Initial experience with the TightRope CCL® technique

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Notwithstanding numerous surgical techniques, both published and unpublished, countless implants, either critically evaluated or hastily marketed, and decades of impassioned debate, it is obvious that the ideal surgical solution to canine cruciate ligament (CCL) insufficiency remains elusive. Although our goal must be to successfully replace the degenerate native CCL with either a biomechanically compatible graft or implant that is able to convey long-term stability, at present we are left with a diverse range of surgical modalities, many of which appear to offer similar outcomes.

A relatively recent addition to the CCL surgery “family” is the TightRope CCL® (TR). An extra-capsular stabilisation technique developed by Dr Jimi Cook for Arthrex Vet, TR utilises two strands of Fibertape® (FT) placed in an extra-articular position to mimic the course of the native CCL. FT consists of a blended polyester/polyethylene jacket over an inner core of woven UHMW polyethylene in a flattened tape-like construct to improve its contact area, and has been used for some time in human surgery to repair conditions such as AC joint luxation and syndesmosis rupture of the ankle. In vitro biomechanical testing has shown FT to be superior to other braided polyethylene implants and monofilament nylon in elongation, stiffness and load to failure in both monotonic and cyclic testing.[1, 2]

The TR technique entails the placement of the FT strands through 3.5mm bone tunnels in the distal femur and proximal tibia respectively. The implant is anchored by a titanium alloy toggle on the medial distal femur and then traverses the distal femur via a bone tunnel to the caudal lateral condyle. It then travels in a cranio-medio-distal direction from the caudal aspect of the lateral femoral condyle across the joint to a point on the lateral proximal tibia adjacent to the fossa of the long digital extensor tendon (LDET). It is this section that acts as the working length of the construct, having its start and finish at similar anatomical locations to the native CCL, albeit in a more abaxial position. From this point the implant passes medially across the proximal tibia via the second bone tunnel to emerge on the medial tibial cortex, where it is secured over a titanium alloy button. A large introducing needle connected via finer Fiberwire® suture to the toggle facilitates direction of the implant through the bone tunnels. A picture of the TR implant and a schematic illustrating implant positioning is shown in Figures 1 and 2.

Figure 1:TR implant. Note the button, toggle, FT and introducing needle

Figure 2: TR schematic

Benefits of TR

TR was conceived out of a requirement to address certain shortcomings in the two main types of traditional CCL surgery techniques; namely the lateral suture (LS) technique and the tibial osteotomy procedures. Purported benefits of TR over the LS include improved mechanical properties and increased isometry. The FT utilised in TR ensures a stronger, stiffer implant that conveys greater abrasion resistance, better handing and improved knot security over the ubiquitous monofilament nylon. Additionally, the bone-to-bone fixation provided by the metallic toggle/button potentially endows a stronger construct than the LS which is traditionally fixed proximally in the soft tissue around the lateral fabella. Such bone-to-bone fixation obviates the risk of the implant slipping off or tearing through the soft tissue and may be less painful than soft tissue purchase. The shorter working length of the implant also improves construct stiffness and reduces the degree of implant elongation.

Asides from mechanical considerations, the TR may present an improvement on the LS by means of improved isometry. The concept of isometry when applied to a joint involves the determination of a point on either side of a joint which do not vary in their distance from each other as the joint undergoes its normal range of motion. Logic dictates that the two points of the stifle with assured perfect isometry in regards to the CCL are at the origin and insertion of the CCL, within the stifle joint. Although it is unlikely that such perfect isometric points exist on the lateral aspect of the stifle, various studies have elucidated anatomical locations that are MORE isometric than others.[3, 4] In a two-dimensional radiographic study Roe et al found the femoral site to be at the caudo-lateral extent of the lateral femoral condyle, directly distal to the distal pole of the lateral fabella, while the three tibial sites were elucidated: at the insertion of the straight patella ligament and the cranial (”tubercle of Gerdi”) and caudal edge of the LDET fossa.[3] Subsequently in a cadaveric study Hulse et al found the same femoral site, termed F2, and the caudal edge of the LDET fossa, called T3, were most isometric.[4] When stifle anatomy is scrutinised, this seems logical as these points correspond well to the location of the CCL origin and insertion in the medio-lateral plane. Although work by Fischer et al disputed these findings, this study exhibited several limitations, including the measurement of strain with potentially compliant soft tissue fixation and differing implant length.[5] A radiograph demonstrating the points of improved isometry are shown in figure 3.

