still need to be strengthened. The future research directions for 3D printing technology are multifaceted, covering material science, design innovation, technology maturity enhancement, and environmental sustainability. These research efforts will not only promote the advancement of 3D printing technology but also have a profound impact on related industries. With the continuous advancement of technology, 3D printing is expected to achieve broader applications and greater influence in the future.

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