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GLASS AS BIOMATERIAL FOR BONE TISSUE REPAIR

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Abstract
Certain glass compositions play an important role in modern medicine for restoring function and facilitating healing for people after injury or disease due to their ability to promote bone growth while dissolving into surrounding body fluid.

Keywords: glass, biomaterials, bone tissue.

Bioactive glasses can be excellent example of application in medicine due to their biocompatibility and bioactivity. Bioactivity is property of an engineered biomaterial to induce a physiological response that is supportive of the biomaterial’s function and performance [1-3]. Bone implant materials are often designed to promote bone growth while dissolving into surrounding body fluid [1-3].

The concept of bioactive or surface active glasses was introduced by Professor Larry L. Hench at University of Florida in late 1960s by the discovery of 45S5 Bioglass® with its chemical composition (wt. %): 45 SiO$_2$, 24.5 CaO, 24.5 Na$_2$O, and 6.0 P$_2$O$_5$ [4]. Nowadays bioactivity was demonstrated not only in silicate but also in borate and phosphate based glass systems.

To interpret bone bonding mechanism of bioactive glasses one should note that the natural bone is a dynamic system that undergo remodeling process. Bone is spread through and lined by various types of bone cells. The surface of the bone is covered by bone-lining cells, which form a thin continuous sheet over the bone where the movement of ions between the bone and the body is controlled. There are two layers of bone cells, periosteum and endosteum. Periosteum is the layer of cells on the outside of the bone and endosperm is the layer of cells on the inside of the bone. Osteoblasts, osteoclasts, bone matrix and osteocytes within the bone are the major components of bone microenvironment[3]. Osteoclasts are large, multinucleate cells derived from precursor cells circulating in the blood. They are responsible for breaking down bone tissues [5]. Osteoblasts are mononuclear bone forming cells located on the surface of osteonseams. Formation of new bone is one of the main functions of osteoblasts. They lay down on collage-
nous matrix fibers, which are then used as a framework for the osteoblast’s work. The osteoblast then deposits calcium phosphate which is hardened by hydroxide and bicarbonate ions. The new bone created by the osteoblasts is called osteoid. Osteoblasts also are the manufacturers of hormones. Whenever the osteoblast finished working, it is imprisoned in the hard bone tissue and connect with neighboring osteocytes and with bone-lining cells by means of gap junctions that allow small molecules through easily. Other osteoblasts, which are not hardened, remain on the surface of the new bone and are used to protect the underlying bones. Bone is constantly remodeled by the resorption of osteoclasts and created by osteoblasts (Fig.1).

The bonding mechanism of bioactive material involves a sequence of 11 reaction steps [6]. The initial five steps occurred on the surface of bioactive material are chemical reactions only, while remaining six steps belong to biological aspects, because the latter include colonization by osteoblasts, followed by proliferation and differentiation of the cells to form a new bone that has a mechanically strong bond to the implant surface. The initial five “chemical” steps occur during 6-7 hours after implantation. The sequence of reactions that take place at the interface between bioactive material and the surrounding biological environment are interpreted as follows: (1) dissolution of bone implant material; (2) precipitation from solution onto material; (3) ion exchange and structural rearrangement at the material/tissue interface; (4) interdiffusion from the surface boundary layer into the material; (5) solution-mediated effects on cellular activity; (6) deposition of either the mineral phase (a) or the organic phase (b) without integration into the material surface; (7) deposition of either the mineral phase (a) or the organic phase (b) with integration into the material; (8) chemotaxis to the material surface; (9) cell attachment and proliferation; (10) cell differentiation; (11) extracellular matrix formation.

All phenomena, collectively, lead to the gradual incorporation of a bone implant material into developing new bone tissue [6].

References