The use of bone tunnels in the TR technique allows the implant to be positioned directly at these determined “isometric points”. In terms of extracapsular stabilisation this is important, since poor isometry will result in either tightening or loosening of the implant as the implant insertion points vary in their distance from each other throughout range of motion.

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Figure 3: Radiograph illustrating points of increased isometry

Theoretical advantages of TR over the osteotomy techniques include the potential to address all abnormal forces acting across the CCL deficient stifle, a lessened risk of catastrophic complications and reduced invasiveness. The native CCL has three main functions: to prevent cranial subluxation of the tibia, stifle hyperextension and internal rotation of the tibia. All biomechanical work for the various osteotomy techniques has focussed only on the prevention of cranial tibial subluxation. The TR, however, is located in a position that allows it to counteract instability in all directions. The placement of an implant that provides similar mechanical capabilities to the CCL may result in a more holistic approach to stabilisation of a CCL deficient joint.

The decreased risk of catastrophic complications is an appealing feature. Unfortunately, uncommon but well recognised complications such as non-union and catastrophic implant failure can occur with any of the osteotomy techniques, the sequelae of which can be limb amputation or euthanasia. Infection or failure of the TR, however, can generally be addressed via either implant removal or replacement. According to the Arthrex multi-centre trial factsheet, an independent investigation performed by Dr. Rich Evans using number needed to harm and number needed to treat analysis showed TR to have the highest safety to efficacy ratio for all commonly used CCL procedures.

Lastly, the two bone tunnels required for TR will intuitively be less invasive than the osteotomy(s), bone plate and screws required for most of the osteotomy techniques. The TR has also been developed with the potential for placement via a minimally invasive approach in conjunction with stifle arthroscopy.

Contraindications

There are a number of stated contra-indications for the use of TR. These include the presence of a pathological tibial plateau slope or angular limb deformity, connective tissue healing abnormalities and poor post-operative compliance. In addition to these the author includes the existence of any skin infection, no matter how mild. Distant infection such as periodontal or aural infection is potentially also a contraindication for TR use. The standard TR can be used in any dog with a cranial to caudal femoral condylar width of >12mm; this typically roughly equates to a 16-18kg dog. However, a mini-TR is now also available for the smaller dog that entails a single loop of Fiberwire® implanted through 2.7mm bone tunnels.

Outcome and complications

In evaluating the peer-reviewed literature, two studies of note can be found concerning the use of TR. The first, by Cook et al in 2010, outlined the technique and presented a partly randomised, prospective clinical cohort study directly comparing TR to TPLO (24 and 23 cases respectively) with a six month follow-up.[1] Outcomes measured included physical and radiographic examination at eight weeks post op and a validated client questionnaire at six months. The authors found that there were no statistically significant differences between the procedures in any of the outcomes measured, with the exception that TR had a lower complication rate and faster anaesthesia and surgery times. However, the study was not blinded, only half of the dogs were randomised, follow-up was only to six months and no objective outcomes measurements were obtained.

A recent study by Christopher et al retrospectively compared TR with TPLO and TTA with a follow-up of one year minimum.[6] Outcomes were compared via a validated client questionnaire and medical records. All techniques were associated with a relatively high success rate, but TR and TPLO were superior to TTA in achieving return to full function. TR had significantly fewer complications than TPLO and TTA, while TTA had a significantly greater complication rate than TPLO and TR. The authors concluded that TR exhibited the highest safety-to-efficacy ratio. Limitations of this study included its retrospective nature, the lack of objective outcome data, the presence of multiple surgeons and joint assessment protocols and the relatively small number of TTA cases.

Arthrex has also conducted a large multi-centre trial of TR. Currently at 2563 cases over 43 centres with a minimum of three months follow-up, they report a 94.9% success rate, of which 64.6% of dogs returned to full previous function without the use of additional therapies and 30.3% achieved restoration to previous function that is limited in duration or requires medication attain. The overall complication rate is 19.1%, of which only 0.2% was considered catastrophic (resulted in death or disfigurement). The major complication rate of 9.8% is comparable to any other major published technique. The three main major complications reported were late meniscal tear (5.2%), instability/implant failure (2.9%) and infection (1.7%).

