Long-Term Clinical and Goniometric Follow-Up of TTA Rapid Surgery in Dogs with Cranial Cruciate Ligament Rupture

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Abstract

This study aimed to evaluate the complications and the short-, medium-, and long-term outcomes following treatment of cranial cruciate ligament (CCL) rupture in dogs using the TTA rapid technique. The patients were ten dogs of various breeds, 54.9 $\pm$ 24.6 months of age, weighing 35.8 $\pm$ 5.6 kg, with unilateral CCL rupture. At 2, 6, 12, 24, and 52 weeks after surgery, the dogs were re-evaluated with clinical examination, gait and pain analysis, and radiography. A major complication was identified in one dog (10%), requiring internal fixation due to detachment and cranial shift of the tibial crest. Minor complications occurred in three dogs: one intraoperative (distal fissure of the tibial crest which healed without intervention) and two postoperative (one late meniscal injury and one case of seroma formation). The short-term outcome at two and six weeks postoperatively was considered good in seven dogs and satisfactory in three dogs, while the mid-term outcome (between 12 and 24 weeks) was good to excellent in nine dogs and satisfactory in one dog. All ten dogs had a good to excellent outcome 52 weeks after surgery. The use of TTA rapid offers an alternative for treatment of CCL insufficiency in dogs, with complication rates comparable to previously reported ones and a high degree of owner satisfaction.

Keywords: Cranial cruciate ligament, dog, treatment, TTA rapid

Introduction

The rupture of the cranial cruciate ligament (CCL) is among the most common causes for pelvic limb lameness in dogs (Harasen, 2008; Kowaleski et al., 2012; Roush, 2013). The exact reason for the condition is still unclear (Comerford et al., 2011). According to some researchers, degenerative changes in the CCL are the causative factors, and ultimate rupture often occurs without substantial trauma (Hoffmann et al., 2006; Lafaver et al., 2007; Steinberg et al., 2011). Dogs from medium- to large-sized breeds between 6 and 10 years of age are the most frequently affected, yet the condition may be observed in 1- to 2-year-old dogs of any size, including miniature and giant breeds (Jerram et al., 2005).

The highest prevalence is in large-breed dogs, in which the stifle joint with craniocaudal instability is prone to chronic mechanical and degenerative articular damage (Kowaleski et al., 2012). In small dog breeds (<15 kg), the conservative treatment of CCL rupture could be still considered (Comerford et al., 2013; Duerr et al., 2014). Others (Berger et al., 2015; Cosenza et al., 2015; Witte & Scott, 2014) prefer surgical treatment, affirming that it provides faster return to normal limb function.

Several surgical techniques for the treatment of ruptured CCL in dogs are described (Vaughan, 2010). During the last few years, attention has been focused on techniques altering stifle joint biomechanics. Their aim is either to eliminate cranial tibial translation occurring during limb loading through osteotomy (TPLO), as described originally by Slocum and Slocum (1993), or to advance the tibial tuberosity forward (TTA), reported initially by Montavon et al. (2002) with clinical results documented by Hoffmann et al. (2006). In 2015, Samoy et al. (2015) proposed a

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variant of the TTA technique termed “TTA rapid,” and reported good to excellent outcome in 48 out of 50 dogs 3 months after surgery.

The available data about the clinical and functional outcome of the TTA rapid surgery in dogs with CCL rupture and the consequent complications that occur are sparse, especially long-term follow-up data. Moreover, this is the first report in Bulgaria documenting the results from application of the TTA rapid method for surgical treatment of canine CCL ruptures.

The purpose of the present clinical survey was to perform a long-term clinical follow-up of patients with ruptured CCL undergoing TTA rapid surgery, and to discuss our experience regarding the clinical outcome, goniometric findings, and postoperative complications of the procedure.

Method

All dogs included in the present study were referred to the Small Animal Clinic of the Faculty of Veterinary Medicine, Stara Zagora, Bulgaria, between September 2017 and March 2019, with a history of unilateral pelvic limb lameness. A complete orthopedic examination was performed to identify the cause of lameness. Upon detection of pain, positive cranial drawer sign, joint effusion suggesting CCL rupture, and a tibial compression test, radiography of both stifle joints was done in two orthogonal views after deep intramuscular sedation with 0.025 mg/kg medetomidine hydrochloride (Dorbene vet®, 1 mg/mL, Syva, Spain) and 0.1 mg/kg butorphanol tartrate (Butomidor®, 10 mg/mL, Richter Pharma, Austria). After confirmation of the tentative diagnosis, dogs with CCL rupture dating back to three weeks maximum were used in the survey. All patients with bilateral CCL rupture, radiographic signs of osteoarthritis, and body weight under 15 kg were excluded.

