Biomechanical properties of braided polyester tapes intended for use as intra-articular cranial cruciate ligament prostheses in dogs

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Objective—To determine the in vitro structural and material properties of braided, multifilament, nonabsorbable polyester tapes, used for intra-articular stabilization of cranial cruciate ligament- (CCL-) deficient stifle joints in dogs, and compare those with properties of multifilament polyamide tapes.

Sample Population—30 polyester tapes (width, 4 mm), 10 polyester tapes (width, 7 mm), and 30 polyamide tapes (width, 4 mm) were tested to failure. Cyclic loading experiments were also performed, using 3 polyester tapes of each width.

Procedure—Tapes were mounted in a tensile tester as single loops, simulating intra-operative conditions, and elongated to failure at 1,000 mm/min. Additionally, the behavior of polyester tapes was tested at different elongation rates. In a second series of experiments, biomechanical variables of the polyester tapes were measured after 25 sets of 2,000 cycles between physiologic force limits.

Results—Mean (± SD) ultimate loads of the 4-mm wide polyamide tapes, 4-mm wide polyester tapes, and 7-mm wide polyester tapes were 266.48 ± 13.19 301.78 ± 16.92, and 726.40 ± 37.74 N, respectively. Corresponding stiffnesses were 15.57 ± 0.49, 21.63 ± 2.19, and 34.85 ± 2.66 N/mm, respectively. Failure properties of polyester tapes were affected by previous cyclic loading.

Conclusions and Clinical Relevance—Polyester tapes of 4- or 7-mm widths should be able to resist forces resulting from weight bearing in dogs, suggesting that these tapes will be effective for stabilization of the stifle joint in dogs with a ruptured CCL. (*Am J Vet Res* 2001;62:48–53)

Rupture of the **cranial cruciate ligament (CCL)** is a common clinical problem in dogs.[1,2] Instability of the stifle joint results in lameness and rapid development of **degenerative joint disease (DJD)**.[3] The major goal of surgical repair of a ruptured CCL is to improve functional performance of the stifle joint.[3] A number of procedures have been developed and evaluated.[4] It is believed that intra-articular implantation of a prosthesis can better mimic the original position and function of the CCL, compared with extracapsular placement of stabilization sutures.[5] Presently, regardless of the surgical procedure performed, consistent restoration of normal stifle joint biomechanics and complete arrest of the progression of DJD is still not possible.[6]

Numerous autografts and synthetic materials have been used for reconstructive surgery of the CCL.[4] In the early 1980's there was considerable interest in the development and use of synthetic prostheses for repair of human cruciate ligaments.[7] Although surgical management of a ruptured CCL in dogs, using various artificial prostheses, has been reported, there have only been a few reports describing the mechanical behavior of synthetic extra-articular CCL substitutes.[8,9] Any replacement material should behave in a manner similar to the natural ligament in the expected range of loading and should have load-elongation characteristics that closely resemble those of the original ligament during ultimate loading. However, the suitability of a prosthesis does not depend solely on tensile behavior. The recoverable elastic characteristics of the synthetic material are equally important for clinical use. Joint stability can not be guaranteed should the implant become severely elongated and stretched.[4]

Braided polyester sutures are often used in humans when a strong nonabsorbable suture is needed to help permanently repair tissue. The intra-articular use of braided, multifilament, nonabsorbable polyester suture material to repair ruptured CCL in dogs was described in 1986.[10] This technique has been used clinically ever since. The purpose of the study reported here was to determine the in vitro structural and material properties of a braided, multifilament, nonabsorbable polyester tape commonly used for intra-articular stabilization of CCL-deficient stifle joints in dogs and compare those with properties of a multifilament polyamide tape.

Materials and Methods

Sample population—Thirty 4-mm wide tapes and ten 7-mm wide tapes of a braided, multifilament, nonabsorbable polyester suture material,[a] commonly used as CCL prostheses in dogs, and thirty 4-mm wide tapes of multifilament polyamide material[b] were used to determine structural and material properties in a load-to-failure test. Because of the inferior material properties of polyamide in the simple load-to-failure test, the effects of cyclic loading on structural and material properties were determined, using 3 sets of each width of polyester tapes only.

