Veterinary Surgery
35:476–479, 2006

Mechanical Evaluation of Two Loop Tensioning Methods for Crimp Clamp Extracapsular Stabilization of the Cranial Cruciate Ligament-Deficient Canine Stifle

ANDREW P. MOORES, BVSc, DSAS(Orth), Diplomate ECVS, ALISON L. BECK, BVSc(Hons), CertSAS, Diplomate ECVS, KARIN J. M. JESPERS, BSc, MSc, and ALAN M. WILSON, BSc, BVMS, PhD

Objectives—To describe a method of tightening nylon loops secured with a crimping system for extracapsular fabello-tibial stabilization of the cranial cruciate ligament-deficient stifle and to compare this with a method using a commercially available tensioning device.
Study Design—In vitro mechanical testing.
Methods—Fourteen standardized nylon loops were tensioned using a tensioning device and secured with crimp clamps. Another 14 loops were tightened by partially securing the crimp clamp, followed by tightening of the loop by hand, before definitively securing the crimp clamp. Loops were loaded to failure in a materials testing machine.
Results—Mean ultimate loads for instrument-tightened and hand-tightened loops were 383.7 and 371.4 N, respectively. Mean stiffness values for instrument-tightened and hand-tightened loops were 59.7 and 59.3 N/mm, respectively. These differences were not significant.
Conclusions—The hand tightening method does not affect the mechanical properties of the loop.
Clinical Relevance—The hand tightening method described is a valuable technique for unassisted surgeons without access to tensioning devices.

INTRODUCTION

CRUCIATE LIGAMENT disease results in partial or complete rupture of the cranial cruciate ligament (CCL) of the stifle and is a common cause of lameness in dogs. The resulting stifle instability is managed surgically in most dogs. The instability has traditionally been addressed by physically preventing the abnormal cranial–caudal movement, either by placement of an intraarticular graft or an extracapsular, fabello-tibial suture prosthesis.[1,2] More recently surgical techniques such as the tibial plateau leveling osteotomy (TPLO) have been described.[3] TPLO aims to create functional stifle stability during weight bearing, rather than physically preventing stifle instability. Despite the popularity of TPLO, extracapsular suture techniques have demonstrated equivalent efficacy[4,5] and remain a popular means of managing this condition.[6]

Various materials have been advocated for use as extracapsular sutures but most surgeons favor monofilament nylon leader line. Knotting large gauge nylon results in a bulky knot, which is one reason why the use of stainless-steel tubes (known as crimp clamps or crimp tubes) to secure the line has become a popular alternative to knotting. The 2 ends of the nylon line are passed through the crimp clamp in opposite directions and a crimping tool is used to pinch or "crimp" the metal tube thus securing the nylon line within. Previous studies have investigated the mechanical properties of different nylon lines, the effect of sterilization method on their mechanical properties and the effect of different knotting or crimping methods.[7–15] Crimp clamps offer biomechanical

From the Departments of Veterinary Clinical Science and Veterinary Basic Sciences, Royal Veterinary College, London, UK.
This study was supported by the donation of materials by Securos Inc., Charlton, MA.
Address reprint requests to Andrew Moores BVSc DSAS(Orth) DipECVS MRCVS, Department of Veterinary Clinical Science, Royal Veterinary College, Hawkshead Lane, North Mymms, Hatfield, Herts AL9 7TA, UK. E-mail: amoores@rvc.ac.uk.
Submitted March 2006; Accepted April 2006

0161-3499/06
doi:10.1111/j.1532-950X.2006.00178.x

advantages over knots. Investigators have consistently demonstrated that crimped nylon loops elongate less than knotted loops under tension.[7,10,13,14]

