The clinical outcome of three procedures for extraarticular stabilization of cranial cruciate ligament injuries in dogs

Cornel IGNA*, Roxana DASCĂLU, Daniel BUMB, Bogdan SICOE, Cristian ZAHA, Larisa SCHÜSZLER
Department of Veterinary Surgery, Faculty of Veterinary Medicine, Banat’s University of Agricultural Sciences and Veterinary Medicine “King Michael I of România,” Timișoara, Romania

Abstract: The objective of this study was to evaluate the long-term outcomes in dogs with cranial cruciate ligament injury in which the stifle was stabilized with lateral suture stabilization, lateral suture stabilization-modified, or Securos lateral bone anchor tibial suture and monofilament nylon sutures placed at quasi-isometric points of the stifle. It is a retrospective study comprising a sample population of 49 client-owned dogs. Medical records from 2014–2016 were reviewed to identify dogs that had a cranial cruciate ligament rupture in which the stifle was stabilized using one of the aforementioned methods. The overall complication rate was 16.3% and the documented complication rate requiring implant removal was 0%. Owners reported full or acceptable function in 96% of cases. There were no significant statistical differences between the 3 techniques. Stabilization of cranial cruciate ligament-deficient stifles in dogs with lateral suture stabilization, lateral suture stabilization-modified, or Securos lateral bone anchor tibial suture is reliable with acceptable complication rates. The 3 procedures tested may be appropriate in medium-sized nonathletic dogs whose owners have limited budgets.

Key words: Dog, cranial cruciate ligament, cranial cruciate ligament injury, extracapsular stifles stabilization, bone anchor

1. Introduction

For the treatment of cranial cruciate ligament (CCL) injuries in dogs, extraarticular suture stabilization includes lateral suture stabilization (LSS) [1–3] and another variant that utilizes bone anchors and tunnels to fix the prosthetic suture across the stifle.

Lateral bone anchor tibial suture (LBATS) represents the development of extraarticular stabilization techniques consisting of in vitro testing of several types of suture anchors [4–7]. There are a few studies that refer to clinical applications [8–15] with various types of suture anchors (Mitek, USA: G2; Innovative Animal Product, USA: Bone Biter; Arthrex, USA: Corkscrew/FasTak Anchor, SwiveLock Anchor; Kyon Switzerland: Ruby), but according to our literature review there are no clinical studies on the use of Securos bone anchor (US).

The most frequently used sutures are made of monofilament nylon leader line (MNL) that has suitable mechanical properties for tensions within the stifle [16–19] and in vitro testing showed that stifle stability was maintained more effectively by crimped nylon loops when compared to knotted loops [20,21].

* Correspondence: ignacornel@gmail.com

When inserting the suture, the focus has been on isometric points to maximize stability and reduce implant failure [22–26]. True isometry has not been achieved in any study; therefore, “quasi-isometric points” is a more appropriate term [27].

Postoperative complications associated with extraarticular suture stabilization techniques are well described [12,14,28]. Complications include implant infection, tearing of the fabello-femoral ligament, incisional issues, implant failure or pull through, meniscal tear, failure to control stability, and nerve injury [28–31].

The aim of this study was to determine the ease of execution, postoperative complication rates, and long-term functional outcome (evaluated by both owner and surgeon) for 3 extraarticular stabilization techniques with monofilament nylon sutures placed in 3 combinations of quasi-isometric points of the stifle. The techniques used were LSS, lateral suture stabilization-modified (LSS-M), and LBATS. We assigned dogs to each group based on owners’ preferences when presented with the surgical options and costs.
Our hypothesis was that all 3 procedures would result in appropriate long-term functional outcomes.

2. Materials and methods
Medical records from the last 3 years were reviewed to identify dogs that had a CCL rupture which benefited from stifle stabilization using one of the following procedures: LSS, LSS-M, and LBATS.

Inclusion criteria in the study were: diagnosis of partial/complete unilateral CCL rupture of 1–25 days; procedure used; the use of MNL; follow-up by surgeon at 7 days and 3, 6, and 12 months; at least one postoperative radiographic investigation; and completion by the owner of a preoperative questionnaire and a long-term follow-up questionnaire [12,32] at 3, 6, and 12 postoperative months.

The following data were recorded: sex, age, breed, and body weight of the patient; type of CCL injury - partial or complete tear; whether meniscal surgery was performed (partial meniscectomy) or not; the chosen method for extraarticular stabilization; and the type of bone anchor used.

2.1. Surgical procedures
Anesthesia consisted of premedication with diazepam (Terapia SA, Romania) and ketamine (Ketamidor, Richter Pharma AG, Austria), induction with propofol (Fresenius SE& C, Germany), and maintenance with isoflurane (Anestaran, Rompharm Company, Romania) in oxygen.

A lateral approach was used for all affected stifles. All surgical procedures were performed by the same surgeon. Torn remnants of the CCL were removed. The menisci were assessed for injury, and segmental meniscectomy [33] was performed via sharp debridement only when meniscal pathology was present.

Three stabilization procedures of the stifle were used, consisting of placing a suture between quasi-isometric points [24], as follows:

1. LSS-suture placed between quasi-isometric points: \( f_1 \) (circumferential around the fabella) - \( t_1 \) (near the tibial insertion of the patellar tendon) [1–3]-placement of only one lateral circumfabeellar-tibial tuberosity prostheses;

2. LSS-M-suture placed between quasi-isometric points: \( f_1 - t_2 \) (located in the center of the bony protuberance, cranial to the sulcus of the long digital extensor tendon) [24];

3. LBATS-suture placed between \( f_2 \) (site located caudally in the lateral femoral condyle adjacent to the articular cartilage line and 3 mm distal to the articulation of the fabella and lateral condyle) and \( t_2 \). Insertion of the anchors in the femur was made cranial and distal to the lateral fabella-femoral condyle junction and within the caudal portion of the condyle [24] (Figure 1).

