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Introduction to Biomaterials Used in Medical

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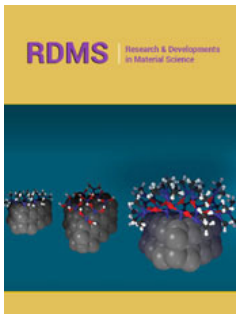

Abstract

Today in the field of biomedical, there were a lot of materials used for different problems. On introducing the nanotechnology, the physical as well as the chemical properties of a substance is manipulated at the molecular level. A byproduct or extension of nanobiotechnology, nanomedicine promises a wide range of uses in fields ranging from therapies to drug delivery and biomedical imaging. In this article we examine how bioceramics are utilizes in drug delivery system in nanophase.

Keywords: Biomaterials; Nanotechnology; Drug delivery; Bioceramics

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Introduction

The present advancement of the human condition and quality of life is greatly aided by the fascinating and very interdisciplinary field of biomaterials. The currently used definition, formulated by the 6th Annual International Biomaterials Symposium is: "a biomaterial is a systemically, pharmacologically inert substance designed for implantation within or incorporation with a living system" [1]. An equivalent concept was proposed in 1986 at the European Society for Biomaterials Consensus Conference: "a biomaterial is a substance or material used alone or in the fabrication of a medical device designed to interact with human tissues to monitor body functions or to deal with pathological conditions of the body" [2].

Due to their favourable and compatible physio-chemical characteristics with particular human body parts, bioceramics play a significant role in the biomedical industry. In the 18th century, bioceramics porcelain was first applied to crown treatments. Plaster of Paris was next employed in dentistry applications in the 19th century [3]. In the 20th century, advances in processing technology led to a significant growth in the use of ceramics in the medical industry [4].

They are typically solid materials made of non-metallic, inorganic components. Glasses and glass-ceramics (partially crystallised glasses) are subclasses of ceramics that come in both crystalline and non-crystalline (amorphous) forms [5]. According to the type of interaction that occurs in the physiological environment during body implants and tissues, synthetic ceramic materials are divided into three subgroups: bioinert, bioactive, and bioresorbable. Synthetic bioceramics are utilized to create heart valves, stents, implants, fillers for teeth, and other medical devices. Additionally, the application of bioceramics opens up new possibilities for the regeneration and repair of soft tissue [6]. The development of process technology makes it possible to adjust the physical, structural, and mechanical qualities to the requirements of the body parts and applications [7].

Ceramics are becoming more and more significant because of their biocompatibility, corrosion resistance, and primarily because mineral phases make up a significant portion of bones. Ceramics are therefore utilized to replace bone or to encourage bone regeneration [8]. Excellent biocompatibility, great wear resistance, high corrosion resistance, high strength, exceptionally high stiffness, and hardness are typical characteristics of ceramics. Orthopaedics

and dentistry have been the primary areas of concentration for ceramic material advancement in the biomedical sector. Some of the most commonly used bioceramics are alumina (Al_2O_3), zirconia (Zr_2O_3), pyrolytic carbon, Titanium oxide, Bioglass, hydroxyapatite and bioresorbable ceramics such calcium phosphates etc.

Bioinert ceramics

Ceramics that are bioinert do not react biologically with the tissues around them. In a physiological environment, it can prevent corrosion. Alumina and partially stabilized zirconia are examples of oxide bioinert ceramics, while carbon- and nitride-based ceramics are non-oxide bioinert ceramics.

a) Dental and orthopaedic implants typically employ alumina. It is biocompatible with the human body, has a low friction coefficient, and strong mechanical strength [7]. The first commercially available bioceramics for dental implants and acetabular cup replacement in complete hip prosthesis were made of alumina.

b) Zirconia is an allotropic oxide that, depending on the temperature, forms in three different crystal structures: monoclinic (1170 °C), tetragonal (2370 °C), and cubic (2680 °C). It has been noticed that other oxides, including CaO, MgO, CeO_2, and yttria (Y_2O_3), are utilized as stabilizers for zirconia [9]. It has frequently been chosen in dentistry (pins, crowns, bridges, veneers, and orthodontic brackets) because of its mechanical qualities and color, which are similar to those of genuine teeth [10].

