TREATMENT OPTIONS FOR CRANIAL CRUCIATE LIGAMENT RUPTURE IN DOG – A LITERATURE REVIEW

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Abstract

Cranial cruciate ligament (CrCL) breaks in dogs can be treated by surgical and non-surgical methods. Choice of the treatment method of cranial cruciate ligament rupture in dog continues to constitute a real problem for veterinarian clinicians. This topic has been the subject of many studies. The investigation of the speciality literature data concerning the surgical treatment options in the management of cranial cruciate ligament breaks in dog, remains in the conditions of an informational avalanche a present concern. The purpose of this study was to analyze additional evidence which have appeared in the literature in the period of 2006 - January 2017 and which advocate with concrete evidences in the favour or disfavour of a particular method of dog’s cranial cruciate ligament breaks treatment. Analysis of online searches using PubMed engine in 403 articles suggest that the data analyzed do not allow accurate comparisons between different treatment procedures of cranial cruciate ligament deficiency in dogs and did not show significant differences and major changes compared to previous reports (from 1963 to 2005). New long-term clinical studies must designed and further biomechanical and kinematic analyses are required to determine the optimal technique, and whether these procedures are superior to other stabilization methods.

Key words: cranial cruciate deficiency, dog, treatment procedures, trend.

INTRODUCTION

Choice of the treatment method of cranial cruciate ligament (CrCL) rupture in dog continues to constitute a real problem for veterinarian clinicians. This topic has been, since 1963 (Foster et al., 1963), the subject of many concerns and studies. CrCL breaks in dogs can be treated by surgical and non-surgical methods.

The latest study investigating the speciality literature on surgical treatment options in the management of CrCL ruptures in dogs was published in 2005 (Aragon and Budsberg, 2005) after an online bibliographic search through Medline, PubMed, Veterinary Information Network, and Commonwealth Agricultural Bureau Abstracts were found and analyzed 240 sources and it ends with the conclusion „At this time, the application of evidence-based medicine in analyzing the current available evidence suggests that there is not a single surgical procedure that has enough data to recommend that it can consistently return dogs to normal function after CCL injury”.

Referring only to the surgical procedures used to treat dog’s CrCL ruptures, a review from 2011 (Tonks et al., 2011) was focused only on extracapsular procedures and shows that there is no data to allow recommendation of a specific technique being necessary „future studies should be directed toward outlining the virtues and inadequacies of the current techniques” and another study investigating the literature (444 paper works) with constant referring only on surgical procedures occurred in 2014 (Berg et al., 2014) conclude that tibial plateau levelling osteotomy (TPLO) is superior to the extracapsular lateral side suturing procedures, but there are insufficient data to properly assess other surgical methods.

There are also several studies comparing the effectiveness of surgical and non-surgical therapeutic methods, the latest being dated in 2013 (Baker and Baker, 2013; Comerford et al., 2013; Wucherer et al., 2013).
The purpose of this study was to analyze additional proof which have appeared lately in the speciality literature in the favour / disfavor of a particular method of CrCL breaks treatment in dog.

MATERIALS AND METHODS

In January 2017 was conducted an online search, using three searching engines: Google scholar (https://scholar.google.ro), PubMed – US National Library of Medicine National Institutes of Health (https://www.ncbi.nlm.nih.gov/pubmed) and Taylor & Francis Online (http://www.tandfonline.com). There have been used as basic search term "cranial cruciate ligament rupture in dog" preceded into three main additional insights by the terms „treatment”, „nonsurgical treatment”, „surgery treatment”, last with the following secondary insights „lateral extracapsular stabilization treatment”, „tibial plateau levelling osteotomy - TPLO”, “ tibial tuberosity advancement - TTA”, “ triple tibial osteotomy - TTO” and “Maquet”. Filtering of the results was done using „most recent” and „best match” for PubMed engine, „article” for Google scholar and „subject” and „publication date” for Taylor & Francis Online. The results obtained by investigating PubMed were analyzed and classified according to the method proposed by Aragon and Budsberg, 2005, after the evaluation method used: 1 - force plate analysis, 2 - subjective and objective evaluation by the clinician and 3 - subjective evaluation by the pet owner, being considered relevant in this order (1 – maximum and 3 - minimum).

RESULTS AND DISCUSSIONS

Results of the bibliographic online introspection are shown in Table 1. The analysis of search results with PubMed engine reveals 403 articles (for the period 1963 - January 2017), respectively 391 after manual excluding of those in whose abstract was not evidenced a connection with CrCL. In the period 2006 - January 2017 were found 216 articles about CrCL in dog, data that reveals a near doubling of number of articles reviewed by Aragon and Budsberg until August 2004 (Aragon and Budsberg, 2005).

In the period of 2006 - January 2017 have appeared instead only 115 articles for therapeutic results evaluation of dog’s CrCl ruptures from which only 23 were relevant articles of level 1, according to the criterion (evaluation by force plate analysis), 86 articles of level 2 (subjective and objective evaluation by the clinician) and 6 articles of level 3 (subjective evaluation by the pet owner).

