Tissue replacement from mechanical point of view

Transplantation of natural tissues is not always possible due to lack of availability of natural organ or tissue. In such cases, artificial tissue analogues such as blood substitutes, artificial aortic valves, or bone-like polymeric composites are used as substitutes.

Problems

However, there are a number of problems in making artificial tissues safe in clinical use. The ideal materials should:

1. have physical properties and structure (eg, elasticity, smoothness of surface, and durability) as close as possible to the natural tissue to be replaced;
2. be non-allergic, so they do not trigger inflammatory reactions;
3. be non-toxic, so they do not release toxic substances, causing tissue or organ damage;
4. be bio-degradable, in the case of temporary tissue replacement like surgical sutures.

New materials

Like in other areas of biomedical research, nature provides a good examples in design of new materials. The development of replacement materials should be based on understanding of the structure and functions which are to be substituted.

Examples

Two examples of these properties in clinical practice are artificial aortic valve prosthesis and artificial bone replacement materials.
Elasticity and smoothness of the graft material is especially important in artificial aortic valve prostheses. **Elasticity** ensures proper hemodynamic behavior of the artificial valve, and **smoothness** of the surface prevents excessive agglutination, thus preventing clot formation. Excessive blood clotting on the surface of artificial heart valves is one of the most important problems in artificial heart valve replacement.
Enhancement of **stiffness** and **strength** is important in replacement of mineralized tissue, such as bones and teeth. I will concentrate on that later.
Natural bone structures with variable density ranging from very dense and stiff (eg, the cortical bone), to a soft, foamy structure (eg, the trabecular bone). The trabecular bone is built of flexible, type 1 collagen fibers, which are reinforced by minerals (hydroxyapatite crystals) responsible for the hardness of the natural bone.
The first bone implants used for example for for total hip replacement were done of metal prostheses, which are much stiffer than typical bone. This stiffness difference between natural bone and metal caused problems under typical physiological conditions often leading to osteoporosis or other healing problems.
To overcome this undesirable mechanical side effect, the concept of mixture of two different materials was developed to create achieve a mechanical behavior as close as possible to the natural bone.
The researcher has been focused on the design of a prosthesis device on a combination of two materials: flexible porous polymers, reinforced with a ceramic material. Light and flexible polymers, in this setting played the role of tubular bone, while the ceramic material gave mechanical reinforcement to the polymer. Bone prostheses built of such a combination of materials much closer imitate the mechanical property of the natural bone.
Other promising materials investigated for polymer reinforcement are *aramid fiber* (also known as Kevlar), natural *bamboo fibers*, and *bioactive glass* which is a special type of glass which gives mechanical reinforcement to the polymer matrix.
The greatest advantage of composite materials is that the mechanical properties can be be adjusted as needed by changing the proportions of the polymer and reinforcement agent. The use of such composite materials avoids the stiffness difference problems between metal implants and bone which caused complications like osteoporosis, mentioned earlier.
In future research other materials will be also investigated. Some attention has been recently paid to carbon fibers which offer hope for finding an even better solution as they are radiolucent, heat-resistant, very light weight, and extremely strong.

Links

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