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Long term follow-up of TPLO surgery

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Abstract

The aim of this thesis was to examine the long-term results of tibial plateau leveling osteotomy (TPLO) in dogs operated at the Small Animal Clinic of the University of Veterinary Medicine in Budapest. This was accomplished by sending questionnaires via email to the owners of dogs with cranial cruciate ligament rupture who were operated on with this procedure from 2017 to 2020, as well as collecting their clinical data from the clinic's database.

Two questionnaires, the "Canine Brief Pain Inventory" and "Canine Orthopaedic Index", were sent to eighteen owners, six of whom filled them out and returned them for statistical analysis. The results showed that most owners consider the surgery to have been successful with normal (33.3%) or near-normal (50%) stifle function, and minimal (33.3%) or no pain (50%). Only a minority (16.7%) of the owners reported a suboptimal joint function, with associated pain and interference with the dog's general activity.

In conclusion, the majority of dogs who underwent TPLO at the University of Veterinary Medicine in Budapest have a satisfactory outcome over 3 years after surgery.

Absztrakt

A szakdolgozat célja az Állatorvostudományi Egyetem Kisállat Klinikáján végzett tibia plateau leveling osteotomy (TPLO) műtéti technika hosszú távú eredményeinek vizsgálata. A tanulmány kérdőíves felméréssel készült, amelyeket emailen keresztül küldtünk el a 2017 és 2020 között elülső kereszteződő szalag szakaddással diagnosztizált és TPLO műtéten átesett kutyák tulajdonosainak. A betegek adatait klinika adatbázisából gyűjtöttük ki.

Két fajta kérdőívet használtunk: "Canine Brief Pain Inventory" és "Canine Orthopaedic Index". Mindkét kérdőívet 18 tulajdonosnak küldtük el, amelyből 6 érkezett vissza, az eredményeket statisztikai elemzésnek vetettük alá. A kérdőívek alapján a legtöbb tulajdonos sikeresnek ítélte meg a műtétet normális (33,3 %) vagy majdnem normális (50 %) térdízületi funkcióval, illetve minimálisan fájdalmas (33,3 %) vagy fájdalommentes operált végtaggal. Kevés tulajdonos (16,7 %) ítélte meg az ízületi funkciót suboptimálisnak, amely fájdalomban és kisebb általános aktivitásban nyilvánul meg.

Összességében elmondható, hogy a betegek többségének, akik TPLO műtéten estek át az Állatorvstduományi Egyetemen, 3-5 év után is kielégítő a műtét utáni állapota a tulajdonosok véleménye alapján.

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1. Abbreviations

CaCL = Caudal Cruciate Ligament

CCL = Cranial Cruciate Ligament

CCLR = Cranial Cruciate Ligament Rupture

CTT = Cranial Tibial Thrust

cTTA = circular Tibial Tuberosity Advancement

ECR = Extracapsular Repair

MRI = Magnetic Resonance Imaging

PTA = Patellar Tendon Angle

TPA = Tibial Plateau Angle

TPLO = Tibial Plateau Leveling Osteotomy

TTA = Tibial Tuberosity Advancement

TWO = Tibial Wedge Osteotomy

2. Introduction

The stifle is a complex joint with several stabilising structures, such as ligaments, that are put under stress during weight-bearing and movement of the limb. The cranial cruciate ligament (CCL) is more prone to injury since it is one of the ligaments that provide the most support to the stifle, especially against the cranial tibial thrust (CTT) and internal rotation of the tibia. [1] The CCL can rupture from several factors in dogs, such as chronic degenerative disease, excessive trauma, abnormal stifle anatomy, or a combination of these. Since the steepness of the tibial slope affects the strength of the CTT, this will also influence the force the ligament has to resist, and if this force exceeds the strength of the CCL, it will rupture. [2] The loss of the CCL will then increase the CTT since it is no longer inhibited by the ligament, which will increase the instability of the joint, and therefore lead to progression of secondary osteoarthritis and pain. [3]

Due to the relatively high occurrence of cranial cruciate ligament rupture (CCLR), several surgical techniques have been proposed to stabilise the stifle and limit the occurrence of consequences such as pain, osteoarthritis, and loss of joint function. One of these techniques is the tibial plateau leveling osteotomy (TPLO), developed by Slocum and Slocum in 1993 to decrease the CTT by decreasing the tibial plateau angle (TPA). To this day, TPLO remains a popular choice among surgeons to treat patients with CCLR due to its favourable outcome. [2] Patients treated with TPLO return to normal or near-normal joint function within a relatively short amount of time compared to other surgical techniques, such as the tibial tuberosity advancement (TTA). [4] The creator of the procedure found that over 90% of the patients regained normal function of the joint, and could even perform well in demanding activities such as hunting and competitive sports. [2]

There is always some concern about the long-term efficacy of the procedure due to the alteration of the joint anatomy and mechanism, leading to the inevitable progression of osteoarthritis. Studies have found that the majority of patients maintain the postoperative success of TPLO long-term, which is what will be examined in dogs who have undergone TPLO at the University of Veterinary Medicine in Budapest in this thesis. [5, 6]

3. Literature Review

3.1. Anatomy of the Stifle Joint

The stifle is a complex joint divided into the femorotibial and femoropatellar joints. The femorotibial joint is incongruent, meaning that the rounded femoral condyles and the flattened tibial condyles are incompatible with each other, but this incongruency is corrected by two fibrocartilaginous menisci located between the two surfaces on both the lateral and medial side. [1, 7] Both of the menisci are attached to the tibia by meniscal ligaments extending from the cranial and caudal angles of the menisci, but the lateral meniscus has added security from a meniscofemoral ligament going from the caudal part of the meniscus to the medial femoral condyle. [7]

Because of the heavy load and large range of motion of the stifle, the joint is stabilised by strong ligaments, muscles, tendons, as well as fascia. The ligaments that provide the most stabilisation are the medial and lateral collaterals, and the cranial and caudal cruciates. [1, 2] The cranial and caudal cruciate ligaments are situated inside the joint cavity, and they run distally towards the tibia in a diagonal direction from the lateral and medial femoral condyles, respectively. [7]

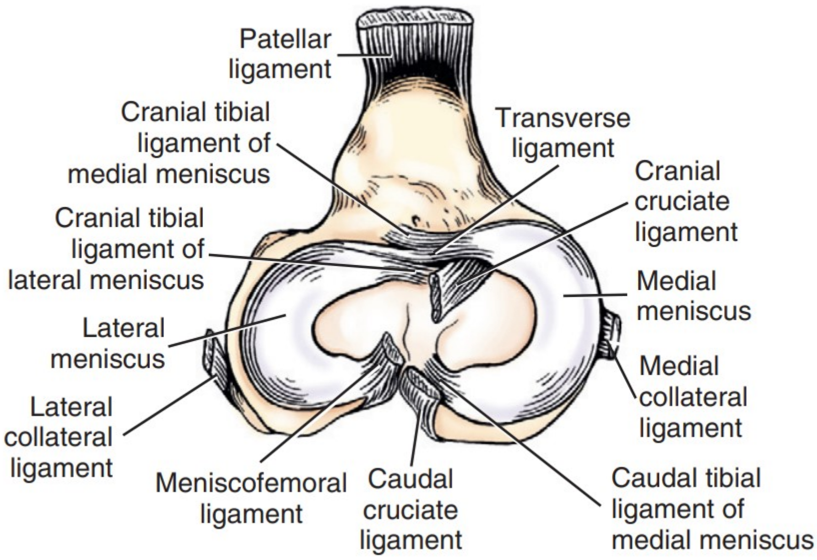

Figure 1 - Illustration of the ligaments and menisci of the stifle joint. (From: Evans HE, de Lahunta A (2013) Miller's Anatomy of the Dog, 4th ed. Elsevier, St. Louis, MO)

The stifle joint motion is primarily extension and flexion, but there is also some internal rotation of the tibia when the lateral collateral ligament loosens during stifle flexion, and external rotation when the ligament tightens again during extension. [7] In addition to these, there is also a cranial shift of the tibia in relation to the femur during weight bearing of the limb. This forward motion of the tibia occurs when the condyles of the femur are compressed to the slope of the tibial plateau, which redirects the downward compression into a cranial shear force known as the cranial tibial thrust. [2, 8] In a healthy stifle, the CTT is limited by the CCL in cooperation with the contraction of the stifle flexor muscles from the thigh, which pull the tibia caudally. [1, 8] When the limb is loaded, the force of compression of the tibia on the femur, and therefore also the degree of CTT, is a combination of the ground reaction forces, stifle extensor muscle contraction, and tibial plateau slope. If these forces exceed the strength of the CCL, the ligament will rupture. [2]

3.2. Cranial Cruciate Ligament Rupture

Cranial cruciate ligament rupture is the most common cause of hind limb lameness in dogs. [9, 10] It can occur as a consequence of trauma, but it is most commonly caused by a progressive and chronic degeneration of the cranial cruciate ligament. [9] There is also a correlation between degenerative- and acute CCLR because the progressive nature of CCL disease weakens the ligament, making it more susceptible to damage by sudden trauma, or even the accumulative stress from repetitive activity. Acute CCLR is mostly associated with a sudden and strong hyperextension and rotation of the tibiofemoral joint, for example by the dog getting its foot stuck in a hole or fence or by jumping with a force strong enough to exceed the breaking point of the CCL. [1]

The stifle is stabilized by several anatomical structures, including the cruciate ligaments located in the intercondylar fossa of the femorotibial joint. In a normal stifle, the cranial and caudal cruciate ligaments inhibit the tibia from sliding cranially and caudally on the femur. [7] The CCL prevents the cranial translation of the tibia that occurs during loading of the limb, especially the craniomedial band off the ligament. This band is taut during both flexion and extension of the stifle, while the caudolateral band is only taut during extension. [1, 9] This means that if only the craniomedial band is torn, the tibia will be able to shift further cranially than normal during flexion of the stifle joint, but can remain in place during extension. This is known as a partial rupture.