For all procedures, the tibial suture site (\( t_1 \), or \( t_2 \)) was prepared by drilling 2 parallel bone tunnels (Figure 1), using a Kirschner wire drill for suture material placement. For LBATS, Securos bone anchors of 3.5 mm type and 4.5 mm were used. Intraoperative fluoroscopy was used to confirm placement of the bone anchor (Figure 2).

MNL was used as a suture material. The 3.5 mm anchor will accommodate 1 strand of 80# monofilament nylon for dogs with 13–16 kg weight. The 4.5 mm anchor will accommodate 2 strands of 80# monofilament nylon for dogs with 17–25 kg weight and 1 strand of 100# monofilament nylon for dogs up to 25 kg in weight. The suture is tensioned using a tensioning clamp (Jorgensen Labs, USA) aided by a standard Gelpi retractor. For all procedures (LSS, LSS-M, and LBATS) crimp tubes were used (Securos Monofilament Crimp Clamps Surgical Grade Stainless Steel, Securos Europe GmbH, Germany), which use a stainless-steel crimp clamp (Securos Universal Tensioning Device, Securos Europe GmbH, Germany). The crimp pattern consisted of 3 crimps evenly distributed. Tightening of the suture was performed with the stifle slightly extended at 100°–130° [26]. The effectiveness of the stabilization was confirmed by a negative cranial drawer test.

The joint capsule was closed by a single interrupted suture. Polyglycolic acid (Bicril, Biosintex SRL, Romania) of Ph. Eur. size of 2 or 3 metric for dogs up to 20 kg and Ph. Eur. size of 3.5 or 4 metric for dogs with 20–30 kg body weight were used. The fascia was closed similarly. Subcutaneous tissue was closed by continuous sutures. Polyglycolic acid (Bicril, Biosintex SRL, Romania) of Ph. Eur. size of 2 or 3 metric was used. The skin was closed by single interrupted sutures (Biopro, Polipropilene, Biosintex SRL, Romania). We did not use capsular-fascial imbrications.

Postoperative radiographs were obtained to confirm placement of the bone anchor. Preoperative examination and all surgical procedures were performed by the same surgeon.

Postoperatively all dogs received the same pain medication, butorphanol (Butomidor, Richter Pharma AG, Wels, Austria) at 0.3 mg/kg intravenously, q8h, for one day, followed by 4 mg/kg carprofen (Rimadyl, Pfizer) orally for 3 days.

Complications and functionality during the postoperative period were classified according to the proposed definitions and criteria published by Cook et al. [34].

Preoperative and postoperative assessments (surgeon’s examination and owner’s satisfaction) were made.

Orthopedic examination [35] was performed by another surgeon at 7 days and 3, 6, and 12 months postoperatively, during which more aspects were assessed (Table 1). Mediolateral and craniocaudal radiographs were evaluated preoperatively and within 3 and 6 months
after surgery. Postoperative radiographic/fluoroscopic investigations (Figure 3) were performed to evaluate the anchors’ and/or crimps’ positions and identify possible signs of osteoarthritis (OA) existence and/or progression [36,37]. Mediolateral views were obtained with the stifle extended at 120°–135°. Craniocaudal radiographs were performed with the central X-ray beam at a 15° proximal/distal angle. Preoperative images were obtained from anesthetized dogs and follow-up radiographic studies were obtained from sedated dogs. Evaluations concerning the degree and progression of OA and the soft tissue changes were made by 2 radiologists. New bone production,
including both enthesophytes and osteophytes, were noted at specific anatomic locations. The presence of new bone production was recorded at 11 specific sites [37]. New bone production at a specific site was graded as 0 when not identified, as 1 for mild osteophytes, as 2 for moderate osteophytes, and as 3 for marked osteophytes.

Modified questionnaires [12,32] were completed by the owners prior to surgery and during follow-up at 3, 6, and 12 months after the surgery. A subjective scale of 1–6 was established (1 = the worst, 6 = the best) and was used to answer each question of the questionnaire. The records were reviewed and owners were questioned regarding the occurrence of postoperative complications.

The orthopedic examinations based on the questionnaires from the surgeon and the owners were grouped [34] into the following results: full function (normal level of duration and function of activities without medication; subjective owners’ scale of 5–6); acceptable function (maintenance of intended activities to limited level and/or medication to achieve intended activities; subjective owners’ scale of 3–4); and unacceptable function (all other outcomes; subjective owners’ scale of 1–2). Data were used to compare the differences between the techniques used.

2.2. Statistical analysis

Body weight and age were statistically reviewed using the t-test. The Mann–Whitney U test was used to rank the grouped data and demonstrate possible differences in owners’ satisfaction and number and severity of postoperative complications following the use of 3 different surgical procedures. Significance was established at P < 0.05.

To quantify the effects of the types of surgery, a chi-square test of association (chi-square procedures for two dimensions of categorization) was performed with the calculation of the phi coefficient of association with a probability of 0, which indicates that the type of surgical procedure has no effect on the result, and 1, which means that it has maximum effect [38].

