

THESIS

Jacob Hinds

2016

UNIVERSITY OF VETERINARY MEDICINE OF BUDAPEST
Department And Clinic Of Surgery And Ophthalmology

**cTTA - A NEW METHOD FOR TREATING
CRANIAL CRUCIATE LIGAMENT RUPTURE
IN DOGS: EARLY RESULTS**

By Jacob Hinds

Supervisor:

Dr Zólyomi Dorottya DVM

Contents

I.	Introduction	1
II.	Literature Review	2
II.I.	The anatomy of the canine stifle joint (articulatio genus)	2
II.I.I.	Ligaments of the Stifle	3
II.I.II.	Muscles of the stifle	5
II.I.III.	Functional anatomy of the CrCL	6
II.II.	Biomechanics of the stifle	7
II.III.	Pathogenesis of CrCL rupture.....	9
II.IV	Diagnosis of CrCL rupture	10
II.V.	Surgical techniques in CrCL rupture	14
II.V.I.	Intracapsular	15
II.V.II.	Extracapsular	16
II.V.III.	Tibial Plateau Leveling Osteotomy – TPLO.....	18
II.V.IV.	Tibial Tuberosity Advancement – TTA.....	21
II.V.	Complications of TTA surgery	25
III.	Goals and questions.....	27
IV.	Materials and Methods	28
IV.I.	Case selection.....	28
IV.II.	Preoperative planning	29
IV.III.	Anaesthesia protocol	33
IV.IV.	Surgical technique	34
IV.V.	Post-operative evaluation of cTTA surgeries	36
V.	Results	37
VI.	Discussion	40
VII.	Summary	42
	List of References.....	45

I. Introduction

The canine stifle is a complex joint that must transmit large forces, making it relatively susceptible to injury. The cranial and caudal cruciates are ligamentous structures in the centre of the stifle which provide craniocaudal stability. (de Rooster, 2001)

Hind limb lameness is often associated with the stifle, most frequently the cranial cruciate ligament (CrCL) which is subjected to excessive forces during extremes of motion. CrCL rupture is one of the most common causes of lameness in dogs, and one of the most frequent indications for orthopaedic surgery. (Tuan & Farrell, 2015)

CrCL deficiency leads to (cranio-caudal) translational and rotational instability within the stifle, which contributes to the development of osteoarthritis (OA) and degenerative joint disease (DJD). (de Rooster, 2001; Boudrieau, 2009)

Many causal mechanisms CrCL rupture exist, and many surgical techniques have been proposed to treat deficient stifles, each aiming to stabilise the joint and neutralise tibiofemoral shear forces. The varying surgeries can be grossly divided into intra- and extracapsular which provide passive stabilisation, or osteotomies providing dynamic stability to the loaded joint. (Boudrieau, 2007; Rovesti et al., 2013; Tuan & Farrell, 2015)

Recently, following investigations into forces acting around the stifle there has been increasing interest in osteotomies to provide dynamic stabilisation. The three most common techniques today are the Lateral Suture Technique, Tibial Plateau Leveling Osteotomy (TPLO), and the Tibial Tuberosity Advancement (TTA). (Rovesti et al., 2013; Bergh et al., 2014)

The many surgical techniques proposed differ in concept, technical difficulty, invasiveness, potential complications, required equipment, recovery rate and cost. No method has been found to be superior, and each only slows the progression of DJD, none limiting it completely. For this reason there is an ongoing search for a superior method of treatment for CrCL disease. (de Rooster, 2001; Tuan & Farrell, 2015)

One such recent development is a refinement/variation of the existing TTA surgery – the circular TTA (cTTA). Whilst the potential benefits of a cTTA have been discussed, there is limited research on this new technique. I aim to look at the cTTA procedure compared to a more traditional linear TTA rapid to see if the technique could be

standardised for wider use. I will also look at the complications encountered in the first 30 clinical cases of cTTA performed at the Surgery and Ophthalmology Department of the University of Veterinary Medicine, Budapest. This will give an indication of the procedures efficacy and suitability as a treatment option.

II. Literature Review

II.I. The anatomy of the canine stifle joint (articulatio genus)

The stifle is a composite, incongruent hinge joint made up of the femorotibial (articulatio femorotibialis) and femoropatellar (articulation femoropatellaris) joints. (Nickel et al., 1984; Konig & Liebich, 2009)

The femorotibial joint joins the condyles of the femur with those of the tibia. The medial and lateral femoral condyles are round, slightly spiralled and separated by the intercondylar fossa, whilst the tibial condyles are flat and their articular surfaces are separated by the intercondylar eminence. The round femoral and flat tibial condyles render the articular surfaces incongruent. This is compensated with a fibrocartilaginous articular meniscus on either side of the joint – semilunar plates, with thin concave axial, and thick convex abaxial surfaces. During movement of the stifle the menisci move with the tibia over the condyles of the femur. (Nickel et al., 1984; Konig & Liebich, 2009)

The extensive joint capsules fibrous layer attaches to the margins of the articular surfaces and the outer convex edges of the medial meniscus. This fixes the medial meniscus in place, leading to a higher incidence of injury to the medial meniscus when compare to the freer lateral meniscus. The synovial membrane covers the cruciate ligaments, separating the joint into communicating medial and lateral compartments, each with proximal and distal segments either side of the menisci. The lateral sac forms a distal pouch in the sulcus extensorius of the tibia, creating the tendon sheath of the long digital extensor (m. extensor digitorum longus), and the medial sac communicates dorsally with the patellar synovial sac. The joint capsule also encloses the joints between the femoral condyles and the sesamoids of the gastrocnemius (Vesalli), and ensheaths the origin of the popliteal muscle. (Nickel et al., 1984; Konig & Liebich, 2009)

The femoropatellar joint is formed by the femoral trochlea and the articular surface of the patella. A sledge joint, the patella glides on the trochlea. It moves simultaneously with the femorotibial joint. (Nickel et al., 1984; Konig & Liebich, 2009)

II.I.I. Ligaments of the Stifle

The stifle ligaments can be placed into three groups – femorotibial, meniscal and femoropatellar ligaments.

A. Femorotibial ligaments

- Medial and lateral collateral ligaments (ligament collaterale) originate from the epicondyles of the femur and insert on the tibial epicondyles, with the lateral ligament also attaching on the head of the fibula. The lateral collateral ligament is connected to the medial meniscus, unlike their lateral counterparts. The eccentric attachment of the ligaments (coupled with the spiral shape of the femoral condyles), make them shorter in a normal position than in flexion or extension, giving a brake like effect to the moving joint. They prevent medio-lateral movement of the joint.

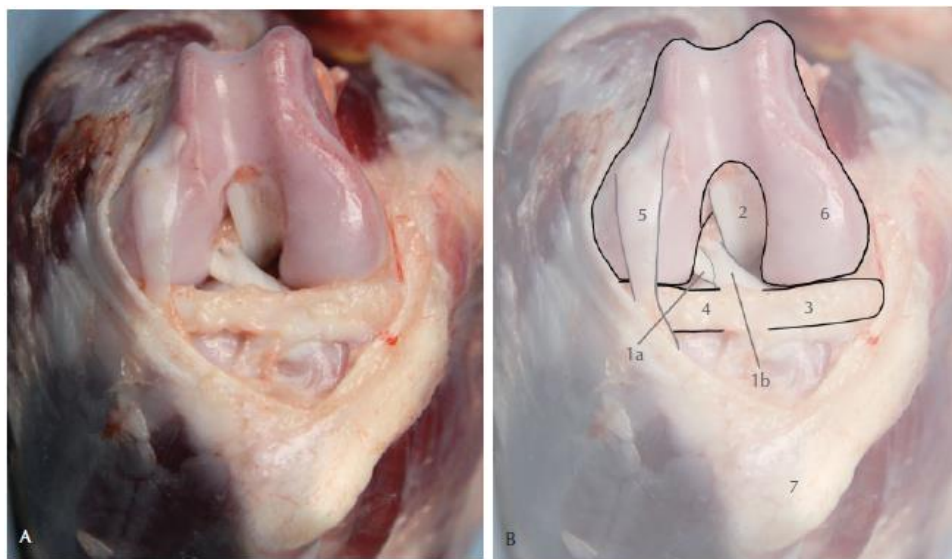


Figure 1 - 1a: caudolateral bundle of the cranial cruciate ligament (CrCL); 1b: craniomedial bundle of the CrCL; 2: caudal cruciate ligament; 3: medial meniscus; 4: lateral meniscus; 5: tendon of the long digital extensor: medial humeral condyle; 7: tibial tuber (Muir, 2010)

- The cruciate ligaments of the knee (ligamenta cruciata genus) lie between the medial and lateral synovial sacs. The cranial cruciate ligament (CrCL) originates from the intercondylar surface of the lateral condyle of the femur, extends craniodistally and inserts on the central intercondylar area of the tibia. The caudal cruciate (CaCL) originates from the intercondylar surface of the

medial femoral condyle, extends caudodistally and inserts on the caudal intercondylar area and popliteal notch of the tibia (see Figure 1 & 2). Their function will be discussed later. (Nickel et al., 1984; König & Liebich, 2009)

B. Ligaments of the menisci (see Figure 2)

- Lig. tibiale craniale menisci laterale et mediale – arise from the cranial aspect of each meniscus and insert on the cranial intercondylar area and medial central intercondylar area of the tibia respectively.
- Lig. tibiale caudale menisci lat. et med. – arise from the caudal aspect of the corresponding meniscus. The lateral ligament inserts in the popliteal notch, and the medial in the caudal intercondylar area of the tibia.

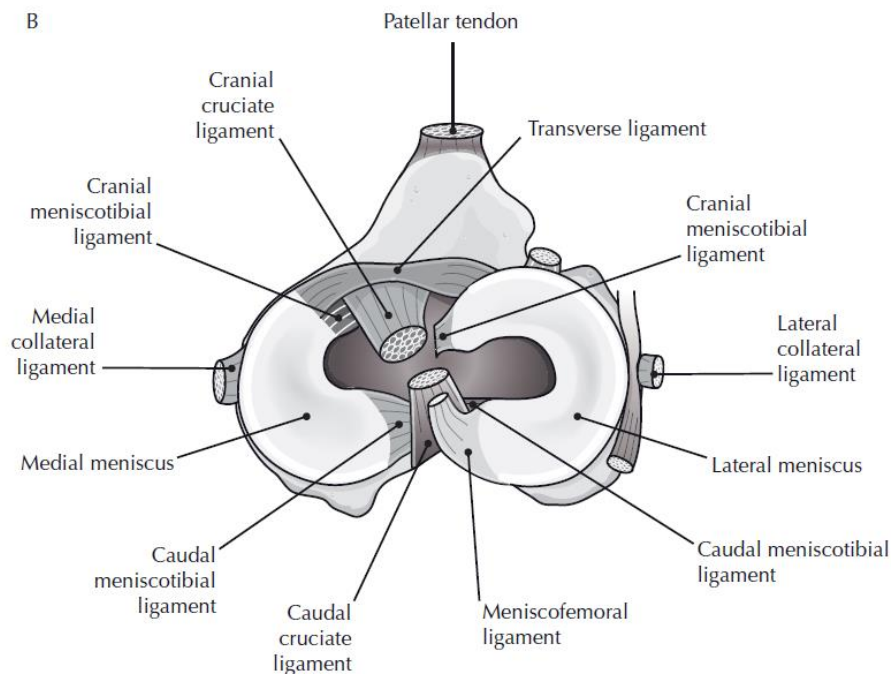


Figure 2 - Drawing of the tibial plateau showing the meniscal ligaments (Muir, 2010)

- Lig. meniscifemorale – only on the lateral meniscus, extending from its caudal border to insert on the intercondylar area of the femur.
- Lig. transversus genus – connects the cranial aspects of the two menisci. (Nickel et al., 1984; König & Liebich, 2009)

C. Femoropatellar ligaments

- Retinaculum patellae laterale et mediale – reinforcing bundles of connective tissue fascia on both sides of the stifle, extending from the tendon of the quadriceps femoris and the patella, to the epicondyles and condyles of the femur.

- Ligg. femoropatellare lat. et med. – partly contributing to the retinaculum, these weak ligaments originate from the deep fascia, run either side of the gastrocnemius sesamoids and insert on the patella.
- Lig. patellae – connects the patella to the proximal extremity of the tibia. The ligament is separated from the synovial sac by the corpus adiposum infrapatellare, with the bursa infrapatellaris close to its insertion. (Nickel et al., 1984; König & Liebich, 2009)

II.I.II. Muscles of the stifle

Many muscles play important roles in the movement of the stifle without it being their primary role, whilst the quadriceps femoris and the popliteus act specifically on the stifle.

- A. M. quadriceps femoris – a complex of four muscle bellies (that may fuse distally) on the cranial aspect of the femur, covered by the tensor fascia lata, the sartorius and the fascia lata. Three heads arise from the proximal femur – m. vastus lateralis, m. vastus medialis, m. vastus intermedius, covering the craniolateral, craniomedial and cranial aspects of the femoral shaft respectively. M. rectus femoris originates from the body of the ilium, and lies over the other three heads. All four insert on the tibial tuberosity and crest via the patella ligament as their tendon of insertion and the patella their sesamoid. Together the quadriceps is the strongest extensor of the stifle. They are innervated by n. femoralis. (Nickel et al., 1984; König & Liebich, 2009)
- B. M. popliteus – a relatively weak muscle lying on the flexor aspect of the femorotibial joint capsule. It originates from the popliteal fossa on the lateral condyle of the femur with a strong tendon, then spirals from the caudal to the medial border of the tibia, fanning out into a wide insertion on the proximal third of the tibia's caudomedial border. There is a sesamoid bone in the tendon of the muscle – *os sesamoideum m. poplitei* – which lies in contact with the lateral femoral condyle. It has a role in flexing the stifle. It is innervated by n. tibialis. (Nickel et al., 1984; König & Liebich, 2009)
- C. The hamstring muscle group:
- M. biceps femoris – on the caudal and lateral regions of the thigh, the muscle consists of both cranial and caudal portions which are closely connected. The stronger cranial portion originates as the vertebral head from the sacrum, and the smaller caudal portion as the pelvic head from the ischiatic tuber. Distally the muscle divides and terminates as aponeuroses, blending with femoral and crural

fascia to insert on the patella, patellar ligament and the tibial crest, as well as the tuber calcanei by the calcaneal tendon. The cranial portion contributes to extension of the stifle, and the caudal portion to its flexion. As a whole the muscle acts to extend and abduct the limb. The cranial portion is innervated by the cranial gluteal nerve and the caudal portion by the tibial nerve.