Partial cranial cruciate ligament rupture generally precedes complete CCL rupture. [9] This is due to the degenerative nature of CCL disease and the increased stress on the remaining intact bundles of the ligament. The partial rupture starts as minimal instability of the joint, but progresses over time, worsening both the rupture itself as well as the presentation of clinical signs. [1] Degenerative changes and chronic inflammation can occur before any noticeable joint instability or appearance of clinical signs, making the diagnosis of partial CCL ruptures difficult. [1, 11] At the beginning of clinical manifestation of the disease, the dog may show only mild weight-bearing lameness after exercise, which resolves itself after rest. As the degeneration of the CCL continues, the lameness becomes more pronounced and no longer disappears after rest, osteoarthritic changes progress, and the meniscus in the stifle becomes increasingly at risk of injury. [1]

3.2.1. Aetiology

The exact aetiology of CCLR is still not fully understood, but there are several risk factors such as genetic potential, breed, sex, body weight, and conformational abnormalities such as the tibial plateau angle. Large breed dogs, such as Newfoundland, Rottweiler, and Labrador Retriever are predisposed to develop CCLR than smaller breed dogs, but among small dogs CCLR can also occur, especially in case of obesity. [10, 12] There are more female dogs reported with CCLR than male dogs, and gonadectomy further increases the risk of disease. [12] TPA is the angle between the slope of the medial tibial condyle and a line drawn perpendicularly from the tibial axis when imaged on a lateral radiograph. [13, 14] The degree of the TPA affects the strength of the CTT during weight bearing, and therefore also has an effect on the stress placed on the CCL. [15]

Since the degenerative type of CCLR, which is the most common, is a chronic process, it needs time before it leads to a rupture of the CCL. This can explain why the average age of rupture is 7 years. The rupture being predominantly a degenerative disease also explains why approximately 30% of patients later develop CCLR in the contralateral limb. [16]

3.2.2. Clinical signs

The predominant clinical sign of CCLR is lameness of the affected limb. In case of acute rupture, the patient is typically partially- or non-weight-bearing, but the lameness can temporarily decrease after 3-6 weeks even without treatment, unless there is a meniscal injury. [17] Patients with chronic injury have a lower severity of lameness than those with acute injury, but they may have started out with an acute non-weight-bearing lameness. [1, 3] The owner may not report any visible lameness, but rather a decrease in the activity level of their dog. A dog that is usually active and playful may become calmer and prefer to lay down rather than run around. [2] Another sign that may be reported by the owners of dogs with CCLR are difficulties rising up and sitting down, and when sitting the dog may hold the affected limb in an extended position and to the side. [1, 17]

Since the majority of CCLR cases are due to a degenerative disease, the lameness gets progressively worse over time, and it often temporarily resolves itself with rest. As the CCL continues to degenerate and tear, the stifle joint instability increases, and the lameness gets more apparent and persist despite resting. [1, 3] Dogs with degenerative CCLR frequently develop lameness in the contralateral leg after some time, as that CCL also deteriorates and eventually ruptures as well. In certain cases, the patient may present with bilateral CCLR and lameness, which can be mistaken for a neurological illness instead of an orthopaedic issue. [1, 18]

3.2.3. Diagnosis

Upon clinical examination of the patient, elicitation of pain when manipulating the stifle joint is indicative that this is the source of the lameness. Dogs with CCLR are often nervous of palpation and manipulation of the affected limb, especially hyperextension of the stifle since this is very painful even with partial CCLR. [3] This apprehension can make it difficult to feel the instability of the joint when palpating due to muscle tension and the patient's reluctance to be handled. [1, 2] Because of this, sedation is often needed to thoroughly examine the leg, and it also makes diagnostic imaging easier to perform.

If the dog has had a chronic CCLR, the muscles of the affected limb will over time atrophy, which can be palpated on clinical examination. In chronic cases, there are also osteoarthritic changes, which can be felt as crepitation when flexing and extending the joint. It can also lead to the formation of a medial buttress, an enlarged medial joint surface caused by osteophyte formation, which can be felt during palpation. [1, 17]

Cranial drawer test is diagnostic of CCLR. A positive test confirms the diagnosis, but a negative test result cannot rule out the disease. [1] Tensing the surrounding musculature can stabilise the stifle, leading to a false negative cranial drawer test. Because of this, the test should be performed under anaesthesia or sedation to eliminate the influence of muscle tone. [1, 19] The patient is placed in lateral recumbency during the test with the examiner standing behind the patient. One hand is wrapped around the femur with the thumb behind the lateral fabellae and the index finger over the patella. The other hand moves the tibia cranially in the plane of the tibial plateau with the thumb placed behind the fibular head, index finger on the tibial crest, and the remaining fingers wrapped around the tibial shaft. [1, 3] A CTT larger than 2 millimetres indicates a positive test, but a partial CCLR might not exceed this because some of the ligament is still holding the tibia in place. [1] This is why a negative cranial drawer test cannot rule out CCLR. A partial rupture may also only reveal a positive cranial drawer test in flexed position because the caudolateral band remains taut in extended stifles, preventing the cranial shift of the tibia. [1] In young dogs, a CTT of 1 to 3 mm can occur without the presence of CCLR, so it is important to always evaluate both hindlegs and compare the findings to determine if the extent of the cranial motion is pathological or not. [17]

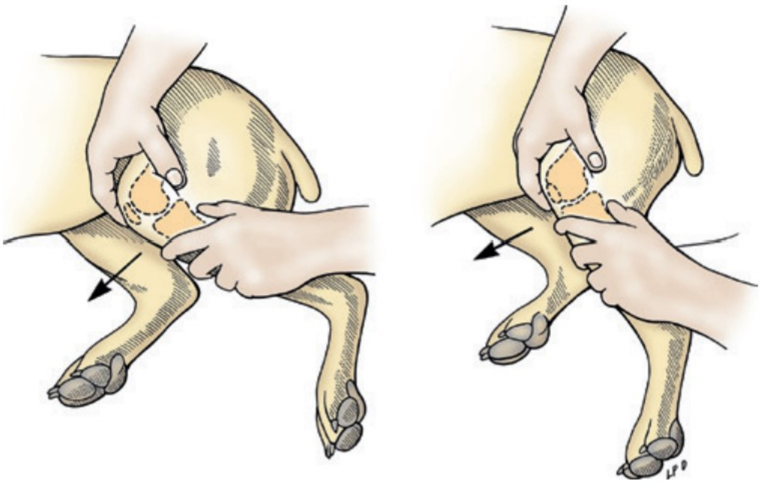

Figure 2 - Illustration of the Cranial Drawer Test for diagnosis of CCLR. (From: Fossum TW, Cho J, Dewey CW, Hayashi K, Huntingford JL, MacPhail CM, Quandt JE, Radlinsky MG, Schulz KS, Willard MD, Yu-Speight A (2019) Small Animal Surgery, 5th ed. Elsevier, Philadelphia, PA)

Tibial compression test is another diagnostic method for CCLR. It can be performed in either standing position or lateral recumbency with the examiner behind the patient. [1] The first hand is placed around the femur, similar to the cranial drawer test, but in this case the index finger extends over the patella to the tibial crest. The other hand holds the metatarsus of the leg and flexes the tarsus, causing the tibia to shift cranially, which can be felt in the index finger of the hand stabilising the femur. [1, 3, 17]

In partial- or early-stage degenerative CCLR, joint instability can be difficult to detect because some of the ligament remains intact. [9] If the caudolateral band is torn, but the craniomedial band remains intact, there is no detectable instability of the joint because the craniomedial band is taut in both flexion and extension of the joint and thus prevents craniocaudal shift of the tibia in both positions. If the craniomedial band is ruptured, there can be some cranial movement of the tibia during flexion of the stifle. This is because the caudolateral band is the remaining part of the CCL holding the tibia in place, but it is loose when the stifle is flexed. [1] This is why diagnostic testing of CCLR should always be performed in varying degrees of stifle extension and flexion to better evaluate the patient.

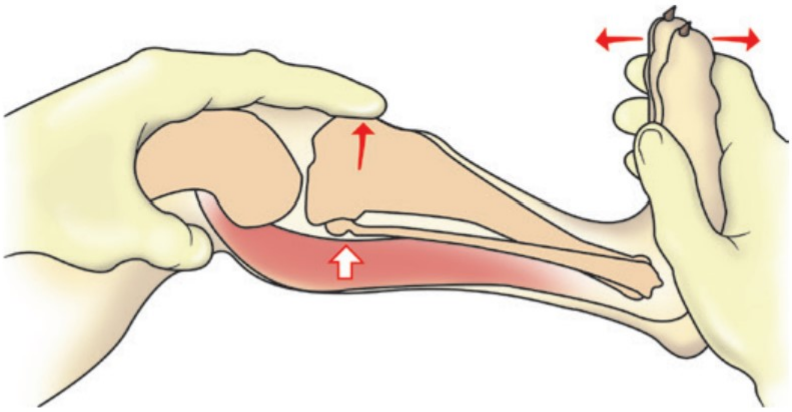

Figure 3 - Illustration of the Tibial Compression test for diagnosis of CCLR. (From: Fossum TW, Cho J, Dewey CW, Hayashi K, Huntingford JL, MacPhail CM, Quandt JE, Radlinsky MG, Schulz KS, Willard MD, Yu-Speight A (2019) Small Animal Surgery, 5th ed. Elsevier, Philadelphia, PA)

An important tool in the diagnostic workup of CCLR is radiography. By taking lateral and cranio-caudal x-rays of the stifle, we can see secondary signs of CCLR, plan for surgical repair, and rule out other bone or soft tissue abnormalities. [3] The findings on the radiograph depends on the timing of the imaging and the development of the disease. In CCLR, there is development of joint effusion that displaces the fat pad cranially, and can also cause distension of the caudal joint capsule. [3, 20] In chronic CCLR, the infrapatellar fat pad shadow may even completely disappear on x-rays. Another finding that can be found in chronic cases is the presence of osteophytes, mainly on the femoral trochlear ridges, distal patella, and femoral and tibial condyles. [21] One of the most important functions of radiography in CCLR cases is the measurement of the TPA. This measurement is necessary in order to plan where to cut the tibia in osteotomy surgeries, and to calculate how much to move the osteotomies.