3. Results

Over a 3-year period, 87 dogs underwent surgical stabilization of the stifle with LSS, LSS-M, or LBATS for a ruptured CCL. Out of the 87 dogs, 49 met the criteria for inclusion in this study.

Among these 49 dogs, 29 were female and 20 were male with a mean age of 4.56 years (ranging from 6 months to 9 years). Several breeds were represented: Labrador (9), Rottweiler (8), Siberian Husky (6), German Shepherd (5), Caucasian Shepherd (4), Beagle (2), American Bulldog (2), Bloodhound, Shar Pei, Cocker Spaniel (1 each), and mixed-breed dogs (10). The mean body weight was 23.04 kg (ranging from 14 to 31 kg) with no statistical differences between the 3 groups.

A complete CCL tear occurred in 87% of the cases, and a partial tear occurred in 13% of cases.

Client-owned dogs (n = 49) diagnosed with unilateral CCL rupture were treated with LSS in 53.1% of the cases (26/49), LSS-M in 24.5% (12/49), and LBATS in 22.4% (11/49). The lateral meniscus was normal in all cases. Injury of the medial meniscus was detected in 11 cases. Eleven dogs had a torn medial meniscus (complex tears), and therefore a caudal hemimeniscectomy was performed. Overall, meniscal surgery was performed in 22.4% (11/49) of the dogs. Presence or absence of degenerative changes of the menisci related to meniscal interventions could not be individually emphasized in the follow-up period.

The cranial drawer test was performed preoperatively in all patients and the tibial compression test in nonsedated dogs was positive in 42 of 49 stifles (85.7%).

Grade 3 lameness at an average of 2.82 ± 0.65 was noted at the time of initial presentation.

Regarding the ease of execution, the most facile was LSS, followed by LSS-M and LBATS, respectively.

Out of 49 cases analyzed for complications, 16.3% had complications. These complications were classified as minor in 12.2% (8/49), major in 4.1% (2/49), and catastrophic in 0%. Minor complications occurred in 4 of the 26 dogs in which the LSS technique was used, in 2 of the 12 dogs in which the LSS-M technique was used, and in...
2 of the 11 dogs in which the LBATS technique was used. The dogs with minor complications (incisional dehiscence: 5 cases and/or incisional discharge: 3 dogs) were given an Elizabethan collar, kept under cage rest, and/or given oral antibiotics. In one dog from the LSS group and one from the LSS-M group, major complications (persistent lameness) occurred, but these did not require additional surgery and were treated with oral analgesics and cage rest.

Table 1. The orthopedic evaluation criteria.

| Lameness degree assessment scale | Degree | Description |
|----------------------------------|--------|-------------|
|                                  | 0      | Normal attitude in stance and in walking - without lameness |
|                                  | 1      | Difficulties in walking, especially at rapid carriage - some lameness |
|                                  | 2      | Difficulties in walking, intermittent lameness in rapid walking |
|                                  | 3      | Evident lameness at every step, pain |
|                                  | 4      | No weight-bearing in standing position and during walking, intense pain |

| Cranial drawer sign              | Positive |
|----------------------------------|----------|
|                                  | Negative |

| Tibial compression test          | Positive |
|----------------------------------|----------|
|                                  | Negative |

| Range of motion                  | Normal |
|----------------------------------|--------|
|                                  | Decreased |

| Joint swelling                   | Mild |
|----------------------------------|------|
|                                  | Moderate |
|                                  | Severe |

| Pain sensation during flexion and extension of the stifle joint | Nonpainful |
|                                                               | Painful during extension/flexion |

Figure 3. Postoperative radiographic examination at 3 months after the surgery by LBATS: (A) mediolateral and (B) craniocaudal views with no signs of OA.
All complications occurred in the perioperative period (0–3 months). Suture failure was not recorded in any of the 49 cases at 3 months after surgery. The cranial drawer test that was performed at 3 months postoperatively was either negative or less than 1 mm in all dogs that underwent surgery.

Based on radiographic findings and clinical examination, we found that none of the 3 methods reduced development or progression of osteoarthritic changes. Radiographs obtained at 6 months after the operation documented the progression of osteoarthritis in 49% (24/49) of the cases compared to 32.6% (16/49) preoperatively.

Implant failure (bone anchor pulled off) and crimp migration were not recorded in any of the 11 cases within 3–6 months after the surgery.

Orthopedic examination performed by the surgeon at 12 months postoperatively revealed 39/49 dogs with no signs of lameness although the cranial drawer test was positive in 24 of 49 stifles (49%) and the tibial compression test was positive in 2 of 49 stifles (4%).

Postoperatively, the grouped results of the orthopedic examination performed by the surgeon and the owners’ questionnaires showed that 83% of dogs regained full function, 13% of dogs regained acceptable function, and unacceptable function was recorded in 4%. Overall, 96% of owners reported full or acceptable function (Table 2).

Statistical analysis between the results obtained from owners’ questionnaires (Table 2) regarding the 3 surgical procedures indicated that postoperative results between applied procedures were not significantly different.

4. Discussion

In the present study, the LBATS appears to be an acceptable extraarticular stabilization procedure for stifles with CCL injury in dogs with a mean weight of 23 kg. Owners’ assessments of the dogs’ quality of life, activity level, and gait showed that they improved significantly after surgical stabilization using all 3 techniques.

