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Application of Plasma Spraying Technology in Surface Modification of Orthopedic Implants

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Abstract: In recent years, the demand for orthopedic implants in the medical field has been continuously increasing. At present, clinical personnel need to pay attention to various performance aspects of orthopedic implants when applying them, such as strength, wear resistance, corrosiveness, antibacterial properties, etc. In terms of surface modification of orthopedic implants, clinical personnel can apply plasma spraying technology. This technology can not only improve surface hardness and wear resistance, enhance biocompatibility and osteogenic ability, but also achieve antibacterial treatment, which helps to improve the clinical treatment effect of orthopedics. To this end, the article explores plasma spraying technology and orthopedic implants, analyzes the application of plasma spraying technology in surface modification of orthopedic implants, and raises some application issues from an industry perspective, hoping to improve the application effect of plasma spraying technology, promote research in the field of surface modification of orthopedic implants, and help better develop clinical treatment in orthopedics in China.

Keywords: Plasma spraying technology; Orthopedic implants; Surface modification; Technical application

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1. Introduction

With the continuous development of society, problems such as the aging population and increasing traffic accidents have led to a higher proportion of orthopedic surgeries. At the same time, as the public pays more attention to the aesthetics of teeth, the restoration of damaged tooth tissue has also received attention, which puts higher demands on orthopedic implants. At present, orthopedic implants used for repairing hard tissue injuries in clinical practice are mainly made of metal materials, including medical stainless steel, cobalt alloys, titanium alloys, nickel-titanium shape memory alloys, tantalum niobium zirconium alloys, and medical magnetic alloys. In the past, the application of orthopedic implants mainly relied on the implant and the bone tissue around the teeth. However, long-term use may lead to some problems that affect normal performance. Therefore, surface modification of orthopedic implants has attracted attention. For example, in clinical treatment, orthopedic implants

may induce infections. An infection not only affects the treatment risk of orthopedic surgery but also causes a greater physical and mental burden on patients. Plasma spraying technology belongs to a type of technology that enhances and modifies performance, which can improve the wear resistance and corrosiveness of materials, as well as enhance their thermal insulation and radiation resistance. Materials commonly used for medical purposes belong to a new type of precision spraying method. In clinical treatment of fractures, implants such as bone plates, bone screws, and intramedullary nails are often used, including trauma and joint implants. In order to improve the compatibility and wear resistance between implants and the human body, plasma spraying technology is generally applied. Plasma spraying technology can improve the surface hardness and wear resistance of orthopedic implants, reduce the risk of surgical infection, and help ensure the application effect of implants [1]. Therefore, this article explores the application of plasma spraying technology in surface modification of orthopedic implants, which has significant value.

2. Plasma spraying technology and orthopedic implants

Plasma spraying technology includes atmospheric plasma spraying method, supersonic plasma spraying method, etc. When there are defects such as pores and microcracks in the coating, using plasma spraying technology can further improve the surface hardness and wear resistance of orthopedic implants, and reduce the risk of surgical infection. This section will explore plasma spraying technology and orthopedic implants, as elaborated in detail below.

2.1. Plasma spraying technology

Atmospheric plasma spraying is one of the plasma spraying technologies. From the perspective of surface modification of the process, it can have good effects on biocompatibility, stability, toughness, and other aspects. Wu *et al.* [2] verified the good biocompatibility of the silica fume coating prepared by atmospheric plasma spraying in simulated body fluid experiments. Cui *et al.* [3] conducted a comparative study on the preparation of magnesium feldspar coatings using atmospheric plasma spray and vacuum plasma spray and found that the bonding strength of the former was significantly higher than that of the latter, but the latter had higher crystallinity. The second method of the plasma spraying technology is supersonic plasma spraying. For example, the presence of defects such as pores and microcracks in the coating weakens the bonding strength between the coating and the metal substrate. The use of plasma spraying technology can further enhance the application effect of plasma spraying technology and reduce the porosity of the coating [1].

2.2. Orthopedic implants

In orthopedic treatment, orthopedic implants are a common treatment method. For example, for orthopedic patients, external fixation brackets, artificial hip joints, artificial knee joints, and other orthopedic implants are often used. Firstly, bone screws, intramedullary nails, external fixation brackets, and bone plates belong to the category of orthopedic implants for trauma. Taking bone plates as an example, they are mainly used in surgery for fracture patients, playing a therapeutic role in repair and fixation and promoting bone healing in patients. From the basic function of bone plates, they can not only alleviate patient pain and shorten healing time, but also provide support and help patients recover as soon as possible. There are various shapes and sizes of bone plates that can meet the repair needs of different parts of fractures, such as limb fractures, spinal fractures, etc. Generally, long-term implantation is determined based on the actual situation of the patient. From the performance indicators of

bone plates, attention should be paid to hardness, surface roughness, biocompatibility, etc. Secondly, vertebral implants, titanium mesh, and fusion devices belong to spinal orthopedic implants. For example, fusion devices are mainly used to replace damaged intervertebral discs and promote fusion between adjacent vertebral bodies. Their functions also include promoting vertebral fusion, enhancing spinal stability, reducing pain, and further improving patients' quality of life. Finally, orthopedic implants such as artificial hip joints, artificial knee joints, artificial shoulder joints, and artificial elbow joints belong to the joint category. For instance, artificial hip joint prostheses mimic the structure of the human hip joint and are implanted into the patient's body to achieve femoral flexion and movement, thereby promoting the rehabilitation of orthopedic surgery patients [2].