- M. semitendinosus – the muscle forms the caudal margin of the buttocks running from the ischiatic tuber to insert with an extensive tendon which blends with the aponeurosis of the gracilis and sartorius, inserting medially on the tibial crest and on the tuber calcanei. The semitendinosus contributes to extending the stifle (or flexion when off the ground) and it is innervated by the tibial nerve.
- M. semimembranosus – on the medial buttocks, it originates from the ventral aspect of the ischiatic tuber and divides into two branches. The branches insert on the medial condyle of the femur and medial tibia. It is innervated by the tibial nerve. (Nickel et al., 1984; Konig & Liebich, 2009)

D. M. sartorius – lies superficially on the medial aspect of the thigh. It extends from the coxal tuber to blend with the fascia of the knee, contributing to extension of the stifle. It is innervated by the femoral nerve, or branches of the saphenous nerve. (Nickel et al., 1984; Konig & Liebich, 2009)

E. M. gracilis – lies caudal to the sartorius, forming the medial aspect of the thigh. It originates via an aponeurosis from the pelvic symphysis and the tendon of insertion of the rectus abdominis, and terminates distally in a wide aponeurosis which blends with the crural fascia and inserts on the tibial crest. It contributes to extension of the stifle and is innervated by the obturator nerve. (Nickel et al., 1984; Konig & Liebich, 2009)

II.I.III. Functional anatomy of the CrCL

The cruciate ligaments are complex and dynamic structures, acting as constraints on stifle motion as a part of a greater restraining system. They act as the primary ligamentous support of cranio-caudal and axial stability through the functional range of motion. Muscle forces, joint compression and other ligaments of the stifle also contribute to joint stability. (de Rooster, 2001; Muir, 2010)

The CrCL originates on the axial aspect of the lateral femoral condyle, and passes diagonally to insert on the cranial intercondyloid area of the tibial plateau. It is narrowest in its middle portion and fans out to both its origin and insertion points. The ligament is

spiralled giving the gross appearance of two distinct anatomic bands – the craniomedial and caudolateral components of the CrCL (based on their relative points of insertion). (de Rooster, 2001; Muir, 2010)

The craniomedial component arises more proximally on the femur and inserts more cranially on the tibia. It is the more spiralled and longer, yet smaller of the two. The caudolateral part of the CrCL originates from the most lateral and distal area of femoral attachment, and inserts on the more caudal area of the tibial attachment, following a straighter path. These two components are not isometric – during flexion of the joint there is elongation of the craniomedial portion, and shortening of the caudolateral (and vice versa in extension). (de Rooster, 2001; Muir, 2010)

During weight bearing active forces are generated which create a cranial tibial thrust relative to the femur. In a sound joint this is opposed by joint compression, muscle forces and the CrCL. During all positions of flexion the craniomedial band is the main contributor to craniocaudal joint stability. The caudolateral component only supports this function if the craniomedial band is damaged or severely stretched. In extension both parts are taut and limit thrust. (de Rooster, 2001; Muir, 2010)

In extension of the joint the caudolateral component of the CrCL shows the greatest tension, providing the primary restraint against hyperextension.

Furthermore during flexion the CrCL and CaCL wrap upon each other, and spiral on themselves. This strain helps to limit normal internal rotation of the tibia. In extension the taut collaterals provide the primary restraint against rotation, and the cruciate ligaments support this. Similarly, the cruciates support the collaterals in restraining varus/valgus angulation of the stifle. (de Rooster, 2001; Muir, 2010)

The CaCl is far less important. It is longer and wider than the CrCL, and can also be separated into bundles however this is not clinically important. It provides a secondary restraint against hyperextension if the CrCL is injured. (de Rooster, 2001; Muir, 2010)

II.II. Biomechanics of the stifle

In Slocum and Devine 1983, cranial tibial thrust was first described – a cranially directed force occurring within the stifle joint. Generated during weight bearing, the tibial tendon of the biceps femoris and the slope of the tibial plateau were said to contribute to the force, and that it may be a factor in CrCL rupture and subsequent joint instability. (Muir, 2010)

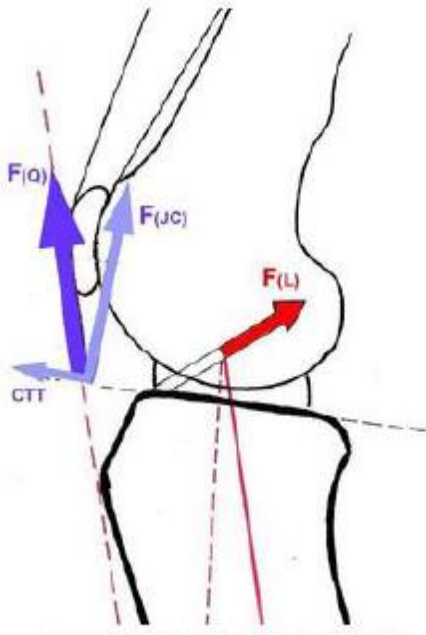


Figure 3 - Schematic presentation of the main forces in a canine stifle joint. $F(Q)$ = Force of the quadriceps, $F(JC)$ = Joint compressive force, CTT = Cranial tibial thrust, $F(L)$ = Counterforce of the CrCL. $F(Q) = F(JC) = CTT$ (Durand et al., 2014)

Slocum and Slocum 1993 went on to suggest that the magnitude of the thrust was dependent on the angle of the tibial plateau slope (TPS). The compressive forces of weight bearing, assumed parallel to the tibia's long axis, are transferred to the femur via the tibial plateau. The angle of the slope splits the compressive force into both cranial and perpendicular (to the plateau) portions. The cranial portion results in the cranial tibial thrust, whilst the perpendicular force gives joint compression. (Muir, 2010)

An alternative theory was suggested in Tepic et al, 2002. Here it was argued that the tibia is not axially loaded,

but instead the total joint forces are taken to be parallel to the patellar tendon (see Figure 3). The thrust is therefore dependent on the angle between the patellar tendon and the tibial plateau slope (let this angle be α). As α changes with flexion of the stifle, there is a point of flexion at which $\alpha = 90^\circ$ resulting in no cranial aspect to the joint's compressive force and so no cranial tibial thrust or load on the cruciates. This is usually when the stifle itself is flexed at approximately 90° . A stifle less flexed than this will increase the cranial thrust and so the load on the CrCL, whilst stifle flexion beyond 90° will load the CaCL. Typical stifle flexion mid stance is around 135° ($\alpha \sim 105^\circ$), and so the CrCL is loaded. (Boudrieau, 2007; Muir, 2010)

The femoropatellar joint is an important contributor to the joint forces. The patella acts as a pulley, transferring the quadriceps contractive force to improve extension. By increasing the lever arm (distance from the centre of rotation to the muscle force), contractions manifest more in extension of the limb, and less as a joint compressive force. However in doing so there is significant compressive force on the femoropatellar joint, termed the retropatellar force. This contributes to the stability of the joint, and puts a cranio-caudal force on the distal femur, straining the CrCL. (Anon., 2011; Durand et al., 2014)

II.III. Pathogenesis of CrCL rupture

Cranial Cruciate Ligament rupture in dogs was historically thought of as a traumatic injury, as it is in humans. Since the late 1980's though, this has been challenged as it was established that dogs with CrCL rupture had a high risk of rupturing their contralateral CrCL also, suggesting a predisposition. Furthermore the typical history and clinical signs were not easily explained by traumatic injury in the majority of cases. (Muir, 2010)

CrCL rupture has since been classified into two main modes – a degenerative syndrome in middle aged to older, small to medium sized dogs, and as a traumatic injury of young, large breeds. Even this view is now challenged, and the exact etiopathogenesis of CrCL rupture is not defined, but is considered the result of various interrelated causes which are not mutually exclusive. (de Rooster, 2001; Muir, 2010)

Purely traumatic CrCL rupture can occur, but is considered incidental and can occur in any breed at any age. Sudden hyperextension, sharp turns whilst weight bearing causing excessive internal rotation, and extreme cranial tibial thrust (such as landing after jumping from a height) are the actions most likely to strain and rupture the CrCL. (de Rooster, 2001)

More likely is a multifactorial reduction of the CrCLs integrity and mechanical strength, leading to rupture of the ligament after minimal trauma or even at normal loading. Before rupture is clinically apparent, gradual degeneration of the CrCL with inflammation in the joint, incremental partial tearing due to imbalanced forces, and then complete rupture. The resultant instability gives rise to secondary changes in the joint, including osteoarthritis and meniscal injury. (de Rooster, 2001; Muir, 2010)

Studies have tried to classify the types of dog affected, with age, breed, body weight and gender all having been considered as risk factors – however these studies mostly lack comparison with normal canine populations, questioning the significance of any reported differences. Many other factors can be responsible for the weakening and deterioration of the ligament. (de Rooster, 2001)

The CrCLs collagen fibril microstructure deteriorates with age, the central core being the most vulnerable as it has having the poorest vascularisation. However if aging were the primary and sole cause of CrCL rupture, one could expect a higher frequency of bilateral disease. (de Rooster, 2001)

Animals that live a sedentary lifestyle typical of many middle aged dogs may also be predisposed, usually compounded by their being overweight also. It is postulated that the reduced activity weakens the CrCL as well other secondary soft tissue joint stabilisers, whilst the joints of overweight animals are subject to higher stresses and forces, potentially accelerating degeneration. (de Rooster, 2001; Conzemius, 2010)

Anatomic variability can also influence the pathogenesis, with changes to the joint or varying conformation and phenotypes putting greater strain on the CrCL, causing faster degeneration of the ligament. For example a tibial plateau angle $>35^\circ$, chronic patellar luxation, angular shaft deformities, and an extended standing angle of the stifle are thought to predispose animals to CrCL disease. Intercondylar notch stenosis of the tibia may be primary (congenital or developmental), or secondary to degenerative changes, and can also strain the ligament causing degeneration. (de Rooster, 2001; Conzemius, 2010)

There is also evidence of immune phenomena involvement in several types of joint pathologies in dogs. With immune mediated synovitis, a gradual relaxation of the cruciate ligaments can be seen. Immune complex deposition in the ligament would also contribute to its degeneration. It has also been shown that animals with CrCL disease have raised auto-antibody titres to collagen, however it is unproven whether this is a cause or effect. Raised antibodies could be part of an auto-immune degeneration of the ligament, but could also be the result of collagen antigen exposure following ligamentous damage. Further research is needed to clarify the role of the immune system in this disease. (de Rooster, 2001; Conzemius, 2010)

In summary, CrCL disease is considered a multifactorial disease for which a primary cause or predilection is yet to be established. In many cases of rupture the complete etiopathogenesis is said to be enigmatic. (de Rooster, 2001)

II.IV Diagnosis of CrCL rupture

Cranial Cruciate Ligament ruptures are mainly diagnosed based upon the patients' history and clinical signs, laxity tests, radiography and arthroscopy. Other imaging modalities and other tests may be of use, but are not currently commonplace in the diagnosis of CrCL disease. (de Rooster, 2001)

The history can give suspicion of disease, but clinical signs may vary – from acute injury to more chronic, insidious lameness. This can be influenced by the degree of

damage to the CrCL, from varying degrees of partial tears to complete rupture. (de Rooster, 2001)

Three different clinical presentations may be associated with varying CrCL injuries – those with acute, chronic or partial tears. Acute tears often present with sudden onset non weight bearing lameness, which usually improves to walking with a limp and only toe touching when standing after 3-6 weeks. In chronic injury animals present with prolonged weight bearing lameness, with or without a history of acute non weight bearing lameness. They may also have a history of difficulties in laying and sitting, or of sitting with the affected limb held out in extension, and lameness being worse following sleeping or exercise. These signs are typical of the associated degenerative joint disease (DJD). Partial tears can be more variable, as the severity of lameness correlates with the degree of ligament disruption. Typically there an initially mild weight bearing lameness that is associated with exercise but resolves with rest, and can last for months. With continued tearing, increasing instability and degenerative changes, lameness worsens. (Fossum & Welch, 2007)

The clinical exam should begin with inspection of the animal, viewing it from behind and its side during rest. One should assess the degree of weight bearing, as well as the stifle position and angle. The animals' stance should be evaluated for any skeletal abnormalities that may predispose them to CrCL damage. (de Rooster, 2001)

Following inspection, palpation of the limb is done. Whilst experience and skill are needed to properly evaluate the stifle, especially in cases with partial tears, this is a very useful method of diagnosing CrCL tears. Patients are often apprehensive of examination, making instability difficult to detect. (de Rooster, 2001; Brinker et al., 2006)

In general palpation of the stifle joint effusion may be palpable as indistinct margins to the patellar tendon. In more chronic cases a typical 'medial buttress' can be felt on the medial aspect of the joint – a firm mass/swelling of the joint formed by periarticular thickening, osteophyte formation and fibrosis as a result of the instability. Atrophy of the quadriceps may also be palpable. Though it is not imperative, if there is concurrent meniscal damage then a click/snap may be felt upon manipulation of the joint. (de Rooster, 2001; Brinker et al., 2006; Fossum & Welch, 2007)

Following general palpation of the limb, laxity tests are performed to assess the joints stability, and therefore indicate the integrity of the CrCL. Two main laxity tests that

are performed are the cranial drawer, and tibial compression tests. If joint instability is clinically detectable then there is substantial biomechanical disruption to the CrCL. (de Rooster, 2001; Muir, 2010)

Cranial drawer should be tested on an unloaded, semi-flexed stifle. The femur is fixed with one hand – fixing the femoral condyles, and patella in place. The other hand should hold the lower limb around the fibular head and the tibial tuberosity (see Figure 4A). With cranial pressure applied to the fibular head, any translocation of the tibia relative to the femur (cranial drawer) is pathognomonic for CrCL rupture, the amount of which may be relative to the degree of damage and the original neutral position (see figure 4).

