BIOMECHANICS OF BRAIDED, LONG-TERM BIODEGRADABLE SCAFFOLDS FOR ACL TISSUE ENGINEERING

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Introduction

Anterior cruciate ligament (ACL) injuries are among the most common sport injuries with an incidence of 1:3500. It is estimated that one million cruciate ligament tears occur worldwide each year. Tendons and ligaments have a limited self-healing capacity.

Current treatment methods are based mainly on autologous implants, which are subject to limited availability, donor site morbidity and a second surgery site. As a result of its inability to sustain the mechanical load in the knee over the long term, synthetic cruciate ligaments are rarely used nowadays. Deficits exist in terms of biological compatibility, fatigue strength, and friction resistance.

In order to regenerate a functional ligament, tissue engineering uses a three-dimensional scaffold that offers temporary mechanical stability and promotes cell ingrowth.

Textile scaffolds are reproducible and scalable, and offer a three-dimensional structural design. Additionally, braided scaffolds can be produced with high strength, efficient loading, and sufficient porosity for cell ingrowth.

The aim of this study is to investigate long-term degradable scaffolds based on poly-ε-caprolactone (PCL) for ACL replacement using the round braiding technique.

Methods

The scaffolds are based on melt-spun PCL monofilaments [1]. The round braiding technique was used for scaffold fabrication. Five different scaffolds based on different braiding parameter combinations are investigated.

The influence of different braiding parameters regarding the maximum tensile load, elongation and stiffness (linear and toe region) are evaluated by tensile test. The tensile testing is performed in physiological length of the ACL (n=10). Furthermore, the critical morphological parameters for tissue engineering like porosity and pore size are characterized by µ-CT scans.

Results

The braided scaffolds reach tensile forces of approximately 4000 N. Thus, all scaffolds exceed the tensile forces of the native ACL (734-2160 N) [2]. Thereby, the implants do not exceed the diameter (9 mm) of the bone channel of the conventional surgical methods.

The filament arrangement, the braid angle and braiding pattern significantly influence the stiffness as well as the maximum tensile force of the braids. The stiffness is a crucial mechanical value for physiological movement of the joint. The stiffness values of the linear region of the braids (131-236 N/mm) matches the native human cruciate ligament (180-242 N/mm) [2].

Porosity and pore size are crucial factors for cell ingrowth and tissue regeneration. Especially three-dimensional textiles provide an interconnected pore structure and possible guidance structure for cells.

Discussion

Overall, it can be concluded from the results of the testing that the requirements for ACL replacement can be achieved successfully. By adjusting the braiding parameters, further ligament applications such as medial and lateral knee ligaments or the rotator cuff can be addressed. Both the cell behavior on the scaffolds and the degradation behavior will be investigated in further research.

References

1. Bauer et al., Fibers, 10(3):23, 2022
2. Noyes, F. R. et al., J of Bone and Joint Surgery, 58, 1976