The effect of strand configuration on the tensile properties of quadrupled hamstring autografts

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Introduction:

Previous biomechanical studies have shown that quadruple hamstring grafts do not replicate the mechanical properties of the normal anterior cruciate ligament (ACL). The ultimate strength and stiffness of conventional hamstring grafts are approximately 100% greater than the corresponding properties of the native ACL. This has led to attempts to modify autografts to better match the stiffness of the ACL without loss of load-carrying capacity. This study was performed to examine the effects of changes in the strand configuration of quadrupled tendon grafts on the balance of graft strength, stiffness, and permanent elongation after repetitive loading.

Material and Methods:

Forty-four medial and lateral hoof extensor tendons were harvested from young calves. Each graft was prepared with two tendons of equal length and diameter looped around a post and arranged in four different geometric configurations: (1) the conventional parallel, (ii) two different braided patterns (braid and bolo), and (iii) a twist configuration. After preparation, each graft was then pretensioned with 100N for 20 minutes, and then attached via the looped end to the base of a servohydraulic testing machine (MTS Corp., MN) with the free tendon ends mounted in a custom-designed cryo clamp. The grafts were cyclically loaded for 60 cycles at 0.5 Hz using a ramped amplitude function which increased the peak applied load by increments of 50N per cycle to a maximum load of 3000N. The load was then removed and the graft tension was allowed to relax to zero load for 120 seconds. The entire loading and relaxation sequence was then repeated (Figure 1).

Results:

The average load to failure of the four graft configurations was 5703N, primarily due to the specialized design of the cryo clamps that prevented premature failure at the tensile grips. The average failure load of the standard parallel configuration was 5569±1082N compared to 6499±490N (+17%), for the twist, 5569±1634N (0%) for the braid, and 5174±1005N (-7%) for the bolo. These differences were not statistically significant (p = 0.171).

Strand configuration significantly reduced the stiffness of the grafts (p<0.0001). The parallel and twisted grafts were the stiffest constructs (1,019±210N/mm and 1018±170N/mm). In comparison, the braided and bolo grafts were less stiff by approximately 30% (734±193N/mm and 675±120N/mm). There was also a dramatic change in the permanent elongation of the different graft configurations after sub-failure loading, ranging from 3.3% for the parallel construct to 7.2% for the braid, 6.6% for the twist and 6.5% for the bolo (p<0.000). Permanent graft strain after a second incremental loading was 1.2% in bolo, 1.1% in braid, 0.7% in twist, and 0.7% in parallel preparations (p = 0.001) (Figure 2).

Discussion/Conclusions:

Our experiments confirm that modifications to the conventional parallel strand configuration of quadruple hamstring grafts does significantly reduce the stiffness of these constructs without appreciable loss of ultimate strength. However, all three variations from the parallel strand configuration led to twice the permanent elongation of each graft after cyclic loading. In clinical practice, this response to repetitive loading is expected to lead to increased patholaxity of the reconstructed knee, outweighing any potential benefits attributable to reduced graft stiffness.