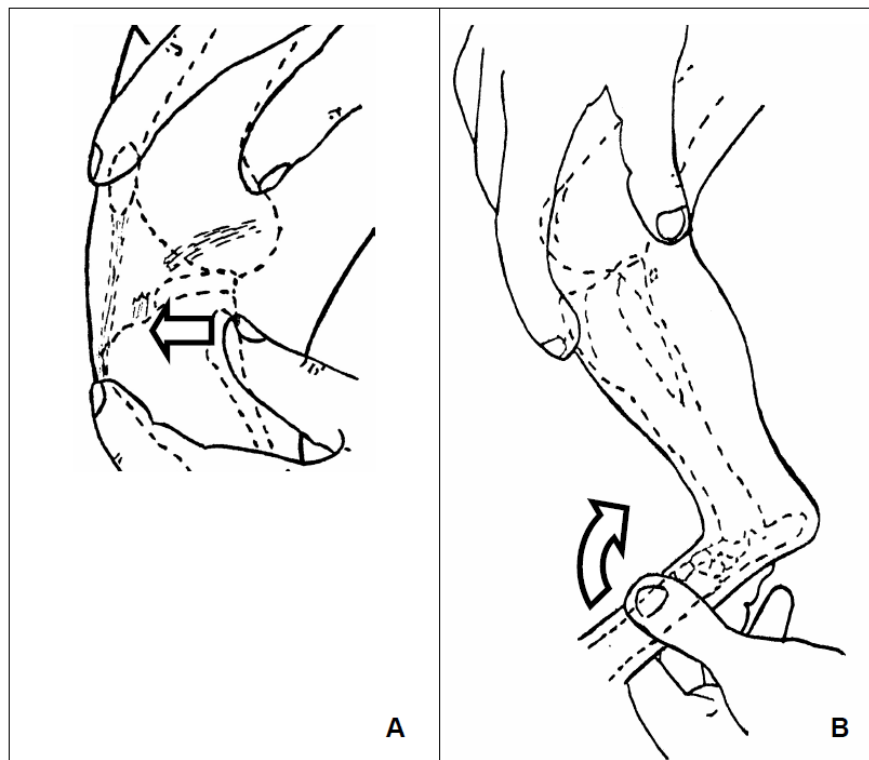


Figure 4 - Manual tests to check for cranial cruciate ligament instability in the dog: A - Cranial drawer test; B - Tibial compression test (de Rooster, 2001)

The tibial compression test should be performed in weight bearing position, with an index finger running down the tibial crest as the palm contours the femoral condyles. The other hand should then be used to flex and extend the tibiotarsal joint (mimicking the gastrocnemius muscle) (see Figure 4B). With the stifle in a fixed degree of flexion/extension, if there is a rupture of the CrCL then the tibia is displaced cranially, which can be felt moving relative to the femur. (de Rooster, 2001)

Laxity tests are extremely useful in the diagnosis of CrCL tears, but are not 100% sensitive and can yield false negatives. The clinicians experience and skill are important

factors, particularly with partial tears or chronic injuries where the amount of drawer motion may be reduced. The state of the animal can also make these tests difficult – apprehensive dogs, or those in pain from an acute injury can offset the instability on examination with increased muscle tone. In these cases a general anaesthetic or heavy sedation may be useful to negate the muscular tension if CrCL rupture is suspected. (de Rooster, 2001; Fossum & Welch, 2007)

If the clinical examination can neither confirm nor rule out CrCL damage, then imaging modalities may be used to gain further information regarding the diagnosis. Radiography is frequently used to assess the stifle for signs of CrCL rupture in conjunction with the clinical exam, and arthroscopy is an increasingly used method for diagnosing/assessing the structures of the stifle. Other imaging modalities such as ultrasound, scintigraphy and MRI may have some diagnostic value but are rarely used due to difficulty, non-specificity and cost/availability of equipment. (de Rooster, 2001)

A standard lateral radiographic view of the stifle can be a useful adjunct to support a tentative diagnosis and to rule out other pathologies. Signs of CrCL rupture may be direct (displacement of the tibia relative to the femur), or indirect. Many of the signs seen however are those of osteoarthritis, and so whilst indicative these are not pathognomonic for CrCL tears. (de Rooster, 2001)

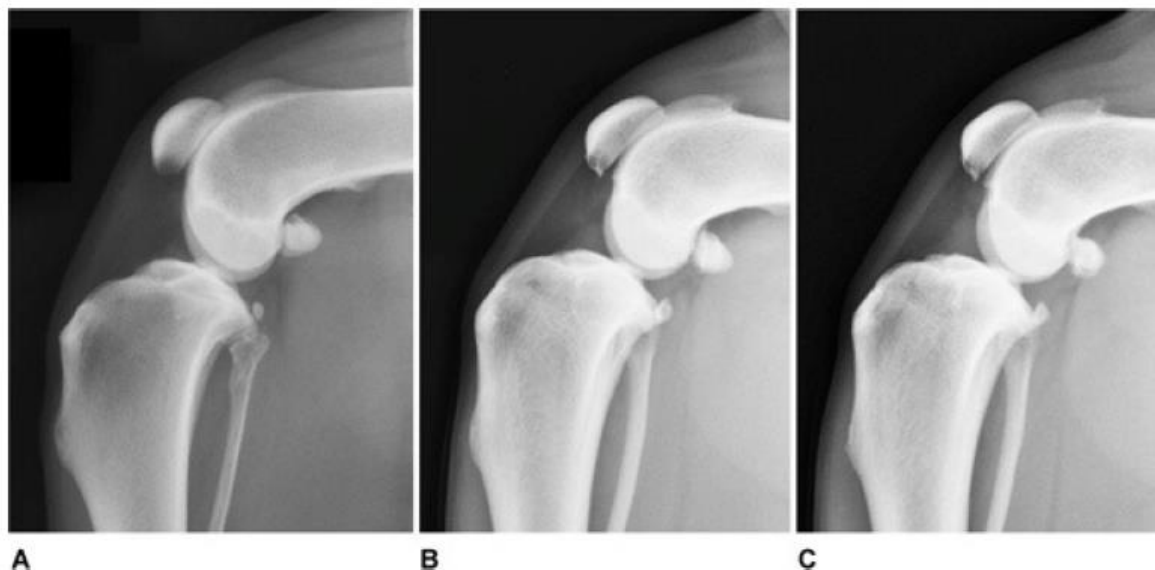


Figure 5 - Radiographic changes in cranial cruciate ligament disease. Normal stifle (A), early stable partial tear (B), early stable partial tear (C). Note the increased soft tissue opacity (B and C) and enthesophyte formation at the cranial intercondyloid area (C). (Kowaleski, n.d.)

One of the earliest indirect signs is the loss/reduction of the infrapatellar fat pad which is usually seen as a radiolucent triangle between the distal pole of the patella, the

femur and the tibia, and a caudal radio-density of the cruciates and menisci (see Figure 5A). Joint effusion associated with CrCL disease, and oedema of the adipose tissue reduces the radiolucent area, with the radio-opaque area extending beyond its normal limits (see Figure 5 B&C). (Kowaleski, n.d.; de Rooster, 2001; Brinker et al., 2006)

Other radiographic signs are typical of osteoarthritis of the stifle resulting from instability. This DJD is not specific to CrCL disease, unless avulsion fragments are seen but this is rare. Blurring and enthesophyte formation at the point of ligament origin and insertion are more specific to ligament pathology. (de Rooster, 2001)

Radiographic signs of DJD that may be linked to CrCL rupture are typically osteophyte formations that are more severe in larger dogs and took 3-4 weeks to start forming experimentally. First seen is a sharpening of the proximal and distal patella, followed by sclerosis of the trochlear groove ridges on the femur, osteophyte development on the tibial plateau, and on the fabellae (see Figure 5C). (de Rooster, 2001; Brinker et al., 2006; Kowaleski, n.d.)

Whilst not as widely available, arthroscopy is an increasingly popular method in the diagnosis and evaluation of CrCL disease. The procedure is minimally invasive and relatively atraumatic when compared to arthrotomy, and allows thorough evaluation of the synovium, joint pouches, articular cartilages, cruciate ligaments and menisci. For this reason it is now considered the gold standard in joint evaluation. (Kowaleski, n.d.)

Arthroscopy can be used both diagnostically and therapeutically. As a diagnostic tool it is largely used to confirm partial tears or meniscal damage, and to assess the degree of osteoarthritis in the joint. Therapeutically arthroscopic removal of tissue remnants, assisted reconstruction, treating meniscal damage, and topical treatment of osteoarthritic lesions are all possible. (Fossum & Welch, 2007)

II.V. Surgical techniques in CrCL rupture

Untreated CrCL injury leads to DJD, the degree of which is proportional to the animals' weight. There will be periarticular osteophytes, articular erosions and meniscal damage. Whilst conservative treatment (cage rest for 4-8w) can yield satisfactory function in most small dogs (<20kg), they will still develop DJD with uncertain future function. It is therefore recommended for all CrCL injuries to be treated surgically. No current technique

consistently stops the development or progression of DJD, but surgical stabilisation is hoped to reduce and slow its development. (Brinker et al., 2006)

Whilst surgery is recommended it remains unclear as to the best procedure and numerous surgeries have been described and refined in an attempt to find a definitively superior treatment. Most retrospective studies show a success rate of ~90% regardless of the technique used. Surgery is currently aimed at treating stifle instability, not toward reconstruction or repair of the CrCL. (Brinker et al., 2006; Fossum & Welch, 2007)

As no technique has been shown to be clearly superior, the method used is often based on the surgeons' preference, experience and technical ability, alongside patient size and cost. Surgical techniques can be divided into intracapsular, extracapsular and osteotomies (of which two predominate and will be looked at in detail – TPLO and TTA).

II.V.I. Intracapsular

Historically popular from adaptations of techniques in human medicine, intracapsular surgeries showed promising results but have since become less popular. Still the preferred option in human ACL (anterior cruciate ligament) injury, intracapsular stabilisation is less successful in canines. Differences in stifle anatomy and the mechanical forces acting, as well as different aetiologies frequently result in premature failure of canine grafts. (Muir, 2010)

Grafts used are predominantly autologous tissues (synthetic grafts aren't economically feasible for widespread use), usually a fascia lata strip which vascularises, then undergoes fibroplasia and reorganisation of collagen fibres to resemble a normal ligament. Their advantage is that intracapsular placement gives the closest anatomical substitution of the CrCL, therefore closest mimicry of its function allowing a more normal joint motion. The disadvantages are that the techniques are invasive, and grafts have a tendency to stretch or to fail. (Muir, 2010)

One of the first intracapsular techniques was the Paatasma technique, first described in the 1950's. Here a 1-2cm wide strip of the fascia lata (still attached distally) is harvested and passed through drill holes in the femur and tibia, then anchored with sutures along the patella ligament. The drill holes should open at the origin and insertion points of the CrCL for isometric placement of the graft. (Muir, 2010; Mattila, 2012)

Following this Arnoczky et al, 1979 described the 'over the top' (OTT) method. Along with a fascia lata strip, the medial 1/3 of the patella-patellar ligament complex is

freed (preserving the patellar articular surface) whilst remaining attached to the tibial tuberosity. This strip of fascia lata, patella and patellar ligament is then passed through the joint, 'over the top' of the lateral femoral condyle and sutured in place. Compared to the Paatasma technique OTT avoids improper hole placement and sheering stress on the graft from tight turns and bony edges. (Muir, 2010; Mattila, 2012)

II.V.II. Extracapsular

Extracapsular techniques have been widely used since the 1960's with good efficacy. They rely on surgical provision of a passive resistance to tibial translation, internal rotation and/or hyperextension, allowing sufficient periarticular fibrosis to take place for long term stability and function. There are many procedures described, most of which use a heavy gauge suture to stabilise the joint, whilst others rely on transposition of soft or bony tissues. (Brinker et al., 2006; Fossum & Welch, 2007; Muir, 2010)

The potential advantages are that the procedures are less invasive, safe, address abnormal internal rotation, are technically easier (relatively speaking), have low equipment demands and costs, and shorter surgery and anaesthesia times. However when using synthetic implants premature rupture may be detrimental. (Muir, 2010)

Fibular Head Transposition (FHT) involves freeing the proximal end of the fibula from its attachments to the tibia, moving it cranially and fixing it with Kirschner wire (K-wire) and a pin to the tibia. As the lateral collateral ligament (LCL) is inserted on the fibular head, it is also translocated. The new direction of the LCL mimics that of the ruptured cruciate, stabilising the joint from cranial tibial thrust and internal rotation forces. The moved LCL however may undergo elongation and remodelling, leading to recurrence of instability and its secondary pathological processes. There is also the risk of damaging the peroneal nerve, intraoperative fractures of the fibular head, and pin or wire migration or failure. (Brinker et al., 2006; Muir, 2010)

One of the most popular and widely used extracapsular techniques is the Lateral Femorotibial Suture (LFTS) (or Lateral Retinacular Imbrication Suture). A high gauge synthetic suture is used to stabilise the joint, resisting cranial tibial thrust and internal rotation (see Figure 6A). Sutures used include monofilament nylon, orthopaedic wire, braided orthopaedic suture, or fishing line. The suture is placed around the lateral fabella, and through a hole drilled in through the tibial crest. The limb is held at a normal standing

angle and the suture is tied at an appropriate tension to stabilise the joint. (Brinker et al., 2006; Muir, 2010)

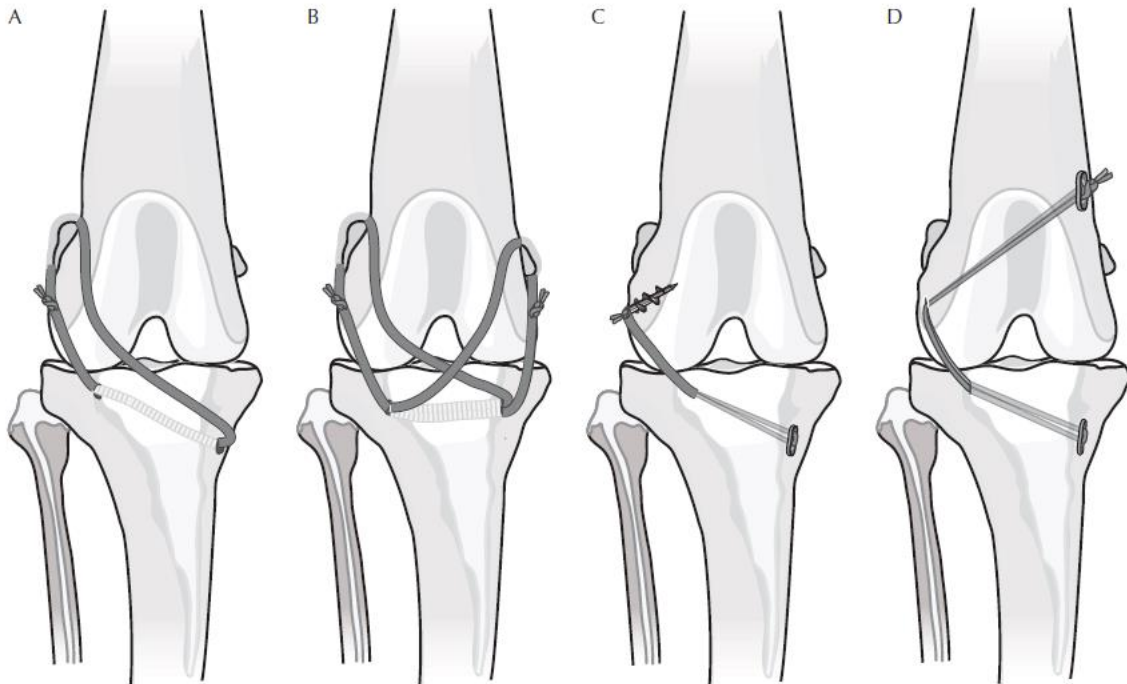


Figure 6 - Illustrations of lateral femorotibial suture (LFTS) (A), modified retinacular imbrication technique (MRIT) (B), lateral suture anchor technique (LSA) (C), and TightRope (TR) (D) methods for extracapsular stabilization in the dog. Copyright © Samantha (Muir, 2010)

There are many variations on the LFTS technique, but the basic principle is the same. Introduction of metal crimps in place of the knot to close the loop allow greater control the tension in the suture, as well as being smaller and less likely to cause reaction. The suture can be anchored directly on the lateral femoral condyle rather than the fabella with use of an anchoring screw. This makes the fixation point more isometric, optimising joint kinetics and minimising wear on the materials. (Brinker et al., 2006; Muir, 2010)

A further adaptation of the LFTS is the tightrope procedure developed by Arthrex vet. Systems (see Figure 6D). This also uses a synthetic suture on the lateral aspect of the joint for stability, but proposed advantages are bone fixation at both sites, more accurate isometric placement, and the strength, stiffness and creep characteristics of the implant (a fibre tape with toggle and implant). To ensure accurate isometric placement of the implant tunnels are drilled through the femur and tibia from the optimal points. “The start site for the femoral tunnel is just distal to lateral fabella-femoral condyle junction (i.e. 2 mm from the caudal edge of the lateral femoral condyle)”, directed to the medial aspect of the distal femoral diaphysis. “The tibial start site is located caudally within the groove of the long digital extensor tendon”, aimed toward the medial aspect of the proximal tibia. The implant

is introduced through the tunnels, fixed with a toggle at one end and knotted with a button at the other. (Muir, 2010; Arthrex, n.d.)