3. Application value of plasma spraying technology in surface modification of orthopedic implants

Orthopedic implants are commonly used materials in clinical orthopedic surgery, such as external fixation brackets, bone plates, etc. They can not only promote patient healing but also improve patient rehabilitation outcomes. Plasma spraying technology includes atmospheric plasma spraying and supersonic plasma spraying, which have various application values in surface modification of orthopedic implants.

3.1. Improving surface hardness and wear resistance

The application of plasma spraying technology in surface modification of orthopedic implants can effectively improve the strength and wear resistance of the implant surface by forming a dense layer on the surface of orthopedic implants, effectively extending the service life of the instrument and improving mechanical tolerance.

3.2. Enhancing biocompatibility and osteogenic ability

The application of plasma spraying technology in surface modification of orthopedic implants can effectively improve biocompatibility and osteogenic ability, promoting patient bone tissue growth and repair. For example, compatibility is the key to orthopedic implants, as it can avoid affecting the patient's body tissue, further promoting the growth and repair speed of the patient's bone tissue, and helping the patient recover as soon as possible [2].

3.3. Supporting antibacterial treatment

The application of plasma spraying technology in surface modification of orthopedic implants can effectively enhance the antibacterial treatment ability of orthopedic implants. Orthopedic implants require certain antibacterial properties to prevent infections during orthopedic surgery. With the support of plasma spraying technology, the antibacterial performance of orthopedic implants has been further improved, which can avoid the risk of infection during surgery.

3.4. Optimizing surface lubricity and friction coefficient

The application of plasma spraying technology in surface modification of orthopedic implants can effectively optimize surface lubricity and friction coefficient. For example, plasma spraying technology can form a relatively tight coating on the surface of orthopedic implants, reduce friction between orthopedic implants and human tissues, and avoid damage. At the same time, the application of plasma spraying technology in orthopedic implants can reduce the friction coefficient during the surgical process, enhance the accuracy of surgery, and thus improve the treatment effect of orthopedic surgery [4].

4. Application of plasma spraying technology in surface modification of orthopedic implants

Surface modification of orthopedic implants is the key to enhancing their clinical orthopedic applications. With the support of plasma spraying technology, it can not only improve surface hardness and wear resistance, enhance biocompatibility and osteogenic ability, but also achieve antibacterial treatment and optimize surface lubricity and friction coefficient. Therefore, the article explores the application of plasma spraying technology in surface modification of orthopedic implants, analyzes the existing problems from an industry perspective, and elaborates in detail below.

4.1. Process issues

The application of plasma spraying technology in surface modification of orthopedic implants may face some process problems, such as insufficient process preparation, defects in equipment, materials, etc., which will affect the application effect of plasma spraying technology. The unreasonable process flow and complex links will affect the application level of plasma spraying technology [5].

4.2. Security issues

The application of plasma spraying technology in surface modification of orthopedic implants may face some security issues, such as the lack of process control measures developed by relevant industries based on the characteristics of plasma spraying technology, which will affect the application effect of plasma spraying technology.

5. Industry recommendations for plasma spraying technology in surface modification of orthopedic implants

In terms of surface modification of orthopedic implants, the application of plasma spraying technology can not only improve surface hardness and wear resistance, but also achieve antibacterial treatment and optimize surface lubricity and friction coefficient. However, in practical applications, there may be issues with improvements, processes, and guarantees. Therefore, this section will propose some solutions based on the application of plasma spraying technology in surface modification of orthopedic implants from an industry perspective, hoping to leverage the advantages of plasma spraying technology and enhance the surface modification effect of orthopedic implants.

5.1. Improving the process plan

Before applying plasma spraying technology for surface modification of orthopedic implants, it is necessary to prepare the process, including equipment preparation, coating material preparation, personnel preparation, etc. First is equipment preparation. The application process of plasma spraying technology cannot be separated from the support of equipment, which is the key to the effective application of plasma spraying technology. Common plasma spraying technology equipment includes spray guns, powder feeders, heat exchangers, etc., all of which are key components of plasma spraying technology equipment. In order to avoid malfunctions of related components, relevant industries should conduct equipment inspections and maintenance, eliminate problems with plasma spraying technology equipment, and ensure that plasma spraying technology equipment can be used normally. Next is the preparation of coating materials. Coating materials are key to the application of plasma spraying technology and can affect the surface modification effect of orthopedic implants. Generally, in terms of coating material selection, relevant industries should do a good job in material procurement, transportation, storage, and quality inspection. For example, in material procurement, quality should be the main focus, and