Magnetic resonance imaging (MRI) can also be used for CCLR. MRI is non-invasive and does not expose the patient or the operator to ionizing radiation. The MRI allows visualisation of the cruciate ligaments, menisci, and surrounding structures for diagnosis of CCLR and planning of surgical therapy. Due to its non-invasive nature, MRI could be preferable to arthroscopy to evaluate the intactness of the menisci and presence of partial ruptures of the CCL, but it is rarely used due to the high cost of the procedure and limited availability of the machine outside larger clinics. [3, 21]

3.2.4. Consequences

A common complication of the joint instability created by CCLR is meniscal tear. [1, 16, 22] The medial meniscus is more firmly attached to the tibia with meniscal ligaments, which makes it more prone to injury than the lateral meniscus which can more freely in the joint. When the tibia is shifted cranially in stifles with CCLR, the caudal part of the medial meniscus becomes trapped between the tibial plateau and the femoral condyle, putting it under increased amounts of compression and shearing forces. [17] Meniscal tear may be detected during physical examination in the form of a palpable, or even audible, clicking when extending the joint from a flexed position. However, it is important to note that a torn meniscus can still be present even if the clicking is absent. [1, 17] The best way to detect meniscal tear is with diagnostic imaging, such as MRI or arthroscopy, the latter of which can also be used therapeutically to perform a meniscectomy. [17, 21]

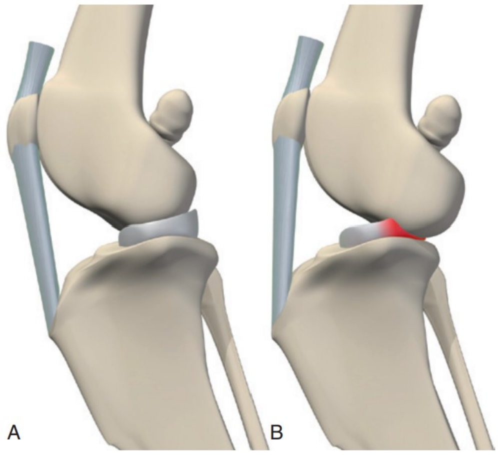

Figure 4 - Illustration of the "wedge effect" that occurs after CCLR. A) Normal stifle. B) CCL deficient stifle with cranially displaced tibia and wedged-in caudal horn of the meniscus. (From: Johnston SA, Tobias KM (2018) Veterinary Surgery: Small Animal, 2nd ed. Elsevier, St. Louis, MO)

The joint instability caused by CCLR leads to secondary osteoarthritis, which is a degeneration of cartilage, new bone development along the joint margins, and periarticular fibrosis. [1, 23] The abnormal movement of the joint leads to increased load on some parts of the articular cartilage, causing an inflammatory response. This inflamamtion causes cartilage destruction, which makes it even more sensitive to weight-bearing, and further stimulates the production of inflammatory mediators, leading to a vicious cycle of inflammation and cartilage damage. [1] A study in 2004 revealed that patients with osteoarthritis due to CCLR also showed osteoarthritic changes in the contralateral joint, supporting the bilateral nature of CCL degeneration. [23]

Arthritic joints are frequently swollen due to joint effusion in acute phase, and periarticular fibrosis in more chronic stages. Osteoarthritis also leads to decreased range of motion, instability, crepitus, and pain. [1] Radiographic findings depend on the chronicity of the condition, but signs that can be seen are osteophytes, joint effusion, intraarticular mineralization, and subchondral sclerosis. [23]

Treatment of osteoarthritis is similar to the one for CCLR. It includes stabilization of the joint with surgery, NSAIDs for pain-relief and its anti-inflammatory properties, and exercise restrictions until the acute inflammation and pain has passed. [1, 24] Chondroprotective supplements such as chondroitin and glucosamine can also slow down cartilage degeneration and aid in cartilage matrix synthesis. Overweight patients will also greatly benefit from weight-loss to decrease the load placed on the joint, and all patients, regardless of size, should be recommended physical therapy to increase range of motion and strengthen the periarticular structures. [1]

Prognosis for osteoarthritis depends on the severity and concurrent conditions. Since osteoarthritis is secondary to CCLR, the stifle should be operated against CCL deficiency in order to stabilize the joint and slow down the progression of the osteoarthritic changes. [1, 24] Even if the joint is stabilized postoperatively, the joint anatomy and function will never return to normal, so it is important to notify the owner that the osteoarthritis is still present and will progress with time, and that long-term therapy may be required as the dog gets older. [24] Despite the chronic and progressive nature of osteoarthritis, most patients, except severe end-stage cases, can return to a normal life with near-normal function of the joint. [1, 24]

3.2.5. Treatment

When it comes to the treatment of CCLR, the choice stands between conservative and surgical therapy. Conservative treatment consists of painkillers and anti-inflammatory medication, weight loss if indicates, and strict movement restrictions. Dogs on conservative treatment for CCLR need to spend a minimum of 6 weeks with activities limited to short walks on leash, no jumping or running, and being confined to a cage when restricting their movements is difficult, for example at night. [1] A study conducted by P.B. Vasseur showed that only 19.3% of dogs over 15kg body weight improved or returned to normal after conservative treatment, compared to 85.7% of dogs weighing less than 15kg. [25] Based on his results, it can be deduced that conservative treatment for CCLR should only be considered for small patients with less than 15kg body weight.

The lameness of small dogs frequently decreases after 6 weeks with this treatment option, and they appear clinically normal after 4 months on average, but the joint instability is still present and the osteoarthrosis associated with CCLR continues to progress. [1, 25] These dogs also often move more of their weight-bearing onto the healthy leg, which can speed up the development of a contralateral CCLR in case of degenerative joint disease. Once a bilateral CCLR has developed, both conservative and surgical treatment is less likely to be successful compared to patients with unilateral rupture. [1]

The success of surgical therapy is around 90% regardless of the technique used, so it is recommended for patients of any size in order to improve the stability and ensure the best possible function of the joint. The different surgical techniques can be divided into three categories; intracapsular, extracapsular, and osteotomies. [1, 26]

The intracapsular and extracapsular techniques are based on the recreation of the CCL and joint capsule fibrosis. Intracapsular reconstruction uses autogenous tissue, usually from fascia lata, and passes it though drilled holes in the tibia or femur, or with a so-called "over-the-top" method of the lateral femoral condyle. [1, 26] Synthetic material is rarely used due to the risk of infection and inflammatory reactions. The advantage of the intracapsular techniques is that the copy the CCL in both position and function, but the downside is that they are invasive and the graft can stretch and fail over time. [1]
The extracapsular technique places sutures outside the joint to recreate the function of the CCL. Many origins and insertions of the sutures have been described, for example around the lateral fabella and through a drilled hole in the tibial tuberosity. [26]

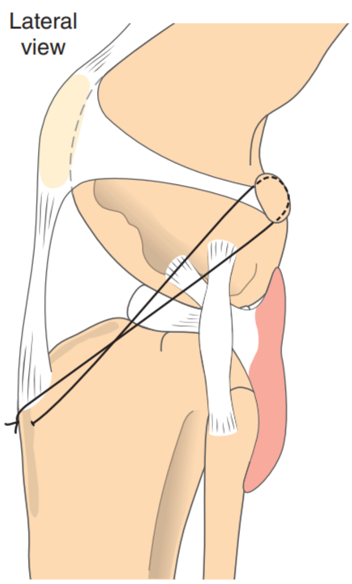

Figure 5 - Illustration of an extracapsular stabilization technique with lateral fabello-tibial suture. (From: Fossum TW, Cho J, Dewey CW, Hayashi K, Huntingford JL, MacPhail CM, Quandt JE, Radlinsky MG, Schulz KS, Willard MD, Yu-Speight A (2019) Small Animal Surgery, 5th ed. Elsevier, Philadelphia, PA)

Several osteotomies have been developed over the years to treat CCLR. Two of the most popular are tibial plateau leveling osteotomy and tibial tuberostiy advancement, including several variations of the latter, such as the circular TTA. The tibial wedge osteotomy (TWO) is the predecessor of TPLO, and it uses the same principle of decreasing the tibial slipe to lower the TPA to 3-7 degrees in order to prevent CTT. Many surgeons prefer TPLO who will be difficult to rehabilitate and keep in rest postoperatively, such as large and active dogs, but the TWO is still valuable for young dogs with open growth plates because it is performed distal to the epiphysis. [1]

The patients receive preoperative opiates and/or epidural analgesia, and they continue with pain management some days postoperatively. The recovery time after surgery is on average 8-12 weeks with restricted activity, regardless of the method used. After this, a study by K.W. Moore and R.A. Read showed owner satisfaction and clinical improvement in over 85% of 79 cases, although less than 50% of the patients regained original function of the joint, with minimal difference between the surgical techniques. [26] Each of the surgical techniques have shown decreased pain and lameness postoperatively, but due to lack of standardization in the measurement of effectiveness and outcome, direct comparison of the various methods has been difficult. [27] However, a literature review from 2014 concluded that TPLO is superior to lateral extracapsular suture and TTA since it is more likely to return the dog to normal limb function. [28]

3.3. TTA – Tibial Tuberosity Advancement

Tibial tuberosity advancement is one of the osteotomy surgeries used to treat CCLR. [1] The TTA technique was developed in 2002 by Tepic and Montavon as an alternative to tibial plateau leveling osteotomy when correcting the CTT occurring due to a deficient CCL. [2, 11] While the TPLO alters the tibial plateau itself to decrease the TPA, the TTA moves the insertion of the patellar ligament to create a 90 degree patellar tendon angle (PTA). Both methods neutralize the tibiofemoral shear force associated with CCLR and restore normal stifle function. [27, 30, 31]

3.3.1. Procedure

TTA is performed with the dog in dorsal recumbency with a medial approach to the tibial tuberosity. [32] The fascia and muscle attachments to the cranioproximal tibia are reflected to get better access to the tibia. Before starting the osteotomy, a plate is placed over the tibial crest to ensure proper location and size of the plate. When assessing the plate size, it should extend past the tibial crest in such a way that it is estimated to fit where the tibial tuberosity will be when advanced. [1] A drill guide is positioned parallel to the tibial crest and the most proximal and distal holes are drilled and pins are placed to ensure the guide stays in place while drilling the remaining holes. [32] An osteotomy is performed from the distal end of the tibial crest to the cranial bony prominence of the extensor groove on the lateral surface of the tibia. The osteotomy is only partial as the lateral cortex is left intact in the proximal third. [1, 31] The plate is positioned in the appropriate position on the tibial tuberosity and a mallet is used to assemble the fork into the drilled holes. The osteotomy is completed, and a T-handle is inserted into the osteotomy gap and rotated to move the tibial tuberosity cranially. [1, 32] The width of the T-handle spreader is matching the width of the cage prepared before the surgery, which is screwed in place to maintain the gap between the tuberosity and the shaft of the tibia. The distal part of the plate is now located centrally on the tibial shaft, where it is secured with screws. [32] After the TTA has been performed, the distal end of the tibial crest remains in contact with the tibia, while the proximal gap is filled with an allograft or bone graft from the distal femur. Before closing the surgery site, the stability of the patella is checked to ensure the TTA has not resulted in patellar luxation. [1, 29]