To date at the author's institution, 73 cases (65 dogs) have undergone TR stabilisation for CCL insufficiency with a minimum of six months follow-up. Dogs ranged in weight from 17-63kg (mean 31.32kg), and in age from one to 12 years (mean 6.14 years). There were 42 (64.6%) de-sexed females, 1 (1.5%) intact female, 20 (30.7%) de-sexed males and 2 (3.1%) intact males. 55 (75.3%) of the cases demonstrated complete CCL tears and 18 (24.7%) partial tears, while 48 (65.7%) dogs underwent meniscal resection at the index surgery, involving either partial menisectomy or caudal pole hemimenisectomy. No menisci were released.

Overall, the complication rate was 21.9%, of which 8.2% were considered minor, and 13.7% were deemed major. There have been no catastrophic outcomes. The two types of major complications noted were late meniscal injury (seven dogs, 9.6%), and implant infection (three dogs, 4.1%). All major complications were noted within the first six months post op; the three cases of implant infection were all seen within the first two months post op and six of the seven late meniscal injuries were seen within the first three months. All cases of implant infection were confirmed via positive culture. Post-liminal meniscal tear typically manifested as acute onset lameness, generally partially responsive to anti-inflammatories and rest. Arthroscopic examination confirmed the meniscal pathology and allowed removal of damaged meniscus as required. All dogs with major complications experienced resolution of their lameness upon either arthroscopic excision of the damaged meniscus or removal of the infected implant and appropriate antibiotic therapy.

No objective measurements have been performed and outcomes can only be extrapolated from the clinical records. However, the author's early experience with TR has been largely favourable. Indeed, complications such as late meniscal injury and infection seem to be at clinically acceptable rates. Moreover, dogs appear to regain substantial operated limb function quite readily with the technique; anecdotally limb function appears to return quicker than is seen after an osteotomy or LS, and is likely due to a combination of reduced invasiveness, lack of soft tissue purchase and assured stability. This in turn appears to lead to a faster return of periarticular muscle mass and function, which is likely important for active stability of the joint.

However, certain concerns remain regarding the TR. Firstly, it appears that in many clinical cases the implant loosens somewhat within the first 4-8 weeks after surgery, typically characterised as 2-5mm of cranial drawer and tibial thrust. The author attributes this loosening to a number of factors including soft tissue compression, implant creep and most importantly the widening of the osseous tunnels. This tunnel widening, especially on the femur probably occurs as a result of direct wear and osteoclastic resorption. Stability does generally return by six months after the surgery, likely as a result of peri-articular fibrosis, however in cases with intact menisci this transient period of instability may make the dog susceptible to a post-liminal meniscal tear. With this in mind, the latest evolution of the TR by Arthrex called the SwiveLock®, which utilises an osseo-integrating bone anchor in the femoral position may prove superior. A second concern involves the potential for infection. Non-absorbable braided implants have long been viewed with scepticism in veterinary surgery due to a historically high rate of implant infection and draining sinus tracts. Although both TR studies, the multi-centre trial of over 2500 cases and the author's own data has demonstrated an acceptable and comparable rate of implant infection, anecdotally many surgeons have noted much higher infection rates. It cannot be emphasised enough the importance of strict asepsis, meticulous surgical technique and the minimisation of implant handling when performing a TR procedure.

The author presently employs a TR technique in cases of complete CCL rupture or where remaining CCL is deemed incompetent. In unstable stifles, it is felt that the immediate stability conveyed by the TR encourages early limb use. Additionally, older dogs, cases of bilateral CCL rupture or situations where the owner cannot countenance the possible risk for a catastrophic outcome are often considered TR candidates. An osteotomy such as a TTO is performed if the stifle is stable and a large amount of healthy appearing CCL is noted on arthroscopic examination, as it has been demonstrated with TPLO and second-look arthroscopy that early intervention can result in preservation of the remaining CCL.[7] This has also been the authors finding in a small number of cases in which early intervention was possible. In line with the previously described recommendations, an osteotomy is also performed in cases of pathological TPA, angular limb deformity and in dogs where poor fibrosis is anticipated.

TR procedure

An excellent description of the TR procedure can be found at www.arthrexvetsystems.com. However, over time the author has developed a few modifications that it is believed simplify and improve the procedure.

Pre-operative radiographs should be obtained to evaluate stifle anatomy, most importantly the position of the lateral fabella relative to the lateral femoral condyle. The dog is positioned in dorsal recumbancy and a routine hanging limp preparation performed. Four quadrant waterproof draping and placement of an Ioban® adhesive incise drape is undertaken after application of Opsite® spray.

