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Short Communication

Essential Requirements in Calcium Phosphate (CaP) 3D Bone Bioprinting

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ABOUT THE STUDY

Around two million bone grafts are performed annually to treat bone lesions, of which roughly one million are performed just in Europe. As a result, bone regeneration is required to replace the damaged tissue, and it is imperative to increase both the quality and quantity of bone healing. Since the cells that make up bone tissue have intricately synchronized roles and successful regeneration is believed to be aided by a complicated interplay between bone-forming and inflammatory cells, repairing bone is not a simple task. Autografts are currently regarded as the best method for replacing missing bone, although they do have some serious disadvantages, such as limited availability of donor sites and potential morbidity. Researchers used Bone Tissue Engineering (BTE) and 3D bioprinting techniques to create cell-laden scaffolds, in which bone biological components are joined to form a 3D environment, to circumvent the drawbacks of grafts. There are a number of bone bioprinting methods that have been created, including inkjet, extrusion, and light-based 3D printers that use various bioinks, or printing ingredients.

In recent years, the field of bone regeneration has seen the introduction of customized medicine approaches thanks to the growing development of additive manufacturing technologies. Because they resemble the mineral phase of bone, Calcium Phosphate (CaP) are among the finest performing materials for this application [1]. The biomimetic Hydroxyapatite (HA) produced under physiological conditions excels because it faithfully reproduces the microstructure and content of bone.

CaP 3D bone scaffolds have been printed using a wide range of additive manufacturing processes. Among them, filamentary-based Direct Ink Writing (DIW) involves generating the required 3D structure layer by layer by manipulating the deposition coordinates while extruding a pseudoplastic ink through a nozzle [2]. Various ink formulations have been suggested, and those that use a hydrogel as a carrier for the ceramic powder offer a number of benefits. They are compatible with the usage of reactive powders, which are the source of the self-hardening ceramic inks, in addition to allowing a large volume fraction of ceramic particles. In this instance, the consolidation of the ceramic scaffold is based on a cement-like reaction that causes the structure to harden at body temperature rather than a high-temperature sintering process [3]. This low-temperature consolidation process can be used with methods using biological molecules or even living cells, unlike high-temperature sintering.

It is difficult to set uniform standards for the involvement of macro and micro porosity in bone regeneration in part because these parameters cannot be taken into account irrespective of other aspects such as pore geometry, textural qualities, or material composition. While some research come to the conclusion that macropore and micropore size barely affect *in vivo* performance, others contend that there is a preferred range of macropore sizes. While the ideal range has often been fixed at 300-500 μm, higher values are now available between 700 and 1200 μm. In any event, blood arteries must be able to penetrate macropores that are larger than 50 to 100 μm [4]. Beyond the effect of pore size, it is evident that interconnected macroporosity is necessary for scaffold vascularization and colonisation by the host tissue, and micropores are crucial for their cellular interaction with bone.

Pore shape, in addition to pore size and interconnectivity, is crucial to the biological effectiveness of bone scaffolds. Numerous studies have shown that a surface's potential to promote bone growth depends on how concave it is. When comparing, for instance, foamed architectures with the same composition to 3D-printed CaP scaffolds, it was discovered that, despite both sample types having excellent osteoconductivity, the foamed architectures had superior osteoinductive properties when tested ectopically, which led to higher osteogenesis also orthotopically. In particular, the sort of surface curvature that predominates in each type of pore geometry convex surfaces for 3D-printed filaments and concave surfaces for foams is highlighted here as having an important impact in pore architecture. But it's still unclear what the underlying mechanisms are. According to some research, this process is related to the microenvironments that are produced in the concavities of the pores, which may encourage the development of mesenchymal stem cells into osteoblasts. The concentrations of soluble species, including proteins and ions, in the concave regions may differ from those in their surroundings because they are shielded from the flow of physiological fluids.

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CONCLUSION

For instance, super saturation levels of calcium and phosphate ions may be attained in the case of calcium phosphate substrates as a result of scaffold disintegration or cell-mediated resorption. This could cause the cells to differentiate into osteogenic lineages together with the material's capacity for adsorbing endogenous molecular signals. Other studies explain the curvature-driven tissue growth to physical or mechanical processes rather than concentrating on chemical factors. The curvature of the adjacent surface has an impact on tissue growth because it affects how forces are applied by cells and the tension that builds up in cell networks. Globally speaking, the underlying physics would be comparable to that which controls diverse processes like crystal growth, phase transitions, membrane mechanics, or surface-wetting by viscous liquids, where the tendency to minimize the system's energy results in the nucleation/accumulation occurring in the regions with the lowest curvature radii and, consequently, lowest surface energy.

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