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An Evolutionary Materials Science Approach to Ligament Tissue Engineering

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Introduction

The anterior cruciate ligament helps to keep the knee stable. It is, unfortunately, the most frequently torn intra-articular ligament. Because of its inadequate vascularization, the ACL has a limited ability to mend and is routinely replaced after substantial damage. The lack of currently available substitutes has motivated the hunt for tissue-engineered ACL repair treatments. Scaffolds now being studied range from twisted silk fibre architectures to complicated three-dimensional braided constructions made of poly l-lactic acid fibres. The goal of these tissue-engineered structures is to use techniques such porous scaffolds, cells, and growth factors to encourage ligament tissue regeneration while maintaining mechanical qualities that are similar to native ligament [1].

Description

The anterior cruciate ligament is the most commonly damaged ligament in the knee. The ACL is the knee's main intra-articular ligament, and it's important for appropriate kinematics and stability. By linking the femur to the tibia and supporting the joint, the regulates mobility and prevents aberrant motion [2]. Its primary duties are to support and strengthen the knee, as well as to avoid excessive anterior translation of the femur, which can result in a dislocation and fracture of the knee's bones. Collagen, elastin, proteoglycans, water, and cells make up the ACL, which is a dense, well-organized, cable-like tissue. The average length of the human ACL is and its cross-sectional area is Ligaments are organised in a hierarchical structure that includes collagen molecules, fibrils, fibril bundles, and fascicles that run parallel to the tissue's long axis. The collagen fibrils in ligaments have a crimp pattern, which is a periodic shift in direction. This crimp pattern is repeated every time in ACL. Collagen fibrils, proteoglycans, and elastin are found in the fascicles. A vascularized epiligament sheath surrounds the ligament. The collagenous network is twisted by roughly 180° from the femoral attachment site to the tibia attachment site, creating an additional level of structure [3].

When exposed to tension, Ligaments exhibit diphasic behaviour. The non-linear or toe area, for example, is characterised by low stress per unit strain. Following this is the linear zone, which is known for having a higher stress per unit strain. The failure is indicated by a modest drop in stress per unit strain in the final section. The yield and failure zone is located here. The ligament's components and their arrangement in the tissue are responsible for this distinct behaviour. Force is transferred to the collagen fibrils when force is first applied to the tissue. Crosslinks, interfibrillar slippage occurs. As a result, the stress per unit strain rises. Finally, defibrillation causes the collagen fibres in the ligament to collapse, resulting in a reduction in stress per unit strain and tissue failure. Inflammation, cellular proliferation and matrix repair, and remodelling are the three steps of ligament healing after an injury [4]. Serous fluid collects in both the ligament and the surrounding tissues at this stage, and the injured area becomes. The wound attracts monocytes, leukocytes, and macrophages. Fibroblasts are present in the cellular proliferation and matrix repair stage, and vascular granulation tissue is generated. Collagen with a high ratio of type III to type I collagen is synthesised, resulting in the formation of a new extracellular matrix. Remodelling is the final stage, which takes several months. The new extracellular matrix grows into a slightly disordered hyper cellular tissue at this stage. The lack of vascularization prevents the ACL from healing. When collagen fibres are kept in a continuous state, optimal healing occurs. The mechanical characteristics of the new scar tissue and the original ligament differ due to a loss of tissue structure and a change in crimp pattern between the new and old extracellular matrix, resulting in a drop in mechanical properties. An insertion point surgery is required when an accident causes a thorough rupture of the ligament midsubstance or detachment of the ligament [5]. The loading of the joint causes inappropriate tension on the articular cartilage, which can lead to early osteoarthritis if the ligament is not healed.

Conclusion

Biological grafts, autografts, and allografts have traditionally been used to treat ACL injuries. ACL autograft material is often derived from the patient's patellar tendon, hamstring tendon, or quadriceps tendon. Most surgeons prefer to use autografts from the patella and hamstring tendons. The patellar tendon graft material is usually removed from the patella and the insertion location on the tibia with a piece of bone. After that, the "bone–patellar–bone" graft is fed. Because of the limitations of both biological and synthetic grafts, tissue-engineered alternatives for ACL restoration are becoming increasingly popular. Biodegradable, inflammatory-free, and porous, the optimal ACL replacement scaffold should be. It should have sufficient mechanical strength, mechanical behaviour similar to that of a native ACL, and encourage ligamentous tissue growth. The scaffold should deteriorate at a rate that allows fresh materials to be added. As the number of ACL injuries rises, novel ligament repair methods are needed to overcome the limits of present treatments. Scaffolds made with tissue engineering techniques are becoming a feasible ACL repair option. These scaffolds may be tweaked to offer just the right amount of mechanical support, which is crucial for load-bearing tissue. Tissue-engineered scaffolds have also been found to increase cell adhesion, proliferation, and proliferation of cells.

Conflict of Interest

None

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