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Editorial

Calcium Phosphates and Bioactive Glasses for Bone Implant Applications

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The worldwide clinical demand for skeletal repair is constantly increasing due to the aging of the population [1,2]. Orthopedic and dental surgeries require biocompatible bone implants with appropriate mechanical properties to replace hard tissue functions [3–5]. The International Union of Pure and Applied Chemistry (IUPAC) defines biocompatibility as the *ability of a material to be in contact with a biological system without producing an adverse effect* [6]. Metallic bone implants are effective in load-bearing applications but need a surface coating to make them bioactive within the human body. Bioactivity is the *property of materials to develop a direct, adherent, and strong bonding with bone tissue* [7]. Coatings of bioactive materials deposited on metallic implants prevent bone anchorage failure and promote long-term stability in the body that delays revision surgery [8,9].

Calcium phosphate and bioactive glass coatings are primary materials developed for decades in the bone implant industry and academic research [10,11]. Their ability to support the osseointegration of metallic bone implants is well established. The bioactivity process starts with the partial dissolution of the bioactive coating in contact with the physiological environment. The dissolution kinetics depends mainly on the bioactive coating's solubility product (Ks). The corresponding ionic releases induce a local supersaturation that triggers the precipitation of biological apatite at the interface between the metallic implant and the bone tissue [12,13]. The newly formed biological apatite layer promotes bone cell growth on the implant surface. As a result, the metal bone implant is chemically and biologically bonded to the bone tissue [14,15].

Calcium phosphates are bioceramic materials with a chemical composition like bone mineral, the inorganic component of bones. Several compounds belong to this family, among which hydroxyapatite (HAP), tricalcium phosphate (TCP), calcium-deficient apatite (Ca-def apatite), octacalcium phosphate (OCP), brushite or dicalcium phosphate dihydrate (DCPD) and tetracalcium phosphate (TTCP) are the most common [16,17]. They are characterized by their stoichiometry, described explicitly in biomaterials science by the calcium-to-phosphorus atomic ratio (Ca/P). The stoichiometry of these phases is related to their solubility in a physiological environment, corresponding to the surface bioactivity they provide to the bone implant [18,19].

Bioactive glasses are materials with osteoconductive and osteoproductive properties that can repair and replace diseased bones [20]. Several compositions of bioactive glasses are of great interest, such as phosphosilicates (45S5, 58S, 13-93, S53P4), borosilicates (13-93B1, 13-93B3) or 70S30C [21]. Among them, the famous 45S5 Bioglass® was developed for the first time by Larry Hench in the 1970s [22]. This quaternary oxide made of SiO_2-CaO–Na_2O–P_2O_5 has the property to bond both to hard and soft tissues (class A bioactivity). Bioactive glasses are synthesized either at very high temperatures by the melt quenching method or by the sol-gel process at low temperatures. The latter produces bioactive glasses of high purity, homogeneity, porosity, and specific surface area that promote bioactivity in a physiological environment [23].

Several methods can be used to produce calcium phosphate or bioactive glass coatings on the surface of metal bone implants [24]. This Special Issue gathers four reviews dealing with the latest developments in the field.

The first review describes the main deposition methods to produce bioactive calcium phosphate coatings on bone implants. Plasma spraying is the primary industrial process but other methods such as magnetron sputtering, pulsed laser deposition, electrospray deposition, electrophoretic deposition, biomimetic deposition, the sol-gel process combined with dip or spin coating, electrodeposition, and the hydrothermal synthesis are also widely studied in academic and industrial research [25]. This article also describes the most important physicochemical properties of calcium phosphate coatings and their impact on the bioactivity of bone implants in a physiological environment. The influences of crystallinity, morphology, roughness, porosity, wettability, adhesion, and ionic substitution are described.

In the second article, Shaikh et al. review recent applications of bioactive glass materials used to heal periodontal lesions, including repairing infrabony defects, gingival recession, and furcation defects [26]. They describe the bioactive properties of bioactive glasses that are suitable in many clinical dental applications or for the regeneration of hard tissues in the craniofacial region.

In another review, we summarize more than three decades of scientific knowledge on the electrodeposition of calcium phosphate coatings. We also describe the current development to produce the next generation of coatings [27]. Electrodeposition is a low-temperature process using metallic electrodes connected to an electric generator and immersed in an aqueous solution containing calcium and phosphate ions. Electrical energy from the generator triggers a series of chemical reactions at the electrode-electrolyte interfaces. The metallic bone implant is connected to the cathode, where the main electrochemical reaction is the reduction in water, the solvent of the electrolyte solution. This reaction results in a local pH variation that induces the precipitation of a calcium phosphate coating on the cathode surface [28]. As a function of the experimental parameters, various chemical compositions, phases, surface topographies, and morphologies are obtained [29–31]. Thermal annealing is required after deposition to evaporate the solvent and to improve the cohesive and adhesive properties of the electrodeposited coating.

In the last review, Robert B. Heimann describes the crystallographic changes of HAP particles in contact with a hot plasma jet during plasma spray deposition [32]. The HAP powder melts incongruently inside plasma at thousands of degrees and undergoes complex dehydration and decomposition reactions. The phase composition and crystallinity of the material are modified, resulting in a coating with physicochemical and biological properties different from those of the initial powder [33].

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