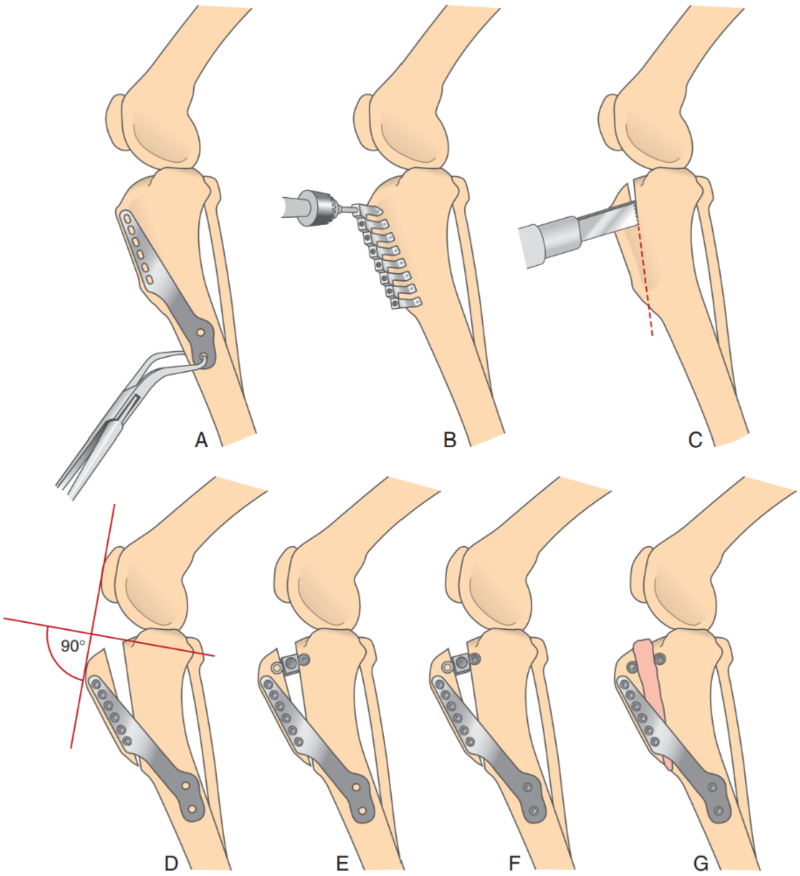

Figure 6 - Illustration of the TTA technique. A) Selecting a proper sized plate. B) Drilling holes using fork template. C) Partial osteotomy of the tibial crest. D) Securing plate to the tibial crest and completing the osteotomy. E) Opening the osteotomy gap, and inserting and screwing in the cage. F) Inserting screws in the distal plate. G) Inserting the cranial screw in the cage, and filling the gap with bone graft. (From: Fossum TW, Cho J, Dewey CW, Hayashi K, Huntingford JL, MacPhail CM, Quandt JE, Radlinsky MG, Schulz KS, Willard MD, Yu-Speight A (2019) Small Animal Surgery, 5th ed. Elsevier, Philadelphia, PA)

3.3.2. Aftercare

In the days after the operation, the dog is given pain relief in the form of NSAIDs or opiates. Movement restrictions are implemented with a gradual increase in the length of the walks for minimum 8 weeks, or until radiography shows adequate bone healing. [1, 6] Physiotherapy may be suggested to improve the musculature and range of motion. [1]

3.3.3. Success rate and Complications

The success rate of TTA is high, with around 85-90% of dogs improving after surgical repair of CCLR, and complications are uncommon. [30, 33, 34] The most seen complication is infection of the surgery site, which may occur after any operation, not just after TTA. Other post-operative complications are even less common, but may include medial meniscal tear, implant failure, fracture of the tibia or tibial tuberosity, or patellar luxation. [30, 32] Despite the success of the surgery, osteoarthrosis is inevitable. [1]

3.4. cTTA – circular Tibial Tuberosity Advancement

Circular tibial tuberosity advancement (cTTA) is a new surgical technique for CCLR developed in 2010 by Petazzoni. [35] The cTTA is based on TTA and works by the same principles of neutralizing the CTT by moving the insertion of the patellar ligament cranially until it is perpendicular to the tibial plateau. However, the radial osteotomy performed in cTTA has the advantage of allowing continuous degree of correction instead of being limited by the predetermined level of correction decided by cage size in the older TTA. It also has the benefit of increased stability and healing by maintaining contact between the cut surfaces of the tibial tuberosity and the tibial shaft. [35]

3.4.1. Procedure

The stifle is approached from the craniomedial direction and a radial osteotomy is created around the tibial tuberosity, parallel to the tibial long axis. [35] The osteotomy is rotated based on the measurements decided with pre-operative radiography until the patellar ligament creates a 90 degree angle with the tibial plateau. [35] The osteotomy is then fixed with a locking plate. In the original paper by Petazzoni, a Fixin locking plate is used, while Zólyomi and the veterinarians at University of Veterinary Medicine Budapest used a String of Pearls locking plate in their surgeries. [35, 36]

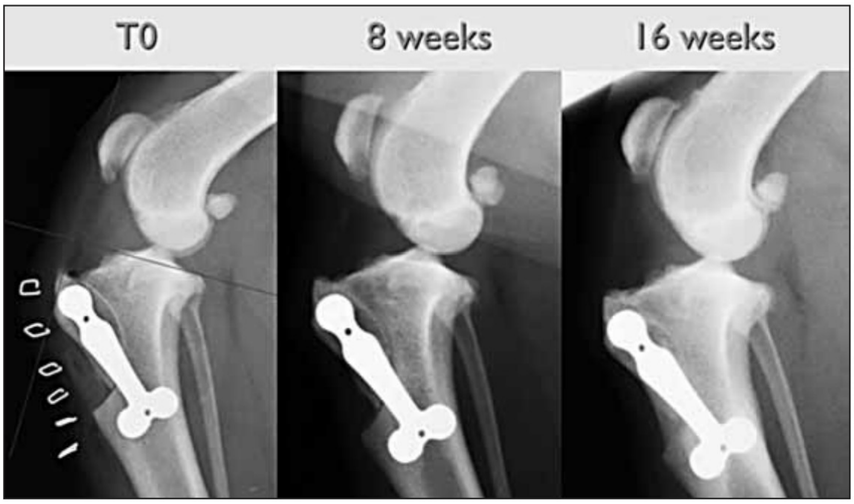

Figure 7 - Radiographs of cTTA at 0, 8, and 16 weeks postoperatively. (From: Petazzoni M (2010) cTTA (circular Tibial Tuberosity Advancement). DOI: 10.13140/2.1.2865.6965)

3.4.2. Aftercare

After surgery, a modified Robert-Jones bandage was used for 2 days, and sutures remained in place for 10 days. An Elizabethan collar was recommended for the first 2 weeks post-operative to prevent surgery site infection. The patients were prescribed Meloxicam for 7 days, chondroprotective supplements for minimum 1 month, and movement restrictions for 8 weeks after the surgery. [36]

3.4.3. Success rate and Complications

In Petazzoni's study using 89 dogs, all the patients were weightbearing on the operated limb immediately after waking from anaesthesia. The average time of radiographical healing was 8 weeks, at which time the patients showed minimal lameness. Out of the 89 dogs, 9 developed fractures which all healed after surgical revision. [35]

Zólyomi et al. performed 30 cTTA procedures on 27 dogs, where 3 dogs needed surgery for bilateral CCLR. None of these had intraoperative complications, and only 1 case resulted in major complications (meniscal injury) post-operatively. Minor complications occurred in 6 patients. [36]

Since the cTTA is a relatively new technique, there is still a lack of information concerning success and complications of the procedure, but there are some known measures that can be implemented to minimise the possible risks. In order to limit the possibility of fractures from excessive rotation of the radial osteotomy, it is recommended that the cTTA is only performed if the TPA is less than 28 degrees. [35] Too high degree of rotation also increases the risk of creating patellar luxation due to alteration of the patellar ligaments position and tension. [37] When sawing the osteotomy, the thinnest part of the tibial shaft should be minimum 60% of the original width prevent increased risk of tibial fractures. [36]

3.5. TPLO – Tibial Plateau Leveling Osteotomy

Tibial plateau leveling osteotomy was first described by B. Slocum and T.D. Slocum in 1993. The previously used intracapsular and extracapsular methods or surgical repair of CCLR would frequently stretch and fail some time after surgery since they replaced the CCL instead of eliminating the driving factors behind the disease. So Slocum hypothesized that by changing the TPA through rotating the tibial slope, the cranial tibial thrust could be eliminated and the stifle stabilised. [2]

The CCL, menisci, stifle ligaments, and joint capsule work as passive constraints of CTT and internal rotation of the tibia, while the muscles and tendons around the joint function as active constraints. [1] By recreating the CCL, we are only replacing one of the passive constraints to prevent the cranial drawer sign, without decreasing the strength of the force it is inflicted by the CTT. Slocum aimed to eliminate the CTT by leveling the tibial plateau, and therefore also increasing the effectiveness of the active constraints, instead of decreasing the cranial drawer by passive constraints. [2]

Studies have shown a strong correlation between the slope of the tibial plateau and the occurrence of CCLR, so it was hypothesized that decreasing the TPA would limit or eliminate the CTT, or change it to a caudal direction. [1, 14] By turning the cranial tibial thrust that is no longer restrained by the ruptured CCL into a caudal tibial thrust, more tension is placed on the caudal cruciate ligament (CaCL). [14] The TPLO was created as a way to decrease the TPA by rotating a radial osteotomy, but in order to avoid overloading the CaCL, excessive rotation must be avoided. [2, 14] Slocum found that aiming for a TPA of 3-7 degrees, with 5 degrees as the median, the tibial thrust can be controlled by the CaCL and active constraints of the stifle joint, without putting excessive stress on the CaCL. [1]

3.5.1. Procedure

Prior to surgery, radiographs are taken of the limb in order to measure the degree of rotation the osteotomy will need. This is calculated based on a series of measurements taken on a medio-lateral radiograph of the stifle and tibia (see **Figure 8**). The functional axis of the tibia is drawn in a line from point A on the centre of the trochlea of the talus, to point B at the centre of the intercondylar eminence of the tibial plateau. [1] A second, yellow, line is drawn along the tibial plateau on the image. From the point where the functional axis of the tibia and the line representing the tibial plateau meet, another green line is added, perpendicular to the tibial axis. [1, 13] The angle measured between this perpendicular line and the line of the tibial plateau is the TPA. [13] A conversion chart is used to determine the necessary osteotomy blade, and the degree the osteotomy should be rotated. [1, 2]

