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Opinion

Interface Techniques for Bone and Biomaterials: Multi-Scale Characterization Advances

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OPINION

Biomaterials production and characterisation have improved as a result of the need for biomedical devices to aid in the functional repair of tissues. Biomaterials technologies are being pursued for a variety of tissues, including bone tissue. Bone, on the other hand, is a hierarchical material with a heterogeneous structure and chemistry over a broad length scale. The development and understanding of osseointegration, or the attachment of bone to implant materials, has remained a challenge due to this intricacy. It's critical to understand the principles of bone's structural and chemical organisation before studying how biomaterials interact with bone tissue.

The two primary components of bone are collagen, an universal protein found in many tissues, and calcium phosphate in the form of Hydroxyapatite (HA), Carbonated-HA (cHA), or Amorphous Calcium Phosphate (ACP).

By weight, bone is made up of around 65 percent mineral and 35 percent collagen. This composite structure is responsible for bone's perfect materials qualities, such as intrinsic strength and toughness. The collagen and hydroxyapatite core components make up the mineralized collagen fibrils. This hierarchical structure also gives bone increased durability, reducing the risk of skeletal fractures in mild blows. Aside from mechanical integrity, bone serves a variety of biological functions, including storing bone marrow, which includes the adaptive immune response and regulates blood cell formation. Brnemark used the term "osseointegration" to characterise the functional link between bone and implant devices in the 1950s. Since then, biomaterials have been investigated for their ability to osseointegrate with bone. Rather than surgical procedures, this connection is governed by the ability of bone-forming cells, osteoblasts, to release mineral towards and on foreign objects. Integrating them into the local bone to establish an attachment to the implant surface that supports mechanical loading.

Furthermore, titanium's mechanical properties provide the necessary strength for the skeleton to maintain structural integrity. A range of natural and synthetic bone implant materials are routinely used in addition to titanium implants, including bone grafts: either autografts, or bone material from the host, or allografts, or bone material from a donor. These grafts, together with other natural biomaterials such as proteins and polymer matrices, can be placed directly to wound sites or around titanium bone implants to promote bone development and reduce device failure.

Despite the fact that titanium has the potential to be a good bone-integrating biomaterial, issues arise due to the higher elastic modulus of titanium compared to bone. Because titanium is substantially stiffer than bone, it can overcompensate for surrounding bone tissue, triggering host tissue resorption; this is a process known as stress-shielding, which is covered in depth elsewhere.

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