Whilst many of the implants from either technique will fail with time, after about 6-8 weeks they will have provided sufficient joint stability. The resulting periarticular fibrosis continues to stabilise the joint. Studies based on kinetics, kinematics, and/or radiographic analysis of osteoarthritis have reported the synthetic extracapsular techniques to be superior to the FHT procedure, but not statistically or clinically different to TPLO or TTA procedures. (Muir, 2010)

II.V.III. Tibial Plateau Leveling Osteotomy – TPLO

The TPLO procedure aims to alter joint mechanics in the CrCL deficient stifle, providing dynamic stabilisation of the joint by active constraint.

The principle of the surgery was based upon the principle of ground reactive forces (GRF) and muscle forces causing a compressive load on the tibial articular surface in weight bearing. As the tibial plateau is a caudally directed slope compared to the axial compressive force (the tibial plateau angle – TPA), the axial load is reduced to two orthogonal components or vectors, one perpendicular and one parallel to the tibial plateau (see Figure 7A). The latter gives rise to the Cranial Tibial Thrust (CTT). (Fossum & Welch, 2007; Boudrieau, 2009)

If the TPA were 0° then the compressive force is not split, and so equals the resultant force - there is no parallel/cranial component and so no CTT (see Figure 7B). TPLO surgery aims to achieve this by means of a radial osteotomy to the proximal tibia, enabling rotation of the tibial plateau. (Boudrieau, 2009)

Prior to the TPLO a closing tibial wedge osteotomy (CTWO) was performed based on similar mechanics. The CTWO used a more distal osteotomy to level the tibial plateau, with a wedge taken from the entire width of the tibia, altering the relative position of the tibial crest and potentially altered the joint extensor mechanism. The angle of the tibial plateau is altered relative to the long axis of the tibia, eliminating CTT. An advantage of the CTWO is that it can be used in immature dogs with open proximal tibial physis; however it does alter the limb conformation more significantly.

The TPLO surgery was first described by Slocum in 1993. Using a radial osteotomy of the proximal tibia, the natural caudo-distal orientation of the slope is decreased, limiting the CTT generated in weight bearing. Slocum Enterprises (Eugene, Ore) initially placed a patent on the procedure, the biradial saw, bone plate and the jig used

for the surgery. This restricted widespread teaching and use of the technique, but the patent has since expired making the procedure more accessible and a wide range of implants are now available. (Brinker et al., 2006; Muir, 2010)

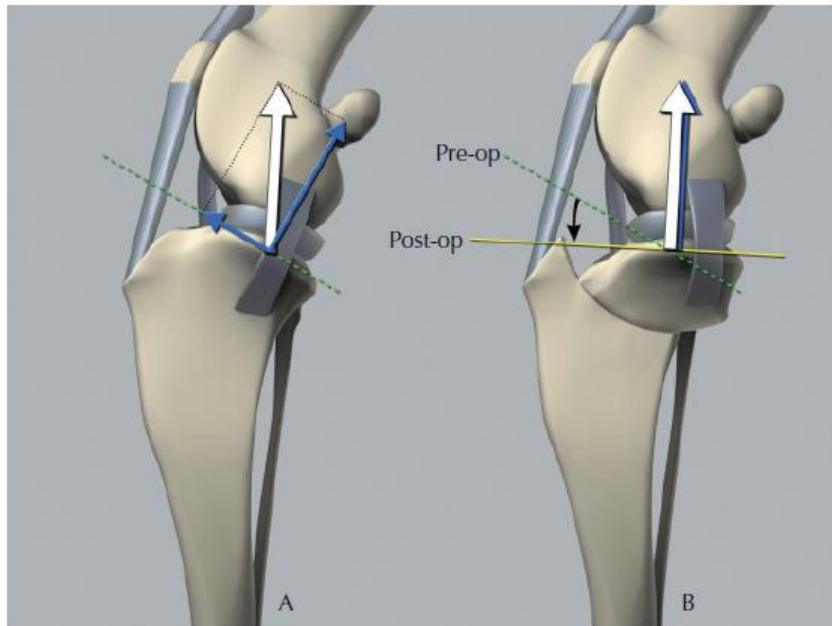


Figure 7 - Schematic representation of the tibiofemoral forces in the stifle joint, according to Slocum before (A) and after (B) TPLO. The resultant compressive force (large white arrow) across the stifle joint is parallel to the tibial axis. Using the tibial plateau slope as the baseline, whereby the femur can move along this surface if the CrCL is deficient, the resultant force can be broken down into its two orthogonal components (small blue arrow heads) – one perpendicular and one parallel to the tibial plateau. The latter represents the tibiofemoral shear force. If the angle of the tibial plateau is reduced to zero, the tibiofemoral shear force vector becomes zero, as the joint compressive force and resultant force become one and the same. (Muir, 2010; Boudrieau, 2009)

Preoperative radiographic assessment is required to measure the TPA and therefore the required rotation. Medial-lateral radiographs of the stifle and hock should be taken, positioned so that the femoral condyles overlap as do the trochlear ridges of the talus. Measurements of the TPA are most accurate when there is < 2mm between the femoral condyles and the beam is centred on the tibial plateau. (Fossum & Welch, 2007)

To measure the TPA you must first mark the centre of the talus' trochlea, the centre of the intercondylar eminence of the tibial plateau and connect the points with a line (line a). A second line is made to estimate the tibial plateau based on its cranial and caudal limits (line b). At the a-b intersection, a third line (line c) is drawn at 90° to line a. The TPA equals the angle between b and c. A chart is provided with the required distance of rotation based on TPA and chosen size of radial saw. (Fossum & Welch, 2007)

A medial approach is made, skin soft tissue including the sartorius and popliteus are reflected, and jig pins are placed in the proximal-caudal tibia as the centre of the osteotomy, and in the distal tibial diaphysis. Both pins should be perpendicular to the sagittal plane and parallel to the transverse plane. The osteotomy should be centred roughly

over the proximal jig pin, and perpendicular to the medial aspect of the tibia. An osteotome is used to mark either side of the saw osteotomy, in two places the appropriate measured distance apart as determined by the TPA. (Fossum & Welch, 2007)

The osteotomy must allow adequate space for the plate on the proximal tibial segment, whilst also leaving sufficient tibial crest intact to avoid fractures. The cut should exit the caudal aspect of the tibia perpendicular to the shaft of the bone.

A large pin is placed in the cranial proximal medial segment (in a caudo-lateral-distal direction) for rotation of the segment caudo-distally until the osteotome lines are matched. The segment should not be translocated medio-laterally to align the tibial cortices as this can cause limb malignment. A smaller pin is placed cranio-caudally through the tibial crest to fix the segment, and joint stability can be confirmed before fixing with a plate and closing. (Fossum & Welch, 2007; VeterinaryInsurumentation, n.d.)

Whilst a TPA of 0° would completely remove the CTT, in practice 5° is the recommended target. As with an overcorrection, at 0° the joint compression forces can generate a caudal thrust in the functioning joint, loading the CaCL and potentially leading to its injury. With a TPA of 5° this risk factor is eliminated, and the remaining CTT can be compensated for by the hamstring muscle group without the passive stability of the CrCL. The condition of the CaCL should be considered as a factor and evaluated as part of a patients' suitability for the procedure. (Palmer, 2005)

There is a strong correlation between the planned amount of rotation and the postoperative outcome. Achieving this without inadvertently creating angular or rotational deformities however is complex. It is a more technically demanding surgery and requires more experience than the less invasive extracapsular techniques. (Muir, 2010)

Overall post-operative complications range from 18-28% depending on a number of factors, such as the skill and experience of the surgeon, the TPA and degree of rotation, and conformation of the limb. Some of the more common complications include haemorrhages, patella tendon enlargement, fractures of the tibia, postoperative damage to the menisci, pivot shift and implant failure. General risk factors associated with these are higher preoperative TPA, greater change in TPA and high body weight of the patient. (Muir, 2010)

Most post-operative studies done have relied on subjective information – lameness scoring, radiographic osteophyte evaluation and client questionnaires. The consistent subjective impression is that TPLO gives faster recovery, which whilst not eliminating it completely should reduce osteoarthritis later on. Objective evaluation can be made with

force plate analysis and kinematics, both giving a good outcome and improved ground reaction forces when compared to LFTS. (Muir, 2010)

II.V.IV. Tibial Tuberosity Advancement – TTA

The Tibial Tuberosity Advancement was first described by Maquet to relieve contact pressure from the femoropatellar joint for sufferers of joint pain in humans. It is not used for treatment of CrCL in humans. The supporting model for this procedure was based upon a model of a human knee. (Muir, 2010; Tuan & Farrell, 2015)

In 2002 it was proposed that Nissel's model of the knee could also be applied to the canine stifle (Montavon et al 2002). Based upon this model, they suggested that the joint compression force was roughly the same magnitude and direction as the patellar tendon force (see Figure 8), not in the axis of the tibia as Slocum had proposed. In this model the patellar tendon compression force is then divided into components parallel and perpendicular to the tibial plateau, due to the angle between the patella tendon and the plateau – the Patella Tendon Angle (PTA). (Boudrieau, 2009; Tuan & Farrell, 2015)

As the typical PTA in a weight bearing limb (135° of flexion) is ~105°, there is a CTT and the CrCL is loaded. In full flexion (80° of flexion) there is a caudal shear force and the CaCL is loaded. At roughly 90° of stifle flexion, the PTA is 90° - the compression force is perpendicular to the tibial plateau and so no CTT is generated. (Boudrieau, 2009)

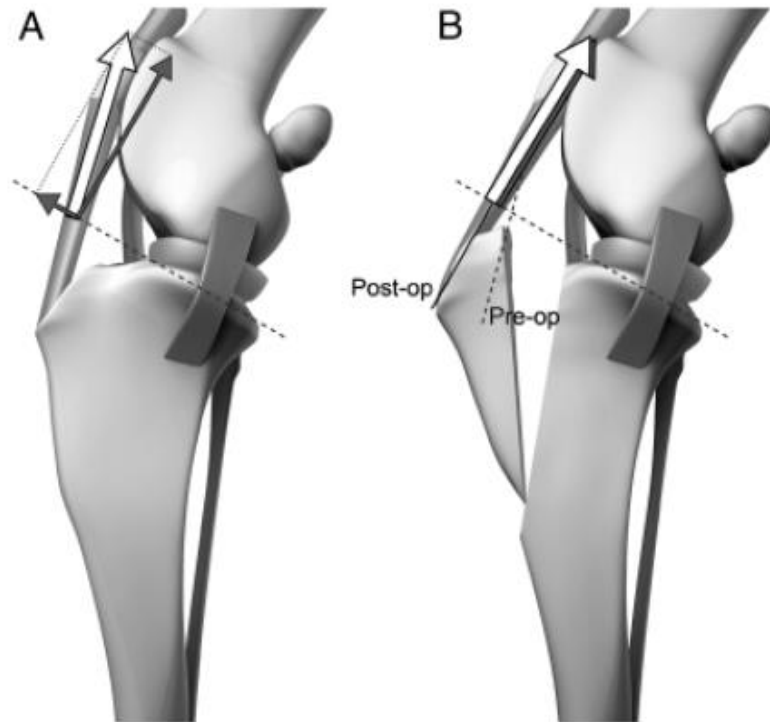


Figure 8 - Schematic representation in the stifle joint of the tibiofemoral forces, according to Tepic et al before (A) and after (B) TTA (see Figure 7). If the angle of the tibial tuberosity is advanced cranially until the patellar tendon angle is reduced to 90°, the tibiofemoral shear force vector becomes zero, and the joint compressive force and resultant force become one and the same. (Boudrieau, 2009)

Montavon and Tepic suggested that by moving the patella tendons insertion cranially, thus reducing the PTA, one could achieve a 90° PTA at 135° of flexion and in doing so neutralise the femorotibial shear force (see Figure 8B). This confers a dynamic stabilisation within the joint with co-activation of the flexors and extensors. (Boudrieau, 2009)

Following three years of clinical testing the TTA was launched by Kyon in 2004, proposed as less invasive than the TPLO. The technique was standardised by performing an osteotomy on the tibial tuberosity in the frontal plane, with a cranial advancement of the tuberosity and fixation so that the PTA is 90° in normal stance. The technique used at the Surgery and Ophthalmology Department of The University of Veterinary Medicine, Budapest will be discussed in more detail later on. (Tuan & Farrell, 2015)

Lateral radiographs should be performed pre-operatively, and the PTA calculated. A TTA template is available to measure the appropriate advancement, or it can be calculated. This can be done either by marking the Tibial Plateau Slope (TPS) as done for TPLO, or more recently by using the common tangents method and comparing the given line to that of the patellar tendon, giving the PTA (see Figure 9). X-rays should be done with the stifle at 135° of flexion, as the size of advancement is based upon this as an end

stance. There are techniques to measure the stifle based purely on the tibia, irrespective of the femur or degree of flexion.

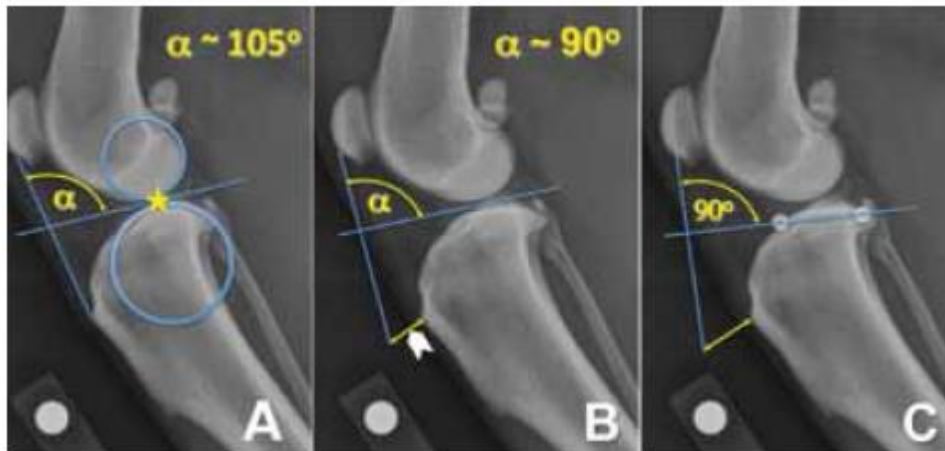


Figure 9 - Pre-operative measurements using the common tangents method (A + B), and Tibial plateau slope method (C) (Tuan & Farrell, 2015)

With the common tangent/tibial plateau and patella tendon established a third line should be drawn. This should be perpendicular to the common tangent/TPS and, at the level of the distal patella (the origin of the patella tendon). The distance between this line and the tibial tuberosity can then be measured giving the necessary advancement.

