NUS Graduate School for Integrative Sciences and Engineering
Research Project Write-up

Title of Project :	Biomimetic functional scaffold and adult mesenchymal stem cells for musculoskeletal tissue engineering applications
Name of Supervisor :	Prof James Goh
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Short Description

Silk from the silkworm, Bombyx mori, has been used as surgical suture material for centuries. Due to its biocompatibility, slow degradability, and remarkable mechanical properties, my group has been studying the use of silk as the scaffold for ligament, cartilage and bone tissue engineering. The silk fibers can be fabricated as a scaffold with excellent mechanical properties similar to the native ligament. Mesenchymal stem cells (MSCs) can attach, proliferate, and differentiate on it. Silk scaffold modified with short polypeptide can significantly increase collagen synthesis on it. To increase cell attachment and tissue infiltration, the silk scaffold can be incorporated with silk-gelatin microsponges. We have designed and developed a novel silk cable-reinforced gelatin/silk fibroin hybrid scaffold, which apart from providing proper mechanical strength and enlarged surface area, also supported the proliferation and differentiation of MSCs on it. The knitted silk mesh is another important silk-based scaffold for its excellent mechanical properties and good nutrients transport. To prevent cells from leaking out of scaffold after seeding, electrospun nanofibers or freeze-dried silk microsponges have been incorporated into the macro pores of knitted scaffold. While the knitted structure held the micro pores or nanofibers together and provided the structural strength, the microporous or nanofibers structure could mimic the ligament extracellular matrix to promote cell proliferation, function, and differentiation. In-vivo animal models have been used to evaluate the functional efficacies of the use of silk scaffolds and stem cells in musculoskeletal tissue repair. There are potentials of new innovative ideas to be incorporated in such tissue engineering strategy for musculoskeletal tissue regeneration.

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Research Project Write-up

Title of Project : Injuries to knee cartilage and ligament following impact loads

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Short Description

High and rapid impact activities are widely known to subject the knee joint to abnormal kinetics and kinematics that will increase injury risk. We hypothesize that impact loads applied to the knee joint to simulate an injurious landing task are able to induce anterior cruciate ligament injury; at the same time, these loads can also inflict significant cartilage damage which may accelerate the risk of developing early-onset osteoarthritis. My group has used the motion analysis capture system with 6-componenets force platform to determine joint reaction forces in the knee during impact landing. This information is essential in designing experiments and development preventive devices. We have also use cadaveric specimens mounted to a material testing system at 70-deg flexion to simulate impact landing. Rotational and translational joint motion during compression was registered using motion-capture system. Compression was successively repeated with higher actuator displacement until a significant decrease in load response was noted; ligament failure was determined by magnetic-resonance imaging and dissection. Pre- and post-test cartilage thickness at anterior, exterior, posterior and interior tibiofemoral regions were measured using magnetic-resonance scans. Osteochondral explants were subsequently extracted from these regions and histologically-assessed using modified Mankin scoring system. Our system is capable of producing anterior cruciate ligament failure, where significant compressive force drop (80 - 91%) and substantial posterior femoral displacement (7.6 -18.0mm) were observed. Significant reduction in cartilage thickness was found post-failure, especially for posterior-exterior tibiofemoral regions. The cartilage damage profiles implied a ligament failure mechanism dominated by anterior tibial translation; this level of damage was analogous to mild-moderate osteoarthritic stages. Large impact loads can cause both anterior cruciate ligament injury and cartilage lesions, which may synergistically lead to early-onset osteoarthritis. These data provide important information for design of prophylactic device for prevention of knee injuries.