Tightening a nylon loop with a crimp clamp can be problematic if an assistant is not available to hold the loop tight as the crimp clamp is pinched. Additionally, whether an assistant is available or not, it can be difficult to vary the tightness of the loop incrementally to determine the optimum loop size to eliminate cranial–caudal stifle instability without adversely affecting stifle mobility. To assist an individual surgeon, tensioning devices have been developed by several manufacturers which allow incremental tightening of the loop and also maintain loop tension while the crimp clamp is secured. In our experience, these devices are not always easy to use and may require the use of additional crimp clamps. One of us (A.P.M.) has used a different method of tightening nylon loops before securing them with crimp clamps which, to our knowledge, has not been reported. This alternative strategy is to pinch the crimp clamp once, tighten the loop and then apply a further 2 pinches to the crimp clamp. The 1st pinch grips the line but is not strong enough alone to prevent further tightening of the loop. The line is pulled through the crimp clamp to tighten the loop and is held tight by the 1st pinch. When the desired loop length is achieved the crimp clamp is secured with a further 2 pinches. It is unclear if this tensioning method adversely affects the mechanical properties of the nylon loop.

Thus, our purpose was to mechanically compare loops tightened by the hand tightening method with loops tightened in a standard manner with a tensioning device. Our null hypothesis was that the tightening method would not influence the mechanical properties of the loop.

MATERIALS AND METHODS

Loops were formed using a commercially available crimping system (36 kg [80 lb] Cruciate Repair System, Securos Inc., Charlton, MA). The nylon line (Hard Type Monofilament Nylon Leader Line, Mason Tackle Company, Otisville, MI) was ethylene oxide sterilized (Anprolene AN79, Andersen Sterilizers Inc., Haw River, NC) for 24 hours at atmospheric pressure in a ventilated and purged sterilizer (Anprolene, Andersen Sterilizers Inc.) before loop formation. Nylon line was cut into 180 mm lengths and each end passed through a crimp clamp. Loops were tightened on a jig fashioned from external skeletal fixation components (Large SK, Imex, Longview, TX). The nylon loops were tightened around 2 carbon fiber connecting rods (9.5 mm diameter) positioned 60 mm from outer edge to outer edge. All loops were created by a single operator.

Fourteen loops were created and tightened using a tensioning device (Universal Tensioning Device, Securos Inc.). Crimp clamps (36 kg [80 lb] crimp clamps, Securos Inc.) were applied to the ends of the nylon line and the loop was placed onto the jig. The crimp clamps on the end of the line were placed into the jaws of the tensioning device as per manufacturer's directions and the tensioning device was opened to the 15th step of its ratchet mechanism (Fig 1), in this way ensuring that all 14 loops were tensioned similarly. Fourteen loops were created as above but tightened without the tensioning device. The crimp clamp was pinched once, with the jaws of the Securos crimping tool fully closed, in the middle of the tube. Each end of the line was then gripped with pliers and the loop was pulled tight, as tight as possible, over the jig. The ends were released and the final 2 pinches were applied to the crimp clamp, either side of the 1st pinch and avoiding the ends of the crimp clamp, before removing the loop from the jig.

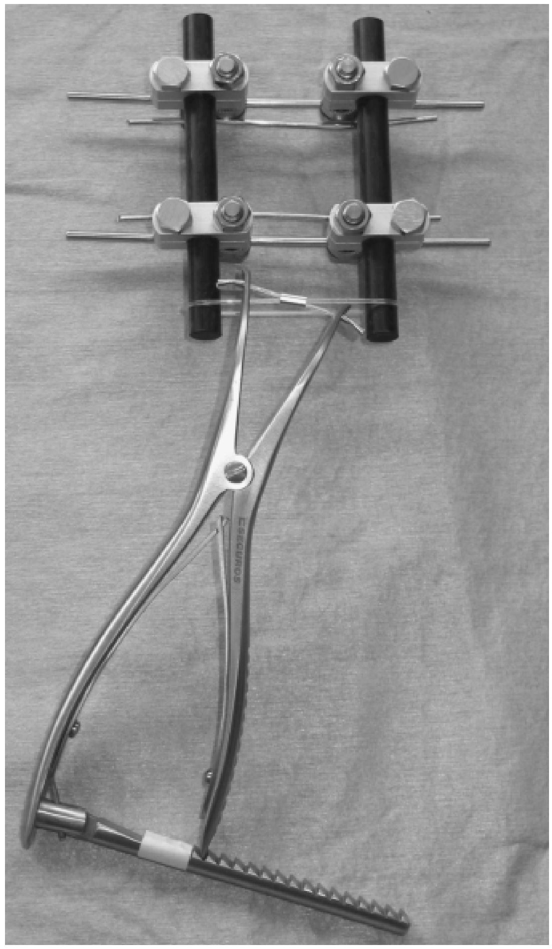

Fig 1. A suture loop mounted on the tightening jig and tensioned with the tensioning device.