According to Hulse et al. [24], LSS around the lateral fabella and near the tibial insertion of the patellar ligament can affect the isometry of the joint and therefore affect the long-term craniocaudal laxity of the stifle. LSS-M with the suture looped around the lateral fabella and secured to the proximal and medial aspect of the tibia through 2 parallel drilled holes had the least change in suture tension during a full range of passive motion [25]. The quasi-isometric points $f_1 - t_1, t_1$ (representing a site near the joint line located at the bony protuberance 2 mm caudal to the sulcus of the long digital extensor tendon) [24] or $f_1 - t_1$ [22] of the stifle are the results of the development of attachment points that are more isometric than the traditional fabello-tibial suture sites (circumfabellar-tibial tuberosity). Increasing tension to eliminate cranial drawer did not affect suture isometry at the tested preloads [24]. Tightening of the suture remains a divergent issue in the specialty literature, as most authors recommend tightening of the suture during a slight flexion of the joint. Our preference for tightening the suture during a slight extension of the joint is based on the reason that tightening during flexion can result in joint instability during extension.

LBATS placed at quasi-isometric points $f_1 - t_1$ did not cause any implant failure, showing that it withstands normal loads developed by dogs weighing between 14 and 31 kg. Similar results were obtained by in vitro tests made with the Securos anchor [6]. Regarding our results, it seems possible to relate the ideal location of the femoral anchor in the caudal part of the lateral femoral condyle adjacent to the articular cartilage line.

Complications encountered herein were classified according to the previously proposed definitions and criteria that may be used as a standardized system to define complications in orthopedic studies in veterinary medicine [34]. Out of 49 cases that were analyzed for complications, 16.3% had complications.

In our study, complications were classified as minor in 12.2% (8/49), major in 4.1% (2/49), and catastrophic in 0% of cases. Complication rates were 15% for minor incisional complications after LSS, 17% after LSS-M, and 18% after LBATS. Complications of the LSS technique are well documented and expected in 17%–25% of cases, including infection, tissue reaction, sinus formation, meniscal tears, pain, and instability [1,28,39].

Rappa and Radasch [14] report a 30.3% postoperative complication rate associated with the stabilization of CCL-deficient stifles in small- to medium-sized dogs with the Arthrex Canine Cranial Cruciate Ligament Repair Anchor System. The complication rate associated with the Arthrex Corkscrew or FAS Tak bone anchor and Fiberwire placed near isometric points of the stifle was 8.8% [12]. Complications requiring surgical revision occurred in 7.3% of cases after CCL-deficient stifles stabilized with a knotless SwiveLock bone anchor preloaded with FiberTape [13]. Guenego et al. [9] report a 21% frequency of pull out of the suture anchor and the early failure of the suture (0.9 mm silicone-braided polyester) after the use of the Bone Biter suture anchor in 2 dogs. Suture weakening has also been recorded, which occurs due to the increased stress placed on the suture where it contacts the eyelet of the suture anchor [30,31]. A retrospective article [40] showed that FiberWire was 6–32 times more likely to fail compared to a single or double stranded nylon leader line, respectively.

Subjective evaluations of postoperative complications following the tibial plateau leveling osteotomy (TPLO) procedure were reported as 5.4%–34% [41–46].
Wolf et al. [47] reported the complication rate for tibial tuberosity advancement (TTA) as 18.9%, but others reported a complication rate of 25% using force plate gait analysis [48]. Major complication rates were not significantly different between TightRope CCL (TR) at 12.5% and TPLO at 17.4% [34].

The placement of the suture at quasi-isometric points has led to avoidance of catastrophic complications in all three procedures used in our study, and minor complications had similar rates as those reported in other studies. Isometric insertion of Securos bone anchors performed under fluoroscopic guidance succeeded in avoiding suture laxity due to decreased distance between the suture loading points, as premature failures are due to increased distance beyond the yielding point.

Meniscal injuries associated with CCL rupture were identified in 22.4% of the dogs included in our study and these findings are similar to those in other reports. Meniscal pathology in conjunction with CCL rupture is recognized in 10%–83% of cases [28,33,42,49,50]. Hayes et al. [50] demonstrate an association between duration of lameness and medial meniscal injury, particularly for complete CCL rupture. In addition, larger dogs with complete rupture of the CCL are at significantly higher risk of developing medial meniscal tears compared to small dogs; therefore, surgical stabilization should not be unnecessarily delayed. Meniscal release decreased the rate of the meniscal tears, thus eliminating the need for revision surgeries in some dogs, but meniscal release had no effects on the owner-assessed outcomes [51].

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Table 2. Comparative surgeon’s and owners’ postoperative evaluations at 12 months.

| Results                              | Technique | Surgeon’s examination | Owners’ satisfaction |
|--------------------------------------|-----------|-----------------------|---------------------|
| Full function scale of 5–6           |           |                       |                     |
| LSS                                  | 77% (20/26) | 85% (22/26)          |                     |
| LSS-M                                | 75% (9/12)  | 84% (10/12)          |                     |
| LBATS                                | 91% (10/11) | 91% (10/11)          |                     |
| Total average                        | 80% (39/49) | 86% (42/49)          | 83%                 |
| Acceptable function scale of 3–4     |           |                       |                     |
| LSS                                  | 19% (5/26)  | 11% (3/26)           |                     |
| LSS-M                                | 17% (2/12)  | 8% (1/12)            |                     |
| LBATS                                | 9% (1/11)   | 9% (1/11)            |                     |
| Total average                        | 16% (8/49)  | 10% (5/49)           | 13%                 |
| Unacceptable function scale of 1–2   |           |                       |                     |
| LSS                                  | 4% (1/26)   | 4% (1/26)            |                     |
| LSS-M                                | 8% (1/12)   | 8% (1/12)            |                     |
| LBATS                                | 0% (0/11)   | 0% (0/11)            |                     |
| Total average                        | 4% (2/49)   | 4% (2/49)            | 4%                  |