| Descriptors                                                                 | Google scholar (https://scholar.google.ro) | PubMed – US National Library of Medicine National Institutes of Health (https://www.ncbi.nlm.nih.gov/pubmed) | Taylor & Francis Online (http://www.tandfonline.com) |
|----------------------------------------------------------------------------|-------------------------------------------|-------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|
| cranial cruciate ligament rupture in dog                                   | 10.600                                    | 403                                                                                                         | 62                                                      |
| treatment cranial cruciate ligament rupture in dog                        | 9550                                      | 267                                                                                                         | 51                                                      |
| surgery treatment cranial cruciate ligament rupture in dog                | 8550                                      | 251                                                                                                         | 41                                                      |
| lateral extracapsular stabilization treatment in cranial cruciate ligament rupture in dog | 735                                       | 5                                                                                                           | 2                                                       |
| tplo treatment in cranial cruciate ligament rupture in dog                | 983                                       | 33                                                                                                          | 4                                                       |
| tta treatment in cranial cruciate ligament rupture in dog                 | 465                                       | 21                                                                                                          | 1                                                       |
| tto treatment in cranial cruciate ligament rupture in dog                 | 384                                       | 3                                                                                                           | 1                                                       |
| triple tibial osteotomy - TTO                                             | 140                                       | 4                                                                                                           | 0                                                       |
| maquet procedure in cranial cruciate ligament rupture in dog              | 162                                       | 3                                                                                                           | 0                                                       |
| bone anchor in cranial cruciate ligament rupture in dog                   | 1340                                      | 3                                                                                                           | 20                                                      |
| nonsurgical treatment in cranial cruciate ligament rupture in dog         | 1120                                      | 3                                                                                                           | 1                                                       |

Of the 23 articles of level 1, six articles promotes kinematics and force plate analysis methods for the diagnosis of dog’s CrCL ruptures (Fanchon and Grandjean, 2007; Sanchez et al., 2010; Pillard et al., 2012; Nelson et al., 2012; Souza et al., 2014; Krotscheck et al., 2014; Wüstefeld et al., 2016), 14 articles describe or compares the results obtained with different techniques of surgical treatment (Thieme et al., 2006; Robinson et
al., 2006; Havig et al., 2007; Schaijk, 2008; Voss et al., 2008; Gordon-Evans et al., 2010; Pozzi et al., 2010; Morgan et al., 2010; Gordon-Evans et al., 2011; de Medeiros et al., 2011; Böddeker et al., 2012; Nelson et al., 2012; Mols et al., 2014; Rey et al., 2014; Berger et al., 2015) and two articles describe and compare the results obtained with different nonsurgical treatment techniques versus surgical (Siva et al., 2013; Wuchereria et al., 2013).

If in 2005 there is the opinion that a correct assessment of effectiveness of dog’s CrCL rupture treatment method only the investigations of level 1 can be considered reliable (Aragon and Budsberg, 2005; Houlton, 2013), reaffirmed subsequently (Fanchon and Grandjean, 2007; Sousa et al., 2014; Wüstefeld et al., 2016) there are some studies appeared quite recently (Mols et al., 2014) which concludes that “ground reaction forces may be inadequate as a sole method for assessing functional outcome after cranial cruciate ligament repair”.

Articles of level 2, for the most part, makes the inventory of postoperative complications of different treatment’s types (Butterworth and Kydd, 2017; Dymond et al., 2010; Fitzpatrick and Solanio, 2010; Frey et al., 2010; Haaland and Sjöström, 2007; Hishenson et al., 2012; Ihmolt et al., 2011; Rotherford et al., 2012; Stauffer et al., 2006; Proot and Cooke, 2009; Taylor et al., 2011; Thompson et al., 2011; Wolf et al., 2012; Moles et al., 2009) or shows mixed results of level 2 with 3 (Christopher et al., 2013; Stein et al., 2008; Steinberg et al., 2011).

The estimated costs of surgical treatment for cranial cruciate ligament ruptures in dogs in USA in 2003 were 1.32 billion dollars (Wilke et al., 2005).

Surgical techniques for the repair of cranial cruciate ligament deficiency can be classified into three categories: intra-articular grafts, extracapsular suture stabilization and proximal tibial osteotomy (Hulton, 2013).

**Intraarticular stabilization techniques** utilize autografts, allografts, xenografts, and synthetic materials to replace the affected CrCL (Paatsama, 1952; Leighton et al., 1976; Arnoczky et al., 1979; Hulse et al., 1980; Meyers et al., 1979; Andnhsh and Woods, 1984; Curtis et al., 1985; Yoshiya et al., 1986; Yoshiya et al., 1987; Vasseur, 1984; Stead et al., 1991; Aiken et al., 1994; Tonks et al., 2011).

Vasseur, 2003, makes the inventory of the main reasons of intra-articular procedures low use: - autografts present inferior stiffness and strength compared with normal ligament; - allografts present the inconvenience of collection and storage; - synthetic materials caused intra-articular fibrosis, bone abrasion and chronic inflammatory response; which has limited their use in veterinary medicine.

**Extra-articular stabilization techniques** include: lateral fabellar suture (LFS), percutaneous placement of the lateral fabellar suture (pLFS), Tightrope (TR) (Cook et al., 2010), transcondylar toggle system (Kunkel et al., 2009), modified lateral extra-capsular technique with bone anchor.

The treatment using lateral fabellar suture (LFS) remains at this moment the most practiced method, applied particularly in small dogs (Hulton, 2013).

The major shortcoming of the method (overloading of suture anchor points) (Fischer et al., 2008) has benefited from the contribution of several studies (Roe et al., 2008; Hulse et al., 2010; De Sousa et al., 2014; Cinti, 2015) which introduced the concept of anchoring in isometric position (relatively isometric) but also the anchor through bone anchors (Guenege et al., 2007; Hulse et al., 2011; Choate et al., 2012; Rask et al., 2013; Citi, 2015).