There are some limitations as to the suitability of an individual for the surgery. If the tibial tuberosity is low down the tibial shaft as opposed to high, then they may be unsuitable for the procedure as there is greater risk of the tuberosity fracturing. It is also unsuitable for animals with excessive tibial plateau angles as the level of advancement would be too high and implants for this are unavailable. The limit appears to be a tibial plateau angle of $\sim 30^\circ$. (Muir, 2010)

The initial Kyon implant consisted of a small cage spacer of determined size between the tibial tuberosity and the proximal tibia, combined with a plate which is fixed to both the tibial crest/tuberosity and the shaft of the tibia and a bone graft in the cavity.

Unlike the TPLO procedure, no patent was placed on TTA and numerous different variations have followed from different manufacturers, as well as advancing methods from Kyon (see Figure 10). New techniques and materials/implants aim to reduce the technical demand of the procedure, reduce complication rates, and reduce the necessity of a bone graft. Some of the more popular variants are: the TTA-rapid, using a single, larger cage with no need for the plate; the MMP-TTA by Orthomed which uses a porous titanium foam wedge as a spacer, fixed with a pin, or more recently an orthopaedic staple; the Leige-MMT, using a standard cage without a plate and a hinged osteotomy.

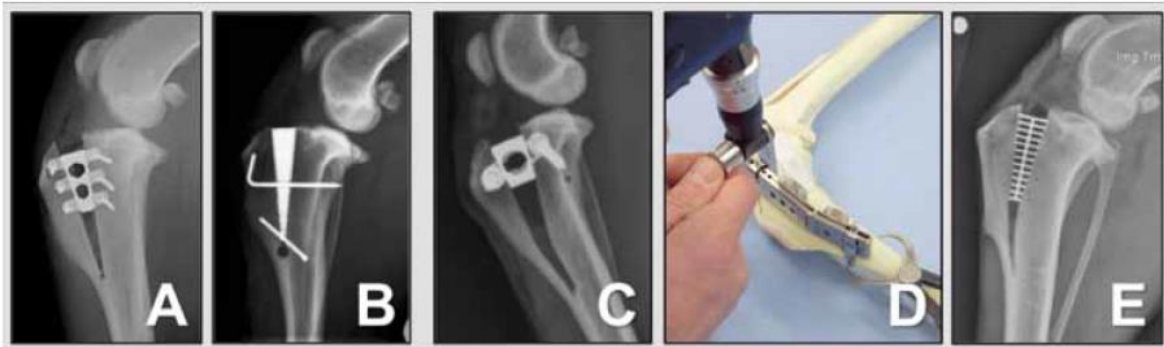


Figure 10 - Variations of the TTA surgery: TTA Rapid (A); MMP - Modified Maquet Procedure (B); Modified Maquet Technique (Liege-MMT) using a standard cage (C); The TTA2 cutting guide (D) facilitates the creation of a hinged osteotomy (E) (Tuan & Farrell, 2015)

Another more recent alteration to the technique is the circular TTA (cTTA), described by Petazzoni in 2010. By using a radial osteotomy around the tibial tuberosity, and cranio-proximal rotation of the segment, one can achieve an advancement of the tibial tuberosity (see Figure 11). Unlike traditional TTA surgeries, there is no need for specific spacers or implants, and traditional plating techniques can be used to fix the segment. Furthermore it allows compression and increased stability of the osteotomy site when compared to traditional TTA, and is a less invasive surgery. (Petazzoni, 2010)

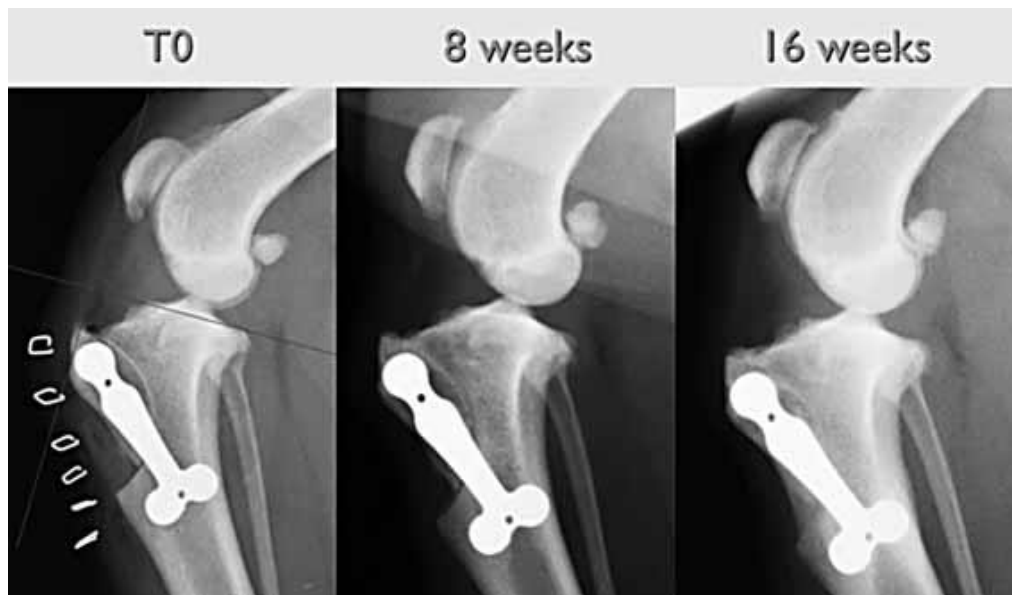


Figure 11 - cTTA at 0, 8 and 16 weeks post operatively (Petazzoni, 2010)

As with the TPLO there are potentially serious complications with such an invasive procedure as TTA. These include meniscal tears, infection, medial patellar luxation, tibial fractures, and catastrophic implant failures. A higher complication rate can be seen when compared to the TPLO, but as this is a relatively new procedure it could be associated with the steep learning curve associated to the procedure. (Muir, 2010)

There is little to no evidence to suggest that TTA is vastly superior to any of the other procedures, but it has good anecdotal results, including a quicker return to normal function (weight bearing) than extracapsular techniques, and comparable to TPLO. (Muir, 2010)

II.V. Complications of TTA surgery

Tibial Tuberosity Advancement is a relatively new procedure in the treatment of CrCL rupture. It is quite an invasive procedure when compared to intra or extra capsular prosthesis techniques, and so raises the question of associated complications (see Figure 12). (Muir, 2010; Kemper et al., 2011)

Early results for the success of the surgery are good to excellent, though these are largely anecdotal reports, with highly subjective clinical and radiographic assessment by the surgeon. Success of surgical treatment is affected by many factors, including the surgeons experience and the population studied. (de Rooster, 2001; Muir, 2010)

Early clinical results were published from three studies (Hoffmann et al. 2006; Lafaver et al. 2007; Stein et al. 2008). The results of the studies have been pooled to look at the relative frequencies of complications associated with TTA surgeries. Further studies have been carried out since. (Muir, 2010)

Each study categorised the complications into minor or major, though their criteria varied slightly. Initially complications were to be categorised as major or minor based upon the perceived clinical significance, but this was considered far too subjective. For this reason a more objective approach was used, major complications being any that required further surgery. This does however give some anomalies – such as lick granulomas that were corrected surgically, but are not a result of the surgical technique. Later studies described major complications as those that needed revision surgeries – giving a clear distinction from subsequent surgeries due to minor, unrelated complications. (Lafaver et al., 2007; Kemper et al., 2011)

Together the three studies showed an overall complication rate of 31.6-59%. Of these, 19.3-21% were considered minor and 12.3-38% major complications with 11.3% requiring re-operation. Not all re-operations were specific to the CrCL or TTA – with lick granulomas and a dog bite abscess included. (Lafaver et al., 2007; Muir, 2010; Kemper et al., 2011)

The combined data found the following to be the most common complications of TTA surgery, in order of frequency: meniscal tears (7.6% total, or 16.5% of the intact menisci); Infection (4.0%); Medial patellar luxation (0.4%); Tibial fractures (0.08%); catastrophic implant failure (0.08%). (Muir, 2010)



Figure 12 - Examples of mechanical failure after TTA: (A) Tibial tuberosity avulsion fracture after kyon TTA; (B) Implant fracture and tibial tuberosity avulsion fracture after MMP-TTA; (C) Diaphyseal tibial fracture after MMP-TTA surgery (Tuan & Farrell, 2015)

All of the studies found two common points – early technical errors, and meniscal injuries. (Muir, 2010)

The data collected was taken from the surgeons' first TTA cases, where they encountered technical mistakes which could be associated with the learning curve of the procedure. (Lafaver et al., 2007)

The cases with tibial fractures were stress fractures through either the proximal or distal screw of the plate. This was attributed to poor pre-operative planning or surgical execution, leading to incorrect size or positioning of the osteotomy and or plate positioning, thus creating increased stress risers. These were encountered within the first ten cases, suggesting a link to the steep learning curve associated with such a procedure. (Lafaver et al., 2007)

Subsequent meniscal tears are more confounding and the subject of some debate – whether or not to perform a meniscal release. Cases were screened prior to surgery, and any with meniscal damage were trimmed. It is possible that subsequent tears could have simply been missed initially, but the number observed was consistent with other studies. (Lafaver et al., 2007)

Meniscal tears may occur due to later trauma or secondary to the altered joint forces. Whilst meniscal release is recommended with TPLO, it was proposed that with TTA the tibial plateau position is unaltered, potentially sparing the caudal portion of the joint and eradicating the need for meniscal release. (Lafaver et al., 2007)

If performing a meniscal release obliterated tears, then major complications of TTA surgeries may drop to as low as 6% - however such extrapolation of the data cannot be validated without further studies. The question surrounding meniscal release is due to the meniscus' role and stabilising effect within the joint being compromised, and with progression of osteoarthritis increased before and after surgery with meniscal damage. Meniscal release is also not a guarantee for the absence of subsequent meniscus associated problems. (de Rooster, 2001; Lafaver et al., 2007; Kemper et al., 2011)

III. Goals and questions

Cranial Cruciate Ligament rupture remains one of the most common causes of lameness in dogs. Many different surgical techniques have been used to stabilise the deficient stifle with success rates reported to be >90% irrespective of the technique used. Unfortunately none of the current techniques completely limits the progression of degenerative joint disease. No clearly superior method of stabilising the CrCL deficient stifle has therefore emerged. (Boudrieau, 2009; Rovesti et al., 2013)

For this reason, the choice of surgical technique is often based upon individual surgeons' preference, rather than evidence that any one procedure is superior. This poses many questions regarding the treatment of CrCL rupture, and there remains an ongoing search for a technique to stabilise the joint that is definitively better than the others. (Boudrieau, 2009)

Circular TTA (cTTA) is one such potential technique which combines two popular methods, integrating the principles of TTA with the radial osteotomy of TPLO. Doing so allows continuous rotation of the tibial tuberosity (rather than being limited to predetermined cage sizes), as well as compression of the osteotomy for improved healing and stability. (Petazzoni, 2010)

With a gap in research on cTTA and its results – only two scientific publications exist to date - it remains to be seen if this could become a more widespread technique in the treatment of CrCL rupture. For this reason I aim to look at the surgical procedure of

cTTA in comparison to a linear TTA rapid, and the complications encountered in the first 30 cTTA surgeries performed at the Surgery and Ophthalmology Department of the University of Veterinary Medicine, Budapest.

The purpose is to determine if surgical technique and procedure is similar to traditional TTA, applicable to general practice, and how the complication rates may compare. If the surgery is comparable, and complications are found to be either equal to or better (in terms of number or severity) than with linear TTA, then cTTA could have potential to become more widely used in today's practice and provide a better treatment option for a leading cause of lameness in dogs.

IV. Materials and Methods

IV.I. Case selection

My sample is comprised of the first thirty animals to undergo cTTA surgery for CrCL rupture at the Surgery and Ophthalmology Department of the University of Veterinary Medicine, Budapest. The surgeries were performed by Dr. Ipolyi Tamás, who has previously performed both the TTA rapid and TPLO surgeries and is familiar with the techniques used in both. The surgeries and all preceding tests were performed at the Surgery and Ophthalmology Department of the University of Veterinary Medicine, Budapest.

The animals in the study were from the general population – with no selective criteria other than presenting with cruciate disease. Therefore, other than natural predisposition (breed, bodyweight etc.) for the disease, and being suitable for an osteotomy, there are no other links between the cases. The sample is therefore essentially random with an even spread and should be representative of a wider population.

Candidates presented with ruptured CrCL were assessed in a general orthopaedic examination and radiographically regarding their suitability for different stabilising surgeries. For dogs to be recommended for osteotomy they should be 15-45 kg's, and should not be obese or have severe muscular atrophy. Either TTA or TPLO are performed, depending upon radiological findings.

On radiographic evaluation the size and shape of the tibia, tibial tuberosity, and the tibial plateau angle were considered. Whilst there are no clinical or experimental studies to support the view, it is suggested that cases with a high patella tendon insertion are more

conducive to TTA, whilst those with low points of insertion are better suited for TPLO. (Boudrieau, 2007; Boudrieau, 2009)

Similarly, dogs with excessive Tibial Plateau Slope (TPS) may be better suited for TPLO than they are for TTA. In these cases TTA is limited by the range of commercially available cages – in Hungary 12mm is the largest – which may provide insufficient advancement to achieve a PTA of 90°. It has been suggested that dogs with a TPS >30° may not be suitable for TTA (see Figure 13), though the limits of the procedure remain to be definitively defined. (Boudrieau, 2009)

Whilst cage size isn't a constraint of cTTA, there is currently insufficient research regarding the maximum possible rotation of the tibial tuberosity, and unlike TPLO the underlying joint conformation would still not be addressed. For this reason dogs with TPS >28° are not recommended for TTA at the Surgery and Ophthalmology Department of the University of Veterinary Medicine, Budapest. Tibial width must also be assessed, ensuring sufficient space for the osteotomy and fixation, whilst leaving a thick enough tibial shaft to provide ample support. (Petazzoni, 2010)

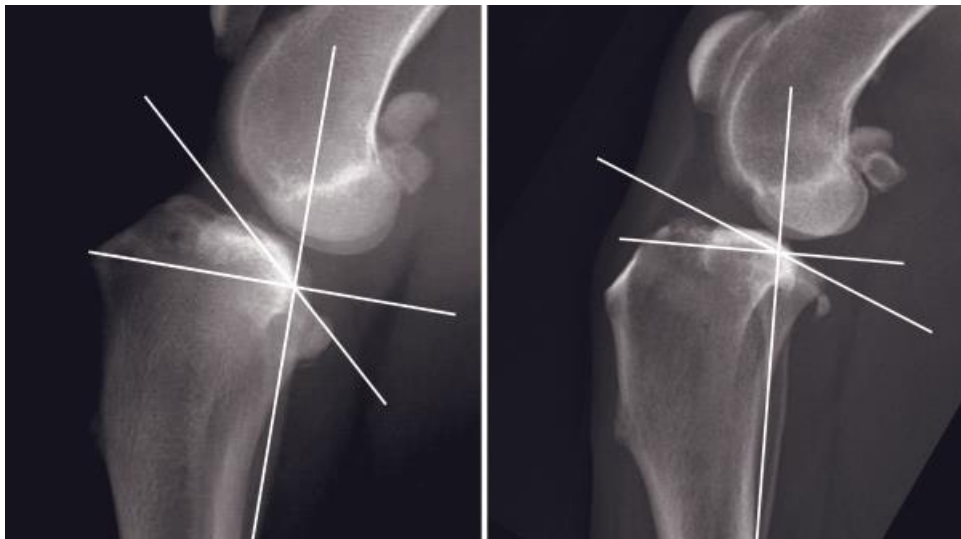


Figure 13 - On the left, a stifle with an excessive TPA of 43°, which is unsuitable for TTA. On the right a normal TPA of 25 – more suitable for TTA. (Muir, 2010)

IV.II. Preoperative planning

Whilst there are only two studies published regarding cTTA, there is more research available regarding planning for the multiple variations of linear TTA. Both the cTTA and

TTA rapid are based on the same principles, and so planning was done in a similar manner for both procedures, allowing for the technical differences between the surgeries.