c) Titania (TiO_2) is employed in alumina-zirconia composites to improve sintering and ceramic performance. Its non-corrosiveness contributed to its outstanding bioactivity. Additionally, it facilitates the rapid adhesion of implants to bone tissues. A recent study also showed the impact of TiO_2 addition on the microstructure of ceramic composites based on alumina, zirconia, and cerium [11]. TiO_2 can be employed in dental applications because it has a significant impact on the evolution of phases and the expansion of grains during sintering.

d) Additionally employed as a biomaterial are non-oxide bioinert ceramics like carbon and nitrides. Carbon and carbon nanotubes (CNT) have good durability, excellent strength, and excellent fracture toughness. At the boundary between materials and tissues, carbon has the power to prevent blood coagulation. These are additionally utilized in heart valve prostheses and as a covering for substrates [12].

Bioactive ceramics

Ceramics generally have good biocompatibility, high corrosion resistance, high compression resistance, and low electrical and thermal conductivities. These qualities make them ideal candidates for implants [13]. Osteoconductivity or "bioactivity" are terms used to describe these materials' capacity to connect with bone. Due to their osteoconductive qualities, these bioactive ceramics are also employed as coating materials to improve the mechanical and corrosion-resistant qualities of bone transplant implants. On their surfaces, they can also serve as a scaffold to promote bone development. Bio glasses and bioactive glass-ceramics, CaP, and HAp are the most popular bioactive ceramics.

a) Hench and coworkers first proposed the idea of a bioactive glass. The Bioglass composition consists of a number of specially designed glasses with the addition of P_2O_5, B_2O_3, and CaF_2 to a Na_2O, CaO, and SiO_2 glass. On the surface of bioactive glasses, a layer of physiologically active Hydroxy-Carbonate Apatite (HCA) developed both in vitro and in vivo. It encourages the growth of fresh bone tissue. This HCA phase promotes direct bonding by connecting host tissue with implants since it is chemically and physically comparable to the mineral phase in bone [14].

b) Glass-ceramics are made by adjusting the crystallization or devitrification of a parent glass. It typically includes a tiny volume of residual glass located at the grain boundary and is composed mostly of fine grain with crystal sizes ranging from 0.1 to 10m. The capacity to manage crystallization and the production of crystal phases allows for the creation of materials with a variety of unique qualities, including as bioactivity, machineability, and enhanced mechanical capabilities. This is one benefit of glass-ceramics [15].

c) The main components of bone mineral are calcium phosphates. It can be created by combining calcium and phosphate solutions in an acidic or alkaline environment. Only a few substances may be implanted into the body with success; due to their high solubility, substances with a Ca/P ratio of less than 1 are not ideal for biological implantation [16]. Porosity, crystalline structure and Ca/P ratio are the very important factors for the success of calcium phosphate in vivo implants.

Bioresorbable ceramics

As an alternative to metallic and polymeric biomaterials, bioresorbable ceramics are used in a variety of medical applications. The term "bioresorbable" describes a substance that dissolves after being inserted into a human body and is progressively replaced by developing tissues (bones). Porous HAp, calcium sulphate, calcium phosphates (CaP) and their salts are typical specimens of biodegradable ceramics [17].

a) An inorganic, crystalline osteoconductive material, calcium sulphate is found in nature. It comes in a variety of hydrate forms, including gypsum, anhydrite, and hermihydrate state ($CaSO_4$-.$0.5H_2O$) ($CaSO_4$.$2H_2O$). It has a compressive strength that is comparable to cancellous bone (99.15MPa). When hydrolyzed, it is weak and rapidly loses strength. They have been utilized as bone grafts and as carriers for antibiotics to prevent infection because of their injectability and quick degradability [18].

b) Bioceramics made of calcium phosphates (CaPs) have exceptional biological properties like biocompatibility, osteoconductivity, and bio resorb ability that allow them to be incorporated into live tissue using the same mechanisms involved in bone remodelling. Additionally, CaPs are inexpensive to create and relatively simple to certify as medical grade. CaPs are mostly utilized as fillers and coatings in the biomedical industry and are only suitable for load-bearing applications due to their weak

mechanical properties, particularly in terms of strength and fatigue resistance [19].