The patients’ owners were informed about the alternative operative techniques offered (extracapsular stabilization with lateral fabellar suture or the intracapsular under-and-over fascial strip technique), and were allowed to participate in the survey after signing an informed consent form.

During the preoperative planning, digital mediolateral stifle radiographs were obtained at a physiological angle of 135° as DICOM format files. The images were transformed to the actual size (magnification factor 0.26). The common tangent TTA technique was used to determine the degree of advancement for obtaining optimal effect (Dennler et al., 2006). Osteotomy length was determined by means of a standard template with an optimal position of Maquet hole vs. cage size. The cranial tibial cortical thickness near the Maquet hole under the tibial crest was measured with the same template or imaging software (iQ-View, Image Information Systems Ltd, Rostock, Germany). The role of the Maquet hole was to limit the length of osteotomy; the diameters used were 3 mm in eight dogs and 2 mm in two dogs. The hole size was proportionate to the patient and cage size, allowing the bone to hinge, and also spreading the load and serving as a distal point for the saw guide.

The surgery was performed following a strict anesthesia protocol. Premedication was done with acepromazine maleate (Neurotranq®, 10 mg/mL, Alfasan International, Netherlands) at a dose of 0.025 mg/kg and buprenorphine (Bupaq®, 0.3 mg/mL, Richter pharma, Austria) at a dose of 0.01 mg/kg, applied together in a syringe in the m. quadriceps femoris. Thirty minutes later, induction was done with intravenous application of 5 mg/kg propofol (Propofol Fresenius®, Fresenius Kabi GmbH, Germany). After endotracheal intubation, inhalational anesthesia was maintained with isoflurane (Forane®, Abbott Laboratories Limited, United Kingdom) at 1.5–2.5 vol%, in 100% O_2. Fluid management was performed with Ringer lactate infusion at a rate of 10 mL/kg/h.

The implants used in the TTA rapid technique, designed by Samoy et al. (2015), are modified and simpler compared to those used by the classical TTA technique described by Montavon et al. (2002). TTA rapid surgery was done as per Samoy et al. (2015), using TTA rapid titanium cages and 2.4 mm titanium screws (Rita Leibinger, Germany). After medial arthrotomy, medial meniscal release was done in all dogs with intact menisci. The osteotomy region was filled with nanocrystalline hydroxyapatite paste (Nano HA Bone Paste 2.5 cc, Veterinary Instrumentation Ltd, UK).

Postoperatively, dogs received amoxicillin/clavulanic acid (Synulox® RTU, Zoetis, Belgium) at a dose of 25 mg/kg, applied subcutaneously for 10 days, and 3 mg/kg carprofen (Carprieve Pet Injection®, 50 mg/mL, Norbrook, Northern Ireland) subcutaneously for 5 days.

All follow-up parameters were registered at the day of surgery (day 1) and on postoperative day 14 (week 2), day 42 (week 6), day 84 (week 12), and day 365 (year 1). At these periods, radiographs of both stifles were obtained (Figure 1), along with goniometric evaluation. Kinetic gait analysis was done, and lameness, pain, and joint effusion were evaluated using the scoring system reported by Cross et al. (1997).

For goniometric studies, a goniometer with arms (GIMA, Germany) was used. The measurements were performed in lateral recumbency, with the studied limb exposed. The stifle range of motion (ROM) was measured in full flexion and extension by placing the tool along the longitudinal axes of the femur (through the trochanter major femoris) and the tibia (through the malleolus lateralis tibiae). The results in the operated limbs were compared with the contralateral healthy joint.

Numerical data were presented as median and range (for kinetic gait score) and as mean ± standard error of the mean (for all other parameters). Statistical analysis of data was done by the non-parametric Mann–Whitney U method at level of significance $p < .05$, using statistical software (MedCalc v. 15.8, Belgium).