then a coating material procurement plan should be formulated from the perspectives of rationality and economy to ensure that the coating material procurement meets the expected requirements. Another aspect is personnel preparation. The application of plasma spraying technology in surface modification of orthopedic implants requires the establishment of a specialized process technology team to prevent problems in the application process of plasma spraying technology. For example, relevant industries should conduct technical process analysis in the application of plasma spraying technology for surface modification of orthopedic implants. Based on their own actual situation, talent introduction and cultivation plans should be formulated to establish a professional technical team and ensure the application of plasma spraying technology in surface modification of orthopedic implants. Then, a process plan is developed. In the process plan of plasma spraying technology for surface modification of orthopedic implants, relevant industries should combine their own reality and some excellent application cases of plasma spraying technology in surface modification of orthopedic implants to formulate a scientific and reasonable process plan, clarify the key points and indicators of each process link, and integrate standardization and normalization principles. When implementing the process plan, relevant industries also need to develop evaluation indicators for the plan, and timely identify problems in the process application through evaluation methods to ensure the application effect of plasma spraying technology in surface modification of orthopedic implants [6].

5.2. Ensuring technical support

The application of plasma spraying technology in surface modification of orthopedic implants may face some security issues. To solve this problem, relevant industries should pay attention to the application guarantee of plasma spraying technology and formulate targeted guarantee measures. One is the guarantee of investment in modern technology. The application of plasma spraying technology in surface modification of orthopedic implants may face some problems in the traditional production and processing process, which may affect its application effect. To solve this problem, relevant industries need to ensure investment in modern technology, such as introducing big data technology, the Internet of Things, artificial intelligence, etc., using modern technology to enhance the application effect of plasma spraying technology in surface modification of orthopedic implants. The second is to strengthen the control of technology applications. Related industries should develop process control measures based on the characteristics of plasma spraying technology, such as designing assessment and reward and punishment indicators according to the key points of plasma spraying technology, and constraining personnel's operational behavior through assessment and reward and punishment methods, so that they can operate according to the application standards of plasma spraying technology. At the same time, in terms of plasma spraying technology control, related industries also need to transform traditional management and integrate digital management, refined management, and other management models. For example, in terms of digital management, related industries can start from the application of digital technology, analyze the key points of plasma spraying technology application, and formulate a plan from the perspective of digital management to integrate digital management into the application process of plasma spraying technology. Through digital acquisition and analysis, problems in the practical application of plasma spraying technology can be identified in a timely manner, further improving the application effect of plasma spraying technology [7].

6. Conclusion

In summary, plasma spraying technology can be applied in surface modification of orthopedic implants, which

can not only improve surface hardness and wear resistance, but also achieve antibacterial treatment and optimize surface lubricity and friction coefficient. Therefore, based on the practical application problems of plasma spraying technology, the article puts forward some suggestions, such as the need for relevant industries to carry out equipment inspection and operation, eliminate the faults of plasma spraying technology equipment, and ensure that plasma spraying technology equipment can be used normally. Related industries should conduct technical process analysis in the application of plasma spraying technology for surface modification of orthopedic implants, and develop talent introduction and cultivation plans based on their actual situation, in order to establish a specialized technical team. Related industries should design assessment and reward and punishment indicators based on the key points of plasma spraying technology, and constrain personnel's operational behavior through assessment and reward and punishment methods. A plan is developed from the perspective of digital management to integrate digital management into the application process of plasma spraying technology. Through digital acquisition and analysis, problems in the practical application of plasma spraying technology can be identified in a timely manner. The discussion and analysis in this study can provide a reference for the application of plasma spraying technology, further enhance the surface modification effect of orthopedic implants, and assist in the better development of orthopedic clinical treatment.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Yuan H, Sun L, Meng Q, et al., 2024, Study on the Microstructure and Thermal Shock Resistance of Plasma Sprayed Cr_2O_3/8YSZ Composite Coating. Journal of Northwestern Polytechnical University, 42(04): 625–633.

[2] Wu X, Yu M, Ge X, et al., 2024, Experimental Study on the Effect of Plasma Sprayed Tantalum Coated Titanium on Osseointegration in Rats. Journal of Practical Stomatology, 40(04): 473–479.

[3] Cui Y, Guo M, Ma Y, et al., 2024, Preparation and Water Oxygen Corrosion Behavior of Si/Mullite+BASA/$Yb_2Si_2O_7$ Environmental Barrier Coating by Atmospheric Plasma Spraying. Journal of Aeronautical Materials, 44(04): 37–45.

[4] Zhang K, Zhang N, Deng Y, et al., 2024, Finite Element Study on the Influence of Surface Curvature and Matrix Thickness on Residual Stress in Plasma Spray Coating. Journal of Hefei University of Technology (Natural Science Edition), 47(06): 753–761.

[5] Ma F, Guo X, He H, et al., 2024, Preparation and Mechanical Properties of Plasma Sprayed High-Strength and Tough Nano TiO_2 Coating. Thermal Spray Technology, 16(02): 99–105 + 112.

[6] Hu F, 2022, Study on the Structure and Properties of Polyether Ether Ketone Implant Plasma Spray Composite Biocoating, dissertation, South China University of Technology.

[7] Liu S, Li K, Zheng X, 2019, Application Research of Plasma Sprayed Biological Coating on the Healing of Pathological Bone Defects. Surface Technology, 48(04): 1–9.