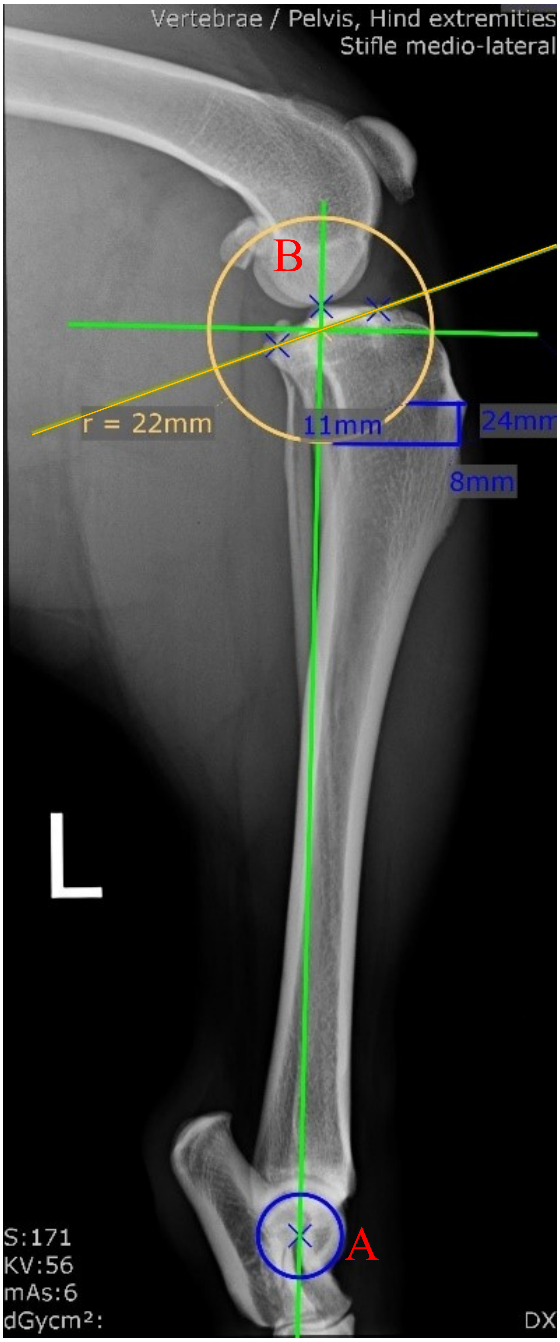

Figure 8 – Preoperative radiographic measurement of TPA and the degree of rotation of TPLO (University of Veterinary Medicine Budapest, Department of Surgery and Ophthalmology)

Before starting the TPLO, the menisci are checked for injury, and any remnants of the ruptured CCL are removed via arthroscopy, arthrotomy, or micro-arthrotomy. [1, 2] If there is a tear in the meniscus, usually the caudal horn of the medial meniscus, a meniscectomy must be performed during the inspection of the stifle joint. If the menisci are intact, a meniscal release of the caudal horn on the medial side can still be performed to prevent future tearing, and the remnants of the CCL can be removed if desired. [1]

The stifle joint is approached from the medial side with an incision centred at the proximal tibia, and the insertions of the sartorius and popliteus muscles are incised and reflected. [2] A jig pin is inserted perpendicular to the sagittal plane through both cortices of the tibia, in what will be the centre of rotation of the osteotomy. A jig is assembled on the pin, and a small skin incision is created at the centre of the tibial shaft where a distal jig pin is inserted through the jig and tibia in a similar manner to the proximal pin. [1, 2] A biradial saw of a predetermined size is placed at the site of the osteotomy, with the centre positioned over the proximal jig pin. While taking care to protect the patellar ligament by pulling it cranially with a retractor, a superficial cut is made to the bone with the saw. After ensuring that the osteotomy is at the correct site, the thickness of the remaining tibial crest and area available for the bone plate are both sufficient, and that the exit of the osteotomy on the caudal aspect of the tibia is perpendicular to the bone, the sawing may continue. [2] The osteotomy is performed parallel to the inserted jig pins, and the saw blade is continuously lavaged with saline to keep it cool. Before completing the osteotomy, and osteotome is used to create a mark on the proximal and distal segments along the edge, at a distance to each other determined by the preoperative measurements of how much the osteotomy should be rotated. [1, 14, 27] After completing the osteotomy, a large pin is inserted into the cranioproximal part of the proximal segment. This is the rotary pin, used to rotate the osteotomy distally and caudally until the two marks align. Once the segment is adequately rotated, a pin is drilled through the tibial crest and into the osteotomy in order to keep it in place until it can be secured with a plate. [1] Before the plate is fixed, the stifle is tested for tibial thrust to make sure it has been eliminated, and any necessary adjustments to the osteotomy rotation is made until the tibial thrust is gone. [2] An appropriately-sized plate is secured with screws distally first, then screws are drilled into the proximal segment parallel to the jig pins in order to avoid accidentally entering the stifle joint. [1]

Figure 9 - Medio-lateral and Caudo-cranial postoperative radiographs of TPLO (University of Veterinary Medicine Budapest, Department of Surgery and Ophthalmology)

After the TPLO has been deemed satisfactory, the surgical wound is closed. The sartorius muscle is sutured to the deep fascia of the tibia, and the remainder of the deep fascia is also sutured together. The superficial fascia is sutured together with the subcutaneous tissues. All these internal sutures use absorbable material in a continuous pattern. The skin incision is closed with non-absorbable material in an interrupted pattern. [1] Post-operative radiographs are taken in both medio-lateral and caudo-cranial views to ensure proper positioning of the plate and screws in relation to the tibia, osteotomy, and stifle joint, as can be seen in **Figure 9**.

3.5.2. Aftercare

The dog receives NSAIDs and Tramadol some days postoperatively, and is placed under strict movement restrictions until sufficient healing can be shown on radiography. For young dogs, this can take as little as 4 weeks, while in older dogs it may not occur until closer to 12 weeks postoperatively, with 8 weeks being the standard time for healing. [2] Exercise is limited to leash walking with gradual increase in length and intensity. [1] After 2 weeks, the pain will subside and the dog will start to feel more normal, which can make it difficult for the owner to prevent them from overexerting themselves. If the owner cannot keep them restrained, tranquilization and restriction to a cage may be necessary. [2]

Physiotherapy is recommended for patients having undergone TPLO surgery to maintain optimal range of motion, prevent excessive muscle atrophy, and to rebuild any lost muscle mass after the recovery period. [1, 3]

3.5.3. Success rate and Complications

TPLO has a high success rate, with over 90% of cases ending with normal or near-normal function and activity. In Slocum's study, 73% of patients had an excellent result from the surgery, 21% good, 3% fair, and only 2% of the cases were considered to be failures. The success of the surgery was further proved by the dogs being able to return to hunting and highly competitive sports with normal function, and even ending up best in class. [2] Further studies have shown that TPLO results in more patients have normal use of the joint after surgery compared to other techniques. [27, 28]

In Slocum's study, complications occurred in only 8.4% of cases. These consisted of broken plates, loose screws, pin migration, and broken wires. Meniscal injury also occurred in 4% of the patients. [2]

Since there is still some tibiofemoral instability after TPLO, except during loading of the limb, the medial meniscus is at risk of crush injuries, similar to a non-operated stifle with CCLR. [2, 14] The unloaded tibia is shifted cranially, placing the caudal horn of the medial meniscus cranial to the femoral condyle. When the limb then becomes loaded, the meniscus shifts caudally with the tibia, resulting in a repeated cranial-to-caudal movement and crushing of the caudal horn. [14] Meniscal tear after TPLO can be prevented by performing a meniscal release while inspecting the meniscus during intraoperative arthroscopy or arthrotomy, since it allows the medial meniscus to stay in such a position where the caudal horn remains caudal to the femoral condyle, avoiding injury. [17]

TPLO can also lead to tibial crest fracture if the osteotomy segment is too large, leaving a smaller and more fragile tibial crest. While it is important to make the osteotomy big enough to make space for the bone plate, it is equally important to preserve enough of the tibial crest to prevent fracture. [1]

Studies have shown that it is possible to over-rotate the proximal segment during TPLO, which puts excessive strain on the CaCL, risking fatigue failure. Because of this, the surgeon should keep the rotation to the minimum required to eliminate the CTT. [14]

3.5.4. Long-term results

Previous studies of the long-term effects of TPLO have shown a high level of success and have also shown TPLO to have a better end-result than other surgical techniques, such as TTA, when considering joint function and pain. [4–6]

An article published in 2020 examined the long-term outcome and osteoarthritis progression in 36 months after TPLO in 35 dogs. The dogs showed increased weight-bearing on the operated limb postoperatively compared to the preoperative CCL-deficient stifle, and this was maintained throughout the 36 months of the study. Despite the improvement in limb function, the osteoarthrosis continued to progress after surgical stabilization of the joint, but it did not affect the weight-bearing of the limb, even by the end of the study. [5]

A study in 2015 showed long-term success of TPLO in 96.9% of the patients when evaluated by their owners. This study compared the results of TPLO with those of TTA and found that TPLO resulted in a higher level of function and lower level of pain in the joint than TTA. Despite TPLO resulting in a lower level of pain than TTA, clients still reported "at least some pain" >1 year postoperatively, meaning that neither of the surgical techniques ended in a long-term pain-free status according to the owners, but that pre-CCLR joint function was achieved in ~75% of TPLO patients nonetheless. [4]

Another long-term outcome study by Nelson and Krotscheck suggests that dogs who undergo TPLO return to normal limb function faster and to a greater extent than dogs who undergo extracapsular repair (ECR) of CCLR. At walk and trot, the dogs who underwent TPLO had a more symmetrical loading of the limbs than those who had the ECR, and their gait analysis results were the same as those in the control group with intact CCL by 1 year after the TPLO. [38]

Nelson and Krotscheck performed another study about the long-term outcome of TPLO in 2016, this time in comparison with TTA as well as the ECR. The dogs who underwent TTA surgery had similar limb function to the control group at walk, but at trot, their results were similar to those with ECR. [6] According to the results of both their studies, TPLO results in a better limb function than either TTA or ECR.

Overall, studies of the long-term success of TPLO and its comparison to other surgical techniques have shown that TPLO results in close-to-normal joint function, and that it can yield more favourable results than TTA and ECR. [4, 6]

4. Objectives

The main objective of this thesis is to gather data on the long-term results of TPLO on dogs operated at the University of Veterinary Medicine in Budapest from 2017 to 2020 through the use of questionnaires to evaluate client satisfaction and opinion on the current status of their dog's joint function. The results are also compared to results from previous studies on the long-term effect of TPLO to evaluate if the achieved results are compatible with those of others.

5. Materials and Methods

5.1. Case selection

The clinical data of dogs treated for CCLR with TPLO was collected from the database of the Small Animal Clinic of University of Veterinary Medicine Budapest. The selected cases were of dogs who had been operated between 2017 to 2020, and whose owners responded to the surveys sent via email concerning the long-term follow-up of the patient. Cases were excluded if the owner failed to return the questionnaire.

5.2. Data collection

Data was collected from the clinical records of the 18 dogs who were operated with TPLO from the year 2017 to 2020. The collected data for each patient consists of the breed, sex, reproductive status, present age, bodyweight in kilograms, date of surgery, and leg(s) operated. The dogs whose owners did not return the client questionnaires were excluded from this study.

5.3. Client questionnaires

Two questionnaires were sent via email to owners of dogs who have undergone TPLO for CCLR at the University of Veterinary Medicine in Budapest. The questionnaires, "Canine Brief Pain Inventory" (https://www.vet.upenn.edu/research/clinical-trials-vcic/our-services/pennchart/cbpi-tool) and "Canine Orthopaedic Index" (https://www.vet.upenn.edu/research/clinical-trials-vcic/our-services/pennchart/canine-orthopedic-index), were both translated to Hungarian for the Hungarian owners to fill out, while owners of other nationalities received the original versions.

Out of the owners who received the questionnaire, six of them filled it out and returned it. While it would be preferred to analyse the results of a higher number of questionnaires, the six we received were deemed sufficient for the purpose of this thesis.