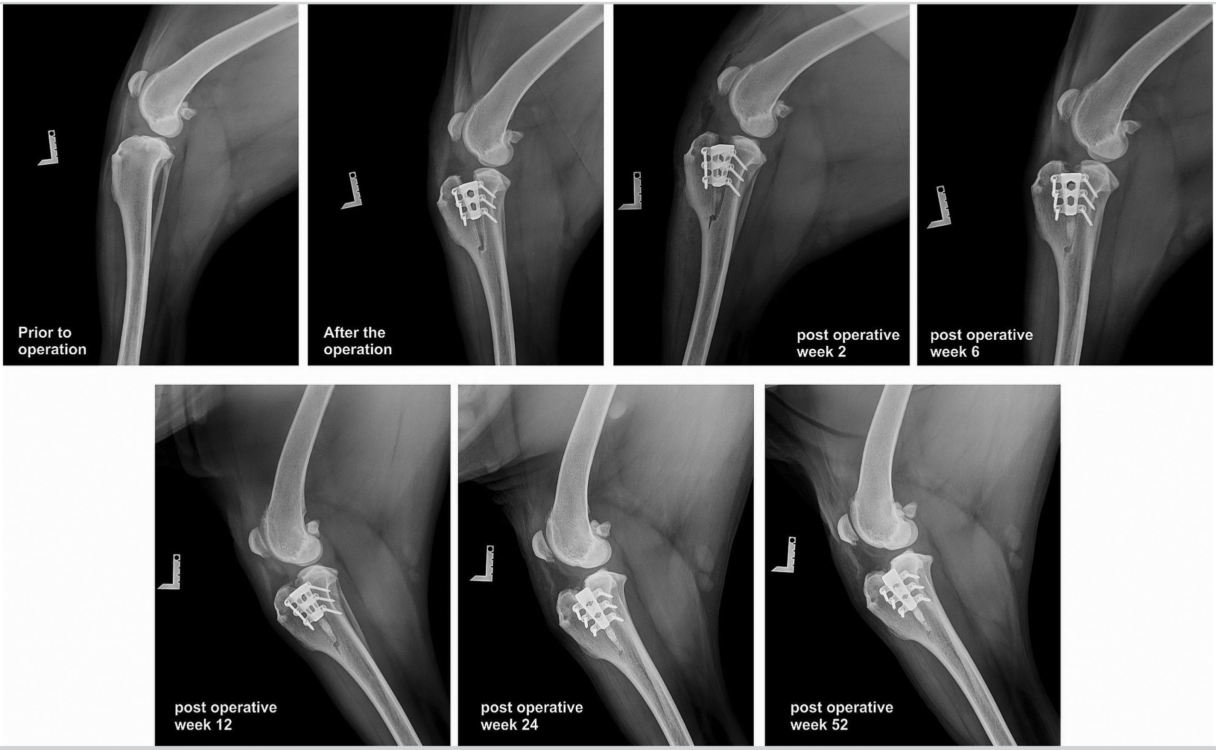

Figure 1
Mediolateral Stifle Radiographs Before TTA Surgery, and at Different Time Periods After TTA Surgery, for Treatment of CCL Rupture in Dogs.

Results

The survey included ten dogs (ten stifles) of different breeds, six females and four males, weighing 35 ± 1.5 kg on an average (min–max 28.8–40.8 kg). The average age of the group was 55 ± 8 months (from two to eight years). After medial arthrotomy and inspection of the stifle joint, the CCL was found to be completely ruptured in seven dogs and partially in three dogs. In seven patients, the left stifle was affected, while the right stifle was affected in three patients. Using a meniscal probe, the medial meniscus was found to be injured in five joints: two bucket-handle tears, one horizontal tear, one longitudinal tear, and one radial tear. The lateral meniscus was intact in all cases.

Intraoperative complications comprised distal tibial fissures related to osteotomy, which were left to heal conservatively (cases one and eight). In one patient, using a titanium cage of 10.5 mm width, separation of the tibial tuberosity from the tibia was achieved by the second postoperative week; it was fixed with two Kirshner wires passing through the wedge-shaped osteotomy (Figure 2). Six months after the TTA rapid surgery, breakdown of the distalmost cranial ear of the cage occurred; however, this caused neither implant displacement nor screw loosening. At that time, the filling of osteotomy region with bone was good, and no change in the degree of advancement or the patella alta was found. Until the 52nd week, complete filling with bone callus (visible proximally, in the middle and distally to the cage), bridging of osteotomy, and removal of wires were observed. In one dog (case 4), there was a minor postoperative complication consisting of infection with seroma, which was treated with a 10-day administration of 30 mg/kg cefalexin monohydrate (Tsefalen®, ICF, Italy). A late meniscal injury was suspected in one patient (case nine) by the 20th postoperative week, yet it was not categorically confirmed by arthroscopy or MRI but was manifested with low-grade lameness, meniscal clicking, and joint effusion visible at radiographs. The condition was treated with two intra-articular applications of 1 mL hyaluronic acid (Steril vit Synovia HA, Vetos Farma, Poland) at 10-day intervals and oral application of meloxicam (Meloxidyl®, 1.5 mg/mL, Ceva, France) for five days.