Efforts to identify the ideal material for suture when lateral fabellar suture is applied were materialized by the dethronement of nylon wires as the main option (Caporn and Roe, 1996; Lewis et al., 1997; Sicard et al., 2002; Sicard et al., 2012; Ledecky et al., 2012; Igna et al., 2014) and by promoting polyethylene wires which are stronger, stiffer and elongate less than nylon leader (Burgess et al., 2010; Tonks et al., 2010; Choate et al., 2012), promising options offers the polyblend wires (Rose et al., 2012) and braided polyester (Guenege et al., 2007).

Securing of the suture reveal the existence of three systems: a square knot (SQ), a slip knot (SL) and a crimp clamp (CR).

Existing data show no new information being maintained the recommendation (Nwadike et
that 27-kgt nylon leader line be secured with a SL, and 27-kgt nylon fishing line be secured with a SQ” as the “clamping the first throw of a square knot in monofilament nylon leader material who increases failure load by two percent and stiffness by 16%, and decreases elongation by 12%” (Caporn and Roe, 1996) although there are studies showing that “crimping suture alters the biomechanical properties of the loop” (Burgess et al., 2010).

Securing the suture through CR remains a superior method of knotting techniques (Anderson et al., 1998; Vianna et al., 2006) and the wave pattern crimp system is more efficient then the single crimp system (Maritato et al., 2012). Using tensioning sutures systems before the applying of a crimp clamp does not bring significant advantages over manual tightening (Moores et al., 2006). Difficulties in various procedures execution are reported to be the bone tunnels creation in TR and anchoring around fabella in LSF and pLSF (Biskup and Griffon, 2014).

Evaluation of extracapsular therapeutic methods efficiency although it is the subject of several studies (Moore et al., 1995; Jevens et al., 1996; Caporn and Roe, 1996; Anderson et al., 1998; Budsberg et al., 1998; Conzemius et al., 2005; Guenego et al., 2007; Kunkel et al., 2009; Cook et al., 2010; Hulse et al., 2011; Havig et al., 2007; Schaijk, 2008) with mostly positive reports, many of these studies are subjective (level 2 and 3). Studies based on analysis of data obtained through force plate measurements show that peak vertical force was 93% and vertical impulse was 96% of normal values in the limbs of dogs that had extra-articular stabilization at six months following surgery (Conzemius et al., 2005), recorded differences being insignificant compared to normal preoperative values in all studies which appeared before 2006 (Jevens et al., 1996; Budsberg et al., 1998) and after (Havig et al., 2007; Schaijk et al., 2008).

Postoperative complications reported after the application of extra-articular stabilization techniques are between 4.2 and 17.4% (Casale and McCarthy, 2009; Frey et al., 2010) and a 7.2% of them required reintervention (Casale and McCarthy, 2009). **Proximal tibial osteotomy techniques** include: tibial plateau levelling osteotomy - TPLO, combined tibial plateau levelling osteotomy and tibial tuberosity transposition (TPLO-TTT), tibial tuberosity advancement – TTA with the variants TTA-1, TTA-2 and TTA-rapid, triple tibial osteotomy - TTO and modified Maquet procedure – MMP. All procedures impart primarily change the biomechanics of the stifle and required specialized and custom equipments. The choice of source of this equipment depend of surgeon preferences or/and their affiliated a product companies (Igna, 2013).

Recent assessments of the effectiveness of therapeutic methods of tibial osteotomy reveals unanimously that locomotor function of the limb with CrCL insufficiency can be improved using the techniques of tibial osteotomy (Bruce et al., 2007; Kim et al., 2008; Dymond et al., 2010; Schaijk, 2008; Christopher et al., 2013; Nelson et al., 2013) described so far (Slocum and Devine, 1984, 1993; Slocum, 1996; Leonard et al., 2016; Montavon et al., 2002; Maquet, 1976; Samoy et al., 2014; ***; 2012; Damour et al., 2003). More prospective and retrospective studies (Pacchiana et al., 2003; McCarthy, 2002; Priddy et al., 2003; Carrey et al., 2005; Staufer et al., 2006; Bruce et al., 2007; Haaland and Sjöström, 2007; Lafavere et al., 2007; Stein et al., 2008; Voss et al., 2008; Duerr et al., 2008; Proot and Cooke, 2009; Moles et al., 2009; Dymond et al., 2010; Fitzpatrick and Solano, 2010; Frey et al., 2010; Conkling et al., 2010; Imholt et al., 2011; Taylor et al., 2011; Thompson et al., 2011; Gatineau et al., 2011; Coletti et al., 2011; Steinberg et al., 2011; Etchepareborde, 2011; Hishenson et al., 2012; Rotherford et al., 2012; Wolf et al., 2012; Christopher et al., 2013; Etchepareborde, 2014; Butterworth and Kydd, 2017) reports one or more complications (osteomyelitis, incisional infections, fractures of the tibia or fibula, broken drill bits, hemorrhage, intra-articular implant placement, intra-osteotomy screw placement, retained surgical sponges, broken holding pins or screws, septic arthritis, loose implants, draining tracts, ring sequestrum, incisional inflammation, dehiscence and swelling, osteomyelitis, oedema and seroma formation, bruising, premature staple removal, patellar tendon swelling, and late meniscal
In TPLO postoperative complication rate, until 2006, ranged between 45.7 and 28% (Carrey et al., 2005; Pacchiana et al., 2003; McCarthy, 2002; Priddy et al. 2003) compared to 22.2-8.4% after 2006 (Staufer et al., 2006; Stein et al., 2008; Duerr et al., 2008; Imholt et al., 2011; Fitzpatrick and Solano, 2010; Frey et al., 2010; Conkling et al., 2010; Gatinneau et al. 2011, Coletti et al., 2011) and 4.8% of the cases requiring implant removal (Thompson et al., 2011).