Accurate preoperative planning is essential to obtain accurate measurements for successful surgery. Radiographs should be taken with the limb in 135° of extension, without rotation. Some good radiographic benchmarks for positioning are - femoral condyles overlapping one another; a straight patella tendon with the patella sat in the patellar groove; the proximal half of the fibula should be visualised; and the tibia should be in a normal operating position relative to the femur (not cranially displaced). (Zólyomi et al., 2015)

Once suitable radiographs are obtained (and geometric corrections made as needed) the appropriate measurements can be made to determine the desired amount of advancement of the tibial tuberosity. Radiographs were all digital, with orthopaedic software (dicomPACS – Control-X Medical KFT) used to measure and correct the images.

Two methods of calculating the required tibial tuberosity advancement are used at the Surgery and Ophthalmology Department of the University of Veterinary Medicine,

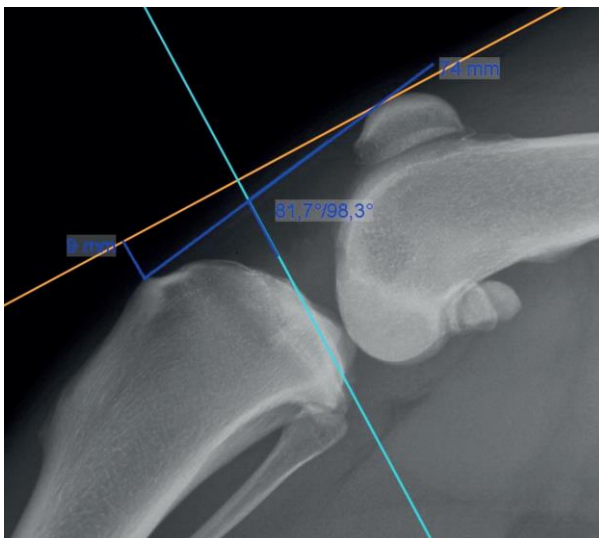


Figure 14 - TPS method as used for TTA rapid. The turquoise line is the TPS, and the orange line is the desired patella tendon, perpendicular to the TPS. The distance between the tibial tuberosity and the orange line is measured, giving the required cage size. (Zólyomi et al., 2015)

Budapest – both the Tibial Plateau Slope (TPS), and the Common Tangents (CT) methods. These are the most commonly used methods of measurement, with several publications addressing which is the most appropriate method. These studies have concluded that measurements often differ, but are yet to determine which is better, or that either method is incorrect.

For the tibial plateau slope the line of the tibial plateau is drawn, by marking the plateaus most cranial and caudal points, then drawing a connecting line. A second line is drawn, perpendicular to the first and coming from the cranial edge of the patella (see Figure 14). This second line represents the patella tendon post-surgery. (Diószegi, 2014)

The common tangents method is based upon the influence of the femoral condyles anatomic shape upon the femoral-tibial joint contact during stifle flexion and extension. It uses an alternate orientation of this contact point as the baseline to define the tibio-femoral shear force, whereby the femur can move along this surface in the CrCL deficient stifle. (Boudrieau, 2009)

For the common tangents method, circumscribe circles over the articular surfaces of both the femoral and tibial condyles. If perfectly aligned then one circle can be used for the femoral condyles, but if both are visible then two circles should be used with the midpoint between their centres used for subsequent measurements. The centre points of the tibial circle and the femoral circle (or the midpoint between two femoral circles) are then joined, and a line perpendicular to this connecting line drawn. This line represents the tibiofemoral shear force. A third line is drawn from the cranial edge of the patella, perpendicular to the shear force line (see Figure 15) – representing the desired patella tendon position post-surgery.

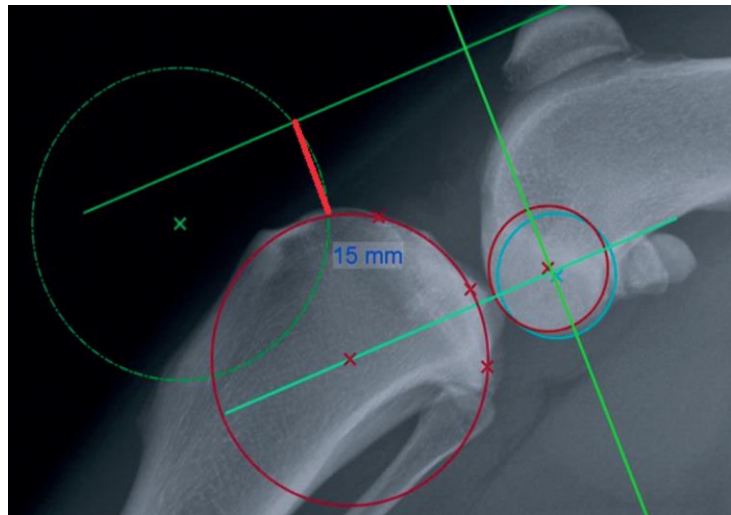


Figure 15 - Common tangent method as used in cTTA. The red and blue circles represent the femoral and tibial condyles, with the blue line connecting their centres. The green lines are perpendicular and parallel to this. The dotted green line shows the osteotomy line, and the red line the required advancement. (Zólyomi et al., 2015)

Both the tibial plateau slope and common tangent methods were considered to find the desired patella tendon and corresponding correction. The two measurements are not usually the same, and so if they differ an average value is used. In our experience, the tibial plateau slope method usually gives a higher value of correction than the common tangents method does. If tibial plateau slope suggests an unrealistically high value then the common tangents method is used alone. (Zólyomi et al., 2015)

For cTTA a circle is chosen that corresponds to the blade size that will be used for the osteotomy (based on the dogs size and conformation) – selected from the 18, 21, 24, 27 or 30mm blades available. This should be placed proximally just behind the insertion of the

patella tendon and distally at the distal extent of the tibial crest (see figure 15 – the dotted green line). It should extend caudally ~1/3 of the tibial width.

Once this circle is placed, the required advancement can be measured. In reality, this would be a curved arc of the circle, from the proximal edge of the patella tendon to the desired patella tendon line. However this curved line is difficult to measure both pre- and intra-operatively, and so a chord of the circle between the two points is measured (see

figure 15). This gives the required amount of rotation. (Zólyomi et al., 2015)

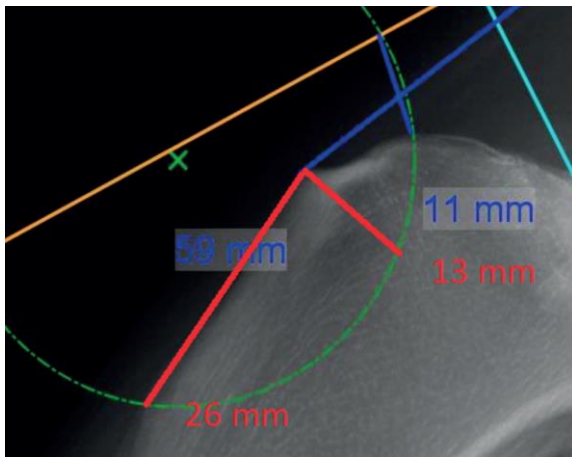
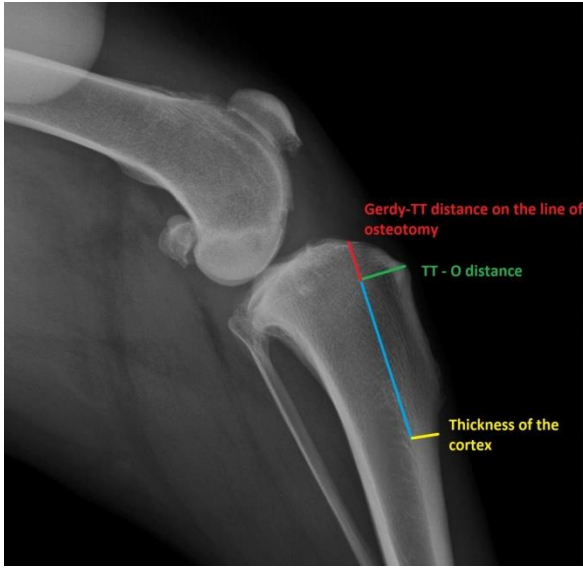


Figure 16 - Measuring for correct intraoperative placement of the osteotomy, relative to the tibial tuberosity. (Zólyomi et al., 2015)

Two further points should be measured relative to the tibial tuberosity which can be used as an intra-operative landmark for positioning the saw-blade (see Figure 16). Both the distance from the tuberosity to the distal point of the osteotomy, and from the tuberosity to the line of the osteotomy directly caudally. (Zólyomi et al., 2015)

For TTA rapid, once the cage size has been determined (see figure 14 – the distance between the tibial tuberosity and the orange line), radiographic landmarks must be found and measured, to ensure correct and accurate placement of the osteotomy in surgery. The distance from the tibial tuberosity to the desired patella tendon line is rounded up to the next available cage size (6, 9, 12 or 15mm), which shall be used in surgery.

First the distal point of the osteotomy is determined on the radiograph – 5-15mm distally from the prominent distal tip of the tibial crest. Here the cortical width is measured and the radiograph marked just caudal to this point. Then the most proximal part of the osteotomy is found – the tubercle of Gerdy. On radiographs it is seen as a prominence cranial to the small groove just cranial to the tibial condyle. (Diószegi, 2014)



Once these landmarks have been made, the distal tibia cortical thickness, the tibial tuberosity to osteotomy distance, and the tubercle of Gerdy to tibial tuberosity distance on the line of the osteotomy should all be recorded (see Figure 17). These are used for correct placement of the osteotomy in surgery. (Diószegi, 2014)

Figure 17 - Pre-operative measurements of landmarks for surgery (Diószegi, 2014)

IV.III. Anaesthesia protocol

The same anaesthetic protocol is employed for both the TTA rapid and the cTTA, and so shall be described as one.

Once admitted patients have an intravenous (IV) catheter placed, and the necessary radiographs are taken. In order to obtain the pre-operative x-rays patients were given midazolam (Midazolam Torrex 5mg/ml at 0.25mg/kg) and propofol (1 or 2%, at 5mg/kg) IV. Once x-rays are obtained and the necessary measurements made (as described above), patients proceed for surgical prep.

At this point, additional agents are needed: fentanyl (Fentanyl-Richter 50mg/ml, 5mg/kg) and ketamine (Calypsol 500mg/10ml, 0.5mh/kg) IV. Propofol is used for induction (1 or 2%, 5mg/kg). Analgesia is given prior to surgery in the form of morphine (Morphium-hydrochloricum Teva 10mg/ml, 0.3mg/kg) intramuscularly (IM), and all patients received IV antibiotics – cefazolin (Cefazolin sandoz 1g for inj, reconstituted with 10mls of saline, 22mg/kg). (Zólyomi et al., 2015)

After premedication and induction, patients were maintained on sevoflurane and oxygen. They all had continuous Ringer or Salsol infusions at 10ml/kg/hr, as well as a fentanyl and ketamine infusion (500ml salsol infusion, to which 12ml of Fentanyl-Richter 50µg/ml for injection and 1.2ml Calypsol 500mg/ml are added) at a rate of 3ml/kg/hr. (Zólyomi et al., 2015)

Meloxicam was given as post-operative pain relief (Melovem 5mg/ml, 0.2mg/kg) subcutaneously (SC). Prophylactic antibiotics were also continued for 24 hours post-op with cephalexin (Solvasol 180mg/ml, 10mg/kg) also SC. (Zólyomi et al., 2015)

IV.IV. Surgical technique

Once anaesthetised and pre-operative radiographs are completed, the leg is prepared for surgery. The hair was removed from the limb, clipping from the hip to the hock. The skin was then cleaned with a chlorhexidine based soap (Bradonett) – repeating three times. Once dried, surgical spirit (Bradoderm skin disinfectant) is then applied five times and allowed to dry once more. Once cleaned the limb is ready for surgery and can be draped.

In both procedures the joint cavity and menisci were examined as the first step of surgery. The degree of damage to the joint structures is assessed, as well as ‘cleaning up’ within the joint. Any remnants of the ruptured CrCL were excised, and in the case of meniscal injury only the damaged parts were removed. Meniscal release was not performed. In the case of the TTA rapid surgeries Dr Diószegi did this via arthroscopy, whilst for the cTTAs' microarthrotomy was performed by Dr Ipolyi. The microarthrotomy facilitates movement of the patella tendon, protecting it from the radial saw blade later in the procedure. Both surgeries make a craniomedial approach with a parapatellar incision extending distally. (Diószegi, 2014; Zólyomi et al., 2015)

The technique for the cTTA was largely as described by M. Petazzoni and Rovesti et al, the only real difference being in the method of fixation.

First of all the tibial crest is prepared and marked according to the pre-operative measurements of the radiographic images. As previously described, the tibial tuberosity is used as a landmark and the recorded distances are marked on the tibia – one distal, and one caudal to the tuberosity. The saw must go through both of these points, and just behind the proximal insertion of the patella tendon.

The osteotomy is made using a biradial saw blade – as was developed by Slocum for the TPLO. Sawing must be done at room temperature to avoid heat necrosis of the tissues. Sterile infusions were applied to the site during osteotomy, reducing friction at the site and cooling the area. This protects tissues and prevents harmful effects of heat build-up which would hinder subsequent bone healing.