Data from the kinetic gait and goniometric analyses are presented in Table 1. Before the surgery, the score of the affected joint was 10 (7-13), and by the second and sixth weeks remained statistically significantly higher ($p < .0001$) compared to contralateral stifle: 7.5 (5–10) and 6 (5-7) respectively. Until the 24th postoperative week, the difference in both stifle scores remained significant ($p = .003$). One year after TTA rsurgery, both joints had equal scores, with restoration of function in the operated limb.

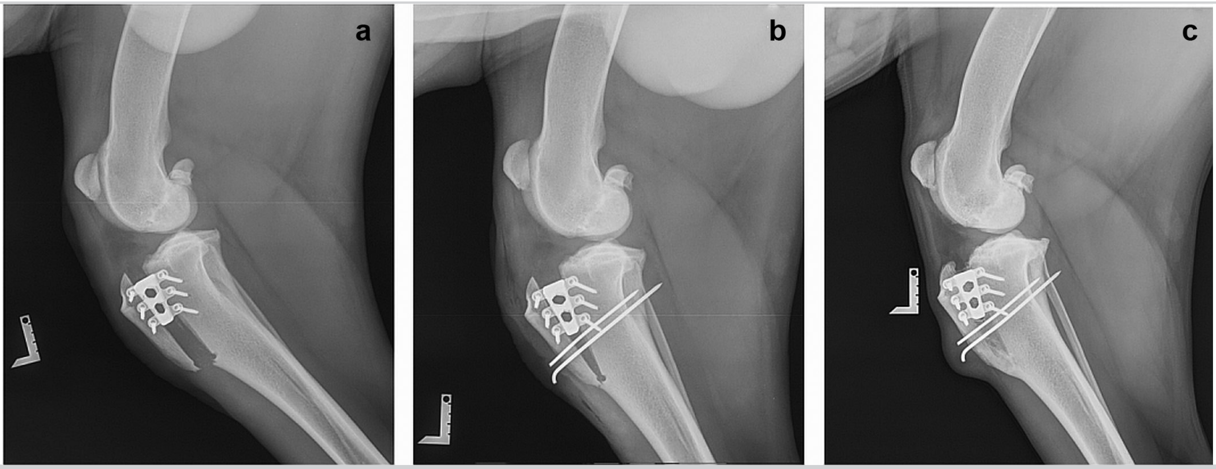

Figure 2
(a) Mediolateral Stifle Radiographs of Separated Tibial Crest Two Weeks After TTA Surgery, (b) After Surgical Fixation with Two Kirschner Wires, and (c) 52 Weeks Postoperative with Complete Bridging of the Osteotomy Gap.

The maximum extension angle exhibited statistically significant difference from the contralateral healthy joint only by the sixth ($p < .05$) and 12th ($p < .01$) postoperative week. On the contrary, the maximum flexion angle and ROM values differed significantly during all follow-up periods. The values of maximum flexion angle and ROM by the first year after surgery (47.0 ± 0.4 and 99.5 ± 0.9 respectively) did not recover to preoperative values (44.8 ± 0.5 for flexion angle and 101.4 ± 0.8 for ROM).

Discussion, Conclusion and Recommendations

The first report on the outcome of TTA rapid was a prospective study in 50 dogs mainly from large breeds (average body

Table 1
Clinical Evaluation Score and Goniometric Analysis in Dogs Undergoing TTA Rapid Surgery for Treatment of CCL Rupture

