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Advances in the Use of Synthetic Bone Augmentation Materials for Oral Implant-related Applications

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Abstract: Insufficient bone in the implant area is a key factor in the outcome of implant restorations. Autogenous bone grafting has long been recognized as the "gold standard" in bone augmentation. However, the problems of secondary damage to the donor area, limited source, easy resorption, and high risk of complications have limited the use of simple autogenous bone in clinical practice. Finding and selecting good autologous bone substitution materials have become the trend of bone augmentation techniques. the use of bone augmentation materials can provide support and stimulate the process of bone augmentation in cases such as bone defects.

Keywords: Oral Implants; Bone Augmentation; Bone Tissue Engineering; Bone Defects; Electroactive Materials; Synthetic Bone Grafting Materials.

1. Introduction

Bone gain research refers to studies that address the increase and enhancement of skeletal tissue. Research in this area has focused on two main areas: bone mass gain and bone density gain. Bone mass gain refers to increasing the total amount of skeletal tissue by promoting the proliferation and differentiation of bone cells. Bone density increase refers to the increase in compressive capacity and durability of bone by increasing the density and strength of bone tissue [3]

In recent years, tissue-engineered materials have been used in the field of oral implants [4]with the aim of avoiding or mitigating many of the complications associated with implants in order to achieve better clinical outcomes. Research organizations and scholars at home and abroad are actively exploring new synthetic materials to improve their biocompatibility, mechanical properties and bioactivity[5]. Meanwhile researchers are also studying how to combine synthetic materials with biomaterials to further improve their application effects[6].The study of bone gain is important for the prevention and treatment of osteoporosis, fractures and other bone-related diseases. Through in-depth study of the mechanism and regulation of bone gain, we can provide more effective protection and treatment for bone health. At this stage, oral implant materials [8] mainly include metals and their alloys [9], ceramics [10], polymers [11], this paper selects three representative titanium alloys, bioceramics, polymers, from the perspective of physicochellical properties, biological properties, clinical applications, and other aspects of the review of the current progress of the research [12], in order to provide a comprehensive overview of the scientific research . The current research progress is summarized from the perspectives of physicochemical properties, biological properties and clinical applications, in order to provide a reference for scientific research [13]and clinical diagnosis and treatment [14].

2. Titanium Alloy

Titanium alloys are widely used in bone additive manufa Wuring [15] in the medical field. The mechanical properties of titanium alloys are improved by improving the mechanical properties and biocompatibility of titanium alloy bone additive materials and adding different proportions of alloy elements (such as niobium, zirconium and copper) to improve the mechanical properties of titanium alloys to meet the needs of specific bone defect repair. In addition, surface coating technology [16] is also widely used to improve the biocompatibility of materials and reduce the risk of infection.

Using 3D printing technology, researchers can manufacture personalized bone additives according to the specific conditions of patients [17]. This technology can model bone defects based on CT or MRI scanning data of patients, and accurately print bone substitutes that meet the needs of patients. In order to promote the integration and bioactivity of bone augmentation materials, bone growth promoters bone growth promoters [18] were integrated into titanium alloy bone augmentation materials. These accelerators can accelerate the proliferation and differentiation of osteoblasts, promote the formation of new bone, and improve the speed and quality of bone repair [19]. Titanium bone augmentation materials have begun to be utilized in the clinical setting. The use of these customized bone augmentations to repair conditions such as fractures, bone tumor resections, and bone defects allows for individualized surgical planning and fabrication of bone augmentations based on the patient's needs [20].

3. Bioceramics

3.1. Hydroxyapatite

The chemical composition of HA is similar to the inorganic composition of bone tissue, and it can release calcium and phosphorus ions in the organism after implantation, which makes it a good scaffold material. Among them, the commercial products OstimM and Endobon TM is a HA bone grafting material. However, synthetic HA has a low degradation rate due to its high calcium to phosphorus ratio and crystallinity. In addition, the mechanical strength of HA is insufficient to function in high load-bearing areas [21]. It has been found that in implant cases with maxillary sinus elevation and periodontal bone loss increment, the quality and quantity of new bone formed after HA implantation alone were insufficient to maintain the alveolar ridge height.

Therefore, the clinical application of HA in the oral cavity is usually limited to low-load stress areas such as implant coatings and bone [22]pin surfaces. Nanoscale HA has better mechanical properties,

degradability and modulation, and can promote the delivery and controlled release of biologically active molecules, so its biological properties and bone regeneration properties are superior.