In TTA, the method introduced in practice in 2002 (Montavon et al., 2002), postoperative complication rate was between 35.5% and 11% (Lafavere et al., 2007; Voss et al., 2008; Hurt et al., 2009; Dymond et al., 2010, Steinberg et al., 2011, Hirshenson et al., 2012; Wolf et al., 2012) with 5.2% reinterventions (Wolf et al., 2012).

In TTO postoperative complication rate was between 18% and 23% (Renwick et al., 2009; Moles et al., 2009).

For MMP two complications were documented (subsequent meniscal injury) from a series of 12 cases (Etchepareborde et al., 2011; Etchepareborde, 2014) and 10.8% postoperative complications with 3.1% reintervention in a series of 65 cases (Bruce et al., 2007).

Comparative analysis of the obtained data (2006-2007) which assess the therapeutic efficiency by force plate measurements or kinematic data between extra-articular stabilization methods and tibial osteotomy methods (Schaijk, 2008; Nelson et al., 2012; Boddeker et al., 2012; Mols et al., 2014; Berger et al., 2015) as well as between different methods of tibial osteotomy (Lee et al., 2007; de Medeiros et al., 2011; Rey et al., 2014) does not show significant differences between methods and no major changes compared to previous reports.

Non-surgical treatment methods include administration of non-steroidal anti-inflammatory drugs, weight control, restriction of spontaneous locomotion, physiotherapy including hydrotherapy (Baker and Bake, 2013; Comerford et al., 2013; Wuchereria et al., 2013). These methods are usually applicable to small dogs with a body weight below 15 kg (Comerford et al., 2013).

In the treatment of obese dogs with ruptured CrCl surgical methods had a success rate (was defined as an affected limb net ground reaction force > 85% of the value for healthy dogs and a ≥ 10% improvement of the initial values) at 52 weeks after surgery by 75% compared to 63.6% in those treated by non-surgical methods (Wuchereria et al., 2013). The data presented are similar to those of previous studies, based only on clinical examination and with a success rate of 85.7% reported for small dogs with body weight below 15 kg (Vasseur, 1984).

Latest data concerning non-surgical methods of treatment (Baker and Bake, 2013; Comerford et al., 2013; Wuchereria et al., 2013) and veterinarians options for these therapeutic modalities (Comerford et al., 2013) did not show a change in trend compared to previous reports (Korvick et al., 1994), the majority of doctors preferring surgical approaches.

CONCLUSIONS

Currently available data does not allow accurate comparisons between different treatment procedures of cruciate cranial deficiency in dogs.

New long-term clinical studies must designed and further biomechanical and kinematic analyses are required to determine the optimal technique, and whether these procedures are superior to other stabilization methods.

ACKNOWLEDGEMENTS

This research work was carried out with the support of the project Dezvoltarea infrastructurii de cercetare, educație și servicii in domeniile medicinei veterinare și tehnologiilor inovative pentru RO 05, cod SMIS-CSNR 2669.

REFERENCES

Aiken S.W., Badylak S.F., Toombs J.P, et al., 1994. Small intestinal submucosa as an intra-articular ligamentous graft material: a pilot study in dogs. Vet Comp Orthop Traumatol, 7, 124–128.

Anderson C.C., Tomlinson J.L., Daly W.R., Carson W.L., Payne J.T., Wagner-Mann C.C., 1998. 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, 1, 27(6):533-539.

Andnsh J.T., Woods L.D., 1984. Dacron augmentation in antenor cruciate ligament reconstruction in dogs. Clin Orthop., 183, 298-302.

Aragon L.C., Budsberg C.S., 2005. Applications of Evidence-Based Medicine: Cranial Cruciate Ligament Injury Repair in the Dog. Vet Surg., 34 (2): 93-98.

Arnoczky S.P., Tarvin G.B., Marshall J.L., et al., 1979. -Hosp Assoc., 15:283–287.

Baker S.J., Baker G.J., 2013. Surgical versus nonsurgical management for overweight dogs with cranial cruciate ligament rupture. J Am Vet Med Assoc., 15, 243(4):479.

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. Tierarzt Prax Ausk K Kleintiere Heimtiere., 43(6):373-80. doi: 10.15654/TPK-150183. English, German.

Bergh M.S., Sullivan C., Ferrell C.L., Troy J., Budsberg S.C., 2014. Systematic review of surgical treatments for cranial cruciate ligament disease in dogs. Journal of the American Animal Hospital Association, 50(5):315-321.

Biskup J.J., Griffon D.J., 2014. Technical difficulties during the training phase for Tightrope® and percutaneous lateral fabellar suture techniques for cranial cruciate ligament repair. Veterinary Surgery, 1, 43(3):347-354.

Böddeker J., Drüen S., Meyer-Lindenberg A., Fehr M., Nolte I., Wefstaedt P., 2012. Computer-assisted gait analysis of the dog: comparison of two surgical techniques for the ruptured cranial cruciate ligament. Vet Comp Orthop Traumatol., 25(1):11-21. doi: 10.3415/VCOT-10-02-0025.

Bruce W.J., Rose A., Tuke J., et al., 2007. Evaluation of the triple tibial osteotomy. A new technique for the management of the canine cruciate-deficient stifle. Vet Comp Orthop Traumatol., 20(3):159-168.

Budsberg S.C., Verstraete M.C., Soutas-Little R.W., Flo G.L., Probst C.W., 1988. Force plate analyses before and after stabilization of canine stifles for cruciate injury. American journal of veterinary research, 49(9):1522-1524.