Once the osteotomy is complete, the desired degree of rotation determined pre-operatively can be measured (see Figure 18) and marked on the osteotomy line with an osteotome. Bone forceps are then used to grasp and rotate the fragment cranio-proximally. The fragment is temporarily fixed with a Kirschner wire (see Figure 19), before the degree of rotation is confirmed and the fragment permanently fixed. (Zólyomi et al., 2015)

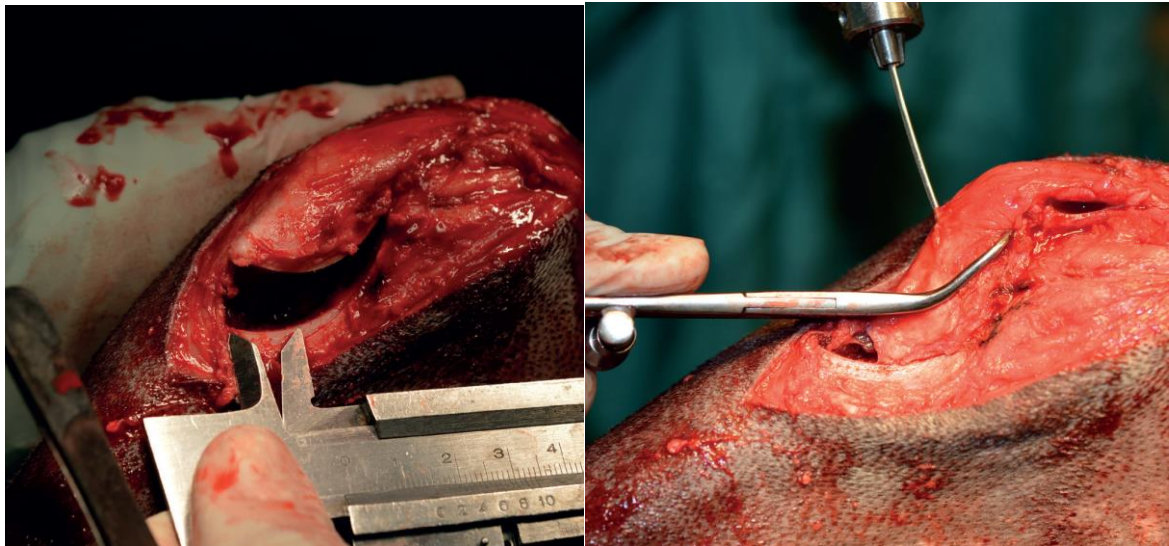


Figure 18 & 19 - once the osteotomy is complete, the correct degree of rotation is measured and marked on the tibia. The fragment is then rotated with bone forceps, and temporarily fixed in place with a K-wire. (Zólyomi et al., 2015)

The appropriate sized implant is then selected. In his original paper Dr Petazzoni described fixing the rotated tibial tuberosity with a Fixin locking plate, whilst for every case in my sample Dr Ipolyi used a String of Pearls (SOP) plate. In either case the plate is placed roughly longitudinally, fixing the separated tibial tuberosity to the tibial diaphysis. A second SOP plate was used for additional stability if the tibia was judged to be too thin following osteotomy, and likely to cause complications. (Petazzoni, 2010)

Once the tuberosity is fixed with a plate, the K-wire was removed (though some cases where no problem was foreseen this was also left in place). The wound was rinsed, the joint capsule and then the wound were closed.

The TTA rapid performed at the Surgery and Ophthalmology Department of the University of Veterinary Medicine, Budapest is done by Dr Diószegi Zoltán, and as described on www.easyfix-TTA.com. Cages are available in 6, 9, 12, and 15mm and are chosen according to the radiographic measurements as previously described. (Diószegi, 2014)

A medial approach is made, with a parapatellar incision. 0.5-1cm distal to the tibial crest a Z-device for drill hole aiming is used to drill at the point previously measured as the tibial cortex width. The drill bit is then used as a fixation point for the saw guide. The tibial tuberosity to osteotomy distance should then be similarly marked and drilled. The osteotomy is then made between the two drill bits and once sufficiently deep, can be completed with the drill bits removed. (Diószegi, 2014)

The osteotomy is opened with a bone bender, until the preselected cage can be inserted. The caudoproximal edge of the cage should be ~3mm distal to the tibial plateau. The cage wings are moulded to the tibia, and 2mm screws are used to fix the implant. As with the cTTA, the wound is rinsed and closed. (Diószegi, 2014)

IV.V. Post-operative evaluation of cTTA surgeries

A total of three post-operative checks were made for each patient – one immediately after surgery, one at suture removal (10-14 days) and finally one at implant removal (3 months). Should owners have any concerns or complaints, then the animal is seen in a consultation and the necessary precautions are taken.

Post-op radiographic images were taken after wound closure to confirm successful correction. If the osteotomy, rotation and implant placement appear ok then the wound was covered with a sterile swab and a modified Robert-Jones bandage for 1-2 days. Immediate adjustments or corrections can be made now if necessary, as was the case in two patients. The radiographs showed both of these to have K-wire protruding caudally from the tibia into soft tissue, which would cause irritation. The wires were readjusted or removed immediately, and so do not show in my sample as post-op complications. (Zólyomi et al., 2015)

Patients were discharged with meloxicam (0.1mg/kg) for two weeks, and Synoquin EFA (Glucosamine hydrochloride 99%, chondroitin sulphate 95%, ascorbic acid, zinc sulphate, dexahan) for at least 2 months, depending upon the condition of the joint. They were given pre-written movement restrictions for one month, and suggested physiotherapy.

Stitches were removed at 10-14 days post-op, whereby the patients were checked again. Any problems with the leg or the wound would be addressed at this stage and further investigations could be made.

The final check was done at 3 months. Control x-rays were taken to monitor bone healing, stability and the correction. Implants were either removed at this stage, or left in place.

V. Results

The details of the first 30 cTTA surgeries performed at the Surgery and Ophthalmology Department of the University of Veterinary Medicine, Budapest are shown in Table 1. The degree of damage to the CrCL is indicated, as is any concurrent damage to the menisci. Any complications encountered are also listed with relevant details.

Any anomaly that delayed or interrupted convalescence, or interfered with the surgical wound is considered a complication. These are not all necessarily associated with the surgical technique. Complications were considered acute if they occurred within the first 14 days post-op, and chronic if over 14 days after surgery.

As with previous studies there is no perfect way to categorise complications, accounting for severity and significance without relying on subjective opinion. I have grouped complications into minor or major based upon the need for revision surgery. (Kemper et al., 2011)

Of the first 30 cTTAs performed, 13 (43.3%) were on the right and 17 (56.6%) on the left leg. These consisted of 6 mixed breed dogs, 5 Italian mastiffs, 4 Staffordshire terriers, 3 Beagles, 2 Central Asian shepherd dogs, 1 French bulldog, 1 American Bulldog, 1 Bernese mountain dog, 1 Boxer, 1 English bulldog, 1 Dobermann, 1 Labrador, 1 Golden retriever, 1 Hungarian Vizsla, and 1 Argentine mastiff.

Through investigation of the joints with microarthrotomy, the CrCL and menisci were inspected. 8 (26.7%) of the cases had partial tears to the CrCL, and the remaining 22 (73.3%) complete tears, of which 15 (50% of total) were older injuries and 7 (23.3%) appeared acute. 14 (46.7%) of the patients had no meniscal damage at the time of surgery. There were 15 (50%) cases with damage to the medial meniscus, of which 7 (23.3%) were considered to have extensive damage. Only 1 (3.3%) case had damage to the lateral meniscus (see Figure 20).

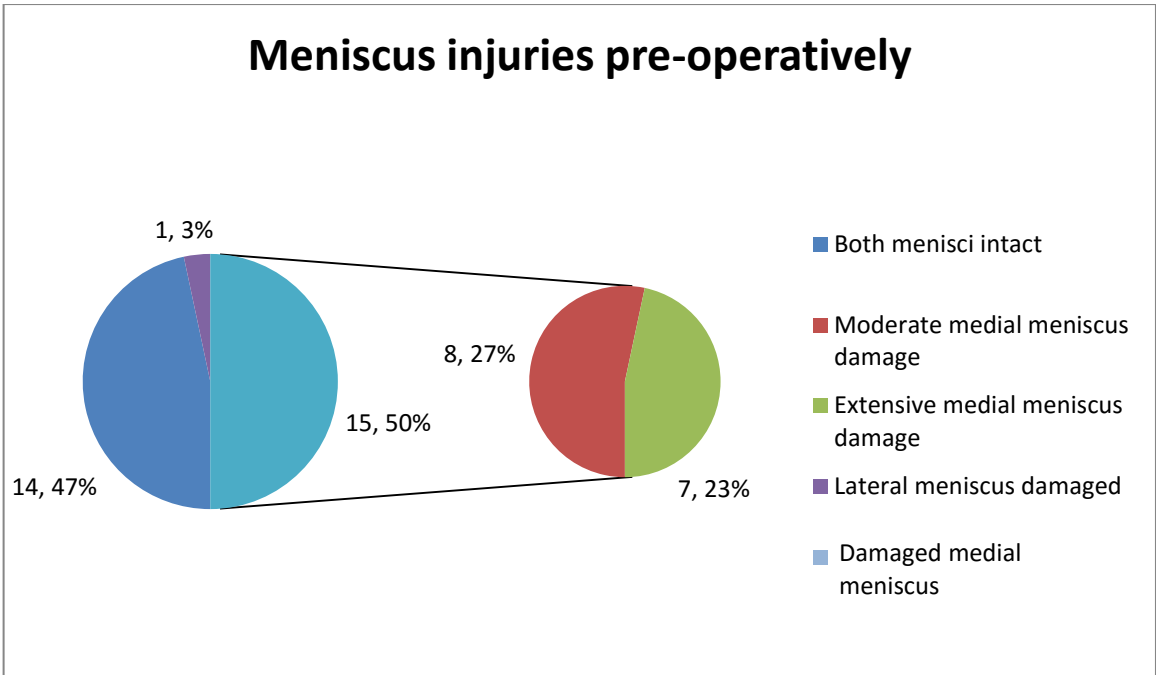


Figure 20 - The ratio of meniscal injuries in the sample

A total of 8 (26.7%) post-operative complications were seen following the 30 surgeries (see Figure 21). One patient had both acute and chronic issues, and so is counted twice. The total complication rate is reduced to 7 (23.3%) without counting these issues separately. The majority of these were minor complications that could be resolved without revision surgery. Only one patient suffered a major complication. The other 23 patients had uncomplicated recovery from the surgery.

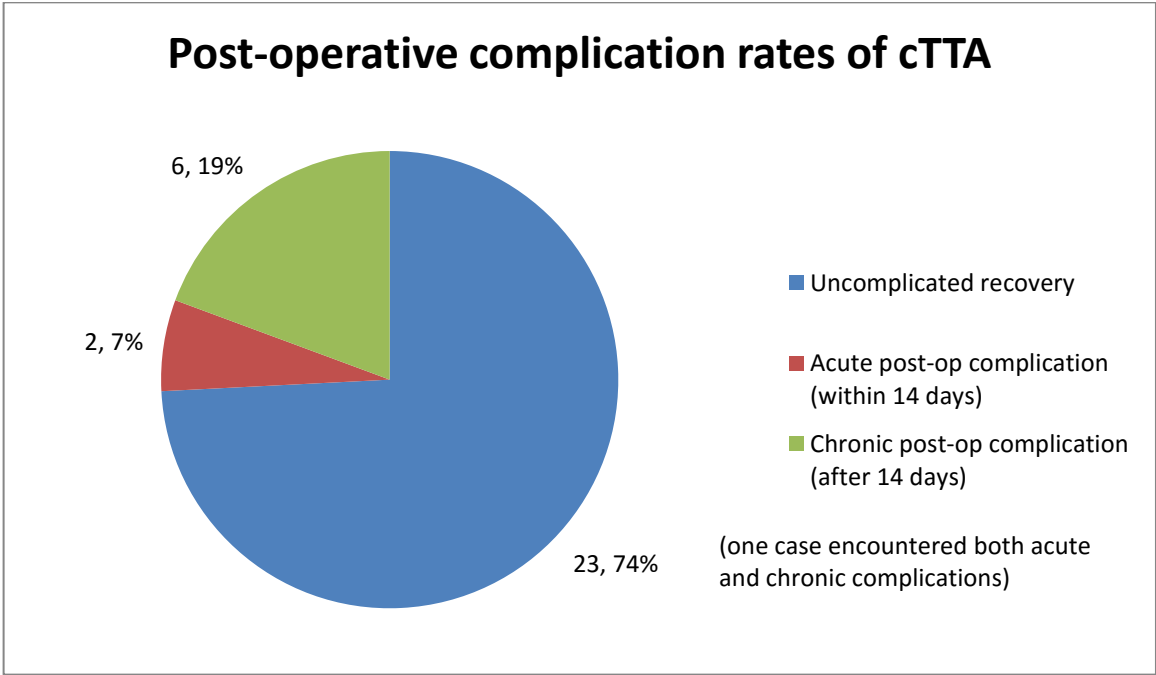


Figure 21 - Post-operative complications in the first 30 cases of cTTA

Only 2 (6.7%) of the patients suffered from acute complications (within 14 days post-op). One animal developed a seroma over the wound, whilst the other dog licked at the wound causing it to become inflamed. Both of these are more likely linked to owner negligence and failure to adhere to post-op instructions, rather than being specific failures of the operative technique.

Chronic complications (over 14 days post-op) were seen in 6 (20%) animals, of which one had also suffered an acute problem.

Four dogs developed lameness post-operatively. One of these was the dog that had licked at its wound causing inflammation. In this case, after three months a control x-ray was taken and the implant removed. On the x-ray a callused and healing tibial shaft fracture could be observed. The other three lame animals showed no signs on physical examination, and so were suggested physiotherapy. Their lameness was resolved following the removal of the implants. (Zólyomi et al., 2015)

One case started limping and developed a fistula over the surgical site, roughly one month post-operatively. Microbiology cultured *Staphylococcus pseudointermedius* which was resistant to Clindamycin, Clarithromycin and Gentamycin, but was found to be sensitive to all other antibiotics. It was therefore treated with Amoxicillin clavulanic acid (Noroclav – 12.5mg/kg twice daily). (Zólyomi et al., 2015)

The one major complication that was encountered was in a dog that developed patella luxation post-operatively. This has been classed as a major complication, as it would usually be an indication for surgery. In this case however, the patient is undergoing physiotherapy and will only have surgery should there be any further problems.

As with linear TTAs, there can be a medial or lateral displacement of the patella tendons insertion upon advancement – depending on the angle of the osteotomy relative to the transverse plane. cTTA may have the added risk of medio-lateral displacement of the fragment, compared to TTA rapid where the tibial crest is still attached distally. The effect of this angulation on the outcome of cTTA was explored by Rovesti et al.

VI. Discussion

cTTA, first described by Petazzoni in 2010 is a relatively new procedure with few scientific publications and little research done into it. It does however have the potential to improve the efficacy of surgical treatment of CrCL rupture - a leading cause of lameness in dogs.

Compared to other current osteotomies, cTTA has several potential advantages. The large area of bone-bone contact should promote good recovery compared to the cavity left with linear TTA, whilst being less invasive than TPLO and leaving the weight bearing tibial shaft intact. Furthermore the osteotomy can be fixed with non-specific implants that are more readily available, and which are easily removed should the need arise.

Of course there are disadvantages to the technique as well – accurate pre-operative planning is essential, but measuring methods are still more uncertain, with subjective methods often giving different results. The surgery is also not universally applicable – patients with narrow tibiae, or underdeveloped tibial tuberosities may be unsuitable. And whilst non-specific implants can be used, the radial saw blade is more specialist. This can also be used for TPLO, but is said to be inefficient and hard to sharpen, leading to excessive heat building up. The procedure is also like linear TTA or TPLO, in that cTTA is technically difficult and invasive surgery that requires a level of competence and experience. (Zólyomi et al., 2015; VeterinaryInstrumentation, 2016)

Whilst a fairly small sample, these surgeries have shown that cTTA can be performed in practice, with good clinical results and may be suitable for wider use. That said, equipment such as the radial saw blade required is less commonly used and surgeons not as familiar with TPLO may find the technique more demanding due to this.