The approach is typically an angled lateral incision, commencing over the lateral fabella and extending in a disto-cranio-medial direction to terminate over the tibial tuberosity (see figure 4). This angling of the incision provides improved access to the caudo-lateral femoral condyle than a standard para-patella approach. The aponeurosis of the biceps femoris and fascia lata is then incised along the same plane proximally to the lateral fabella and distally to the level of the tubercle of Gerdi. The fascia is then elevated off the tubercle of Gerdi and the cranial tibial fascia incised for a short direction caudo-distally to create an "L" shape. The lateral femoral condyle can now be accessed. This dissection is performed prior to joint exploration as it is easier to execute before the anatomical planes are disrupted.

Figure 4: Initial skin incision. Note the patella, lateral fabella and tibial tuberosity

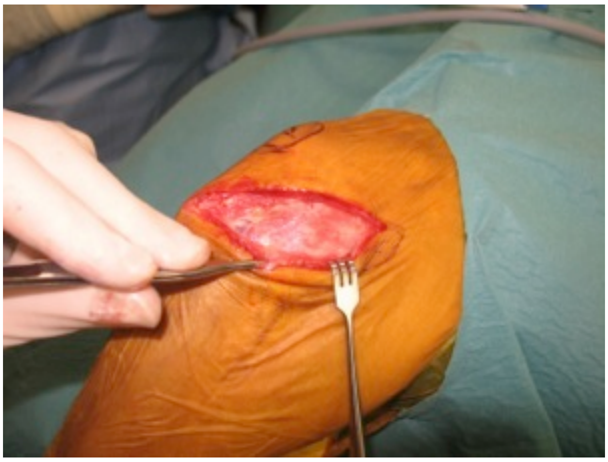

Figure 5: Lateral fascia incised and retracted

The intra-articular portion of the surgery is now undertaken, which can be performed either via routine two portal arthroscopy, single portal lateral arthroscopically assisted mini-arthrotomy or lateral mini-arthrotomy. If gross stifle instability is present and the author has a high index of suspicion for a meniscal tear, arthroscopically assisted mini-arthrotomy with orthogonally placed stifle distracters is typically performed to allow expedient meniscal resection. The cranial leaf of the fascia is retracted cranially and undermined to the lateral aspect of the straight patella ligament. A para-patella mini-arthrotomy is then performed distal to the patella. Intra-articular structures are assessed and pathology addressed as necessary. Joint capsule closure is routine.

The tibial tunnel is the first to be created. This allows the implant to be placed directly after tunnel formation, negating the need to alter limb position and reducing the likelihood of losing the femoral tunnel. The tibial tunnel is started from the tubercle of Gerdi, also known as the cranial extent of the LDET fossa, as high on the tibia as possible. Although it may be that the caudal extent of the LDET is more isometric, it is the author's opinion that this point is more difficult to definitively locate, while placement of the implant at this position poses a greater risk of LDET trauma/impingement and often fails to adequately negate cranial draw, likely as a result of the TR being in a comparatively more upright position.

Firstly, a 1.24mm k-wire is utilised to facilitate optimal placement. The k-wire should be directed in a medio-distal direction to emerge on the medial tibia mid-way between the cranial caudal cortices. Positioning of the k-wire is checked and a 3.55mm cannulated drill bit is the fitted over the k-wire to drill the requisite tunnel. Upon completion of the tunnel the k-wire should be extracted immediately from the cannulated drill bit: If not performed straight away the k-wire can become set inside the bit amongst the milieu of bone, blood and soft tissue. The medial crural fascia of the gracilis and semitendinosis aponeurosis is then undermined to expose the medial tibial exit point. Gloves should be changed, the implant taken out of its packet and inserted through the tibial tunnel via the introducing needle. When inserting the implant, be sure to pull on the suture and not the needle as the needle can break away from the implant if forced.

