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Static tensioning promotes hamstring tendons force relaxation more reliably than cycling tensioning

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ABSTRACT

Background: Graft elongation might be a major reason for increased anterior laxity after anterior cruciate ligament (ACL) reconstruction. This study analyzed the force relaxation values and their stabilization when single strands of the gracilis and semitendinosus tendons underwent cyclic and static tensioning at 2.5% strain level, and compared the efficiency of static and cyclic tensioning in promoting force relaxation.

Methods: Eighteen gracilis tendons and 18 semitendinosus tendons from nine male cadavers (mean age: 22.44 years) were subjected to 10 in vitro cyclic loads at 2.5% strain level, or to a static load at 2.5% strain level.

Results: During cyclic loading, the reduction in force values tended to stabilize after the sixth cyclic load, while, in the case of static loading, this stabilization occurred by the second minute. Comparing static and cyclic loading, the gracilis tendon had similar mechanical responses in both conditions, while the semitendinosus tendon showed greater force relaxation in static compared with cyclic loading.

Conclusions: Considering that the semitendinosus tendon is the main component of the hamstring graft, its biomechanical response to loading should guide the tensioning protocol. Therefore, static tensioning seems more effective for promoting force relaxation of the semitendinosus tendon than cyclic tensioning. The gracilis tendon showed a similar mechanical response to either tensioning protocols.

1. Introduction

The success of surgical reconstruction of the anterior cruciate ligament (ACL) depends on several variables, including: graft selection, bone tunnels positioning, fixation system, postoperative rehabilitation program, and the mechanical behavior of the graft after fixation [1–5]. Graft elongation after definitive fixation might be a major cause of surgical failure [6]. Although tendon

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grafts preconditioning on the graft board seem to be helpful to prevent post-implantation graft elongation, it is not regularly performed in clinical practice. Therefore, during ACL reconstruction, graft tensioning is commonly applied after one of the ends of the graft has been fixed. This procedure aims to reduce the occurrence of excessive graft elongation postoperatively, and it is obtained by loading the graft statically or cyclically before undertaking definitive fixation. However, the ideal level of graft tensioning when using tendon grafts to reconstruct the ACL remains to be established. Graft tensioning is commonly undertaken, but it is still performed in an empirical fashion, as there is no consensus on the ideal tensioning levels [7,8]. Clinically, undertensioning the graft could lead to the risk of residual laxity after implantation. This must be balanced against the risk of overconstraining the knee, which may lead to pathologic stresses on the articular cartilage, graft failure, or infrapatellar contracture [9,10].

Human tendons have no uniform cross-sectional area. Therefore, calculating the adequate tension to be applied to each tendon graft has clinical limitations; this issue is particularly evident when tendons with different diameters and sizes are used together, as in ACL reconstruction.

The response of tendon grafts subjected to tension has been studied [11,12], but the behavior of the grafts used in ACL reconstruction is complex, as commonly two tendons (gracilis and semitendinosus) are used together to reconstruct the ACL [13]. During normal activities, tendons and ligaments in humans are subjected to strain <5%, which is the upper physiological limit before plastic deformation takes place [14,15]. Knowledge of the response of tendons to tensioning may play a major role in optimizing surgical results.

The present study investigated the behavior of single strands of human gracilis and semitendinosus tendons subjected to in vitro static or cyclic tensioning at 2.5% strain to define the response to static or cyclic loading of human gracilis and semitendinosus tendons, and the influence of relative deformation and force on controlling graft tension. This study aimed to determine the force relaxation values and its stabilization when single strands of the gracilis and semitendinosus tendons underwent cyclic and static tensioning at 2.5% strain level. The second aim of the present investigation was to compare the efficiency of static and cyclic tensioning in promoting force relaxation matching the percentage of mean force relaxation values until the second minute and sixth cycle of testing, which is a period where the force relaxation values were stabilized in the respective mechanical tests that were performed.

2. Materials and methods

This study was conducted on 18 human gracilis tendons and 18 semitendinosus tendons removed from nine male cadavers (age range: 16–34 years, mean age 22.44 years). All the procedures described in the present investigations were approved by the Medical Research Ethical Committee of the Medical Science School of this University under Project number 168/99.

All the tendons were harvested within 24 h of death. A longitudinal incision was performed centered on the pes anserinus over the anteromedial aspect of the tibia. The sartorius aponeurosis was opened by sharp dissection, and the insertions of gracilis and semitendinosus tendons on the tibia were visualized. The tendons were isolated and harvested with an open stripper. The tendons were then wrapped in gauze soaked in 0.9% saline solution and stored in sealed plastic bags at −20 °C. Before testing, the tendons were gently defrosted at room temperature overnight (10 h) to conduct the tests [16].

The tendons were divided into two groups according to the mechanical assays: static or cyclic tensioning. The first group of tendons was subjected to 10 in vitro cyclic loads at 2.5% strain, and the value of the deforming load used for each cycle was recorded. The second group was subjected to a 2.5% static strain, and the value of the deforming force was recorded at the end of each minute. In this study, the relative deformation level adopted was 2.5%, as it falls within the physiological limit of human tendons. During the tests, the tendons were fixed to a sinusoidal clamp system with grooves. Each clamp had four screws tightened to a torque of 2.5 N mm using an AVT 100A Britool torquemeter model (Britool Ltd, Sheffield, England) with a scale ranging from

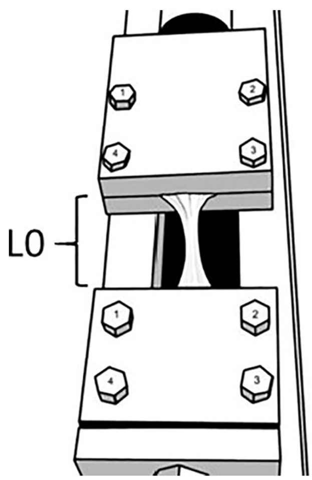

Figure 1. Schematic drawing of the sinusoidal clamp system used in both tensioning and the calculus of initial body test (L0).

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