		Postoperative Week				
Joint	**Before Surgery**	**2**	**6**	**12**	**24**	**52**
Kinetic gait analysis score*						
Operated	10 (7-13)	7.5 (5-10)	6 (5-7)	5 (4-8)	5 (4-6)	4 (4-4)
Control	4 (4-5)	4 (4-5)	4 (4-5)	4 (4-5)	4 (4-4)	4 (4-4)
p	<.001	<.001	<.001	.003	.003	
Maximum extension angle, degress**						
Operated	146.2 ± 0.5	146.2 ± 0.6	145.9 ± 0.5	145.5 ± 0.6	146.2 ± 0.4	146.6 ± 0.6
Control	147.2 ± 0.6	147.8 ± 0.7	147.9 ± 0.8	148.2 ± 0.7	147.5 ± 0.6	147.2 ± 0.5
p			<.05	<.01		
Maximum flexion angle, degress**						
Operated	44.8 ± 0.5	46.5 ± 0.5	46.7 ± 0.5	46.8 ± 0.5	47.0 ± 0.4	47.0 ± 0.4
Control	44.5 ± 0.5	44.9 ± 0.4	45.1 ± 0.5	45.1 ± 0.5	45.0 ± 0.5	45.0 ± 0.5
p		<.05	<.05	<.05	<.01	<.01
Range of motion, degress**						
Operated	101.4 ± 0.8	100.0 ± 0.9	99.3 ± 0.7	98.9 ± 0.8	99.3 ± 0.7	99.5 ± 0.9
Control	102.8 ± 0.9	103.0 ± 0.9	102.8 ± 1.0	103.0 ± 1.0	102.8 ± 1.0	102.7 ± 0.7
p		<.05	<.01	<.01	<.001	<.05

*Data are presented as median (range) for 10 dogs; **Data are presented as mean ± standard error of the mean for 10 dogs.

weight 31.9 ± 13.3 kg), affirming good clinical results and a low rate of complications (Samoy et al., 2015).

Postoperative complications requiring treatment, reported by Butterworth and Kydd (2017), were 7%, which is comparable to our results (10%). The study of Arican et al. (2017) in 17 dogs, demonstrated implant loosening in one case, while complete bone healing was observed by the third postoperative month in all patients. These results are similar to ours as far as severe complications were concerned (10%) and filling with bone of osteotomy region was done by the 12th postoperative week. The rate of minor complications in the cited research was 25% versus 30% in our survey (three cases including seroma, late meniscal injury, and a distal tibial fissure, distal to the Maquet hole).

Butterworth and Kydd (2017) reported tibial fissures distal to the Maquet hole with various lengths and directions in 70% of the operated patients. The occurrence of fissures led to the improvement of the technique associated with the Maquet hole and longer osteotomy (Samoy et al., 2015). Nevertheless, a study using the osteotomy technique, described first by Brunel et al. (2013), without creating a hole at the end of osteotomy, has reported one case of tibial fracture (Ramirez et al., 2015).

Tibial fracture and avulsion of the tuberositas tibiae after TTA rapid surgery due to a fracture distal to Maquet hole were reported by Heremans et al. (2017). The complication was fixed intraoperatively with a screw, and in the postoperative period, ultrasound therapy was applied.

Dyall and Schmökel (2017) reported four osteotomy-related fissures (8.4%) in 48 operated stifles in small dog breeds—two stabilized with screws and another two that healed on their own. The same study also reported two cases of late meniscal injury, two tibial fractures, and two incisional complications. The total complication rate was 14.6%. Our results were somewhat different as we documented one late meniscal injury (10%), one incisional complication (10%), and no tibial fractures. There were three fissures related to osteotomy (30%), among which one involved complete separation of the tibial crest and two healed spontaneously. It should be noted that our patients were of a rather larger size than those of Dyall and Schmökel (2017).

Samoy et al. (2015) established three intraoperative cranial cortical fissures in 50 operated dogs, one with complete separation from the tibia (2.1%). Similarly, in our survey, there were three fissures of cranial tibial compacta, one of them (10%) completely separated. At the time of our study, the manufacturer (Rita Leibinger Medical, Germany) recommended exclusion of the Maquet hole, as experience showed that it did not stop fissure occurrence. Our result suggested that the Maquet hole did not appear to stop cortical fissure and had no control on its direction, as affirmed by others as well (Brunel et al., 2013).

In our study, we performed the TTA rapid technique to repair CCL rupture in ten dogs, which uses the same principle as the classic TTA technique but different preoperative planning and implants (cage and screws), not a plate and fork. In our work, the tibial tuberosity advancement was accomplished by drilling a Maquet hole in the distal part of the osteotomy, acting as a hinge. To stimulate bone healing and fill the osteotomy gap, a nanocrystalline paste was used instead of a cancellous graft from the proximal tibia. In our study, short-term, medium-term, and long-term follow-up evaluations were performed over different periods of time (2, 6, 12, 24 and 52 weeks), not only by clinical examination, but also through radiographic examination and goniometry.

