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Editorial

3D Bioprinting for Tissue Regeneration in Oral and Maxillofacial Surgery

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Maintaining good oral health is a key aspect of overall well-being and a daily concern for most individuals. The different components of dental alveolar tissues, including alveolar bone, dental pulp, teeth, periodontal ligament, gums, blood vessels, and nerves, collaborate harmoniously to facilitate essential functions like chewing and digestion. These tissues are intricately organized within a structured arrangement (as depicted), involving various cell types and showcasing diverse mechanical characteristics, varying from soft to hard. Over time, these tissues can face various issues such as cavities, tooth loss, periodontitis, gingivitis, and bone defects [1].

The restoration of damaged dental tissues is a complex endeavour. While achieving complete restoration of teeth can be challenging, there are multiple strategies that have been developed to address these concerns. For instance, in the case of cavities, the infected portion is carefully removed, and the resulting space is meticulously cleaned before being filled with an inert synthetic material. This approach aims to restore the structure and function of the affected tooth, promoting overall oral health and comfort. In recent times, the concept of 3D bioprinting has emerged as a promising strategy in tissue engineering to tackle the intricate challenges of dental alveolar tissue regeneration. This technique offers precise placement of cells and matrices, utilizes diverse cell types and materials in bioinks, and benefits from its speed, accuracy, and automation. By utilizing data from computed tomography (CT) or magnetic resonance imaging (MRI), 3D bioprinting can craft personalized constructs tailored to individual patients, facilitating the regeneration of complex dental alveolar tissues [1].

When combined with stem cell technology, which enables the creation of human tissues, the application of 3D bioprinting in dental and periodontal tissue restoration becomes an active and evolving area of research. Noteworthy strides have been made in the development of 3D printed scaffolds for cell seeding and in producing 3D bioprinted constructs encapsulating cells, all with the goal of enhancing dentistry regeneration [1].

3D bioprinting is an advanced technology that uses additive manufacturing to create precise structures using biomaterials. It's particularly useful for reconstructing complex biological defects in the human body. Three primary methods are laser-induced bioprinting (LIB), inkjet-based bioprinting (IBB), and micro-extrusion-based bioprinting (EBB). LIB uses lasers to deposit bioink onto a substrate and is suited for delicate structures like oral mucosa. IBB transforms biomaterials into droplets for printing and is suitable for softer tissues like blood vessels and cartilage. EBB, similar to 3D printing, is ideal for bone regeneration, and multiple cartridges can print various cells and materials. The integrated tissue and organ printing (ITOP) system combines polymers and hydrogels for increased mechanical strength, making it a promising solution for complex structures like the mandible [2].

3D bioprinting finds applications in tissue engineering, regenerative medicine, organ transplantation, drug screening, and cancer research. It enables the creation of various tissues with anatomical accuracy using cell-laden scaffolds. Key advantages include customizable scaffold architecture, ease of fabrication, patient-specific scaffolds, multi-material printing, and control over cell behaviour. Unlike traditional 3D printers, it precisely positions cells for heterogeneous tissues, with potential for in vivo implantation. While clinical use awaits approval, it's widely employed in drug testing and high-throughput assays, including liver tissue models for drug screening. In cancer research, 3D bioprinting helps develop in vitro cancer models and personalised medicines through hydrogels and therapeutic implants [3].

Current limitations in 3D bioprinting technology include challenges in vascularization and replicating the complexity of native tissues. Creating functional organs requires establishing complete vascular systems, enabling proper nutrient supply and waste removal. Current methods involve infiltrating host microvessels into constructs, but this lacks control and may lead to distortions or destruction. Ideally, tissues should be built with direct vessel ingrowth before implantation. Moreover, native tissues have intricate cellular arrangements, making replication challenging. Producing large-scale organs like kidneys with millions of glomeruli and nephrons remains a formidable task. Additionally, the economic aspect presents a major hurdle. Developing natural-like, fully functional human tissue requires overcoming these limitations and economic challenges to make biofabrication a reality for creating functional organs [4].

In the realm of oral, maxillofacial, and facial reconstructive surgery, 3D bioprinting offers remarkable applications. It aids in creating prototypes of facial anatomy, enhancing facial symmetry after surgery, and producing pre-contoured grafts. This technology also contributes to crafting high-quality prostheses for patients with scars, asymmetry, or malformations. Moreover, it plays a role in designing advanced simulation models for medical education. By utilizing imaging techniques like CT and MRI, anatomical scans are transformed into 3D prototypes through CAD software. These virtual models guide the 3D bioprinting process, where biomaterial is layered to achieve the desired shape. Research reflects 3D bioprinting's impact in maxillofacial surgery, showing patient outcomes improved in various clinical areas, including dental implantations and mandible reconstruction. The technology is beneficial for trauma surgery, orthognathic surgery, facial prosthetics, TemporoMandibular Joint (TMJ) procedures, and complex facial reconstruction, offering precision, reduced surgical time, and improved outcomes. However, challenges such as high costs and production time still exist. This innovative approach in craniofacial surgeries uses biomaterials compatible with bone and cartilage cells, enabling precise defect reconstruction, and holds potential for transforming craniofacial therapy [5].

In conclusion, 3D bioprinting is revolutionizing tissue regeneration in oral and maxillofacial surgery. This cutting-edge technology enables the creation of precise anatomical structures, enhances surgical precision, and offers tailored solutions for complex cases. From dental implantations to facial reconstructions, the advancements in 3D bioprinting hold the promise of improved patient outcomes and reduced surgical complications. While challenges like vascularization and cost remain, the ongoing progress in biomaterials, printing techniques, and clinical applications suggests a bright future for incorporating 3D bioprinting into routine oral and maxillofacial surgical practices.

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