Table 3. Comparative statistical analysis based on owners’ evaluation at 12 months postoperatively.

| Group | Preoperative assessment | Assessment at 12 months postoperatively | Differences between assessment (pre- and postoperatively) | Mann–Whitney’ U test |
|-------|------------------------|----------------------------------------|----------------------------------------------------------|----------------------|
| LSS   | Mean: 2.82 SD: ±2.5     | Mean: 5.14 SD: ±0.75                    | Z-score is –4.01258; P < 0.00001; result is significant at P < 0.05 |                      |
| LSS-M  | Mean: 2.83 SD: ±2.5     | Mean: 5.25 SD: ±0.75                    | Z-score is –4.01258; P < 0.00001; result is significant at P < 0.05 |                      |
| LBATS  | Mean: 2.81 SD: ±2.5     | Mean: 5.09 SD: ±1.3                     | U-value is 10.5; critical value of U at P < 0.05 is 33; therefore, result is significant at P < 0.05 | Z-Score is –3.25042; P = 0.00116; result is significant at P < 0.05 |

Wolf et al. [47] reported the complication rate for tibial tuberosity advancement (TTA) as 18.9%, but others reported a complication rate of 25% using force plate gait analysis [48]. Major complication rates were not significantly different between TightRope CCL (TR) at 12.5% and TPLO at 17.4% [34].
The limitation of our study is that the presence or absence of degenerative changes of the menisci, consequent to meniscal surgery, could not be individually emphasized in the follow-up period.

Au et al. [29], Morgan et al. [37], and Ledecky et al. [53] reported that radiographic OA scores increased at 6 to 24 months postoperatively compared with preoperative scores. OA scores were not significantly different between the treatment groups for TPLO versus LSS [29] or TR versus LSS [53]. Our results showed that stabilization of CCL-deficient stifles in dogs using all 3 described techniques does not significantly reduce the progression of OA changes; in fact, the number of cases with OA rose from 32.6% preoperatively to 49% at 6 months postoperatively, similarly to other studies [36,37].

The present study evaluated long-term outcomes using an owner assessment questionnaire. Kinetic gait analysis would have resulted in more objective data [32,54], but was not available in our clinic. Molsa et al. [55] stated that ground reaction forces analysis should be used in conjunction with other methods because when it is used alone it may be inadequate for assessing the functional outcomes after CCL repair. Postoperative objective evaluations report either the superiority of the TPLO technique compared to LSS technique [56–58] or identical results between the two [29,59,60]. Other studies demonstrate a return to function following TTA [48].

Other limitations of this study are the small population size, the fact that owners’ ability to objectively evaluate pain and lameness is questionable, and the fact that meniscal tears may be underdiagnosed due to the surgeon’s skills and experiences, which explain the postoperative differences shown in Table 2. Furthermore, only subjective evaluations were used to assess long-term function, although several studies have demonstrated that neither owners nor veterinarians can accurately use subjective lameness scores to predict how lame dogs really are in comparison to kinetic examination (force plate), which is an objective assessment [54]. Generally, 96% of the owners reported full or acceptable function with no statistically significant differences between the three analyzed surgical procedures. Our data are similar to those reported by Rappa and Radasch [14], in which the owners reported full or acceptable function in 96% of cases with an average functional score of 86.5% after the Arthrex Canine Cranial Cruciate Ligament Repair Anchor System, and those reported by Kishi et al. [12] with the Arthrex corkscrew or FASTak bone anchor and FiberWire. Our study on Securos bone anchors, as well as other studies on other types of bone anchors [8,12–15], used only subjective methods of evaluation of postoperative complications. In order to validate these results, future prospective studies using objective methods of evaluation of clinical outcomes are necessary.

Although we are aware that the owners’ perceptions and the accuracy of postoperative assessments may be variable, their ability to evaluate functionality may be reliable [32].

In conclusion, stabilization of CCL-deficient stifles in dogs with LSS, LSS-M, or LBATS is reliable with acceptable complication rates. All the aforementioned techniques are appropriate in medium-sized nonathletic dogs whose owners have limited budgets. However, the optimal surgical procedure for stabilization of the deficient canine stifle remains a contentious issue in veterinary orthopedics. To our knowledge, postoperative complications using the Securos anchor placed at quasi-isometric points of the stifle for CCL injury treatment in dogs were evaluated for the first time in this study.

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Conflict of interest
The authors have no financial interest or other conflict of interest related to this report. All authors read and approved the final manuscript.

References
1. DeAngelis M, Lau RE. A lateral retinacular imbrication technique for the surgical correction of anterior cruciate ligament rupture in the dog. Journal of the American Veterinary Medical Association 1970; 157 (1): 79-84.
2. Flo GC. Modification of the lateral retinacular imbrication technique for stabilizing cruciate ligament injuries. Journal of the American Animal Hospital Association 1975; 11: 570-576.
3. Brinker WO, Piermattei DL, Flo GL. Handbook of Small Animal Orthopedics and Fracture Treatment. Philadelphia, PA, USA: Saunders; 1990.
4. Singer MJ, Pijanowski G, Wiley R, Johnson AL, Siegel AM. Biomechanical evaluation of a veterinary suture anchor in the canine cadaver pelvis and femur. Veterinary and Comparative Orthopaedics and Traumatology 2005; 18 (1): 31-36. doi: 10.1055/s-0038-1632925
5. Robb JL, Cook JL, Carson W. In vitro evaluation of screws and suture anchors in Metaphyseal bone of the canine Tibia. Veterinary Surgery 2005; 34 (5): 499-508. doi: 10.1111/j.1551-2916.2005.00075.x