The frequency of meniscal injuries increases with time (Hayes et al. 2010), and in large- and giant breed dogs could attain up to 81% of affected joint during the first stifle-stabilizing surgery (Guénégo et al., 2007). Harasen (2008) reported a failure rate of 37–48%, and no considerable difference between dogs of small and large breeds. Therefore, the meniscal injury rate of 50% in the present study was comparable, yet no relationship between tibial plate angle and meniscal injuries could be found. Unlike Hayes et al. (2010), our study did not show an increased rate of meniscal injury with a longer duration of lameness. One late meniscal injury was identified (10%), similar to the already reported rates of 4.3% (Dymond et al., 2010), 9.4% (Hoffmann et al., 2006), 8.8% (Lafaver et al., 2007), and 8.6% (Stein & Schmoekel, 2008).

In many publications (Dymond et al., 2010; Hoffmann et al., 2006; Lafaver et al., 2007; Stein & Schmoekel, 2008), the surgical technique used was the classic TTA. Also, follow-up assessments in the short-term, mid-term, and long-term were done either by clinical and radiographic examinations or by a questionnaire for owners. The follow-up assessments were at unequal intervals and some osteoarthritic changes, minor and major complications, and the time taken to fill the osteotomy gap have been documented as the reasons for this.

To sum up, a comparison of previous studies in dogs treated by any other surgical technique and dogs treated by TTA rapid (Casale & McCarthy, 2009; Cosenza et al., 2015; Samoy et al., 2015; Witte & Scott, 2014) reveals that the clinical results and the rate of intraoperative and postoperative complications in our study were similar.

Stifle joint goniometry after CCL rupture has been performed in several studies (Au et al., 2010; Gordon-Evans et al., 2013; Moeller et al., 2010). The resulting pain and altered limb function led to a decreased ROM and muscle atrophy (Monk et al., 2006). Joint motility was improved after surgery (Au et al., 2010; Bruce et al., 2007; Gordon-Evans et al., 2013) and intensive postoperative physical therapy (Monk et al., 2006). In some studies, ROM decreased with time after surgical treatment (Au et al., 2010; Bruce et al., 2007; Gordon-Evans et al., 2013; Jerram et al., 2005). Au et al. (2010) reported a higher preoperative

ROM value that decreased two years after extracapsular repair or TPLO. Our results are in line with other studies that documented lower ROM than that of the contralateral limb from one to five years after TPLO surgery (Moeller et al., 2010; Mölsä et al., 2014). The most probable reason for reduced joint motility is progressing osteoarthritis and the presence of the titanium implant altering stifle joint biomechanics.

On the basis of the reported results with major and minor complication rates of 10% and 30% respectively, the short-term outcome by the second and sixth postoperative weeks was considered good in seven dogs and satisfactory in three dogs. The mid-term outcome (12 and 24 postoperative weeks) was evaluated as good to excellent in nine dogs and satisfactory in one dog. All ten dogs were free of lameness and had a good to excellent outcome 52 weeks after surgery. The use of TTA rapid offers an alternative for treatment of CCL insufficiency in dogs, with good long-term clinical outcome and a high degree of owner satisfaction. Despite the small number of cases in our study, clinical, X-ray and goniometric examinations were performed during all follow-up periods, which provide valuable information and a detailed report of early and late postoperative complications.

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Peer Review: Externally peer-reviewed.

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References

Arican, M., Parlak, K., & Şahin, H. (2017). Evaluation and application of the TTA-rapid method in dogs with cranial cruciate ligament rupture. *Acta Veterinaria*, *67*(2), 238–253. [CrossRef]

Au, K. K., Gordon-Evans, W. J., Dunning, D., O'Dell-Anderson, K. J., Knap, K. E., Griffon, D., & Johnson, A. L. (2010). 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*, *39*(2), 173–180. [CrossRef]

Berger, B., Knebel, J., Steigmeier-Raith, S., Reese, S., & Meyer-Lindenberg, A. (2015). 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. *Tierarztliche Praxis Ausgabe K Kleintiere/Heimtiere*, *43*(6), 373–380. [CrossRef]

Bruce, W. J., Rose, A., Tuke, J., & Robins, G. M. (2007). Evaluation of the triple tibial osteotomy. A new technique for the management of the canine cruciate-deficient stifle. *Veterinary and Comparative Orthopaedics and Traumatology*, *20*(3), 159–168. [CrossRef]