Experimental protocol—Tests were performed in standard climate conditions (ie, relative humidity, 65 ± 2%; temperature, 20 ± 2 C). Load-to-failure tests were used to simulate traumatic overload conditions, whereas cyclic loading tests mimicked physiologic loading during daily activities.

Behavior of polyester and polyamide tapes in a simple load-to-failure test was characterized by determining the

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structural variables of stiffness, load, and energy absorbed and the material properties of static modulus and elongation.

Tensile tester—Polyester and polyamide tapes were mounted as loops in a tensile tester.[c] A personal computer with specialized software programs was connected to the microprocessor of the tensile tester. Data were collected via a built-in load cell and a displacement transducer.

Special clamping devices were designed by the principal investigator (HdR) to simulate in vivo fixation points of a CCL prosthesis; the proximal and distal clamps mimicked the femoral and tibial anchor points, respectively. The upper hook was rigidly mounted on a 1,000-N load cell. The lower clamp was attached to the moving cross head. The direction of loading was along the same orientation as would be used in a clinical setting. To simulate intra-operative conditions, the tapes were tied around the metal devices such that the knot was close to the distal anchor point. One person (HdR) tied all tapes; 4 throws were used and tightened securely as square knots. The knotted tapes had a constant original length of 100 mm.

The standard available computer programs for dynamic loading and relaxation did not meet the requirements for this study. Therefore, new software programs were written to set interclamp distance, lower and upper force limits, and rate of extension for load-to-failure and cyclic loading tests. Data were translated and stored in files on the personal computer connected to the tensile tester. To determine increases in length of the synthetic tapes, direct calculations were made from the displacement of the clamps. Material elongation was zeroed at the lower force limit. Data were written to a file, and test results were further analyzed, using commercially available software[d] on a remote computer.

Load-to-failure tests—To determine load at material failure, 4-mm wide polyester and polyamide tapes and 7-mm wide polyester tapes were loaded at a constant rate of elongation (1,000 mm/min) until they failed (ie, broke). The fast extension rate was used to more closely approximate loading conditions in vivo. Load and displacement data were recorded simultaneously by the testing machine and transferred to a remote computer for analysis. Load versus elongation curves were computed, and the following structural and material variables were obtained: ultimate load, elongation at 20, 50, and 100% of ultimate load, strain, stiffness at 50 and 100% of ultimate load, energy absorbed to failure, and static modulus for the physiologic range of forces.

To assess the influence of loading rate on load versus elongation curves, the polyester tapes were also tested at elongation rates ranging from 100 to 8,000 mm/min. Each polyester tape was divided into 3 equal pieces to minimize the effect of material variability on the elongation versus rate tests. Load versus elongation curves were determined.

Because intra-articular CCL prostheses will be in permanent contact with the synovial fluid of the stifle joint, additional load-to-failure tests were conducted, using 4-mm wide polyester tapes that had been immersed in saline (0.9% NaCl) solution.

Table 1—In vitro biomechanical properties of synthetic materials intended for use as cranial cruciate ligament (CCL) prostheses in dogs

Property	4-mm wide polyamide tape (n = 30)	4-mm wide polyester tape (n = 30)	7-mm wide polyester tape (n = 10)
Ultimate load (N)	266.48 ± 13.19[a]	301.78 ± 16.92	726.40 ± 37.74
Elongation* (mm)			
at 20% of ultimate load	3.02 ± 0.32[a]	2.02 ± 0.32	4.36 ± 0.46
at 50% of ultimate load	9.73 ± 0.58[a]	7.22 ± 0.77	10.82 ± 1.07
at 100% of ultimate load	17.10 ± 0.72[a]	14.03 ± 1.05	20.60 ± 1.66
Stiffness (N/mm)			
at 50% of ultimate load	27.37 ± 0.87[a]	21.12 ± 2.57	33.25 ± 2.94
at 100% of ultimate load	15.57 ± 0.49[a]	21.63 ± 2.19	34.85 ± 2.66

*Increase in length of tape from length at lower force limit.

[a] Significantly ($P < 0.001$) different from value for 4-mm wide polyester tape.

