1. Introduction

Bone plays important roles in our lives, supporting our bodies and enabling us to perform various motions. The techniques used to repair damaged bones also are important and when an area of damaged bone is too large for self-repair, the damaged bones must be repaired by using alternative materials such as ceramics, metals and organic polymers. However, in general, artificial materials implanted in bony defects are encapsulated by fibrous tissue and do not bond to living bone. To solve the problem of this foreign body reaction, bioactive ceramics have received much attention, because they show direct bonding to living bone (bone-bonding ability) after implantation in bony defects.

2. Bioactive ceramics for artificial bone

Some bioactive ceramics have been already been used to repair bone defects, since they show the specific biological activity with bone tissue. But, these bioactive ceramics have not satisfied every clinical application yet because the mechanical properties of ceramic materials are different from those of natural bone. Living bone is a composite of 70 mass% apatite and 30 mass% collagen. Therefore, the combination of an organic substance with bioactive inorganic components would produce a novel bone-repairing material showing not only bioactivity but also mechanical properties similar to living bone.

Previous studies (Hench 1991; Kokubo 1991) revealed that bioactive ceramics form a layer of biologically active bone-like apatite on their surfaces after being implanted in bony defects. It is therefore an important condition for ceramic materials to form a bone-like apatite layer on their surfaces after exposure to the body environment to express the property of the direct bonding to living bone. A similar bone-like apatite layer can form on bioactive ceramics if they are immersed in a simulated body fluid (SBF), as proposed by Kokubo and his colleagues. The SBF of Kokubo et al. is an aqueous solution that has almost same the constituents with regard to inorganic species as human extracellular fluid (Kokubo & Takadama 2006).

3. Design of bioactive organic-inorganic hybrids

According to previous reports (Ohtsuki et al. 1992) that evaluates the capability of the bone-like apatite formation on the glasses in ternary system CaO–SiO₂–P₃O₅ after exposure to SBF, glasses in the CaO–SiO₂ binary system have been identified as basic components for producing bioactivity. The typical composition of such a bioactive glass is 50CaO-50SiO₂ mol%. The detailed investigation of the formation of bone-like apatite layers on a glass with a composition of 50CaO-50SiO₂ mol% proposed a mechanism for the induction of heterogeneous nucleation on these materials triggering the formation of bone-like apatite layers in SBF. The existence of silanol (Si-OH) groups on the surface of the
material is important to induce heterogeneous nucleation of apatite, as well as the release of Ca$^{2+}$ from the materials. This finding introduces the idea that bioactive organic–inorganic hybrids can be produced through organic modification of chemical species that allow the formation of Si-OH groups and release Ca$^{2+}$ after exposure to body environments.

The development of several types of organic–inorganic hybrids was attempted through sol-gel processing, which is a popular processes for preparing hybrids of inorganic and organic components because the process can be conducted at low temperature. I have attempted to synthesize organic–inorganic hybrids starting from methacryloxypropyl trimethoxysilane (MPS) and 2-hydroxyethyl methacrylate (HEMA) with the addition of a calcium salt (Ohtsuki et al. 2007). MPS has alkoxysilane groups that provide silanol groups after hydrolysis, whereas HEMA provides a hydrophilic polymer matrix in the hybrid. This type of MPS-HEMA hybrids has the potential to show the ability of bone-like apatite formation, that is bioactivity, after the examination using SBF.

Moreover, bioresorbable organic–inorganic hybrids can be developed from alginate, an extract of brown seaweed, after modification with silanol groups as well as calcium chloride. The idea on modification of calcium silicate with organic polymer with bioresorbability brings novel organic–inorganic hybrids exhibiting both bioactivity and bioresorbability, available for scaffold on bone tissue engineering.

4. Conclusion

Organic modification of calcium silicate that is essential constituents of bioactive ceramics provides a novel design of various bioactive organic–inorganic hybrids. The concept is given on Figure 1. Apatite-forming ability can be provided by the addition of alkoxysilane and calcium salt into organic polymers with different biological and mechanical performances.

![Figure 1  Concept of bioactive hybrids for artificial bone.](image)

References


Keywords

Bioactive ceramics: generally, bioactive materials are regarded as materials that are designed to induce specific biological activity for repairing damaged organs. For repairing bone tissues, the bioactivity is regarded as the capability to making direct contact with living bone after implantation in bony defects. Osteoconductivity: the phenomenon of new bone formation on the surfaces of bioactive ceramics.