Burgess R., Elder S., McLaughlin R.O., Constable P., 2010. 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, 1, 39(2):208-215.

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, 1, 58(1):35-41.

Caporn T.M., Roe S.C., 1996. Biomechanical evaluation of the suitability of monofilament nylon fishing line and leader line for extra-articular stabilization of the cranial cruciate-deficient stifle. Vet Comp Orthop Traumatol., 9:126–133.

Carey K., Aiken S.W., DiResta G.R., Herr L.G., Monette S., 2005. Radiographic and clinical changes of the patellar tendon after tibial plateau leveling osteotomy. Veterinary Surgery, 18(4):235-242.

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, 15, 234(2):229-235.

Choate C.J., Pozzi A., Lewis D.D., Hudson C.C., Conrad B.P., 2012. Mechanical properties of isolated loops of nylon leader material, polyethylene cord, and polyethylene tape and mechanical properties of those materials secured to cadaveric canine femurs via lateral femoral fabellae, toggles placed through bone tunnels, or bone anchors. American journal of veterinary research, 73(10):1519-1529.

Christopher S.A., Beetem J., Cook J.L., 2013. Comparison of long-term outcomes associated with three surgical techniques for treatment of cranial cruciate ligament disease in dogs. Veterinary Surgery, 1, 42(3):329-334.

Cinti F., Signorelli C., Lopomo N., Baracchi M., Del Magno S., Foglia A., Zaffagnini S., Pisoni L., 2015. Two different approaches for novel extracapsular cranial cruciate ligament reconstruction: an in vitro kinematics study. Journal of Small Animal Practice, 1, 56(6):398-406.

Citi S., 2015. L’Ancora di suture nell’incompetenza del LCA nel cane: modifiche alla tecnica mininvasiva extracapsulare standard. Aivpa Journal, 1, 4(3):22-26.

Coletti T., Anderson M., Gorse M.I., Madsen R., 2012. Complications and Biostatistics Associated with Tibial Plateau Leveling Osteotomy 1,519 Cases. Veterinary Surgery, 1;40(7):E24.

Comerford E., Forster K., Gorton K., Maddox T., 2013. Management of cranial cruciate ligament rupture in small dogs: a questionnaire study. Vet Comp Orthop Traumatol., 26(6):493-497. doi: 10.3415/VCOT-12-06-0070.

Conkling A.L., Fagin B., Daye R.M., 2010. Comparison of tibial plateau angle changes after tibial plateau leveling osteotomy fixation with conventional or locking screw technology. Veterinary Surgery, 1, 39(4):475-481.

Conzemius M.G., Evans R.B., Besancon M.F., Gordon W.J., Horstman C.L., Hoeftl W.D., Nieves M.A., Wagner S.D., 2005. 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, 15, 226(2):232-236.

Cook J.L., Luther J.K., Beetem J., Karnes J., Cook C.R., 2013. Comparison of long-term outcomes associated with three surgical techniques for treatment of cranial cruciate ligament disease in dogs. Veterinary Surgery, 1, 42(3):329-334.

Curtis R.J., Delee J.C., Drez D.J., 1985. Reconstruction of the anterior cruciate ligament with freeze dried...
fascia lata allografts in dogs: A preliminary report. The American journal of sports medicine, 1, 13(6):408-414.

Damur D.M., Tepic S., Montavon P.M., 2003. Proximal tibial osteotomy for the repair of cranial cruciate-deficient stifle joints in dogs. VCOT Archive, 16(4):211.

de Medeiros M., Sánchez Bustinduy M., Radke H., Langley-Hobbs S., Jeffery N., 2011. Early kinematic outcome after treatment of cranial cruciate ligament rupture by tibial plateau levelling osteotomy in the dog. Vet Comp Orthop Traumatol., 24(3):178-184. doi: 10.3415/VCOT-10-02-0028.

De Sousa R.J., Knudsen C.S., Holmes M.A., Langley-Hobbs S.J., 2014. Quasi-Isometric Points for the Technique of Lateral Suture Placement in the Feline Stifle Joint. Veterinary Surgery, 1, 43(2):120-126.

Duerr F.M., Duncan C.G., Savicky R.S., Park R.D., Egger E.L., Palmer R.H., 2008. Comparison of surgical treatment options for cranial cruciate ligament disease in large-breed dogs with excessive tibial plateau angle. Veterinary Surgery, 1, 37(1):49-62.

Dy mond N.L., Gold smid S.E., Simpson D.J., 2010, Tibial tuberosity advancement in 92 canine stifles: initial results, clinical outcome and owner evaluation. Australian veterinary journal, 1, 88(10):381-385.

Etchepare borde S., Brunel L., Bollen G., Balligand M., 2011. Preliminary experience of a modified Maquet technique for repair of cranial cruciate ligament rupture in dogs. Vet Comp Orthop Traumatol., 24(3):223-227.

Etchepare borde S., 2014. Adaptation de la procedure de maquet pour le traitement chirurgical de la rupture du ligament croise cranial chez le chien. Universite de Liege PhD thesis.

Fanchon L., Grandje an D., 2007. Accuracy of asymmetry indices of ground reaction forces for diagnosis of hind limb lameness in dogs. Am J Vet Res., 68(10):1089-1094.

Fischer C., Cherres M., Grevel V., Oechtering G., Böttcher F., 2010. 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, 1, 39(3):334-342.

Fitzpatrick N., Solano M.A., 2010. Predictive variables for complications after TPLO with stifle inspection by arthrotomy in 1000 consecutive dogs. Veterinary surgery, 1, 39(4):460-474.