Cyclic loading tests—The effects of cyclic loading on 3 tapes of each width of polyester tape were determined in an attempt to reflect biomechanical conditions and abrasions resulting from daily activities. The test method was similar to that used previously to evaluate yarns.[11] The ideal resting time between sets of cyclic loading was determined in a preliminary study. Lower and upper force limits were calculated from the weight-bearing forces determined by use of force plate analysis, using dogs weighing approximately 12 and 25 kg, respectively.[12] The force limits were thus set at 25 and 87 N for the 4-mm wide tapes and 42 and 137 N for the 7-mm wide tapes.

Each polyester tape was cut in half. One half was repetitively loaded for 25 sets of 2,000 cycles between the 2 force limits at an elongation rate of 500 mm/min. This extension rate resulted in approximately 2 cycles per second; the hind limb stride frequency in healthy dogs at the trot approaches 2 Hz.[13] Between each set of 2,000 cycles, the synthetic material was allowed to recover for 20 minutes. During each cyclic loading test, residual elongation and the dynamic modulus were determined. A load-to-failure test was performed on each precycled tape at an elongation rate of 1,000 mm/min. For comparison, the other half of the same tape was elongated without cycling at the same rate until it failed. To facilitate comparison of load versus elongation curves, several variables were defined, including ultimate load, elongation at failure, stiffness at 50 and 100% of ultimate load, energy to failure, and static modulus.

Statistical analyses—Data were analyzed, using a commercially available software package.[e] Descriptive statistics were used to test for normality. Structural variables determined in the load-to-failure tests were compared between the 4-mm wide polyester and polyamide tapes by use of nonparametric Kruskal-Wallis rank tests. Differences in stiffness at 50 and 100% of ultimate load were compared among groups by use of a parametric 2-sample *t*-test. Mechanical data were compared between precycled and noncycled polyester tapes by use of paired *t*-tests. Differences were considered significant when $P < 0.05$.

Results

Load at failure—Ultimate load (ie, the force acting on the tested material at the moment of failure) and maximal linear load to failure (ie, to first sign of rupture) were not significantly different among any of the synthetic materials. At the moment of failure, the synthetic material most often immediately and almost completely ruptured. Mean (± SD) ultimate loads were 301.78 ± 16.92 N and 726.40 ± 37.74 N for the 4-mm and 7-mm wide polyester tapes, respectively. The 4-mm wide polyamide tape was significantly ($P < 0.001$) weaker than the 4-mm wide polyester tape (**Table 1**).

All relations between load and elongation during loading were expressed by the load versus elongation curves (**Fig 1**). The initial toe region, which was not

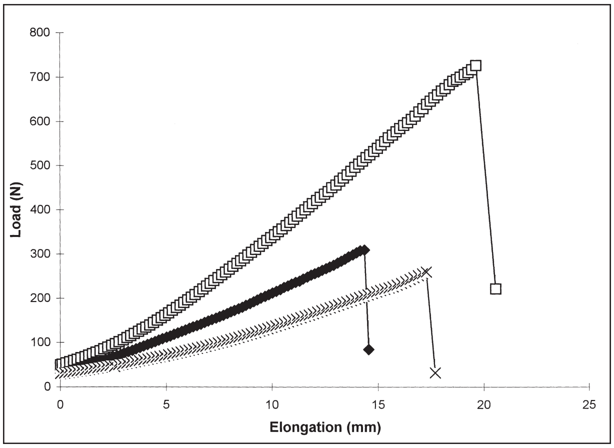

Figure 1—Representative load versus elongation curves obtained during load-to-failure testing of 4-mm wide polyester tapes (◆), 7-mm wide polyester tapes (□), and 4-mm wide polyamide tapes (X).

present in all curves, was not expressed. In that area, extension occurred with only a slight increase in load. All curves had a fairly linear pattern until failure. Only one mode of failure was observed during the load-to-failure tests, and the site of rupture was always located near the knot.