Mechanical testing was performed using a servohydraulic materials testing machine as previously described.[15] Tensile loading to failure was performed at a distraction rate of 9.5 mm/s. Data was collected using a personal computer and data acquisition software (Matlab, version 6.5.0.180913a, release 13, The MathWorks Inc., Natick, MA) and imported into Excel (Microsoft, Redmond, WA) from which the ultimate load and the stiffness (during the elastic phase of each test) was calculated. Each test was filmed with digital video at 25 frames/s (DCR-PC110E, Sony Corporation, Tokyo, Japan) and reviewed with digital video editing software (iMovie on a PowerBook G4, Apple Computers, Cupertino, CA).

Data were analyzed with SPSS 13.0 for Windows (SPSS Inc., Chicago, IL). Descriptive statistics were reported as mean ± SEM. The Kolmogorov–Smirnov test was used to ensure data satisfied normality. Groups were compared with a 2-sample (independent) t-test. A P-value $< .05$ was considered significant.

RESULTS

Mean ± SEM ultimate loads for instrument-tightened and hand-tightened loops were 383.7 ± 7.2 and 371.4 ± 5.8 N, respectively. Mean stiffness values for instrument-tightened and hand-tightened loops were 59.7 ± 1.3 and 59.3 ± 1.1 N/mm, respectively. These differences were not significant. All loops failed by one end of the line slipping through the crimp clamp.

DISCUSSION

We found that a novel hand tightening method in which the crimp clamp is partially secured, the loop tightened, and then the crimp tube fully secured, does not affect the mechanical properties of the loops created. This is despite the nylon being pulled through a semi-tight crimp clamp before being definitively tightened. It is possible that forcing nylon through a semi-tight crimp clamp could damage the nylon's structure, and thus affect its mechanical properties. This may or may not be true, although nylon leader line has previously been documented to be resistant to external trauma; clamping of nylon lines during knotting did not adversely affect loop properties in one study.[12] With the hand tightening method we describe, the nylon which is potentially damaged by the 1st pinch of the crimp clamp is subsequently pulled out of the loop during tightening and the majority of the nylon line which contributes to the final loop is unaffected by the tightening method. The only part of the line which is potentially damaged is that part contained within the crimp clamp itself and has been forced through a pinched crimp clamp during tightening. Any adverse effects on the small amount of nylon within the crimp clamp does not seem to affect the loop's mechanical properties.

The hand tightening method we report is a useful technique for all surgeons using crimp clamps to secure extracapsular fabello-tibial sutures but it is a particularly useful technique when a surgical assistant is not available. Alternative strategies for the unassisted surgeon include using specialized tensioning devices or using knots, such as the self-locking knot,[16] which can maintain tension and be adjusted incrementally. However, tensioning devices may not be available and can be cumbersome to use and loops secured with a self-locking knot elongate to a greater extent when tensioned than loops secured by other knots or by crimp clamps.[7]

The tightening method we describe does require some strength to pull the loop tight after the crimp clamp has been partially pinched. This is particularly true if the Securos crimping system is used and the initial pinch of the crimp clamp is created by fully closing the jaws of the crimping tool as performed in this study. This protocol was used as it was felt it would maximally distort the nylon line as it was pulled through the crimp clamp and was thus most likely to adversely affect the loop's mechanical properties. Fully closing the crimping tool's jaws was also readily repeatable between loops, thus standardizing the technique. In clinical practice, however, it is not necessary to apply maximum force to the crimp clamp with the initial pinch to create enough grip on the line to prevent the loop slipping after it has been tightened. If the crimp clamp is only partially pinched in this way it becomes easier to tighten the loop by hand but the 1st pinch must be re-pinched fully once the desired loop size has been created.