5.4. Statistical analysis

The data collected from the clinic's database was written into and analysed in Excel. The results of the surveys were received by email, and input into to IBM SPSS Statistics for further analysis.

6. Results

6.1. Case selection

Eighteen dogs who underwent TPLO between 2017 and 2020 were identified, nine of whom were operated on both hind legs. Out of the 18 patients, 12 (66.7%) were excluded because the owners failed to fill out and return the survey. The remaining 6 (33.3%) cases were suitable to be analysed and discussed in this thesis.

6.2. Patient signalment

The dogs included in this study include one Cane Corso, one Staffordshire Terrier, one Golden Retriever, one Caucasian Shepherd, and two mixed breeds. Five (83%) of these dogs are female, and only one (17%) is male. All (100%) of the dogs have been neutered. At the time of data collection, the dogs' ages ranged from 6 years 11 months to 12 years 8 months, and the average age of all the dogs are 9 years and 4 months. The average bodyweight of the patients is 34.2 kilograms, with 18.4kg being the lightest and 58kg being the heaviest. Out of the 6 dogs, 4 (67%) were operated on both legs, while the remaining two dogs had a TPLO performed on only one leg, either the left or the right. The dogs who developed CCLR in both legs underwent surgery for each leg on separate dates.

6.3. Client questionnaires

Six clients filled out and returned the questionnaires that were sent out to owners whose dogs underwent TPLO more than 3 years ago. The results of the questionnaires where input into Excel and later into IBM SPSS Statistics for further analysis. The results from the "Canine Brief Pain Inventory" and "Canine Orthopaedic Index" can be seen in **Table 1** and **Table 2,** respectively.

Table 1 – Owners answers to the Canine Brief Pain Inventory based on the past 7 days.

		Count	Column N %
The number that best describes the pain at its worst in the last 7days.	**0 (No pain)**	**3**	**50.0%**
	1	0	0.0%
	2	**1**	**16.7%**
	3	**1**	**16.7%**
	4	0	0.0%
	5	0	0.0%
	6	**1**	**16.7%**
	7	0	0.0%
	8	0	0.0%
	9	0	0.0%
	10 (Extreme pain)	0	0.0%
The number that best describes the pain at its least in the last 7days.	**0 (No pain)**	**4**	**66.7%**
	1	0	0.0%
	2	0	0.0%
	3	**1**	**16.7%**
	4	**1**	**16.7%**
	5	0	0.0%
	6	0	0.0%
	7	0	0.0%
	8	0	0.0%
	9	0	0.0%
	10 (Extreme pain)	0	0.0%
The number that best describes the pain at its average in the last 7days.	**0 (No pain)**	**3**	**50.0%**
	1	**1**	**16.7%**
	2	0	0.0%
	3	**1**	**16.7%**
	4	0	0.0%
	5	**1**	**16.7%**
	6	0	0.0%
	7	0	0.0%
	8	0	0.0%
	9	0	0.0%
	10 (Extreme pain)	0	0.0%
The number that best describes the pain as it is right now.	**0 (No pain)**	**4**	**66.7%**
	1	0	0.0%
	2	0	0.0%
	3	**1**	**16.7%**
	4	0	0.0%
	5	**1**	**16.7%**
	6	0	0.0%
	7	0	0.0%
	8	0	0.0%
	9	0	0.0%

	10 (Extreme pain)	0	0.0%
The number that best describes how pain has interfered with your dog's general activity in the last 7 days.	**0 (Does not interfere)**	**3**	**50.0%**
	1	0	0.0%
	2	**1**	**16.7%**
	3	**1**	**16.7%**
	4	0	0.0%
	5	0	0.0%
	6	0	0.0%
	7	0	0.0%
	8	**1**	**16.7%**
	9	0	0.0%
	10 (Completely interferes)	0	0.0%
The number that best describes how pain has interfered with your dog's enjoyment of life in the last 7 days.	**0 (Does not interfere)**	**3**	**50.0%**
	1	0	0.0%
	2	**1**	**16.7%**
	3	0	0.0%
	4	0	0.0%
	5	0	0.0%
	6	0	0.0%
	7	**1**	**16.7%**
	8	0	0.0%
	9	**1**	**16.7%**
	10 (Completely interferes)	0	0.0%
The number that best describes how pain has interfered with your dog's ability to rise to standing from lying down in the last 7 days.	**0 (Does not interfere)**	**2**	**33.3%**
	1	0	0.0%
	2	**2**	**33.3%**
	3	**1**	**16.7%**
	4	0	0.0%
	5	0	0.0%
	6	0	0.0%
	7	0	0.0%
	8	0	0.0%
	9	0	0.0%
	10 (Completely interferes)	**1**	**16.7%**
The number that best describes how pain has interfered with your dog's ability to walk in the last 7 days.	**0 (Does not interfere)**	**2**	**33.3%**
	1	0	0.0%
	2	**2**	**33.3%**
	3	**1**	**16.7%**
	4	**1**	**16.7%**
	5	0	0.0%
	6	0	0.0%
	7	0	0.0%
	8	0	0.0%
	9	0	0.0%
	10 (Completely interferes)	0	0.0%
	0 (Does not interfere)	**2**	**33.3%**

The number that best describes how pain has interfered with your dog's ability to run in the last 7 days.	1	0	0.0%
	2	**2**	**33.3%**
	3	**2**	**33.3%**
	4	0	0.0%
	5	0	0.0%
	6	0	0.0%
	7	0	0.0%
	8	0	0.0%
	9	0	0.0%
	10 (Completely interferes)	0	0.0%
The number that best describes how pain has interfered with your dog's ability to climb stairs, curbs, doorsteps, etc. in the last 7 days.	**0 (Does not interfere)**	**2**	**33.3%**
	1	0	0.0%
	2	**2**	**33.3%**
	3	**2**	**33.3%**
	4	0	0.0%
	5	0	0.0%
	6	0	0.0%
	7	0	0.0%
	8	0	0.0%
	9	0	0.0%
	10 (Completely interferes)	0	0.0%
The number that best describes your dog's overall quality of life in the last 7 days.	Poor	0	0.0%
	Fair	0	0.0%
	Good	**2**	**33.3%**
	Very good	**3**	**50.0%**
	Excellent	**1**	**16.7%**

The above table, **Table 1**, displays the questions belonging to the “Canine Brief Pain Inventory”, the answer alternatives available for owners to choose from, the answers the owners chose, and the percentage of the number of owners who chose each alternative. More than half of the owners chose number alternatives lower than “5”, and all of them described the quality of life of the dogs as “Good” or better than.

*Table 2 – Owners answers to the Canine Orthopaedic Index based on the past 7 days. *missing answer from one owner.*

		Count	Percentage %
How severe is your dog's stiffness after first wakening in the morning?	**None**	**1**	**16.7%**
	Mild	**2**	**33.3%**
	Moderate	**3**	**50.0%**
	Severe	0	0.0%
	Extreme	0	0.0%
Later in the day, how severe is your dog's stiffness after lying down for at least 15 minutes?	**None**	**1**	**16.7%**
	Mild	**3**	**50.0%**
	Moderate	**2**	**33.3%**
	Severe	0	0.0%
	Extreme	0	0.0%
How much of a problem does your dog have rising to standing after lying down for at least 15 minutes?	**None**	**1**	**16.7%**
	Mild	**2**	**33.3%**
	Moderate	**2**	**33.3%**
	Severe	**1**	**16.7%**
	Extreme	0	0.0%
In general, over the past 7 days, how much difficulty has your dog had with his or her joints?	**None**	**2**	**33.3%**
	Mild	**3**	**50.0%**
	Moderate	0	0.0%
	Severe	**1**	**16.7%**
	Extreme	0	0.0%
Jumping up (as in getting into the car or onto the bed) ?	**No problems**	**1**	**16.7%**
	Mild problems	**3**	**50.0%**
	Moderate problems	**1**	**16.7%**
	Severe problems	**1**	**16.7%**
	Extreme problems	0	0.0%
Jumping down (as in getting into the car or onto the bed) ?	**No problems**	**1**	**16.7%**
	Mild problems	**4**	**66.7%**
	Moderate problems	**1**	**16.7%**
	Severe problems	0	0.0%
	Extreme problems	0	0.0%
Climbing up (as in stairs, ramps or curbs) ?	**No problems**	**3**	**50.0%**
	Mild problems	**3**	**50.0%**
	Moderate problems	0	0.0%
	Severe problems	0	0.0%
	Extreme problems	0	0.0%
Climbing down (as in stairs, ramps or curbs) ?	**No problems**	**3**	**50.0%**
	Mild problems	**3**	**50.0%**
	Moderate problems	0	0.0%
	Severe problems	0	0.0%
	Extreme problems	0	0.0%
On average, how severe was your dog's limp during mild activities (such as short walks)?	**None**	**5**	**83.3%**
	Mild	**1**	**16.7%**

	Moderate	0	0.0%
	Severe	0	0.0%
	Extreme	0	0.0%
On average, how severe was your dog's limp during moderate activities (such as long walks, playing or running)? *	**None**	**4**	**80.0%**
	Mild	0	0.0%
	Moderate	0	0.0%
	Severe	**1**	**20.0%**
	Extreme	0	0.0%
How often did your dog limp the day after moderate activities (such as long walks, playing or running)? *	**Never**	**1**	**20.0%**
	Rarely	**3**	**60.0%**
	Occasionally	**1**	**20.0%**
	Frequently	0	0.0%
	Constantly	0	0.0%
How often have you been aware of your dog's joint problems?	**Never**	**1**	**16.7%**
	Rarely	**3**	**50.0%**
	Occasionally	0	0.0%
	Frequently	**1**	**16.7%**
	Constantly	**1**	**16.7%**
How often did your dog 'pay' for over-activity, with increased pain or stiffness the following day? *	**Never**	**2**	**40.0%**
	Rarely	**2**	**40.0%**
	Occasionally	0	0.0%
	Frequently	**1**	**20.0%**
	Constantly	0	0.0%
In the past 7 days, what has been your level of concern that your dog's joint problems will shorten his or her life?	**None**	**3**	**50.0%**
	Mild	**2**	**33.3%**
	Moderate	0	0.0%
	Severe	**1**	**16.7%**
	Extreme	0	0.0%
In the past 7 days, what has been your level of concern that your dog is generally slowing down?	**None**	**4**	**66.7%**
	Mild	0	0.0%
	Moderate	**1**	**16.7%**
	Severe	0	0.0%
	Extreme	**1**	**16.7%**
Overall, how would you rate your dog's quality of life over the past 7 days?	Poor	0	0.0%
	Fair	**1**	**16.7%**
	Good	**2**	**33.3%**
	Very good	**2**	**33.3%**
	Excellent	**1**	**16.7%**

In **Table 2** you can see the results from the “Canine Orthopaedic Index”. The table includes the frequency of owners’ answers to each of the response alternatives, as well as the percentage of owners that chose each of these alternatives. Over half the owners chose the answers below “Moderate” or “Occasionally” to all the questions, except the one concerning the dogs’ quality of life, to which all but one owner considers the quality to be “Good” or better.