During load-to-failure tests, elongation was defined as the increase in length at any moment during the test. Elongation of the material at the lower force limit was considered the baseline elongation measurement. Change in length was measured relative to this reference point. Elongation prior to this point was attributable to knot tightening. At failure, mean elongation of the 4-mm polyester tape was 14.03 ± 1.05 mm, whereas elongation of the 7-mm wide tape was 20.60 ± 1.66 mm. Mean elongation at failure was significantly ($P < 0.001$) greater for the 4-mm wide polyamide tape, compared with the 4-mm polyester tape (Table 1). Elongation at 20 and 50% of the ultimate load accounted for 14 and 51% of the ultimate elongation of the 4-mm wide polyester tape, 21 and 52% of the elongation of the 7-mm wide polyester tape, and 17 and 57% of the elongation of the 4-mm wide polyamide tape.

To provide a better expression of real specimen elongation, strain to ultimate load was calculated and expressed as a percentage of elongation (ie, elongation at failure divided by mean initial length of the synthetic tape). The mean strain to ultimate load was 14.03 ± 1.05% for the 4-mm wide polyester tape, 20.60 ± 1.66% for the 7-mm wide polyester tape, and 17.10 ± 0.72% for the 4-mm wide polyamide tape. Strain was significantly ($P < 0.001$) greater for the 4-mm wide polyamide tape, compared with the 4-mm wide polyester tape.

Mean stiffness, which characterizes the rigidity of the material, at 50% of ultimate load was 21.12 ± 2.57 N/mm and 33.25 ± 2.94 N/mm for the 4- and 7-mm wide polyester tapes, respectively. The 4-mm wide polyamide tape was significantly ($P < 0.001$) stiffer at 50% of the ultimate load than the 4-mm wide polyester tape (Table 1). Stiffness of either width of polyester tape at 100% of ultimate load was not significantly different from stiffness at 50% of ultimate load. Both polyester tapes resisted loading in a similar manner throughout the entire test, as indicated by the linear pattern of the load versus elongation curves. In contrast, stiffness of the 4-mm wide polyamide tape at 100% of ultimate load was significantly ($P < 0.001$) decreased, compared with its stiffness at 50% of ultimate load. Mean stiffness at failure of the 4-mm wide polyester tape was significantly ($P < 0.001$) greater than that of the polyamide tape.

The amount of energy required to rupture the tested materials was represented by the area under the load versus elongation curves. For the 4- and 7-mm wide polyester tapes, mean energy to failure was 2,252 ± 170 N • mm and 7,877 ± 736 N • mm, respectively. Energy to failure of the 4-mm wide polyamide tape (2,212 ± 157 N • mm) was not significantly different, compared with the 4-mm wide polyester tape.

The modulus was also determined as the ratio of increase in force to the corresponding increase in length. The static modulus between the lower and upper force limits was 15.47 ± 1.48 N/mm and 20.01 ± 2.26 N/mm for the 4- and 7-mm wide polyester tapes, respectively. The static modulus of the 4-mm wide polyamide tape (8.83 ± 0.38 N/mm) was significantly ($P < 0.001$) less, compared with the 4-mm wide polyester tape.

Effects of extension rate on elastic and failure characteristics were determined for both widths of polyester tape. The lower force limits (25 and 42 N for the 4- and 7-mm wide tapes, respectively) were chosen as the first Y-value recorded. Extension rate did not significantly affect load versus elongation relationships. Immersion of the polyester tapes in saline solution prior to tensile testing also did not significantly alter any biomechanical characteristic measured.

Effects of cyclic loading—Pronounced differences were detected in the mechanical characteristics of the braided polyester tape as a result of cyclic loading (**Table 2**). Cyclic loading significantly reduced the strength of the 4-mm wide tape. However, no significant reduction in ultimate load was detected for the 7-mm wide tape. For both widths of polyester tape, energy to failure was significantly affected by precycling.

A significant decrease in further elongation at failure was detected for precycled tapes, compared with noncycled tapes. In addition, the load versus elongation curves for precycled and noncycled tapes revealed that the change in mechanical behavior of polyester tape was affected by cyclic loading (**Fig 2**). The initial slope of the curve for precycled tape was steeper, compared with noncycled tape. Stiffness at 50 and 100% of ultimate load for both widths of precycled tape was significantly greater, compared with noncycled tape (Table 2). Moreover, for both widths of precycled tapes, stiffness at 50% of ultimate load was significantly greater than that at 100%. Differences in stiffness were not detected for noncycled tapes.

