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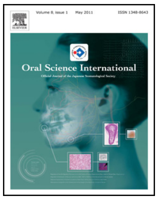

Review

Unraveling the mechanical strength of biomaterials used as a bone scaffold in oral and maxillofacial defects

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ABSTRACT

Three-dimensional printed natural and synthetic biomaterials have evolved as gold standards for tissue engineering scaffolds in recent trends owing to their superior role in hard tissue regeneration. The major drawback of these scaffolds is their relatively poor mechanical strength. Another key consideration in the design of the scaffolds is the difficulty in replicating the complex structural composition of hard tissues such as bones, and its structure cannot be reproduced with a single material that provides a limited range of properties. Sufficient mechanical strength is provided by the structure required for the replacement tissue. The mechanical properties of the scaffold play an important role in many applications of tissue engineering. Therefore, is it sufficient to withstand the force with only a single material used for the scaffold? There are many materials such as natural resin, synthetic resin, and polymers. They are used in combination to fulfill the function and to act as a kingpin by solving their drawbacks. The added material is not only superior in mechanical strength but also compatible with the tissues surrounding the implant, promoting cell adhesion and gradually degrading rather than intoxicating the patient. This review focuses on the various biomaterials used as scaffolds for critical size defects and the aftermath in their mechanical properties.

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1. Introduction

1.1. Background

Bone defects occur in the alveolar bone of the maxilla and mandible because of multiple reasons such as congenital anomaly, trauma, and osseous deficiency following resection of tumors, alveolar bone loss due to periodontal disease, and subsequent tooth loss. Biomaterials are required for bone augmentation for the dental implant. Clinicians attempting to regenerate the tissue and restore its function and aesthetics because of trauma, pathology, or congenital defects face a substantial challenge [1]. The concept of using scaffolds in bone tissue engineering is a key factor in the regeneration of critical size bone defects. The cells adhere and grow on the porous surfaces of the implanted scaffolds. The structural morphology and mechanical strength are provided by the surface of the scaffolds, over which the adhering cells can grow. The presence of scaffolds makes the cells generate the biological structural components of the extracellular matrix [2,3]. A variety of biomaterials have been researched to find the ideal scaffold material. The scaffolds used should be bioactive, biocompatible, and biodegradable and should possess a porous morphology and mechanical strength [4]. Scaffolds with a square pore morphology present a higher compressive strength, a higher modulus, and greater weight loss rate than those with other pore morphologies [5]. There are various biomaterials such as inorganic ceramics or glasses used in the fabrication of scaffolds for bone tissue engineering [6]. Tissue engineering techniques that involve reconstruction or regeneration of bone for replacing the oral and maxillofacial defects require a temporary porous scaffold. The scaffold usually regulates the growth of cells that either shift from neighboring tissue or arise inside the porous structure of the scaffold. Synthetic scaffolds are semi-crystalline materials, and owing to their cost-efficiency, high toughness, and biocompatibility, they are one of the most extensively used biodegradable polymers [7–9]. The gross design, microstructure, material composition, and mechanical property play a major role in controlling the local environment and growth of the adhered cells on the scaffolds [10–12].

1.2. Statement of problem

Scaffolds, growth factors, and cell seeding are the main blueprints used in bone tissue engineering [13]. Implanted scaffolds are typically exposed to different mechanical stresses that include compression, tension, torsion, and shearing. Hence, the mechanical properties play an important role in their in vivo performance [14]. Mechanical properties of a scaffold are expected to match with the native tissues to be repaired [15]. After fabrication, it is necessary to characterize the mechanical properties of the scaffolds before their implantation to make certain the appropriate performance; if not, the implanted scaffold may not succeed in the following repair processes [16,17]. Mechanical properties of scaffolds play an important role in many applications of tissue engineering, and the mechanical properties of scaffolds for bone tissue engineering may be the most critical one. The important mechanical properties of the bone include Young's modulus, toughness, shear modulus, tensile strength, fatigue strength, and compressive strength [18]. Imitating these characteristic mechanical properties to fuse with the bone architecture at a macroscopic level is vital for a bone scaffold during the implantation stage and eventually to sustain these properties for the regeneration of new tissue. There are many studies conducted in an attempt to improve the mechanical properties of scaffold by means of surface coating. To improve mechanical properties and also to promote osteoconductivity, many copolymers were added to the scaffold. The composite scaffold exhibits good mechanical performance and appreciable cell compatibility [19,20]. The medical device industry was interested in substituting metal devices (plates, screws, nails, etc.) with biodegradable implants, but most biomaterials did not possess the mechanical properties required for high load-bearing applications. Many materials such as natural and synthetic resins have been added to overcome its downside. The materials added should not only possess mechanical strength but also be compatible with the tissue surrounding the implant, be able to encourage cell adhesion, and degrade gradually without being toxic. This review focuses on the various biomaterials used as a scaffold for oral and maxillofacial defects and their aftermath of the mechanical properties.

2. Bone tissue engineered scaffolds for critical size defect in the maxillofacial region

2.1. Natural vs synthetic biomaterials

Polymers have been the material of choice for maxillofacial defects and in the field of tissue engineering. There can never be one factor that favors the selection of the scaffold material. The material properties of the scaffolds, such as surface roughness, porosity, pore size, solubility, and mechanical strength, play a key role in the selection of the scaffolds for the defect area. The three main factors for the selected scaffold are that it should be biocompatible, be biodegradable, and possess sufficient mechanical strength to withstand the forces acting on it [21].

2.2. Classification of scaffold materials

Scaffold materials can be broadly classified according to their synthesis and usage. According to the synthesis of the scaffold, it may be natural or synthetic. Synthetic scaffolds can be further subdivided into biodegradable and nonbiodegradable scaffolds. Depending on the use and clinical application, the scaffolds can be classified into synthetic or biologic, degradable or nondegradable, and rigid or nonrigid [22].

2.3. Natural polymers

Natural biomaterials have good cell compatibility. They support cell survival and function thereby enhancing the cells' performance and biocompatibility. Their drawbacks are source variability, immunogenicity, the pore size not being controllable, and lack of mechanical properties. Some natural biomaterials used in bone tissue regeneration include proteins such as silk, collagen, gelatin, fibrin, fibrinogen, elastin, keratin, actin, and myosin; polysaccharides such as chitosan, hyaluronic acid, alginate, agarose, cellulose, amylose, dextran, chitin, and glycosaminoglycans; and polynucleotides such as DNA, RNA, chitosan, hyaluronic acid, alginate, and agarose [23].

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