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Short Communication

3D Printed scaffold for periodontal regeneration

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Abstract

In order to restore function and appearance, periodontal therapy seeks to remove the underlying causes and, when practical, replace lost soft and hard tissues. True regeneration, which involves new bone, cementum, and periodontal ligament, necessitates surgical intervention and tissue engineering techniques, even though non-surgical therapies can accomplish restoration (such as long junctional epithelium). Barrier membranes are used in the surgical procedures known as Guided Tissue Regeneration (GTR) and Guided Bone Regeneration (GBR) to stop epithelial migration and promote the selective repopulation of regenerative cells such as fibroblasts, osteoblasts, and cementoblasts. Regenerative results are significantly influenced by membrane characteristics such pore size, permeability, and architecture. Although the ideal hole size is still up for debate, too big of a pore can weaken the membrane and permit unwanted cell migration.

Keywords: Periodontal Regeneration, 3D Printing, 3D Scaffolds.

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1. Introduction

In order to restore function and appearance, periodontal therapy seeks to remove the underlying causes and, when practical, replace lost soft and hard tissues. True regeneration incorporating new bone, cementum, and periodontal ligament necessitates surgical intervention and tissue engineering techniques, even though non-surgical therapy can accomplish restoration (e.g., long junctional epithelium). Barrier membranes are used in the surgical procedures known as Guided Tissue Regeneration (GTR) and Guided Bone Regeneration (GBR) to stop epithelial migration and promote the selective repopulation of regenerative cells such as fibroblasts, osteoblasts, and cementoblasts. Regenerative results are significantly influenced by membrane characteristics such pore size, permeability, and architecture. Although the ideal hole size is still up for debate, too big of a pore can weaken the membrane and permit unwanted cell migration. 3D printing and bioprinting are recent developments that allow for the creation of personalised scaffolds and membranes, even incorporating living cells and bioactive compounds through the use of bioinks. Biomaterial inks are seeded post-printing inks that don't include cells, while bioinks are cell-rich and used to print living tissue structures. By closely resembling the architecture of original tissue and encouraging interactions between cells and between cells and matrices, these technologies improve biological functionality and promote improved periodontal regeneration.[1]

1.1 Scaffolds

Scaffolds are three-dimensional matrices or structures that offer the conditions necessary to promote tissue development.

Scaffolds are three-dimensional (3D) biomaterials that are porous, fibrous, or permeable. They encourage cell contact, viability, and the deposition of extracellular matrix (ECM) while generating little toxicity or inflammation and biodegrading under regulated conditions. The periodontium's multiphasic scaffolds, which comprise both soft tissues (gingiva and PDL) and hard tissues (bone and cementum), are mechanically competent in addition to being tissue-specific. In recent years, scaffolds with regionally varied internal

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microstructures appropriate for cementum, PDL, and/or alveolar bone have been created using 3D printing to simulate multi-phase tissue compositions. Moreover, 3D-printed scaffolds can be paired with different growth agents to promote the regeneration of every periodontal tissue.[2] In addition to the internal microstructure, a scaffold that is specifically shaped and sized to match the anatomical shape of each periodontal defect can be created via layer-by-layer deposition 3D printing.

1.2. Properties of 3D scaffolds

Should have a sufficient level of roughness, hydrophilicity, and specific surface topography; in order to mimic the natural process of bone regeneration, a micro- and sub-micrometer-scale topographic environment must be created. Because the overall porosity of human cancellous bone ranges from 30% to 90%, the pores must have a size between 30% and 90%. The ideal pore diameter is between 150 and 500 μm, which allows for the entry of new tissues and vascularization. without sacrificing the scaffold's mechanical strength The rate of degradation need to be in line with the target tissue's remodelling activities. Biomaterials should be biocompatible and bioactive, meaning they shouldn't cause cytotoxic or inflammatory reactions.[3]

1.3. Types of 3D printers

Inkjet printing, extrusion printing, fused deposition modelling, light-assisted printing, and electrospinning are the three main categories into which 3D printers can be generally divided. Inkjet printing uses acoustic, thermal, or electromagnetic force to allow a controlled flow of biological fluid usually polymer to pass through an aperture on the printer head with the aid of a binder, this procedure makes it easier for the polymers to bond together to create a multilayered product.