6. Giles JT 3rd, Coker D, Rochat MC, Payton ME, Subramanian V et al. Biomechanical analysis of suture anchors and suture materials in the canine femur. Veterinary Surgery 2008; 37 (1): 12-21. doi: 10.1111/j.1532-950X.2007.00341.x

7. Choate CJ, Pozzi A, Lewis DD, Hudson CC, Conrad BP . Clinical case applications of Mitek tissue anchors in veterinary orthopedics. Veterinary and Comparative Orthopaedics and Traumatology 1993; 6 (4): 208-212. doi: 10.1055/s-0038-1633060

8. Edwards M, Taylor RA, Franceschi RA. Clinical case applications of Mitek tissue anchors in veterinary orthopedics. Veterinary and Comparative Orthopaedics and Traumatology 2007; 20 (1): 43-50. doi: 10.1055/s-0037-1616587

9. Guenego L, Zahra A, Madelenat A, Gautier R, Marcellin-Little DJ et al. Cranial cruciate ligament rupture in large and giant dogs. A retrospective evaluation of a modified lateral extra-articular stabilization. Veterinary and Comparative Orthopaedics and Traumatology 2007; 20 (1): 43-50. doi: 10.1055/s-0037-1616587

10. Hulse D, Saunders B, Beale B, Kowaleski M. Extra-articular stabilization of the cranial cruciate deficient stifle with anchor systems. Tierärztliche Praxis Ausgabe K: Kleintiere - Heimtiere 2011; 39 (5): 363-367. doi: 10.1055/s-0038-1623601

11. D’Amico LL, Lanz OI, Aulakh KS, Butler JR, McLaughlin RM et al. The effects of a novel lateral extra-articular suture system on the kinematics of the cranial cruciate deficient canine stifle. Veterinary and Comparative Orthopaedics and Traumatology 2013; 26 (4): 271-279. doi: 10.3415/VCOT-12-04-0055

12. Kishi NE, Hulse D, Raske M, Saunders WB, Beale SB. Extra-articular stabilization of the canine cranial cruciate ligament injury using Arthrex corkscrew and FAS Tak anchors. Open Journal of Veterinary Medicine 2013; 3 (2): 156-160. doi: 10.4236/ojvm.2013.32024

13. Raske M, Hulse D. SwiveLock bone anchor stabilization of the cranial cruciate ligament deficient stifle in dogs: clinical outcome. Open Journal of Veterinary Medicine 2013; 3 (7): 297-301. doi: 10.4236/ojvm.2013.37048

14. Rappa SN, Radasch MR. Post-operative complications associated with the Arthrex Canine Cranial Cruciate Ligament Repair Anchor System in small- to medium-sized dogs: a retrospective analysis (2009–2012). Canadian Veterinary Journal 2016; 57 (8): 847-852.

15. Muro NM, Lanz OI. Use of a novel extracapsular bone anchor system for stabilisation of cranial cruciate ligament insufficiency. Journal of Small Animal Practice 2017; 58 (5): 284-292. doi: 10.1111/jsap.12669

16. Caporn TM, Roe SC. Biomechanical evaluation of the suitability of monofilament nylon fishing and leader line for extra-articular stabilization of the canine cranial cruciate ligament deficient stifle. Veterinary and Comparative Orthopaedics and Traumatology 1996; 9 (3): 126-133. doi: 10.1055/s-0038-1632517

17. Lewis DD, Milthorpe BK, Bellenger CR. Mechanical comparison of materials used for extra capsular stabilisation of the stifle joint in dogs. Australian Veterinary Journal 1997; 75 (12): 890-896.

18. Peycke LE, Kerwin SC, Hosgood GJ, Metcalf B. Mechanical comparison of six loop fixation methods with monofilament nylon leader line. Veterinary and Comparative Orthopaedics and Traumatology 2002; 15 (4): 210-214. doi: 10.1055/s-0038-1632741

19. 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 extra-articular stabilization of canine cruciate deficient stifles. Veterinary Surgery 2010; 39 (2): 208-215. doi: 10.10111/j.1532-950X.2009.00637.x

20. Anderson CC, Tomlinson JL, Daly WR, Carson WL, Payne JT 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. Veterinary Surgery 1998; 27 (6): 533-539. doi: 10.1111/j.1532-950X.1998.tb00528.x

21. Vianna ML, Roe SC. Mechanical comparison of two knots and two crimp systems for securing nylon line used for extra-articular stabilization of the canine stifle. Veterinary Surgery 2006; 35 (6): 567-572. doi: 10.1111/j.1532-950X.2006.00190.x

22. Roe S, Kue J, Gemma J. Isometry of potential suture attachment sites for the cranial cruciate ligament deficient canine stifle. Veterinary and Comparative Orthopaedics and Traumatology 2008; 21 (3): 215-220. doi: 10.1055/s-0037-1617364

23. Cook JL. Extra capsular stabilization. In: Muir P (editor). Advances in the Canine Cranial Cruciate Ligament. Hoboken, NJ, USA: John Wiley & Sons; 2017. pp. 163-168.

