Challenge based learning (CBL)

Design of a smart scaffold with a bioelectronic sensor to sense BMP-2 release and bone formation in bone grafts

Note for teachers: A CBL user guide can be found at www.jandeboerlab.com/TissueEngineering with instructions and tips to run an effective CBL teaching session.

Background and vision

Small bone defects can be treated with bone graft materials and recombinant growth factors but the golden standard for the treatment of large bone defects is the autograft, in which bone is moved from one part to another within the body. Many engineers attempt, and succeed, to improve the osteogenic potential of graft materials but assays to predict in vivo bone formation using in vitro assay are unreliable. Animal experiments and imaging are the only way to conclusively demonstrate the efficacy of a novel graft. In these models, bone formation is an endpoint measurement, in which the tissue is surgically removed from the euthanized animal after weeks to months of implantation to evaluate bone quality. This totally ignores the dynamics of tissue formation and leaves the researcher with little information about the in situ bio-activity of the grafts. The long-term vision is to design experimental grafts which are able to monitor the bone formation process in living animals.

Motivation and stakeholders

The field of bio-electronics has many opportunities, with ever smaller size of the electronics and incorporation of molecular analysis. There is an opportunity to design biosensors that rely on electrical signals generated once the bone is loaded and unloaded to unveil bone formation and quality. Newly designed grafts to monitor in situ bone formation should consider the needs, requirements and regulatory, financial and technical boundary conditions defined by stakeholders such as Orthopaedic surgeons, biomaterial engineers and micro-electronic experts.

Problem definition

Bone morphogenetic protein-2 (BMP-2) is a growth factor involved in bone formation, and it has been applied for spinal fusion therapy for years now. However, the amount of BMP-2 needed to achieve fusion far exceeds physiological levels. Still, the use of BMP-2 and other growth factors may eventually also substitute autologous grafting but for this, its in vivo bio-activity should be closely monitored.

Challenge

To design a bone graft using electrical signals generated when the bone is loaded/unloaded which is able to monitor BMP-2 activity and bone formation in situ.

Learning framework

Reading the Bone Tissue Engineering chapters and related literature will help you to understand:

1. Critical size bone defects.
2. Graft materials used to treat large bone defects.
3. The use of BMP-2 as a bone inducing growth factor.

For a more focused examination of the challenge, read scientific literature and create a mind map to include information about the following:

4. Bioelectronics and which biomaterials are conducive to biosensors.
5. Manufacturing of bioelectronic sensors.
6. Current techniques used to study the release of BMP-2 in tissue microenvironment.
7. Biomarkers in the tissue microenvironment to monitor BMP-2 activity

End product

A three-minute video explaining the solution of your challenge. Please include your motivation and the steps to execute your solution.