1.4. 3D scaffold design in periodontal regeneration

One significant obstacle in regenerative periodontal therapy is creating a scaffolding design that accurately mimics the intricate form of periodontal tissues. Synthetic polymers and ceramic biomaterials are widely used in applications involving periodontal regeneration. One of the most often used polymers in 3D printing is polycaprolactone (PCL) mixed with other polymers or ceramics (such as calcium phosphate, CaP, and bioactive glasses).[4]

1.5. Monophasic scaffolds

Monophasic scaffolds are scaffolds that have only one compartment. To encourage the regeneration of the periodontal tissues, they might be supplied with growth factors or cells. used polylactic acid to create a 3D-printed framework of woven fabric, which was then filled with platelet-rich plasma and mesenchymal cells generated from bone marrow. Dogs with experimentally produced mandibular bone deficiencies were subsequently given the scaffold. The periodontal tissues within the generated defects showed better regeneration, according to the study.

1.6. Biphasic Scaffolds

The creation of human teeth periodontal ligament-bone complexes is facilitated by the biphasic scaffolds' unique compartments for the PDL and bone. The most common method for creating these scaffolds is indirect 3D printing. In order to create biphasic scaffolds with the required architecture, wax moulds are made and then cast. The wax moulds' features vary with regard to tissue-specific compartments, channel orientation, and pore size.

1.7. Triphasic scaffolds

Using the FDM approach, triphasic scaffolds are an expansion of biphasic scaffolds. To enable regulated delivery, the scaffold design incorporates distinct compartments for the alveolar bone, PDL, and cementum/dentin interface.

1.8. Applications of 3D printing in periodontology

The regeneration of the PDL, alveolar bone, and gingival tissues are the primary uses of 3D bioprinting in periodontics. The regeneration of these tissues is complicated by their unique structural and functional needs.

1.9. PDL regeneration

The attachment of teeth to the alveolar bone depends critically on the PDL, a soft connective tissue. The PDL is frequently harmed in situations of periodontal disease, and it can be difficult to regenerate. Using cells like MSCs, which are known to have regeneration potential, researchers have utilised 3D bioprinting to produce scaffolds that resemble the natural PDL. These MSCs have shown the capacity to develop into functional PDL cells when paired with extracellular matrix (ECM) components like collagen. Research has also looked into the use of growth hormones like TGF-β to encourage cell migration and differentiation and further improve PDL regeneration.[5]

1.10. Bone regeneration

Restoring alveolar bone is essential for preserving tooth stability because it is frequently lost as a result of periodontal disorders. Functional bone scaffolds that blend seamlessly with the host bone have been produced by 3D bioprinting. To encourage bone formation, osteoblasts or MSCs are frequently coupled with biocompatible and osteoconductive calcium phosphate and hydroxyapatite. The potential of 3D-bioprinted bone scaffolds to promote bone regeneration and lessen the requirement for conventional bone grafting has been demonstrated by recent studies. Furthermore, the longevity of sizable bioprinted bone constructions depends on vascularization techniques like endothelial cells or angiogenic agents.

1.11. Gingival tissue regeneration

Periodontal disease frequently causes gingival recession, and in order to preserve the underlying structures and enhance aesthetic results, gingival tissue must be restored. Using gingival fibroblasts in conjunction with collagen and other extracellular matrix proteins, 3D bioprinting has been investigated for the creation of gingival tissue constructions. These bioprinted gingival structures have demonstrated the ability to improve tissue integration and encourage healing. Enhancing the vascularization of bioprinted gingival tissues is the goal of more study on growth factors like vascular endothelial growth factor (VEGF), which will guarantee the tissue's survival and host integration.

2. Conclusion

Advanced imaging techniques combined with biomaterial scaffolds have shown promise in recent years for improving the structure and content of scaffolds for efficient periodontal regeneration. Although infrastructure upgrades and strict quality control procedures are required, these technologies allow for the non-invasive monitoring of in vivo scaffold degradation, which could raise treatment costs. Despite the intrinsic complexity of periodontitis and tissue regeneration, biomaterial scientists, biologists, chemical engineers, and clinicians work together to advance the goal of functional regeneration of periodontal tissues.

3. Source of Funding

None.

4. Conflict of Interest

None.

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