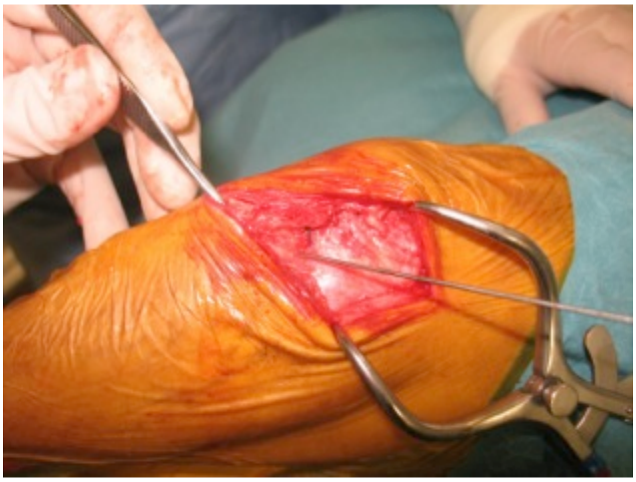

Figure 6: Insertion of the k-wire at the tubercle of Gerdi for the tibial tunnel

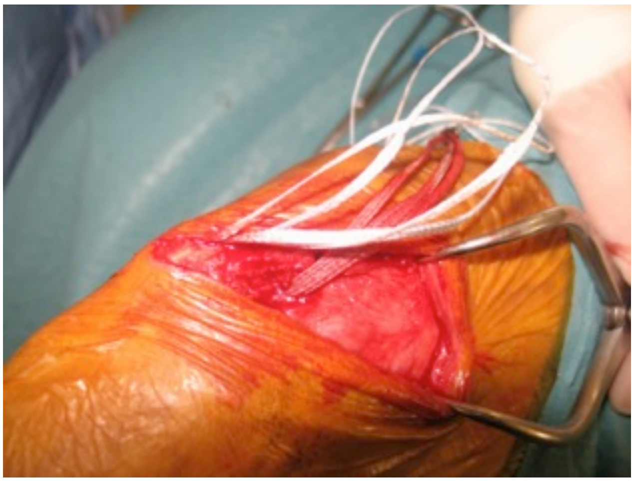

Figure 7: Passage of the TR through the tibial tunnel

The femoral tunnel is now created. In the author's opinion this is the most critical step in the TR procedure, and the most difficult part to correctly perform. The optimal position is directly distal to the lateral fabella at the caudal extent of the lateral femoral condyle (the F2 point). The common error here is to position the tunnel too far cranial on the condyle, resulting in an implant that is too vertical and unable to successfully resist cranial drawer. The fabello-femoral joint can be palpated with a hypodermic needle or the k-wire, and the k-wire inserted across the distal femur in a cranio-medio-proximal direction, to emerge in the middle of the distal medial femur at the level of the cranial pole of the patella. After over-drilling with cannulated bit, the drill is removed and the introducing needle immediately placed into the tunnel. The implant is pulled across the femoral tunnel and once the toggle is felt to emerge on the medial femoral cortex it is directed in a proximal direction to flip the toggle over and secure the implant. Visual assessment of correct toggle placement directly on bone by a mini approach over the medial femur is advised when starting out with the TR.

The implant is then tightened over the tibial button with a single throw in each suture strand. Cranial drawer is assessed and the stifle taken throughout its full range of motion. If instability or poor isometry is present tightness of the implant or erroneous tunnel positioning should be assessed. The implant is re-tightened if required and a minimum of six additional throws placed. The suture ends and introducing needle are then removed and closure is routine, being sure to cover the button and suture knots with soft tissue and imbricate the lateral fascia.

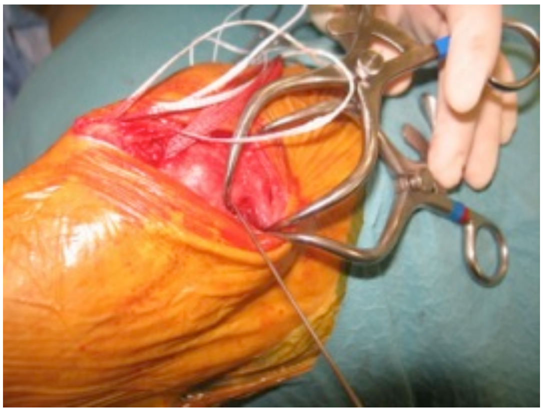

Figure 8: Insertion of the k-wire at the F2 point for the femoral tunnel

Figure 9: TR implant in situ. The forceps denote the lateral fabella

Post op radiographs should be obtained to evaluate for the placement of the bone tunnels, the femoral toggle and the tibial button. The toggle and button should be located in the correct position, firmly anchored against bone.