The static modulus was determined from the linear part of the load versus elongation curves between the lower and upper force limits. Significant increases in this modulus were detected for both widths of tape after 25 sets of 2,000 cycles (Table 2). In addition, dynamic modulus and residual elongation data were recorded

Table 2—Effects of precycling* on in vitro biomechanical properties of synthetic materials intended for use as CCL prostheses in dogs

Property	4-mm wide polyester tape		7-mm wide polyester tape	
	Precycled (n = 3)	Noncycled (n = 3)	Precycled (n = 3)	Noncycled (n = 3)
Ultimate load (N)	271.32 ± 7.71[a]	317.46 ± 9.64	663.41 ± 20.25	678.22 ± 41.45
Elongation† (mm)				
at 100% of ultimate load	9.47 ± 0.57[b]	14.27 ± 0.40	14.40 ± 0.46[b]	19.87 ± 0.06
Stiffness (N/mm)				
at 50% of ultimate load	44.50 ± 4.80[a]	21.56 ± 0.47	54.92 ± 1.04[b]	31.86 ± 1.49
at 100% of ultimate load	28.69 ± 0.92[b]	22.25 ± 0.12	46.08 ± 1.35[a]	34.13 ± 2.04
Energy to failure (N • mm)	1,586.39 ± 113.1[a]	2,372.79 ± 142.3	5,707.19 ± 184.6[a]	6,847.76 ± 112.1
Static modulus (N/mm)	34.56 ± 5.00[b]	17.13 ± 2.04	55.30 ± 1.93[c]	21.17 ± 0.85

*Precycled tapes were subjected to 25 sets of 2,000 cycles between the lower and upper force limits (4-mm wide tape, 25 and 87 N, respectively; 7-mm wide tape, 42 and 137 N, respectively) before load-to-failure testing. †Increase in length of tape from length at lower force limit.

[a]Significantly ($P < 0.05$) different from value for the noncycled tape of the same width. [b]Significantly ($P < 0.01$) different from value for the noncycled tape of the same width. [c]Significantly ($P < 0.001$) different from value for the noncycled tape of the same width.

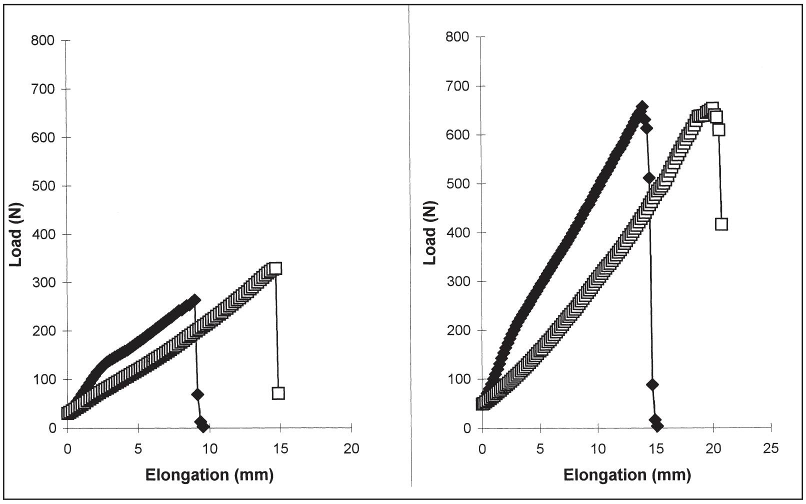

Figure 2—Representative load versus elongation curves obtained during load-to-failure testing of 4-mm wide polyester tapes (left) and 7-mm wide polyester tapes (right). Tapes were either subjected to cyclic loading (◆) before load-to-failure tests or were tested without prior cyclic loading (☐).

during the successive sets of cyclic loading. Dynamic modulus did not significantly change as the number of cycles increased. Because of the viscoelastic properties of the polyester tape, there was insufficient time for complete recovery of length between cycles. Residual elongation after each cycle thus accumulated, resulting in a gradual increase in length of the tape throughout the experiment. Elongation of the tapes at the lower force limit was set at zero. Further elongation was measured relative to this reference point. Residual elongation after dynamic loading is a measure of the permanent elongation when no stress is applied. After the first set of 2,000 cycles, mean residual elongation of the 4- and 7-mm wide tapes was 0.282 ± 0.07 mm and 0.253 ± 0.03 mm, respectively. At the start of the 25th set, elongation of the 4- and 7-mm wide tapes was 0.405 ± 0.147 mm and 0.333 ± 0.014 mm, respectively.