Foster W.J., Imhoff R.K., Cordell J.T., 1963. "Closed-joint" repair of anterior cruciate ligament rupture in the dog. J Am Vet Med Assoc., 1, 143:281-283.

Frey T.N., Hoelzler M.G., Scavelli T.D., Fulcher R.P., Bastian R.P., 2010. Risk factors for surgical site infection-inflammation in dogs undergoing surgery for rupture of the cranial cruciate ligament: 902 cases (2005–2006). Journal of the American Veterinary Medical Association, 1, 236(1):88-94.

Gatineau M., Dupuis J., Planté J., Moreau M., 2011. Retrospective study of 476 tibial plateau levelling osteotomy procedures. Vet Comp Orthop Traumatol., 24:333-341.

Gordon-Evans W.J., Dunning D., Johnson A.L., Knap K.E., 2011. Effect of the use of carprofen in dogs undergoing intense rehabilitation after lateral fabellar suture stabilization. J Am Vet Med Assoc., 1, 239(1):75-80. doi: 10.2460/avma.239.1.75.

Gordon-Evans W.J., Dunning D., Johnson A.L., Knap K.E., 2010. Randomised controlled clinical trial for the use of deracoxib during intense rehabilitation exercises after tibial plateau levelling osteotomy. Vet Comp Orthop Traumatol., 23(5):332-335. doi: 10.3415/VCOT-09-11-0121.

Guenego L., Zahra A., Made lenat A., et al., 2007. Cranial cruciate ligament rupture in large and giant dogs. A retrospective evaluation of a modified lateral extra capsular stabilization. Vet Comp Orthop Traumatol., 20; 43-50.

Haaland P.J., Sjöström L., 2007. Luxation of the long digital extensor tendon as a complication to Tibial Plateau Levelling Osteotomy - A presentation of four cases, Vet Comp Orthop Traumatol., 3, 224-226.

Havig M.E., Dyce J., Kowaleski M.P., Reynolds L.R., Budsberg S.C., 2007. Relationship of tibial plateau slope to limb function in dogs treated with a lateral suture technique for stabilization of cranial cruciate ligament deficient stifles. Vet Surg., 36(3):245-251.

Hirshenson M.S., Krotscheck U., Thompson M.S., Knapp-Hoch H.M., Jay-Silva A.R., McConkey M., Bliss S.P., Todhunter R., Mohammed H.O., 2012. Evaluation of complications and short-term outcome after unilateral or single-session bilateral tibial tuberosity advancement for cranial cruciate rupture in dogs. Veterinary and Comparative Orthopaedics and Traumatology (VCOT), 25(5):402-409.

Houlton E.F.J., 2013. Stifle surgery: cranial cruciate disease and management of patellar luxations. Crieff 2 Day Small Animal CPD Meeting May 2013 notes, Vets Now Ltd, 27-49.

Hulse D., Hyman W., Beale B., Saunders B., Peycke L., Hosgogol, 2010. 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), 23(3):163-167.

Hulse D., Saunders B., Beale B., Kowaleski M., 2011. Extra-articular stabilization of the cranial cruciate deficient stifle with anchor systems. Tierärztliche Praxis Kleintiere, 39(5):363-367.

Hulse D.A., Michaelson F., Johnson C., Abdelbaki Y.Z., 1980. A technique for reconstruction of the anterior cruciate ligament in the dog: Preliminary report. Veterinary Surgery, 1, 9(4):135-140.

Igna C., Bumb D., Tascu M., Rusu L., Dascalu R., Sala A., Schuszler L., 2014. In vitro mechanical testing of monofilament nylon fishing line, for the extracapsular stabilisation of canine stifle joint. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Veterinary Medicine, 71(1):124-129.

Igna C., 2013. TPLO or TTA, treatment options for cranial cruciate ligament rupture in dog – a literature
Maritato K.C., Møller S., Fehr M., Meyer-Lindenberg A., 2011. Lameness and osteoarthritis following Tibial Plateau Leveling Osteotomy (TPLO) and potential prognostic predictors. Tierärztliche Praxis Kleintiere, 39(5):323-335.

Jevens D.J., DeCamp C.E., Hauptman J., Braden T.D., Richter M., Robinson R., 1996. Use of force-plate analysis of gait to compare two surgical techniques for treatment of cranial cruciate ligament rupture in dogs. American Journal of Veterinary Research, 57(3):389-393.

Korvick D.L., Johnson A.L., Schaeffer D.J., 1994. Surgeons' preferences in treating cranial cruciate ligament ruptures in dogs. Journal of the American Veterinary Medical Association, 205(9):1318-1324.

Krotscheck U., Todhunter R.J., Nelson S.A., Sutter N.B., Mohamed H.O., 2014. Precision and accuracy of ground reaction force normalization in a heterogeneous population of dogs. Vet Surg., 43(4):437-445. doi: 10.1111/j.1532-950X.2014.12176.x.

Kunkel K.A., Basinger R.R., Suber J.T., Gerard P.D., 2009. Evaluation of a transcondylar toggle system for stabilization of the cranial cruciate deficient stifle in small dogs and cats. Vet Surg., 38:975-982.

Laflafer 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, 1, 36(6):573-586.

Ledecky V., Knazovickz A.J., Naber S.J., 2012. In vitro mechanical comparison and comparison of two crimping devices for securing monofilament nylon and multifilament polyethylene for use in extracapsular stabilization of the canine stifle. Veterinary and Comparative Orthopaedics and Traumatology (VCOT), 25(6):466-471.

McCarthy, J.R., 2002. Tibial Plateau Leveling Osteotomy, WSAVA Congress.