24. Hulse D, Hyman W, Beale B, Saunders B, Peycke I 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 2010; 23 (3): 163-167. doi: 10.3415/vcot-09-05-0054

25. Fischer C, Cherres M, Grevin 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 2010; 39 (3): 334-342. doi: 10.1111/j.1532-950X.2010.00659.x

26. Reichert EE, Kunkel KAR, Suber JT, Basinger RR, Gerard PD. Radiographic localization and isometry of the origin and insertion of the canine cranial cruciate ligament. Veterinary Surgery 2013; 42 (7): 860-866. doi: 10.1111/j.1532-950X.2013.12047.x

27. Roe SC. The challenge of isometry for extracapsular devices. Veterinary and Comparative Orthopaedics and Traumatology 2013; 26 (4): VII. doi: 10.3415/VCOT-13-05-0066

28. Casale SA, McCarthy RJ. Complications associated with lateral fabellotibial suture surgery for cranial cruciate ligament injury in dogs: 363 cases (1997–2005). Journal of the American Veterinary Medical Association 2009; 234 (2): 229-235. doi: 10.2460/javma.234.2.229
29. Au KK, Gordon-Evans WJ, Dunning D, O’Dell-Anderson KJ, Knap KE et al. Comparison of short- and long-term function and radiographic osteoarthrosis in dogs after postoperative physical rehabilitation and tibial plateau leveling osteotomy or lateral fabellar suture stabilization. Veterinary Surgery 2010; 39 (2): 173-180. doi: 10.1111/j.1532-950X.2009.00628.x

30. Meyer DC, Nyffeler RW, Fucentese SF, Gerber C. Failure of suture material at suture anchor eyelets. Arthroscopy 2002; 18 (9): 1013-1019. doi: 10.1053/jars.2002.36115

31. Aktay SA, Kowaleski MP. Analysis of suture anchor eyelet position on suture failure load. Veterinary Surgery 2011; 40 (4): 418-422. doi: 10.1111/j.1532-950X.2011.00834.x

32. Hudson JT, Slater MR, Taylor L, Scott HM, Kerwin SC. Assessing repeatability and validity of a visual analogue scale questionnaire for use in assessing pain and lameness in dogs. American Journal of Veterinary Research 2004; 65 (12): 1634-1643. doi: 10.2460/ajvr.2004.65.1634

33. Cook JL, Pozzi A. Surgical treatment of concurrent meniscal injury. In: Muir P (editor). Advances in the Canine Cranial Cruciate Ligament. 1st ed. Ames, IA, USA: Wiley-Blackwell, 2010. pp. 217-222.

34. Cook JL, Luther JK, Beetem J, Karnes J, Cook CR. Clinical comparison of a novel extracapsular stabilization procedure and tibial plateau levelling osteotomy for treatment of cranial cruciate ligament deficiency in dogs. Veterinary Surgery 2010; 39 (3): 315-323. doi: 10.1111/j.1532-950X.2010.00658.x

35. Berger B, Knebel J, Steigmeier-Raith S, Reese S, Meyer-Lindenberg A. Long-term outcome after surgical treatment of cranial cruciate ligament rupture in small breed dogs. Comparison of tibial plateau leveling osteotomy and extra-articular stifle stabilization. Tierärztliche Praxis Ausgabe K: Kleintiere - Heimtiere 2015; 43 (6): 373-380. doi: 10.15654/tpk-150183

36. Vasseur PB, Berry CR. Progression of stifle osteoarthrosis following reconstruction of the cranial cruciate ligament in 21 dogs. Journal of the American Animal Hospital Association 1992; 28 (2): 129-136.

37. Morgan JP, Voss K, Damur DM, Guerrero T, Haessler M et al. Correlation of radiographic changes after tibial tuberosity advancement in dogs with cranial cruciate-deficient stifles with functional outcome. Veterinary Surgery 2010; 39 (4): 425-432. doi: 10.1111/j.1532-950X.2010.00669.x

38. Nakagawa S, Cuthill I. Effect size, confidence interval and statistical significance: a practical guide for biologists. Biological Reviews of the Cambridge Philosophical Society 2007; 82 (4): 591-605. doi: 10.1111/j.1469-185x.2007.00027.x

39. Chauvet AE, Johnson AL, Pijanowski GJ, Homco L, Smith RD. Evaluation of fibular head transposition, lateral fabellar suture, and conservative treatment of cranial cruciate ligament rupture in large dogs: a retrospective study. Journal of the American Animal Hospital Association 1996; 32 (3): 247-255. doi: 10.5326/15473317-32-3-247

40. Lodato D, Wardlaw J, Rowe D. Retrospective study comparing two materials commonly used in the LFS technique for CCLR. Journal of the American Animal Hospital Association 2013; 49 (2): 108-114. doi: 10.5326/JAAHA-MS-5841

41. Bergh MS, Peirone B. Complications of tibial plateau leveling osteotomy in dogs. Veterinary and Comparative Orthopaedics and Traumatology 2012; 25 (5): 349-358. doi: 10.3415/VCOT-11-09-0122

42. Priddy NH, Tomlinson JL, Dodam JR, Hornibostel JE. Complications with and owner assessment of the outcome of tibial plateau leveling osteotomy for treatment of cranial cruciate ligament rupture in dogs: 193 cases (1997–2001). Journal of the American Veterinary Medical Association 2003; 222 (12): 1726-1732. doi: 10.2460/javma.2003.222.1726

43. Fitzpatrick N, Solano MA. Predictive variables for complications after TPLO with stifle inspection by arthrotomy in 1000 consecutive dogs. Veterinary Surgery 2010; 39 (4): 460-474. doi: 10.1111/j.1532-950x.2010.00663.x