Discussion

Biomechanically matched prostheses that provide full joint stability after cruciate ligament surgery in humans or dogs are not yet available. The present study focused on the biomechanical properties of a material commonly used for CCL prostheses in dogs. This prosthesis, made of braided, nonabsorbable polyester tape, was compared with a polyamide tape because of the great similarity of the braiding structure and size of the implants. Unfortunately, we could not directly compare the synthetic materials with the CCL from a healthy dog.

Simple load versus elongation curves are particularly well suited for characterization of material behavior during loading. These curves can provide information on biomechanical properties that occur at the time of acute overload. The mean strength of the CCL from dogs, measured in vitro, is 46 N/kg of body weight.[14-16] A fast elongation rate was chosen for the load-to-failure tests in our study to mimic the in vivo loading conditions of acute overload. To assess synthetic materials intended for use as CCL prostheses, it is imperative to know the forces that the CCL must endure in vivo. Under physiologic weight-bearing conditions, ligaments from humans are subjected to loads ranging from only 10 to 25% of their ultimate load.[17] Accurate predictions of the functional demands of the CCL in dogs would aid in the search for the ideal prosthesis. However, the structural properties of CCL prostheses do not depend solely on the strength of the material. Results of cyclic loading tests can provide more data on mechanical variables than simple load-to-failure tests. The extension rates and force limits for the cyclic loading experiments in our study were chosen to be comparable with those encountered during normal activity. The loading of a particular limb and the stride frequency can be accurately determined by use of force plate analysis.[12,13] The polyester and polyamide tapes in our study were tested, using in vitro conditions that simulated the intra-articular stabilizing technique of Lieben.[10] The bony anchorages were mimicked by the design of the clamps, and a surgical knot was applied close to the distal tunnel.

Load versus elongation curves obtained with natural ligaments reveal an initial concave and a final convex region.[18] In contrast, we found a fairly linear relationship between load and elongation of the polyester tapes. These results suggest that polyester tapes may not be as strong as the CCL during in vitro testing, but these tapes should easily be able to resist the forces of weight bearing when used as a prosthesis in dogs. We found that all characteristics of the polyester tapes were superior to those of polyamide tapes of the same size.

Inclusion of a knot in the test procedure decreases the load at failure for most materials.[9] Additionally, testing a longer length of material will result in a decrease in the final load (weak link theory).[19] For technical reasons, the original length of the synthetic tapes was 100 mm, whereas the CCL in dogs is typically only 13.5- to 17.5-mm long.[16,20] Even when results of tensile loading experiments reveal that a synthetic material has superior strength, compared with the original CCL, there is no guarantee that such strength can be maintained for the rest of a dog's life. As do natural ligaments, synthetic prostheses have viscoelastic properties. However, a prosthesis is not able to elongate and recover to the same extent as the natural ligament. In dogs, the CCL should completely regain its original length following as much as a 14% increase in length.[20] Prostheses also are not able to repair microlesions and are susceptible to abrasion.[7] An inevitable decrease in biomechanical properties will thus occur.

Knot slide did not appear to be a notable problem in this study. By using knotted tapes, we were able to evaluate both the prosthetic material and knot properties. Elongation under loading is a measure of elasticity and knot tightening.[21] During tying of knots, a considerable loss in tension may occur.[8,22] We are not aware of data that describes the correct tension for grafts intended to restore joint stability.