Meyers J.F., Grana W.A., Lesker P.A., 1979. Reconstruction of the anterior cruciate ligament in the dog: comparison of results obtained with three different porous synthetic materials. The American journal of sports medicine, 7(2):85-90.

Moles A.D., Hill T.P., Glyde M., 2009. Triple tibial osteotomy for treatment of the canine cranial cruciate ligament-deficient stifle joint. Veterinary and Comparative Orthopaedics and Traumatology (VCOT), 22(6):473-478.

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 Vet Res., 19, 10:266. doi: 10.1186/s12917-014-0266-8.

Montavon P.M., Damur D.M., et al., 2002. Advancement of the tibial tuberosity for the treatment of cranial cruciate deficient canine stifle, 1st World Orthopaedic Veterinary Congress, Munich, Germany, 152.

Moores A.P., Beck A.L., Jesspers K.J., Wilson A.M., 2006. Mechanical evaluation of two loop tensioning methods for crimp clamp extracapsular stabilization of the cranial cruciate ligament-deficient canine stifle. Veterinary Surgery, 1, 35(5):476-479.

Morgan J.P., Voss K., Damur D.M., Guerrero T., Haessig M., Montavon P.M., 2010. Correlation of radiographic changes after tibial tuberosity advancement in dogs with cranial cruciate-deficient stifles with functional outcome. Vet Surg., 39(4):425-432. doi: 10.1111/j.1532-950X.2010.00669.x.

Nelson S.A., Krotscheck U., Rawlinson J., Todhunter R.J., Zhang Z., Mohammed H., 2013. Long-Term Functional Outcome of Tibial Plateau Leveling Osteotomy Versus Extracapsular Repair in a Heterogeneous Population of Dogs. Veterinary Surgery, 1, 42(1):38-50.

Nwadike B.S., Roe S.C., 1998. Mechanical comparison of suture material and knot type used for fabello-tibial sutures. VCOT Archive, 11(1):52-57.

Paatsama S., 1952. Ligament injuries in the canine stifle joint. [Thesis]. Kauppakirjapaino, O Y, Helsinki, Finland.

Pacchiana P.D., Morris E., Gillings S.L., Jessen C.R., Lipowitz A.J., 2003. 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, 1, 222(2):184-193.

Pillard P., Gilbert S., Viguier E., 2012. 3D accelerometric assessment of the gait of dogs with cranial cruciate ligament rupture. Comput Methods Biomech Biomed Engin, 15 Suppl 1:129-131.

Poizzi A., Kim S.E., Lewis D.D., 2010. Effect of transection of the caudal menisco-tibial ligament on medial femorotibial contact mechanics. Vet Surg.,
Sicard G.K., Meinen J., Phillips T., Manley P.A., 1999. Evaluation 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, 1, 222(12):1726-1732.

Proot J., Cooke S., 2009. Tibial tuberosity advancement: Technique and postoperative complications. Companion Animal, 1, 14(5):25-30.

Tofts M., Hulse D., 2013. Swive Lock Bone Anchor Stabilisation of the Cranial Cruciate Ligament Deficient Stifle in Dogs: Clinical Outcome. Open Journal of Veterinary Medicine, 29, 3(07):297.

Rey J., Fischer M.S., Böttcher P., 2014. Sagittal joint instability in the cranial cruciate ligament insufficient canine stifle. Caudal slippage of the femur and not cranial tibial subluxation. Tierarzt Prax Ausg K Kleintiere Heimtiere, 42(3):151-156.

Robinson D.A., Mason D.R., Evans R., Conzemius M.G., 2006. The effect of tibial plateau angle on ground reaction forces 4–17 months after tibial plateau leveling osteotomy in Labrador Retrievers. Veterinary Surgery, 1, 35(3):294-299.

Roe S.C., Kue J., Gemma J., 2008. Isometry of potential suture attachment sites for the cranial cruciate ligament deficient canine stifle. Veterinary and Comparative Orthopaedics and Traumatology (VCOT), 21(3):215-220.

Rose N.D., Goerke D., Evans R.B., Conzemius M.G., 2012. Mechanical testing of orthopedic suture material used for extra-articular stabilization of canine cruciate ligament-deficient stifles. Veterinary Surgery, 1, 41(2):266-272.

Rutherford S., Bell J.C., Ness M.G., 2012. Fracture of the patella after TPLO in 6 dogs. Veterinary Surgery, 1, 41(7):869-275.

Samoy Y., Verhoeven G., Bosmans T., Van der Wakens 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, 1, 44(4):474-484.

Sanchez-Bustinduy M., de Medeiros M.A., Radke H., Langley-Hobbs S., McKinley T., Jeffery N., 2010. Comparison of kinematic variables in defining lameness caused by naturally occurring rupture of the cranial cruciate ligament in dogs. Vet Surg., 39(4):523-530. doi: 10.1111/j.1532-950X.2010.00672.x.

Schajik F.V., 2008. Force plate gait analysis to assess functional outcome of tibial tuberosity advancement versus lateral capsular imbrication. Faculty of Veterinary Medicine, Utrecht University PhD thesis.

Sicard G.K., Hayashi K., Manley P.A., 2002. Evaluation of 5 types of fishing material, 2 sterilization methods, and a crimp-clamp system for extra-articular stabilization of the canine stifle joint. Veterinary Surgery, 1, 31(1):78-84.

Sicard G.K., Meinen J., Phillips T., Manley P.A., 1999. Comparison of fishing line for repair of the cruciate deficient stifle. VCOT Archive, 12(3):43-46.