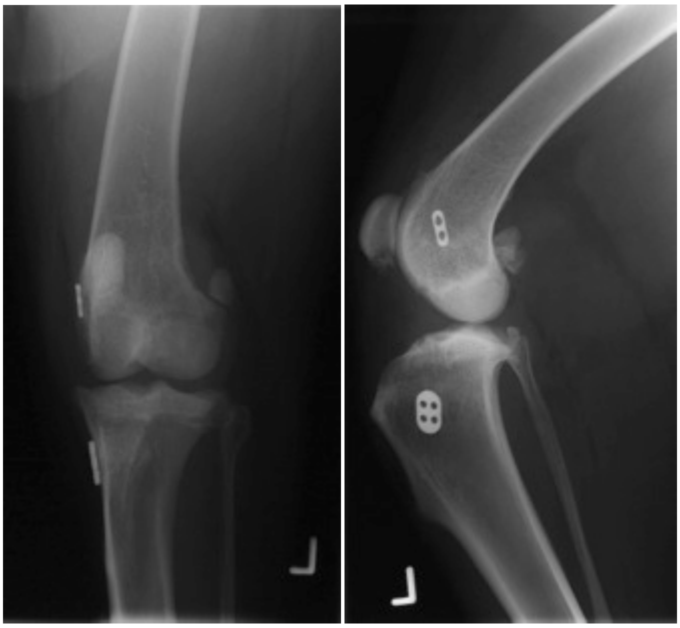

Figure 10: Post op radiographs demonstrating optimal TR placement.

Aftercare consists of peri-operative antibiosis and post-operative antibiotic cover for ten days after surgery as per the manufacturer's recommendations. Analgesia typically consists of a morphine/bupivicaine epidural, a fentanyl transdermal patch, non-steroidal anti-inflammatories starting the day after surgery and regular icing of the stifle for the first 72 hours.

Dogs are discharged on six to eight weeks of strict confinement, with leash walks only for toileting. Passive ROM exercises can be started on day three after surgery, and if progress is satisfactory short five minute daily walks can be started at four weeks, increasing incrementally each week. Physiotherapy is advised from the first week but there is to be no exuberant activity such as running or ball chasing for four months.

The majority of dogs are weight bearing on the limb at discharge one to two days after surgery, and lameness is typically less than before surgery by one week post-op. At six to eight weeks after surgery dogs have recovered to approximately 80% of eventual function, with the remaining improvement taking place by four months post op. An increase in instability is almost always seen at the four to eight week mark; however this does not necessarily translate to weight-bearing instability or clinical lameness.

1. Cook JL, Luther JK, Beetem J, Karnes J, Cook CR. Clinical comparison of a novel extracapsular stabilization procedure and tibial plateau leveling osteotomy for treatment of cranial cruciate ligament deficiency in dogs. *Veterinary surgery : VS* 2010;39:315-323.

2. Burgess R, Elder S, McLaughlin R, Constable P. In vitro biomechanical evaluation and comparison of FiberWire, FiberTape, OrthoFiber, and nylon leader line for potential use during extraarticular stabilization of canine cruciate deficient stifles. *Veterinary surgery : VS* 2010;39:208-215.
3. Roe SC, Kue J, Gemma J. Isometry of potential suture attachment sites for the cranial cruciate ligament deficient canine stifle. *Veterinary and comparative orthopaedics and traumatology : VCOT* 2008;21:215-220.
4. Hulse D, Hyman W, Beale B et al. Determination of isometric points for placement of a lateral suture in treatment of the cranial cruciate ligament deficient stifle. *Veterinary and comparative orthopaedics and traumatology : VCOT* 2010;23:163-167.
5. Fischer C, Cherres M, Grevel V, Oechtering G, Bottcher P. Effects of attachment sites and joint angle at the time of lateral suture fixation on tension in the suture for stabilization of the cranial cruciate ligament deficient stifle in dogs. *Veterinary surgery : VS* 2010;39:334-342.
6. Christopher SA, Beetem J, Cook JL. Comparison of long-term outcomes associated with three surgical techniques for treatment of cranial cruciate ligament disease in dogs. *Veterinary surgery : VS* 2013;42:329-334.
7. Hulse D, Beale B, Kerwin S. Second look arthroscopic findings after tibial plateau leveling osteotomy. *Veterinary surgery : VS* 2010;39:350-354.