Brunel, L., Etchepareborde, S., Barthélémy, N., Farnir, F., & Balligand, M. (2013). Mechanical testing of a new osteotomy design for tibial tuberosity advancement using the Modified Maquet Technique. *Veterinary and Comparative Orthopaedics and Traumatology*, *26*(1), 47–53. [CrossRef]

Butterworth, S. J., & Kydd, D. M. (2017). TTA-rapid in the treatment of the canine cruciate deficient stifle: Short- and medium-term outcome. *Journal of Small Animal Practice*, *58*(1), 35–41. [CrossRef]

Casale, S. A., & McCarthy, R. J. (2009). 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*, *234*(2), 229–235. [CrossRef]

Comerford, E. J., Smith, K., & Hayashi, K. (2011). Update on the aetiopathogenesis of canine cranial cruciate ligament disease. *Veterinary and Comparative Orthopaedics and Traumatology*, *24*(2), 91–98. [CrossRef]

Comerford, E., Forster, K., Gorton, K., & Maddox, T. (2013). Management of cranial cruciate ligament rupture in small dogs: A questionnaire study. *Veterinary and Comparative Orthopaedics and Traumatology*, *26*(6), 493–497. [CrossRef]

Cosenza, G., Reif, U., & Martini, F. M. (2015) Tibial plateau levelling osteotomy in 69 small breed dogs using conically coupled 1.9/2.5 mm locking plates. A clinical and radiographic retrospective assessment. *Veterinary and Comparative Orthopaedics and Traumatology*, *28*(5), 347–354. [CrossRef]

Cross, A. R., Budsberg, S. C., & Keefe, T. J. (1997). Kinetic gait analysis assessment of meloxicam efficacy in a sodium urate-induced synovitis model in dogs. *American Journal of Veterinary Research*, *58*(6), 626–631

Dennler, R., Kipfer, N. M., Tepic, S., Hassig, M., & Montavon, P. M. (2006). Inclination of the patellar ligament in relation to flexion angle in stifle joints of dogs without degenerative joint disease. *American Journal of Veterinary Research*, *67*(11), 1849–1854. [CrossRef]

Duerr, F. M. , Martin, K. W., Rishniw, M., Palmer, R. H., & Selmic, L. E. (2014). Treatment of canine cranial cruciate ligament disease: A survey of ACVS Diplomates and primary care veterinarians. *Veterinary and Comparative Orthopaedics and Traumatology*, *27*(6), 478–483. [CrossRef]

Dyall, B., & Schmökel, H. (2017). Tibial tuberosity advancement in small-breed dogs using TTA Rapid implants: Complications and outcome. *Journal of Small Animal Practice*, *58*(6), 314–322. [CrossRef]

Dymond, N. L., Goldsmid, S. E., & Simpson, D. J. (2010). Tibial tuberosity advancement in 92 canine stifles: Initial results, clinical outcome and owner evaluation. *Australian Veterinary Journal*, *88*(10), 381–385. [CrossRef]

Gordon-Evans, W. J., Griffon, D. J., Bubb, C., Knap, K. M., Sullivan, M., & Evans, R. B. (2013). 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*, *243*(5), 675–680. [CrossRef]

Guénégo, L., Zahra, A., Madelénat, A., Gautier, R., Marcellin-Little, D. J., & Hulse, D. (2007). Cranial cruciate ligament rupture in large and giant dogs. *Veterinary and Comparative Orthopaedics and Traumatology*, *20*(1), 43–50. [CrossRef]

Harasen, G. (2008). Canine cranial cruciate ligament rupture in profile: 2002–2007. *Canadian Veterinary Journal*, *49*(2), 193–194. [CrossRef]

Hayes, G. M., Langley-Hobbs, S. J., & Jeffery, N. D. (2010). Risk factors for medial meniscal injury in association with cranial cruciate ligament rupture. *Journal of Small Animal Practice*, *51*(12), 630–634. [CrossRef]

Heremans, J., de Bakker, E., Van Ryssen, B., & Samoy, Y. (2017). Therapeutic ultrasound as an aid in tibial fracture management in a dog. *Vlaams Diergeneeskundig Tijdschrift*, *86*(1), 29–34. [CrossRef]

Hoffmann, D. E., Miller, J. M., Ober, C. P., Lanz, O. I., Martin, R. A., & Shires, P. K. (2006). Tibial tuberosity advancement in 65 canine stifles. *Veterinary and Comparative Orthopaedics and Traumatology*, *19*(4), 219–227. [CrossRef]

Jerram, R. M., Walker, A. M., & Warman, C. G. A. (2005). Proximal tibial intraarticular ostectomy for treatment of canine cranial cruciate ligament injury. *Veterinary Surgery*, *34*(3), 196–205. [CrossRef]

Kowaleski, M. P., Boudrieau, R. J., & Pozzi, A. (2012). Stifle joint. In K. M. Tobias & S. A. Johnston (Eds.), *Veterinary surgery: Small animal* (1st ed, pp. 914–918). St. Louis, MO: Elsevier, Saunders.