3.2. Tricalcium Phosphate Bioceramics

It has good histocompatibility, but its osteogenic ability is unstable after implantation in vivo [23]. The different biological characteristics of the two kinds of calcium phosphate ceramics urge people to try to combine them, so that the composite materials not only maintain good osteogenic activity, but also have good degradability. Thus, biphase calcium phosphate ceramics (HA/ B- TCP) was further promoted [24].

3.3. Duplex Calcium Phosphate Ceramics

In the past decades, researchers have developed a B - Biphasic calcium phosphate ceramics, a bone graft material with the absorptive properties of TCP and the bone conduction properties of HA. MasterGraftM, a foreign brand, and Gubang Bone Powder, a domestic brand, all belong to the dual phase calcium phosphate ceramic bone graft material [25]. Some studies have confirmed that in periapical surgery, biphasic calcium phosphate ceramics as a bone substitute showed good clinical effects within two years, and the alveolar bone was repaired. Therefore, biphasic calcium phosphate ceramics can be used for the repair of localized bone tissue defects, alveolar ridge elevation, maxillary sinus elevation and other operations [26].

3.4. Calcium Phosphate Cement

CPCs usually include two systems, namely water agent and powder, wherein the powder contains calcium phosphate material, such as a - TCP and HA. When the above systems are mixed, a paste with strong operability can be formed, which can enough to undergo in situ curing and form HA nanocrystals. Commercially available Nor ianTM, objectM, HydrosetTM, BoneSourceM and domestic Rebond. The main advantages of CPCs include self-curing ability, easy contouring in the bone defect area, and good biocompatibility and osteoconductivity [27]. Therefore, CPCs can be used for bone defect repair and fracture reconstruction in dental clinical applications. However, the main drawbacks of CPCs are the incomplete reaction of the components, which can lead to inflammatory reactions, and the lack of pore structure of the material, which limits the rate of bone tissue regeneration to a certain extent[28].

3.5. Bioactive Glass

Bioactive glass has good osteogenesis, angiogenesis and tissue repair effects, and its excellent biological properties make it more promising[29]. Some researchers implanted nano BG material into the periodontal bone defect area. Three months later, the X-ray film found that the boundary between the bone defect area and the normal bone tissue was unclear, and the bone density was similar, which laid a theoretical foundation for clinical repair of angular absorption of periodontal bone[30]. The above studies fully confirmed that BG as a bone substitute material has a significant effect in repairing jaw and periodontal bone defects. Although BG has made great progress in clinical practice, improving the degradation performance of BG 31 and achieving the balance between degradation and new bone regeneration has always been a problem puzzling the medical community,

4. Polymers

Polymers, including polylactic acid, polyglycolic acid, polycaprolactone and their copolymers or derivatives, can be used as bone tissue regeneration materials, with the main advantages of various implantable forms, low immunogenicity, controlled degradation and porous nature. However, polymer-based implantable materials are prone to produce acidic products during degradation, causing local pH changes and affecting cell adhesion, which limits their clinical applications.

4.1. Polyether Ether Ketone (PEEK):

PEEK is a semi crystalline special, polymer material [32], which is resistant to high temperature and chemicàl corrosion, and has good mechanical properties and biocompatibility. Its elastic modulus is 3. 0-4. 0GPa.Compared with pure titanium, PEEK is closer to human bone and will not appear stress shielding. In addition, PEEK can penetrate X-ray and avoid artifacts [33]. However, PEEK is a kind of biologically inert material. When it is implanted into the body, it is not conducive to its good combination with the surrounding bone tissue, limiting its potential application [34].

4.2. Polycaprolactone HRSyntheticBoneTM

Polyvinyl lactone is a commercially available polymer-based bone grafting material composed of PMMA, polyhydroxyethyly methacrylate, and calcium hydroxide, which has been successfully to repair periodontal bone pockets and root bifurcation zone bone defects.

5. Concluding Remarks

In recent years, oral implant technology has been developing and maturing, and implant dentures have become one of the main choices for the restorative treatment of patients with missing teeth, and the ideal implant material is the key to obtaining long-term stable clinical results. More clinical trials are needed in the future to explore the actual clinical effects and long-term prognosis.

Author Contributions

Rui Han: main writer, collected and andyzed literature, completed the first draft of the paper.

Xuan Liu, Meng Li, Xiaolu Hou: Participated in the analysis and organization of the literature.

Jiupeng Deng: Conceptualized the topic and was responsible for supervising the writing of the review, reviewing, annotating and revising it.

Conflict of Interest

The author declares that there are no conflicts of interest in this article.

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