Drug delivery system

The development of ultrapure, high-surface-to-volume ratio, nanosized particles, and cost-effective fabrication procedures with tight control over particle size, shape, and porosity in nanotechnology have further increased these benefits. High surface area-to-volume ratios of nanoparticles and their corresponding high surface activities can improve the efficiency and stability of drug loading. These tools allow paramedics to better manage drug release and control. Additionally, nanotechnology offers a number of abrasive methods to regulate drug distribution throughout the body, allowing drugs to be released in ways that are precise, timely, targetable, or responsive to the environment [20]. Ceramic nanoparticles are distinct from polymeric or metallic nanoparticles due to a number of special characteristics.

a) Longer biodegradation periods are typically exhibited by ceramic nanoparticles, which is a characteristic essential to diffusion-controlled drug release kinetics. Ceramic matrices that degrade slowly, or even very slowly, can hold onto pharmaceuticals longer after administration. In these circumstances, drug release can be protracted and is dependent on concentration gradients.

b) The ability of correctly produced ceramic nanoparticles to have the same chemistry, crystalline structure, and size as the components of targeted tissues (such as different forms of calcium phosphate found in bone) may be the most remarkable of all. Even before drugs are released, their manufacture improves the material's bioactivity and biocompatibility.

c) Ceramic nanoparticles in aqueous solutions typically do not swell or change porosity, unlike polymers, and are more stable when pH or temperature changes are present. For example, ceramics' low swelling ratios inhibit the rapid release of drugs, which is a common issue with hydrogels like poly (2-hydroxyethyl methacrylate) (pHEMA) drug delivery systems

d) The nanoparticles can also be designed to have advantageous mechanical, magnetic, optical, and electrical properties that are not often found in polymeric or metallic nanoparticles, such as ferro electrical and dielectric properties, piezoelectric properties, ultrahigh hardness, superparamagnetic properties and photothermal effects.

Some nanophase ceramics which are recently used in drug delivery system are calcium phosphate, silica, iron oxides, calcium carbonate, alumina, titania etc. Most significantly, calcium phosphates have been extensively explored because of their bioactivity, biocompatibility, and customizable bio absorbability.

For example, gentamicin sulphate, tetracycline, salicylic acid, indomethacin, analgesic and anticancer drugs (mercaptopurine, estradiol), growth factors (e.g., transforming growth factors (TGF-)), proteins (e.g., collagen I and osteocalcin), and genes have all been delivered using calcium phosphates (e.g., DNA) Recent research have also shown that the calcium phosphate nanoparticle grain size, surface area, and calcium-to-phosphorus ratios could be customized to further control the drug release kinetics [21].

There are two quickly developing areas of ceramic nanoparticle drug delivery that merit additional study. One of these is Photodynamic Treatment (PDT), while the other is layered double hydroxides at the nanoscale (LDHs). PDT is a new technique being used to treat a number of illnesses, including ophthalmic, dermatological, cardiovascular, and oncological ailments [22]. PDT includes absorbing a photosensitizer (like silica) into problematic tissue, such tumour tissue, and then photo irradiating that tissue. Due to their photostability, easily controllable size, shape, and monodispersity, as well as the suitable pore diameters, ceramic nanoparticles are excellent carriers for photosensitizers (0.5nm - 1nm). The anticancer medicine (2-devinyl-2-(1-hexyloxyethyl) pyropheophorbide) was efficiently captured by silica-based nanoparticles, which are about 30nm in size and are produced through hydrolysis [23].

Anions from the hydrate gallery and charged metal hydroxide layers make up the LDHs class of anionic layered ceramic materials, also known as anionic nanoclays. The interlayer anions in the LDHs can be CO_3^{2-}, NO_3-, SO_4^{2-} or other anionic species. The metallic cations in the LDHs can be Mg^{2+}, Zn^{2+}, Ni^{2+}, Cu^{2+}, Al^{3+}, Fe^{3+}, etc. LDHs exhibit strong anionic-exchange capacity, high swelling characteristics, and pH-mediated solubility. They are also bioresorbable. These are the characteristics that make them promising for medication and gene delivery [24].

Conclusion

Now a days by using these nanophase bioceramics in medical, many problems have been resolved. Nanophase ceramics, in contrast to polymeric platforms, can be excellent platforms for drug transportation and controlled, prolonged release due to their extraordinary properties, which include size, structural advantages, highly active surfaces, unique physical and chemical properties, and ease of modification.

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