44. Kowaleski MP, Boudrieau RJ, Beale JS, Piras A, Hulse D et al. Radiographic outcome and complications of tibial plateau leveling osteotomy stabilized with an anatomically contoured locking bone plate. Veterinary Surgery 2013; 42 (7): 847-852. doi: 10.1111/j.1532-950x.2013.12048.x

45. Pacchiana PD, Morris E, Gillings SL, Jessen CR, Lipowitz AJ. Surgical and postoperative complications associated with tibial plateau leveling osteotomy in dogs with cranial cruciate ligament rupture: 397 cases (1998–2001). Journal of the American Veterinary Medical Association 2003; 222 (2): 184-193. doi: 10.2460/javma.2003.222.184

46. Stauffer KD, Tuttle TA, Elkins AD, Wehrenberg AP, Character BJ. Complications associated with 696 tibial plateau leveling osteotomies (2001–2003). Journal of the American Animal Hospital Association 2006; 42 (1): 44-50. doi: 10.5326/0420044

47. Wolf RE, Scavelli TD, Hoelzler MG, Fulcher RP, Bastian RP. Surgical and postoperative complications associated with tibial tuberosity advancement for cranial cruciate ligament rupture in dogs: 458 cases (2007–2009). Journal of the American Veterinary Medical Association 2012; 240 (12): 1481-1487. doi: 10.2460/javma.240.12.1481

48. Voss K, Damur DM, Guerrero T, Haessler M, Montavon PM. Force plate gait analysis to assess limb function after tibial tuberosity advancement in dogs with cranial cruciate ligament disease. Veterinary and Comparative Orthopaedics and Traumatology 2008; 21 (3): 243-249. doi: 10.1055/s-0037-1617368

49. Ritzo ME, Ritzo BA, Siddens AD, Summerlott S, Cook JL. Incidence and type of meniscal injury and associated long-term clinical outcomes in dogs treated surgically for cranial cruciate ligament disease. Veterinary Surgery 2014; 43 (8): 952-958. doi: 10.1111/j.1532-950x.2014.12220.x

50. Hayes GM, Langley-Hobbs SJ, Jeffery ND. Risk factors for medial meniscal injury in association with cranial cruciate ligament rupture. Journal of Small Animal Practice 2010; 51 (12): 630-634. doi: 10.1111/j.1748-5827.2010.01003.x

51. Thieman KM, Tomlinson JL, Fox DB, Cook C, Cook JL. Effect of meniscal release on rate of subsequent meniscal tears and owner-assessed outcome in dogs with cruciate disease treated with tibial plateau leveling osteotomy. Veterinary Surgery 2006; 35 (8): 705-710. doi: 10.1111/j.1532-950x.2006.00214.x
52. 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 2013; 42 (3): 329-334. doi: 10.1111/j.1532-950X.2013.12001.x

53. Ledecky V, Hluchy M, Freilichman R, Hornak S, Knazovicky D. Clinical comparison and short-term radiographic evaluation of tight rope and lateral suture procedures for dogs after cranial cruciate ligament rupture. Veterinarni Medicina (Praha) 2014; 59; 502-505.

54. Aragon CL, Budsberg SC. Applications of evidence-based medicine: cranial cruciate ligament injury repair in the dog. Veterinary Surgery 2005; 34 (2): 93-98. doi: 10.1111/j.1532-950X.2005.00016.x

55. Mölsä SH, Hyytiäinen HK, Hielm-Björkman AK, Laitinen-Vapaavuori OM. Long-term functional outcome after surgical repair of cranial cruciate ligament disease in dogs. BMC Veterinary Research 2014; 10 (1): 266-276. doi: 10.1186/s12917-014-0266-8

56. Böddeker J, Drüen S, Meyer-Lindenthomb A, Fehr M, Nolte I et al. Computer-assisted gait analysis of the dog: comparison of two surgical techniques for the ruptured cranial cruciate ligament. Veterinary and Comparative Orthopaedics and Traumatology 2012; 25 (1): 11-21. doi: 10.3415/VCOT-10-02-0025

57. Gordon-Evans WJ, Griffon DJ, Bubb C, Knap KM, Sullivan M et al. Comparison of lateral fabellar suture and tibial plateau leveling osteotomy techniques for treatment of dogs with cranial cruciate ligament disease. Journal of the American Veterinary Medical Association 2013; 243 (5): 675-680. doi: 10.2460/javma.243.5.675

58. Nelson SA, Krotscheck U, Rawlinson J, Todhunter R, Zhang Z et al. Long-term functional outcome of tibial plateau leveling osteotomy versus extracapsular repair in a heterogeneous population of dogs. Veterinary Surgery 2013; 42 (1): 38-50. doi: 10.1111/j.1532-950x.2012.01052.x

59. Ballagas AJ, Montgomery RD, Henderson RA, Gillette R. Pre- and postoperative force plate analysis of dogs with experimentally transected cranial cruciate ligaments treated using tibial plateau leveling osteotomy. Veterinary Surgery 2004; 33 (2): 187-190. doi: 10.1111/j.1532-950x.2004.04027.x

60. Conzemius MG, Evans RB, Besancon MF, Gordon WJ, Horstman CL et al. Effect of surgical technique on limb function after surgery for rupture of the cranial cruciate ligament in dogs. Journal of the American Veterinary Medical Association 2005; 226 (2): 232-236. doi: 10.2460/javma.2005.226.232