We observed a fairly linear elongation to failure for both widths of polyester tapes. Elongation of the 7-mm wide tape was greater, compared with the 4-mm wide tape, especially during the first part of the test. Macroscopically, both widths are braided with an even number of fiber bundles. The 7-mm wide tapes, however, contain a higher number of filaments within each bundle. Because of the braided nature of the material, the filaments within the fiber bundles first stretch during loading. This effect will initially be more pronounced in the 7-mm wide tape, because its width can be reduced to a greater extent. Because of the periarticular structures in vivo, it is unlikely that this difference in elongation will have any clinical repercussion within the normal range of motion following surgical placement of the prosthesis.

The stiffness of the 100-mm long polyester tape loops only amounted to approximately 10% of the stiffness of a natural CCL.[6] A greater stiffness is expected for shorter loops.[23] The 7-mm wide polyester tape had more resistance to loading than the 4-mm wide tape. A CCL prosthesis should be stiff enough to avoid micromotion that may delay ingrowth of autogenous tissue during the early recovery period.[21] However, complications, such as rapid progression of DJD, are associated with prostheses that are too stiff. [24] The multifilamentous nature of the synthetic tapes may allow or promote ingrowth of autogenous tissue.[25-28] This tissue matures into collagen aligned parallel to the long axis of the prosthesis and will form an adequate neoligament.[26,28] A lack of ingrowth may be related to a chronic inflammatory response.[29] In contrast to autografts,[16,30] we found that the braided polyester tape absorbed a great amount of energy to failure, suggesting that this material may withstand vigorous trauma immediately after surgery.

The static modulus between 2 force limits indicates the amount of load necessary to increase the length of the prosthesis. In the present study, static modulus was low for both widths of polyester tape.

The rate of elongation used during load-to-failure testing of femur-CCL-tibia preparations significantly influences all failure characteristics.[18] However, rate of elongation has no effect on such preparations within the recoverable range of load and elongation.[20] Likewise, we did not detect any effect of elongation rate on the behavior of the polyester tape in the load-to-failure tests.

To properly reflect biomechanical conditions and abrasions resulting from daily activities, a special test procedure was designed in which the lower and upper force limits were load-controlled. During walking, the CCL is subjected to a rapid application and removal of force.[17] With no forces applied, viscoelastic recovery occurs. Cyclic loading between 2 force limits that are within physiologic range is intended to simulate the loading of a limb during normal ambulation. The lower and upper force limits that we used were derived from data on vertical weight-bearing forces in walking dogs that weighed 12 and 25 kg, respectively. The extension rate was representative of the loading conditions to which the stifle joint is subjected in a trotting dog. After cycling, the mechanical response of the polyester tapes was significantly different than that of the noncycled tapes. The 4-mm wide precycled tape failed at a lower ultimate load, but the ultimate strength of the 7-mm wide tape was not affected by precycling. Both widths of polyester tape progressively elongated under repetitive load cycles. Elastic deformations will disappear when the load is removed and when sufficient time is allowed for the material to return to its original length. However, we found that the precycled polyester tapes became permanently elongated; mean elongation of these tapes in the load-to-failure test was less, compared with that of the noncycled tapes. Both widths of precycled polyester tapes absorbed far less energy prior to failure than noncycled tapes. However, precycled tapes were still capable of absorbing the shock of traumatic overload.

A qualification of the data from the present study relates to the number of tapes tested during the cyclic loading experiment. Insufficient numbers of tapes were tested to allow for accurate determination of the dynamic modulus. Testing a larger number of tapes was impractical because of the duration of a single cyclic loading test.

Results of our study provide information on material properties of polyester and polyamide tapes under loading conditions. Direct extrapolation of the results to in vivo situations, nevertheless, is inadvisable. In vivo assessment is required to determine the biocompatibility and clinical efficacy of the braided polyester tape as CCL prosthesis in dogs.

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[a] Mersilene, Ethicon Ltd, distributed by Johnson & Johnson Medical bv, Dilbeek, Belgium.

[b] Lacs suspenseurs, Davis & Geck, distributed by Sherwood Benelux nv, Mechelen, Belgium.

[c] Statimat, Textechno-Herbert Stein, München Gladbach, Germany.

[d] Excel, Microsoft nv, Brussels, Belgium.

[e] Statistix, Analytical Software, Tallahassee, Fla.

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