Lafaver, S., Miller, N. A., Stubbs, W. P., Taylor, R. A., & Boudrieau, R. J. (2007). Tibial tuberosity advancement for stabilization of the canine cranial cruciate ligament-deficient stifle joint: Surgical technique, early results, and complications in 101 dogs. *Veterinary Surgery*, *36*(6), 573–586. [CrossRef]

Moeller, E. M., Allen, D. A., Wilson, E. R., Lineberger, J. A., & Lehenbauer, T. (2010). Long-term outcomes of thigh circumference, stifle range-of-motion, and lameness after unilateral tibial plateau levelling osteotomy. *Veterinary and Comparative Orthopaedics and Traumatology*, *23*(1), 37–42. [CrossRef]

Mölsä, S. H., Hyytiäinen, H. K., Hielm-Björkman, A. K., & Laitinen-Vapaavuori, O. M. (2014). Long-term functional outcome after surgical repair of cranial cruciate ligament disease in dogs. *BMC Veterinary Research*, *10*, 266. [CrossRef]

Monk, M. L., Preston, C. A., & McGowan, C. M. (2006). Effects of early intensive postoperative physiotherapy on limb function after tibial plateau leveling osteotomy in dogs with deficiency of the cranial cruciate ligament. *American Journal of Veterinary Research*, *67*(3), 529–536. [CrossRef]

Montavon, P. M., Damur , D. M., & Tepic, S. (2002). Advancement of the tibial tuberosity for the treatment of the cranial cruciate ligament deficient stifle. *Proceedings of the 1st World Orthopaedic Veterinary Congress* (pp. 152). Munich, Germany

Ramirez, J. M., Barthélémy, N., Noël, S., Claeys, S., Etchepareborde, S., Farnir, F., & Balligand, M. (2015). Complications and outcome of a new Modified Maquet technique for treatment of cranial cruciate ligament rupture in 82 dogs. *Veterinary and Comparative Orthopaedics and Traumatology*, *28*(5), 339–346. [CrossRef]

Roush, J. K. (2013). Canine cranial cruciate disease: Updating our knowledge about pathogenesis & diagnosis. *Todays Veterinary Practice, 3*, 16–20.

Samoy, Y., Verhoeven, G., Bosmans, T., Van der Vekens, E., de Bakker, E., Verleyen, P., & Van Ryssen, B. (2015). TTA rapid: Description of the technique and short term clinical trial results of the first 50 cases. *Veterinary Surgery*, *44*(4), 474–484. [CrossRef]

Slocum, B., & Slocum, T. D. (1993). Tibial plateau leveling osteotomy for repair of cranial cruciate ligament rupture in the canine. *Veterinary Clinics of North America: Small Animal Practice*, *23*(4), 777–795. [CrossRef]

Stein, S., & Schmoekel, H. (2008). Short-term and eight to 12 months results of a tibial tuberosity advancement as treatment of canine cranial cruciate ligament damage. *Journal of Small Animal Practice*, *49*(8), 398–404. [CrossRef]

Steinberg, E. J., Prata, R. G., Palazzini, K., & Brown, D. C. (2011). Tibial tuberosity advancement for treatment of CrCL injury: Complications and owner satisfaction. *Journal of the American Animal Hospital Association*, *47*(4), 250–257. [CrossRef]

Vaughan, L. C. (2010). The history of canine cruciate ligament surgery from 1952–2005. *Veterinary and Comparative Orthopaedics and Traumatology*, *23*(6), 379–384. [CrossRef]

Witte, P. G., & Scott, H. W. (2014). Tibial plateau leveling osteotomy in small breed dogs with high tibial plateau angles using a 4-hole 1.9/2.5 mm locking T-plate. *Veterinary Surgery*, *43*(5), 549–557. [CrossRef]