From the first 30 cases, post-operative complications were seen in 7 patients (23.3%), with just 1 having a major complication that may require further surgery (3.3%). More of the complications were seen in the earlier surgeries, with a lower rate seen in the second half of the sample. This could suggest that the initial complications were due to the learning curve associated with a new procedure, however with a small sample size it is difficult to comment on the significance of this trend.

The majority of the complications encountered were considered minor, and all were resolved following pain relief and physiotherapy, or removal of the implant. The only major complication was patella luxation post-operatively. This could be a technical error,

due to the angulation of the osteotomy in the frontal plane, or could be due to the animals conformation combined with the tuberosity advancement. Either way the problem could be avoided in the future with additional planning regarding the osteotomy angle, and the tibial conformation.

Overall we can say that although cTTA is a new procedure with little scientific research or clinical experience, it is applicable in practice. Whilst further research is needed in the area, and in standardizing the procedure, early clinical results show a promising complication rate compared to other surgeries for CrCL rupture. Less subjective information could offer further information on the validity of the surgery when compared to other techniques. Objective evaluation with force plate analysis and kinematics to show ground reaction forces post-op would give direct, quantifiable comparisons.

VII. Summary

Injury to the Cranial Cruciate Ligament of the stifle is one of the leading causes of lameness in dogs. It is best treated surgically, and so one of the main indications for orthopaedic surgery. Many surgical techniques have been proposed, none of which have proven better efficacy than the others.

This study looks at a relatively new technique - the circular Tibial Tuberosity Advancement (cTTA), as presented by Massimo Petazzoni in 2010. The cTTA combines principles of two common procedures - the Tibial Plateau Leveling Osteotomy (TPLO) and the Tibial Tuberosity Advancement (TTA). The resultant surgery has several proposed advantages, such as being less invasive than TPLO whilst maintaining bone to bone contact at the osteotomy, unlike TTA. This promotes faster healing and allows easier removal of the implant, should the need arise.

cTTa is a relatively new procedure, with few scientific reports currently available on it. Clinical reports are also short in number, and the technique has yet to be standardized for widespread use. To see if the technique may be suitable for further studies and development, I have reviewed the technique alongside TTA and then looked at the complications encountered in the first 30 cases treated with cTTA.

The surgical procedure was found to be technically comparable to TTA, though the preoperative planning is slightly less defined. There is still some uncertainty regarding the best means of measuring the required correction, and the process is yet to be clarified.

Of the 30 surgeries, 8 cases suffered complications. Of these only was considered major, based upon the possible need for remedial surgery. Whilst a relatively small sample, this complication rate appears favourable when compared with the other techniques. It is also slightly subjective, based on clinical opinion. Further investigation into post-operative ground reaction forces could offer more information regarding recovery compared to the other techniques.

In summary, whilst the technique is new and we have few reports of it, our clinical results were good. It is a promising technique, and warrants further studies on a larger scale. With more research and exposure, the technique could become more widespread in general practice, offering a new and potentially better treatment for CrCL injury in dogs.

Table 1 - Results and post-operative complications from cTTA surgeries

ID number	Breed	Side	Meniscus	Ligament	Post-op complications		Significance
					Acute	Chronic	
230778	Staffordshire terrier	Right	intact	partially torn	No	no	
221037	Staffordshire terrier	Left	intact	older complete	No	No	
215940	Staffordshire terrier	Left	med. men	older complete	No	lameness, physio	minor
234580	Beagle	Right	Extensive, medial	older complete	No	No	
235160	Mixed	Left	intact	partially torn	licking wounds, fractures post pn	lameness, physio	minor
224055	French bulldog	Right	Extensive, medial	older complete	No	lameness, physio	minor
235449	Central Asian shepherd dog	Right	Intact	older complete	No	No	
235445	Mixed	Left		complete	seroma	No	minor
235709	Beagle	Left	medial meniscus	older complete	No	No	
235560	Mixed	Left	Intact	older complete	No	No	
236054	Cane Corso	Left	extensive medial meniscus	older complete	No	No	
236117	Mixed	Left	Intact	older complete	No	No	
236674	Cane Corso	Left	Intact	partially torn	No	2 months after discharge	minor
237651	Cane Corso	Right	medial meniscus	older complete	No	no	
237994	American bulldog	Right	extensive medial	partially torn	No	No	
238184	Bernese mountain dog	Right	extensive medial	older complete	No	No	
238761	Beagle	Right	medial meniscus	older complete	No	No	
239672	Central Asian shepherd dog	Right	lateral meniscus	complete	No	No	
239615	Boxer	Left	Intact	complete	No	No	
236117	Mixed	Right	medial meniscus	complete	No	No	
240379	English bulldog	Left	medial meniscus	partially torn	No	No	
241259	Dobermann	Right	medial meniscus	older complete	No	lameness, physio	minor
236674	Cane Corso	Right	Intact	partially torn	No	No	
237651	Cane Corso	Left	Intact	partially	No	No	

				torn			
243631	Mixed	Left	Intact	complete	No	No	
243288	Labrador	Left	extensive medial	older complete	No	No	
244051	Golden Retriever	Left	Intact	older complete	No	No	
211344	Hungarian Vizsla	Left	medial meniscus	partially torn	No	No	
223891	Argentine mastiff	Left	extensive medial	complete	No	No	
245073	Staffordshir e terrier	Right	Intact	complete	No	patella luxation	major

List of References

- Anon., 2011. *Basic Biomechanics: moment arm & torque*. [Online] Available at: <http://www.aaronswansonpt.com/basic-biomechanics-moment-arm-torque/> [Accessed 2016].
- Arthrex, n.d. *Arthrex Products and Techniques*. [Online] Available at: http://www.arthrexvetsystems.com/en/products/techniques/upload/VLT1-0004-EN_G-TightRope-CCL.pdf [Accessed 2016].
- Bergh, S. et al., 2014. Systematic Review of Surgical Treatments for Cranial Cruciate Ligament disease in dogs. *American Animal Hospital Association*, pp.315-21.
- Boudrieau, R., 2007. [Online] Available at: http://www.kyon.ch/wp-content/uploads/2009/10/SYMP_2007_TTA_Boudrieau_TPS-vs-Common-Tangent.pdf [Accessed 2016].
- Boudrieau, R., 2009. Tibial Plateau Leveling Osteotomy or Tibial Tuberosity Advancement? *Veterinary Surgery*, pp.1-22.
- Brinker, Piermattei & Flo, 2006. In *Handbook of Small Animal orthopaedics and fracture repair*. 4th ed. Saunders Elsevier. pp.582-605.
- Conzemius, M., 2010. Pathogenesis of cranial cruciate ligament disease in the dog - genetics and anatomy. In *WVOC*. Bologna, 2010.
- de Rooster, H., 2001. *Ghent University Academic Bibliography*. [Online] Available at: <https://biblio.ugent.be/publication/522123> [Accessed 2016].
- Denny, H.R. & Butterworth, S.J., 2000. In *A guide to canine and feline orthopaedic surgery*. 4th ed. Blackwell publishing. pp.11-16, 532-545.
- Diószegi, Z., 2014. *EasyFix TTA system: Preoperative Planning and Execution*. [Online] Available at: <http://easyfix-tta.com/easyfix-tta-system> [Accessed 28 October 2016].
- Durand, Newell & Wright, 2014. *Canine Stifle Stabilisation System for cTTA*. [Online] Available at: https://www.wpi.edu/Pubs/E-project/Available/E-project-043014-205227/unrestricted/MQP1407_Durand_Newell_Wright.pdf [Accessed 2016].
- Fossum & Welch, T., 2007. Diseases of the joints. In *Small Animal Surgery*. 3rd ed. Mosby Elsevier. pp.2068-103.

Kemper, M., Koch, D., Bass, M. & Inauen, R., 2011. *Major complication rate after 214 tibial tuberosity advancements as a therapy for cranial cruciate ligament rupture*. Diessenhofen/Switzerland: Koch&Bass GmbH, Small Animal Referral Clinic.

Konig & Liebich, 2009. *Veterinary Anatomy of Domestic Mammals 4th edition*. Stuttgart: Schattauer. pp.238-243, 256-264.

Kowaleski, M.P., n.d. *Diagnose and treat early and partial Cranial Cruciate Ligament rupture*.

Kyon, n.d. *TTA principles*. [Online] Available at: <http://www.kyon.ch/current-products/tibial-tuberosity-advancement-tta/tta-principles> [Accessed 2016].

Lafaver, S. et al., 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*, pp.36:573-586.

Ltd, O., n.d. *MMP canine cruciate repair system - resources*. [Online] Available at: <https://www.orthomed.co.uk/resources/mmp/> [Accessed 14 April 2015].

Mattila, J., 2012. [Online] Available at: <https://helda.helsinki.fi/bitstream/handle/10138/33595/lisensiaatin%20tutkielma%20Jan%20Mattila.pdf?> [Accessed 2016].

Muir, P., 2010. Clinical features. In *Advances in the Canine Cranial Cruciate Ligament*. Wiley-Blackwell. pp.95-97, 101-106,.

Muir, P., 2010. Etiopathogenesis of Cruciate Ligament Rupture. In Wiley-Blackwell, ed. *Advances in the Canine Cranial Cruciate Ligament*. pp.43, 53, 59-60, 77-78.

Muir, P., 2010. Structure and function. In *Advances in the Canine Cranial Cruciate Ligament*. Wiley-Blackwell. pp.5-6, 10-11, 13-19, 29-31,37-41.

Muir, P., 2010. Surgival Treatment. In *Advances in the Canine Cranial Cruciate Ligament*. Wiley-Blackwell. pp.143, 163-167, 169-174, 177-186, 189-193.

Nickel, Schummer & Seiferle, 1984. *The Anatomy of Domestic Animals Volume 1*, 5th edition. Berlin and Hamburg: Parey. pp.204-208, 402-405.

Palmer, R., 2005. *Understanding tibial plateau leveling osteotomies in dogs*. [Online] Available at: <http://veterinarymedicine.dvm360.com/understanding-tibial-plateau-leveling-osteotomies-dogs> [Accessed 2016].

Petazzoni, M., 2010. cTTA: circular Tibial Tuberosity Advancement. *Proceedings of the World Veterinary congress*, pp.295-96.

Rovesti, G. et al., 2013. Effects of Rotation and Osteotomy Angulation on Patellar Tendon Insertion Position during circular Tibial Tuberosity osteotomy. *Veterinary Surgery*, Issue 1 Volume 42. pp.51-59.

Slocum, B. & Devine, T., 1983. Cranial Tibial Thrust: a primary force in the canine stifle. *Journal of the American Veterinary Medical Association*, 183, pp.456-59.

Slocum, B. & Slocum, T., 1993. Tibial Plateau Leveling Osteotomy for repair of cranial cruciate rupture in the canine. *The Veterinary Clinics of North America. Small Animal Practice.*, 23, pp.777-95.

Tepic, S., Montavon, P. & Damur, D., 2002. Biomechanics of the stifle joint. In *Proceedings of the first world Orthopaedic Veterinary Congress*. Munich, 2002.

Tuan, J. & Farrell, M., 2015. Tibial tuberosity advancement: What have we learned so far? *Companion Animal*, February. pp.92-104.

VeterinaryInstrumentation, 2016. www.veterinary-instrumentation.co.uk. [Online] Available at: <http://www.veterinary-instrumentation.co.uk/skin1/admin/UserFiles/chapter%205.pdf> [Accessed 14 November 2016].

VeterinaryInstrumentation, n.d. *Tibial Plateau Leveling Osteotomy by Radial Cut*. [Online] Available at: <http://www.vetinst.com/skin1/admin/UserFiles/File/JS%20PDF/TPLORADIAL%20STEP%20BY%20STEP.pdf> [Accessed 2016].

Zólyomi, D. et al., 2015. cTTA: Egy új módszer kutyák elülső keresztesdőlőszalagszakadásának gyógykezelésére 1. rész: preoperatív tervezés, 2. rész: műtéti technika. *MAGYAR ÁLLATORVOSOK LAPJA*, pp.463-473, 595-602.

Appendix 6. Electronic License Agreement and Copyright Declaration

HuVetA - SZIA
ELECTRONIC LICENSE AGREEMENT AND COPYRIGHT DECLARATION*

Name: JACOB HINDS
Contact information (e-mail): jake - 30@hotmail.co.uk
Title of document (to be uploaded): CTTA - A new method for
creating cranial cruciate ligament rupture in dogs:
early results.
Publication data of document: 2016
Number of files submitted: 1

By accepting the present agreement the author or copyright owner grants non-exclusive license to HuVetA and SZIA over the above mentioned document (including its abstract) to be converted to copy protected PDF format without changing its content, in order to archive, reproduce, and make accessible under the conditions specified below.

The author agrees that HuVetA and SZIA may store more than one copy (accessible only to HuVetA and SZIA administrators) of the licensed document exclusively for purposes of secure storage and backup, if necessary.

You state that the submission is your original work, and that you have the right to grant the rights contained in this license. You also state that your submission does not, to the best of your knowledge, infringe upon anyone's copyright. If the document has parts which you are not the copyright owner of, you have to indicate that you have obtained unrestricted permission from the copyright owner to grant the rights required by this Agreement, and that any such third-party owned material is clearly identified and acknowledged within the text of the licensed document.

The copyright owner defines the scope of access to the document stored in HuVetA/SZIA as follows (mark the appropriate box with an X):

- I grant unlimited online access,
 I grant access only through the intranet (IP range) of the Szent István University,
 I grant access only on one dedicated computer at the Veterinary Science Library,
 I grant unlimited online access only to the bibliographic data and abstract of the document.

* The present declaration is based on Ordinance no. 5/2011 of the Rector concerning the scholarly database of institution (i.e. Szent Istvan University) affiliated publications.

Please, define the **in-house accessibility of the document** by marking the below box with an **X**:



I grant in-house access (namely, reading the hard copy version of the document) at the Library.

If the preparation of the document to be uploaded was supported or sponsored by a firm or an organization, you also declare that you are entitled to sign the present Agreement concerning the document.

The operators of HuVetA/SZIA do not assume any legal liability or responsibility towards the author/copyright holder/organizations in case somebody uses the material legally uploaded to HuVetA/SZIA in a way that is unlawful.

Date: Budapest, ...24...day ...11...month...2016...year

S. Hinder

Author/copyright owner
signature

HuVetA Magyar Állatorvos-tudományi Archívum – Hungarian Veterinary Archive is an online veterinary repository operated by the Veterinary Science Library, Archives and Museum. It is an electronic knowledge base which aims to collect, organize, store documents regarding Hungarian veterinary science and history, and make them searchable and accessible in line with current legal requirements and regulations.

HuVetA relies on the latest technology in order to provide easy searchability (by search engines, as well) and access to the full text document, whenever possible.

Based on the above, HuVetA aims to:

- *increase awareness of Hungarian veterinary science not only in Hungary, but also internationally;*
- *increase citation numbers of publications authored by Hungarian veterinarians, thus improve the impact factor of Hungarian veterinary journals;*
- *present the knowledge base of the Faculty of Veterinary Science, Szent István University and its partners in a focussed way in order to improve the prestige of the Hungarian veterinary profession, and the competitiveness of the organizations in question;*
- *facilitate professional relations and collaboration;*
- *support open access.*

SZIA Szent István Archive is the online repository of scholarly publications affiliated with the Szent István University.