We found that 2 tightening methods—one using partial crimping of the loop before final tightening and crimping and one using the Securos crimp clamp system—were equally effective and both methods can be recommended for clinical use. The hand tightening method can be recommended to all surgeons and is particularly useful for unassisted surgeons without access to a tensioning device.

REFERENCES

1. Arnoczky SP, Tarvin GB, Marshall JL, et al: The over-the-top procedure: a technique for anterior cruciate ligament substitution in the dog. J Am Anim Hosp Assoc 15:283–290, 1979
2. Deangelis M, Lau RE: A lateral retinacular imbrication technique for surgical correction of anterior cruciate ligament rupture in the dog. J Am Vet Med Assoc 157:79–84, 1970
3. Slocum B, Slocum TD: Tibial plateau levelling osteotomy for repair of cranial cruciate ligament rupture in the canine. Vet Clin North Am: Small Anim Pract 23:777–795, 1993
4. Conzemius MG, Evans RB, Besancon MF, et al: Effect of surgical technique on limb function after surgery for rupture of the cranial cruciate ligament in dogs. J Am Vet Med Assoc 226:232–236, 2005
5. Aragon CL, Budsberg SC: Applications of evidence-based medicine: cranial cruciate ligament injury repair in the dog. Vet Surg 34:93–98, 2005
6. Lampman TJ, Lund EM, Lipowitz AJ: Cranial cruciate disease: current status of diagnosis, surgery, and risk for disease. Vet Comp Orthop Traumatol 16:122–126, 2003
7. Peycke LE, Kerwin SC, Hosgood G, et al: Mechanical comparison of six loop fixation methods with monofilament

nylon leader line. Vet Comp Orthop Traumatol 15:210–214, 2002
8. Anderson CC, Tomlinson JL, Daly WR, et al: Biomechanical evaluation of a crimp clamp system for loop fixation of monofilament nylon leader material used for stabilization of the canine stifle joint. Vet Surg 27:533–539, 1998
9. Nwadike BS, Roe SC: Mechanical comparison of suture material and knot type used for fabello-tibial sutures. Vet Comp Orthop Traumatol 11:52–57, 1998
10. Sicard GK, Hayashi K, Manley PA: Evaluation of 5 types of fishing material, two sterilization methods, and a crimp-clamp system for extra-articular stabilization of the canine stifle joint. Vet Surg 31:78–84, 2002
11. Sicard GK, Meinen J, Phillips T, et al: Comparison of fishing line for repair of the cruciate deficient stifle. Vet Comp Orthop Traumatol 12:138–141, 1999
12. Caporn TM, Roe SC: Biomechanical evaluation of the suitability of monofilament nylon fishing and leader line for extra-articular stabilisation of the canine cruciate-deficient stifle. Vet Comp Orthop Traumatol 9:126–133, 1996
13. Banwell MN, Kerwin SC, Hosgood G, et al: In vitro evaluation of the 18 and 36 kg Securos Cranial Cruciate Ligament Repair System™. Vet Surg 34:283–288, 2005
14. Anderson CC III, Tomlinson JL, Daly WR, et al: Biomechanical evaluation of a crimp clamp system for loop fixation of monofilament nylon leader material used for stabilization of the canine stifle joint. Vet Surg 27:533–539, 1998
15. Moores AP, Beck AL, Jespers KJM, et al: Mechanical evaluation of two crimp clamp systems for extracapsular stabilization of the cranial cruciate ligament-deficient canine stifle. Vet Surg 35:470–475, 2006
16. McKee WM, Miller A: A self-locking knot for lateral fabellotibial suture stabilization of the cranial cruciate ligament deficient stifle in the dog. Vet Comp Orthop Traumatol 12:78–80, 1999