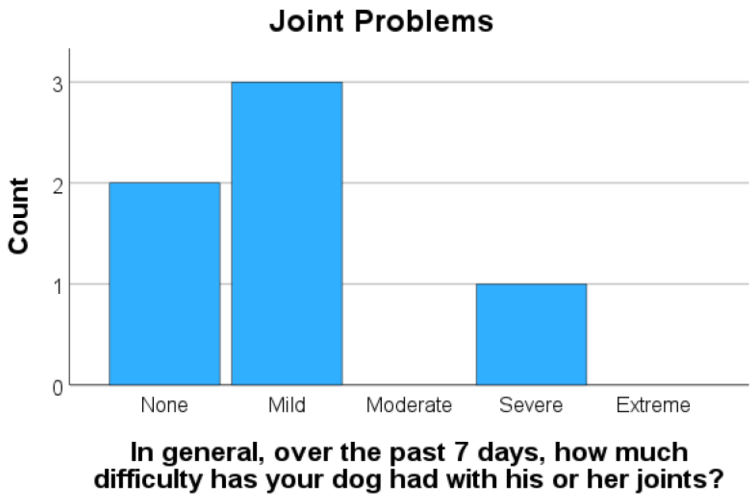

Figure 10 - Bar-chart showing the dogs' joint problems in the past 7 days

In **Figure 10** the severity of how much difficulty each dog has had with their joints in the past 7 days is displayed in a bar-chart. Most of the owners (3) reported that their dog has mild joint problems, while 2 of the others reported no problems. Only one of the owners considers their dog to have severe difficulties with his or her joints.

Figure 11 shows that three (50%) of the dogs have no pain associated with their joint problems and TPLO in the past 7 days prior to sending the filled-in questionnaires. This is one more than the number of owners who said their dog has no joint-related problems in the same time period in **Figure 10**. The remaining three owners had their answers spread out equally, with one owner grading their dog's pain as a 2, one saying grade 3, and the final saying grade 5, which would be a moderate level of pain on the 1-10 scale we used.

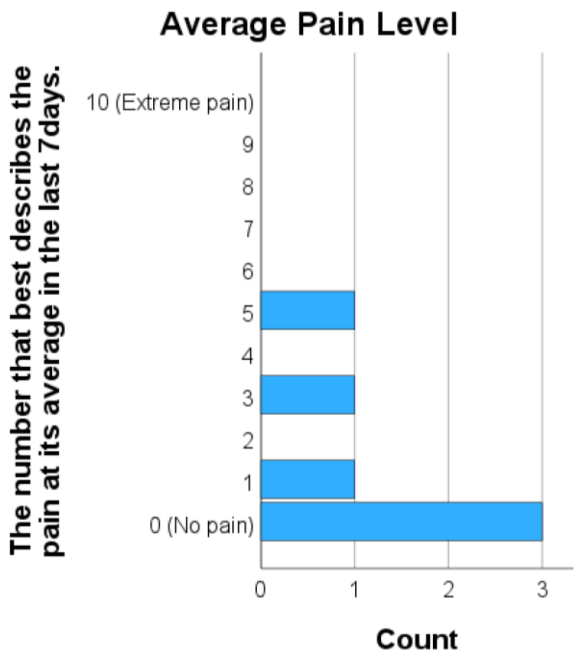

Figure 11 - Histogram showing the average pain level of the dogs in the past 7 days.

On average, how severe was your dog's limp during mild activities (such as short walks)?

		Frequency	Percent	Valid Percent
Valid	None	5	83.3	83.3
	Mild	1	16.7	16.7
	Total	6	100.0	100.0

Table 3 - Severity of lameness during mild activities.

On average, how severe was your dog's limp during moderate activities (such as long walks, playing or running)?

		Frequency	Percent	Valid Percent
Valid	None	4	66.7	80.0
	Severe	1	16.7	20.0
	Total	5	83.3	100.0

Table 4 - Severity of lameness during moderate activities.

In the above two tables, **Table 3** and **Table 4**, the severity of limping during mild and moderate activities are displayed in separate tables. For both levels of activity, most owners (≥80%) reported no limping, while only 1 owner differed. For mild activities, the highest severity of lameness is "Mild" (1), while for moderate activities, the last (1) answer stated that the lameness is "Severe". One of the owners did not answer the question concerning lameness during moderate activities, so the percentages of the results from that question are different to those concerning mild activities, even if all but one of the submitted answers differed from the rest.

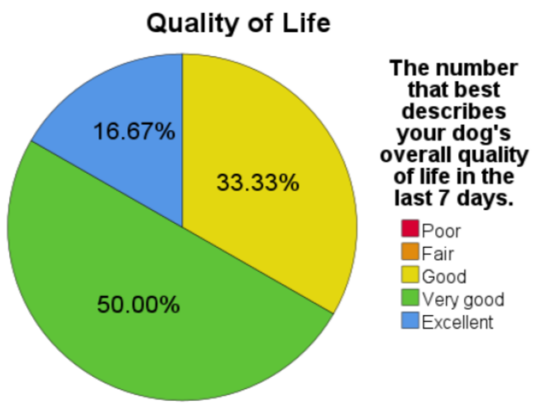

Figure 12 - Pie-chart of owners' opinions of their dog's present quality of life from the Canine Brief Pain Inventory

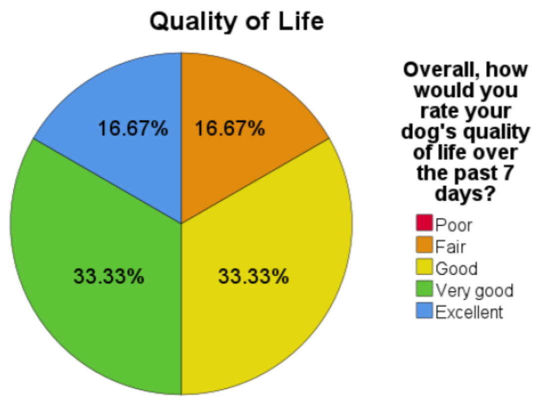

Figure 13 - Pie-chart of owners' opinions of their dog's present quality of life from the Canine Orthopaedic Index

The two above pie-charts, **Figure 12** and **Figure 13**, show what owners answered about their dog's quality of life in the "Canine Brief Pain Inventory" and "Canine Orthopaedic Index", respectively. In the first chart, all owners consider their dog's quality of life to be "Good" or better, with 50% of owners saying "Very Good". In the second chart, it can be seen that at least one owner has changed their answer regarding quality of life in the past 7 days, changing the distribution in the chart. In **Figure 13**, one owner (~17%) considers their dog's quality of life to be "Fair", while another owner (~17%) reported the opposite and considers their dog to have an "Excellent" quality of life. The majority of owners answered that their dogs have a "Good" (~33%) or "Very good" (~33%) life quality in this questionnaire.

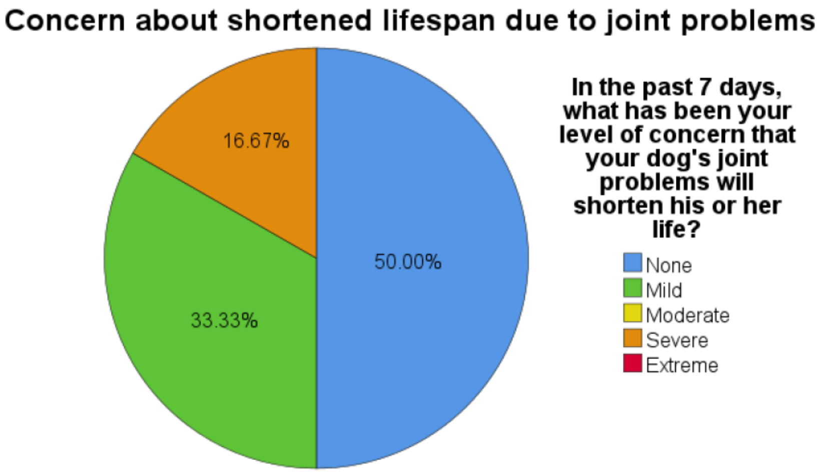

Figure 14 - Pie-chart showing how concerned owners are about their dog's lifespan due to joint issues.

As seen in **Figure 14**, when asked about their concern that the joint problems will shorten their dog's life, 50% of respondents reported no concern, ~33% expressed "Mild" concern, and one of the owners (~17%) reported a "Severe" level of concern.

7. Discussion

Two questionnaires were sent out to evaluate the pain and function of the limbs operated with TPLO. The "Canine Brief Pain Inventory" (**Table 1**) focuses mainly on the presence of pain and its influence on the life of the dog within the past 7 days. With regards to the questions concerning the level of pain, the owners were asked to evaluate their dog's pain at its worst, least, and average in the last 7 days, as well as at the time of filling out the survey. Most owners (≥50%) answered that their dog is in no pain at all. On a scale of 0 to 10, with 0 being "No pain" and 10 being "Extreme pain", the highest reported number was 6, which was for the evaluation of the pain at its worst, and this level of pain was only reported by one owner. For the other questions regarding the pain level of the dogs, all the answers stayed at a 5 or below. Overall, the dogs were considered to have only mild or no pain.

When asked about how the pain interferes with several aspects of their dog's lives on a scale of 0-10, the owners generally reported a low level of interference, with a maximum number of 4 in most cases. The only exceptions to this are for three of the questions, and it was still a minority of owners who answered anything other than a moderate level of interference.

For one of the questions, one owner (16.7%) chose answer 10, meaning the pain completely interferes with the dog's ability to stand up from lying down within the last 7 days. The other owners answered "3" (16.7%), "2" (33.3%), or "0" (33.3%) to the same question.
The same owner who chose option 10 in the previously mentioned question, also chose a relatively high level of interference ("8") when asked about how pain has interfered with their dog's general activity in the past 7 days, while the other owners chose "0" (50%), "2" (16.7%), or "3" (16.7%).
For the question regarding the dog's enjoyment of life, half the owners (50%) answered "0", saying the pain does not interfere with their dog's enjoyment of life, while one owner (16.7%) chose option 2, which is still a low level of interference. The remaining two owners chose higher levels of interference, "7" and "9", which would mean that the pain their dogs experience greatly interferes with their enjoyment of life.
Aside from these three questions with only one or two bad results, the remaining questions about how pain interferes with the patients' lives showed good results, with "0" (does not interfere) being the most popular answer to all questions. The only questions where the number of clients who answered "0" did not exceed all the other answer options are the ones where the response "0" was equal to other low numbers, mainly "2" and/or "3", with an answer percentage of 33.3% each.

