New Bioengineering Approaches for Management of Soft Tissue Injuries

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Ligaments and tendons are bands of dense connective tissue that bind the skeleton. Laboratory experiments have demonstrated that ligaments and tendons display complex biomechanical behavior, including nonlinear stress-strain relationships and time and history dependent nonlinear viscoelastic properties. With these properties, ligaments help the joints to move smoothly while limiting excessive displacement between the two bones. Tendons, on the other hand, attach muscle to bone and their major function is to transfer the force generated by muscles to move the joint. As such, ligaments and tendons can experience large, repetitive forces during normal activities. Thus, their injuries are extremely common. Tendinopathy, which is associated with overuse of tendons, is a disability that accounts for 30-50% of all sports injuries and more than 48% of the reported occupational illnesses. Further, these tissues are subject to frank tears during sports.

In this lecture, we will briefly review the current status of our understanding of the anatomy, biology, and biomechanics of the normal and healing ligaments and tendons. Along the way, we will demonstrate how laboratory science has changed the clinical management paradigm. For example, basic science studies have discovered that a ruptured medial collateral ligament of the knee can heal spontaneously and surgical management is no longer needed. However, the healed tissue has abnormal tensile and viscoelastic properties together with abnormal biochemistry and ultrastructure.
As a result, new functional tissue engineering approaches are being explored to improve the quality of these healing tissues.

For the anterior cruciate ligament (ACL) of the knee, a midsubstance tear of this tissue will not heal, and surgical reconstruction using tissue autografts are frequently done. Unfortunately, 20-25% of the patients have shown to have less than satisfactory results and investigations designed to examine the function of replacement grafts in comparison to those from the normal ACL, are being conducted. In our research center, a novel testing system based on robotic technology has been developed to obtain quantitative data on multiple degrees of freedom (DOF) of kinematics of the knee and the in situ forces in the normal ACL and replacement grafts. As a result, better understanding of the complex function of the ACL can be appreciated and new and improved strategies for surgical approaches have been suggested.

It is clear that the complexity of ligament and tendon research will require collaboration between different disciplines. Therefore, major efforts will need to be made in order to develop cooperation between biologists, biochemists, biomedical engineers, physicians, and surgeons to work together seamlessly such that the outcome of the treatment of ligament and tendon injuries for our patients can be improved. Specifically, developments of tools and techniques, as well as mathematical modeling, are advocated. With these improvements, better knowledge of the loading conditions during *in vivo* activities such as rehabilitation and sports exercises will be gained.