Silva R.F., Carmona J.U., Rezende C.M., 2013. Intra-articular injections of autologous platelet concentrates in dogs with surgical repairation of cranial cruciate ligament rupture: a pilot study. Vet Comp Orthop Traumatol., 26(4):285-290.

Slocum B., Devine T., 1984. Cranial tibial wedge osteotomy: a technique for eliminating cranial tibial thrust in cranial cruciate ligament repair. J Am Vet Med Assoc., 184:564–569.

Slocum B., Devine T., 1993. Tibial plateau leveling osteotomy for repair of cranial cruciate ligament rupture in the canine. Vet Clin North Am Small Anim Pract., 23:777–795.

Slocum D.B., 1996. Jig for use in osteotomies. United States patent US 5,578,038.

Souza A.N., Tatarunas A.C., Matera J.M., 2014. Evaluation of vertical forces in the pads of Pitbulls with cranial cruciate ligament rupture. BMC Vet Res., 1, 10:51. doi: 10.1186/1746-6148-10-51.

Stauffer K.D., Tuttle T.A., Elkins A.D., Wehrenberg A.P., Character B.J., 2006. Complications associated with 696 tibial plateau leveling osteotomies (2001–2003). Journal of the American Animal Hospital Association, 42(1):44-50.

Stead A.C., Amis A.A., Campbell J.R., 1991. Use of a polyester fibre as a prosthetic cranial cruciate ligament in small animals. J Small Anim Pract., 32: 448–453.

Stein S., Schmoeckel 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, 1, 49(8):398-404.

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.

Taylor J., Langenbach A., Marcellin-Little D.J., 2011. Risk factors for fibular fracture after TPLO. Veterinary Surgery, 1, 40(6):687-693.

Thieman K.M., Tomlinson J.L., Fox D.B., Cook C., Cook J.L., 2006. 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. Vet Surg., 35(8):705-710.

Thompson A.M., Bergh M.S., Wang C., Wells K., 2011. Tibial plateau levelling osteotomy implant removal: A retrospective analysis of 129 cases. Veterinary and Comparative Orthopaedics and Traumatology (VCOT), 24(6):450-456.

Tonks C.A., Lewis D.D., Pozzi A., 2011. A review of extra-articular prosthetic stabilization of the cranial cruciate ligament-deficient stifle. Veterinary and Comparative Orthopaedics and Traumatology (VCOT), 24(3):167-177.

Tonks C.A., Pozzi A., Ling H.Y., Lewis D.D., 2010. The Effects of Extra-Articular Suture Tension on Contact Mechanics of the Lateral Compartment of Cadaveric Stifles Treated with the TightRope CCL® or Lateral Suture Technique. Veterinary Surgery, 1, 39(3):343-349.
Vasseur P.B., Stevenson S., Gregory C.R., Rodrigo J.J., Pauli S., Heitter D., Sharkey N., 1991. Anterior cruciate ligament allograft transplantation in dogs. Clinical orthopaedics and related research, 1, 269:295-304.

Vasseur P.B., 2003. Stifle joint. In: Slatter D., editor, Textbook of Small Animal Surgery, 3rd edition, Philadelphia, Saunders, 2090–2133.

Vasseur P.B., 1984. Clinical Results Following Nonoperative Management for Rupture of the Cranial Cruciate Ligament in Dogs. Veterinary Surgery, 13: 243–246. doi:10.1111/j.1532-950X.1984.tb00801.x

Vianna M.L., Roe S.C., 2006. Mechanical Comparison of Two Knots and Two Crimp Systems for Securing Nylon Line Used for Extra-Articular Stabilization of the Canine Stifle. Veterinary Surgery, 1, 35(6):567-572.

Voss K., Damur D.M., Guerrero T., Haessig M., Montavon P.M., 2008. Force plate gait analysis to assess limb function after tibial tuberosity advancement in dogs with cranial cruciate ligament disease. Vet Comp Orthop Traumatol., 21(3):243-249.

Wilke V.L., Robinson D.A., Evans R.B., Rothschild M.F., Conzemius M.G., 2005. Estimate of the annual economic impact of treatment of cranial cruciate ligament injury in dogs in the United States. Journal of the American Veterinary Medical Association, 1, 227(10):1604-1607.

Wolf R.E, Scavelli T.D., Hoelzler M.G., Fulcher R.P., Bastian R.P., 2012. 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, 15, 240(12):1481-1487.

Wucherer K.L., Conzemius M.G., Evans R., Wilke V.L., 2013. Short-term and long-term outcomes for overweight dogs with cranial cruciate ligament rupture treated surgically or nonsurgically. J Am Vet Med Assoc., 15, 242(10):1364-1372. doi: 10.2460/javma.242.10.1364.

Wustefeld-Janssens B.G., Pettitt R.A., Cowderoy E.C., Walton M.B., Comerford E.J., Maddox T.W., Innes J.F., 2016. Peak Vertical Force and Vertical Impulse in Dogs With Cranial Cruciate Ligament Rupture and Meniscal Injury. Vet Surg., 45(1):60-65.

Yoshiya S., Andrish J.T., Manley M.T., Bauer T.W., 1987. Graft tension in anterior cruciate ligament reconstruction: an in vivo study in dogs. The American journal of sports medicine, 15(5):464-470.

Yoshiya S., Andrish J.T., Manley M.T., Kurosaka M., 1986. Augmentation of anterior cruciate ligament reconstruction in dogs with prostheses of different stiffnesses. Journal of orthopaedic research, 1, 4(4):475-485.

*** 2012. Kyon Pharma I: TTA-2. Zurich, KYON Pharma, Inc. (http://www.kyon.ch/research/development/hta-2),