The "Canine Orthopaedic Index" focuses mostly on joint function and stiffness, with 5 possible answers to choose from in ascending order of severity. All the questions with their answers can be seen in **Table 2**. For daily activities such as walking and running, ≥80% of dogs were found to have mild or no limping, while only one dog had a severe limp only noticeable during moderate activities. The same dog "Occasionally" limps and "Frequently" experiences stiffness the day after moderate activities, while the rest only do "Rarely" or "Never". One owner did not fill out the questions about moderate activities, marked by an asterisk in **Table 2**, but left a comment that they do not allow their dog to perform such activities out of concern for the dog's joint issues. The same owner chose the most severe answer options compared to the other owners, and also answered that they are severely concerned that the joint problems will shorten their dog's life, and are extremely concerned that their dog is slowing down.
The overall results of the "Canine Orthopaedic Index" indicate a low level of joint problems such as decreased function and increased stiffness, with only one, occasionally two, owners reporting more severe issues.

In addition to being asked about specific situations related to the joint function of their dogs, the owners were also asked more general questions about their opinions on how the potential joint issues are affecting their dogs as a whole. For example, one of the questions asks how often the owners are aware of their dog's joint problems, to which one owner (16.7%) responded "Never", three (50%) "Rarely", one (16.7%) "Frequently", and one (16.7%) "Constantly". The owner who said they are constantly aware of their dog's joint problems is also the one who did not answer the questions concerning moderate activities in the Canine Orthopaedic Index because they have placed restrictions upon what activities their dog is allowed to perform.

When asked about how concerned they are that their dogs are slowing down, the majority of owners (66.7%) said they are not at all concerned, while the remaining two owners reported a "Moderate" and "Extreme" level of concern. They were also asked about their level of concern regarding the possibility of a shortened lifespan due to joint problems, to which half of them said they are not concerned, two (33.3%) said they are only mildly concerned, and the final owner (16.7%) said they are severely concerned.

The final question in both surveys asked how owners would rate their dog's quality of life within the last 7 days, with 5 possible answer ranging from "Poor" to "Excellent". For this question, there was some inconsistency between the questionnaires. In the "Canine Brief Pain Inventory", the lowest result was "Good", with two owners (33.3%) choosing this option, while three (50%) of the owners said their dogs have a "Very good" quality of life, and the last owner (16.7%) said it is "Excellent". However, in the "Canine Orthopaedic Index", two of the owners had changed their answers from "Very good" and "Good" to "Good" and "Fair", respectively. This changes the distribution of answers for this questionnaire to 16.7% "Fair", 33.3% "Good", 33.3% "Very good", and 16.7% "Excellent". Despite the change in answers, the overall impression achieved from the surveys is that the dogs lead good lives with few joint problems after TPLO.

Even if all the owners filled out the same questionnaires and gave mostly the same answers, there are still some factors that must be taken into account when evaluating the results of this study. One limitation we had is the limited number of owners who filled out the questionnaires. The small sample size influences the validity of the results since it creates single outliers, leading to a greater standard deviation (SD). An example of this is in the "Canine Brief Pain Inventory" where one owner gave an answer (10) on the other side of the spectrum to the others (0-3), making the mean = 2.83 and the SD = 3.71, giving the coefficient of variation = 1.31, which means that the answers to this question are spread out far from the mean. Therefore, the results from this study cannot accurately represent the long-term outcome of the population of dogs who underwent TPLO at the University of Veterinary Medicine Budapest.

Another factor to consider is that despite the owners filling out the same questionnaire, the responses are subjective since the owners have different expectations for how their dog should be post-operatively, sensitivity and reaction to their dog's possible discomfort, and interpretations of the questions in the surveys. For example, one owner may notice subtle signs of discomfort in their dog and decide that their activities should be restricted based on that, while another may not notice these signs and consider their dog to be without pain even if the dog itself is limiting its own activities due to the joint issues. The owners might also interpret the survey questions differently, or even misunderstand the question completely, leading to discrepancies in the survey results. An example of this is in the results from the "Canine Brief Pain Inventory" (**Table 1**) to the question "Fill in the oval next to the one number that best describes how, during the last 7 days, pain has interfered with your dog's enjoyment of life" where two owners reported a relatively high level of interference (7 and 9), despite none of the owners going above a "5" when asked about the dog's average level of pain in the last 7 days in the same questionnaire ("0" = 3, "1" = 1, "3" = 1, "5" = 1). In the same survey, all of the owners also reported a Good (2), Very good (3), or Excellent (1) quality of life, which would be contradictory to a high level of interference of pain on the enjoyment of life of the dogs.

One must also consider that the activity level, on which many of the questions in the surveys are based on, can vary greatly between dogs based on age, breed, owner activity level, general personality, and other illnesses that can affect energy level and musculoskeletal function. For example, one of the dogs in the study is a Golden Retriever, which is a sporting breed with medium to high energy, while another is a Caucasian Shepherd, a guardian breed that often has a lower energy level. Since the dogs have not been brought in for a clinical examination, one also cannot predict if some of the negative results from the client questionnaires are from problems in the stifle related to the TPLO or CCLR, or if they have some other issue in the background, for example spondylosis in the spine, or osteoarthritis in other joints.

Considering the small sample size of this study, and therefore limited results with wide variability, it makes sense to compare the achieved results with those of other studies on the long-term outcome of TPLO in dogs to see if any resemblance can be found. When viewing this study's results alongside those from the studies in section **3.5.4**, similarities can be seen in the pattern of good results. Christopher et al. published an article in 2013 with results of a questionnaire-based long-term follow-up of 65 TPLO patients, showing satisfactory results in 96.9% and pre-CCLR joint function in 75% of the dogs. The owners still answered that their dogs were in “at least some pain”, which agrees with the results of this study. [4] This could be explained by the fact that osteoarthritis will still progress over time, even in the surgically stabilised joint, which can create an inflammatory reaction, cartilage degeneration, and bony projections within the joint. Therefore, it is important to inform clients prior to surgery that TPLO is not a cure to the pathological reactions that have begun in the joint, and that the dogs can experience at least some level of pain.

In a study by Shimada et al. in 2020 the outcome of TPLO up until 36 months postoperatively was examined, and it was found that all the dogs had increased weight-bearing on the operated limb in the entire post-operative period compared to their pre-operative status. The osteoarthritis of these dogs continued to progress despite surgery, but this did not affect the function of the limbs. [5] In the study conducted for this thesis, limb function after the 36 month mark post-TPLO was examined. At this point, it is possible that the osteoarthritis in some of the dogs has advanced to a point were visible changes in weight-bearing, range of motion, and use of the limb occur, which did not appear in the 2020 study.

Considering the similarities in results concerning pain and joint function between this study and the above mentioned, it can be presumed that the achieved results match up to the opinion of surgeons and researchers that TPLO proved satisfactory results even long term.

In conclusion, this study showed good results of the long-term follow-up of TPLO with only some outliers, which is in accordance with results from previous studies conducted on the topic. Care should still be taken when evaluating these results due to the small sample size and questions of reliability stated previously in the discussion. For more definite results, a more extensive study of the TPLO patients at the University of Veterinary Medicine in Budapest should be performed, acquiring a larger sample size as well as implementing more objective methods of evaluation, such as osteoarthritis scoring.

8. Summary

Cranial Cruciate Ligament Rupture is a common cause of lameness in dogs, and thus, various treatment options have been developed for this disease. Conservative treatment with pain management, anti-inflammatories, and exercise restrictions is one such treatment, but it is only a viable option for dogs smaller than 15kg. Surgical therapy is another, and more preferred treatment option regardless of patient size since it stabilizes the joint and slows down the progression of secondary osteoarthritis. There have been several surgical techniques developed over the years, with none being proved to be significantly more superior to others, so the chosen method is often a matter of the surgeon's own preference.

TPLO is one of the most commonly used surgical techniques to improve the stability of the cranial cruciate ligament deficient stifle. It is based on the principle that leveling out the tibial plateau will decrease the tibial plateau angle, and therefore also decrease the cranial tibial thrust. This decrease in the cranial shift of the tibia on the femur will stabilise the joint and prevent excessive degeneration of cartilage and osteoarthritis progression.

Even if TPLO provides stabilization of the stifle, the alteration in joint anatomy and mechanism will lead to a continuous progression of osteoarthritis, although it will be slower than if the joint had been left unstable. This means that joint function can deteriorate over time as the osteoarthritis evolves, and that pain will likely be present at one point or another. This study aimed to examine the long-term results of TPLO in order to see if it provides satisfactory joint function and pain-status in patients more than 3 years after surgery.

The results of our study agree with the results from previous studies conducted on the topic, which indicate that most dogs have at least some pain in the operated limb, and varying degrees of joint function. Even if a smaller percentage of patients had undesired results in regard to pain levels and joint stiffness, both of which affecting the dog's ability to perform various activities, the majority of patients have a low level of pain and good joint function even more than 3 years following surgery. This leads to the conclusion that TPLO gives proper stabilisation and satisfactory results which allow the patients to lead relatively pain free lives with little interference from the operated joint, not only in the short-term follow-up, but also in the long run.

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INTERNATIONAL STUDY PROGRAMS
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Thesis progress report for veterinary students

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Name and title of the supervisor: Dr. Dorottya Zólyomi

Department: Department of Surgery and Ophthalmology

Thesis title: Long-term follow-up of TPLO surgery

Consultation – 1st semester

	Timing			Topic / Remarks of the supervisor	Signature of the supervisor
	year	month	day		
1.	2022	12	12	Submission of Literature review 1st draft	[signature]
2.	2023	03	26	Consultation about 1st draft	[signature]
3.	2023	06	14	Submission of Literature review 2nd draft	[signature]
4.	2023	06	28	Recieving grade for the semester	[signature]
5.	2023	07	11	Consultation about 2nd draft	[signature]

Grade achieved at the end of the first semester: 5

Consultation – 2nd semester

	Timing			Topic / Remarks of the supervisor	Signature of the supervisor
	year	month	day		
1.	2023	09	09	Re-evaluation/change of topic	[signature]
2.	2023	10	09	Evaluation of 3rd draft	[signature]
3.	2023	10	13	Collection of data/results	[signature]
4.	2023	10	31	Evaluation of 4th draft	[signature]

5.	2023	11	05	Final changes to thesis: Hungarian title and abstract	[signature]

Grade achieved at the end of the second semester: 5

The thesis meets the requirements of the Study and Examination Rules of the University and the Guide to Thesis Writing.

I accept the thesis and found suitable to defence,

[signature]
signature of the supervisor

ÁLLATORVOSTUDOMÁNYI EGYETEM Sebészeti és Szemészeti Tanszék és Klinika 1787 BUDAPEST

Signature of the student: Aina B. Lindbeck

Signature of the secretary of the department: [signature]

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