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ACL Healing with Degradable Scaffolds

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I. Introduction

A. Management of ACL Injuries

B. Mismatch Between Anatomy & Function

C. Renewed Interest in ACL Healing

II. Background –

A. Study 1: Healing of central third defect of patellar tendon (PT) (rabbit)

Message: Can make more neo tissues

B. Study 2: Healing of MCL gap injury (goat)

Message: Can grow better tissues

III. Biological augmentation – Extracellular Matrix Bioscaffolds - Porcine Small Intestine Submucosa (ECM-SIS) and SIS Hydrogel for ACL Healing (goat model)

A. ECM-SIS has contact guidance ability and its growth factors can heal ligaments and tendons. Adding injectable SIS hydrogel would better fill wound sites and promote more effective release of growth factors

B. Surgical model: Wrap wound site with ECM-SIS sheet and inject with hydrogel into a transected ACL

C. After 12 weeks, all transected ACL healed. Results showed:

1. Continuity of ACL was restored and without tissue hypertrophy
2. Collagen fibers in the healing ACL were parallel with spindle-shaped cells
3. A new synovium was formed around the neo-ligament to protect the healing tissue
4. A-P tibial translation was reduced & in-situ forces in the healing ACL were close to those for the intact ACL
5. The structural properties (stiffness and ultimate load) were more than twice that of suture-repaired controls and they were comparable to ACL-reconstruction

Message: Biological augmentation improved ACL healing significantly

D. From 12 to 26 Weeks

1. The healed ACL has a full and dense collage matrix
2. Failure mode during tensile testing changed from transection site (no longer the weakest link) to femoral attachment
3. Deterioration of the insertion sites was caused by disuse during ACL healing

IV. Mechanical Augmentation – Adding a device that could load the ACL as well as to help stifle joint stability during healing

A. Magnesium (Mg) ring

1. Patent application filed in the US, China and EU

2. Mg is biocompatible, has suitable mechanical properties and it is biodegradable and bioresorbable – so that its functional role can be replaced by the healing ACL

B. In Vitro Testing

1. The Mg-based ring was found to restore initial A-P stability and load the repaired ACL as well as the insertion sites at time-zero

C. In-Vivo Goat Model: Mechanical Augmentation plus Biological Augmentation

D. Early Healing (6 weeks)

1. Healing tissue has formed
2. ECM sheet had degraded
3. Mg ring has also begun to degrade

E. At 12 Weeks

1. Histologically, transected ends of the ACL are no longer visible; ECM and sponge resorbed; only small particles of Mg were embedded within the healing ACL
2. Healing ACL composed of continuous, opaque tissue with aligned collagen fibers; no hypertrophy; no cytotoxicity; no osteochondral lesions or defects
3. Stiffness and strength were 145%-150% of ECM treatment and 142%-180% of reconstructed ACL

Message: Mechanical augmentation that stabilized the stifle joint and aided tissue healing that resulted in a robust healing ACL!

V. On Going Studies – 26 week study for long term results

A. To examine if the weakening of the femoral attachment can be prevented and further, the positive results of the healing ACL are persisted and improved

VI. Preparation for Clinical Translation

A. Analysis and design (scaling up)

B. Cadaveric studies

C. Arthroscopic delivery

D. Biocompatibility studies