THESIS

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CANINE TPLO – THE ADVANTAGES OF ONE HOLE TPLO

A literature review

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1. Introduction

The stifle joint of the dog is very similar to a human's knee. The cranial cruciate ligament (CrCL) is located inside the joint and is responsible for maintaining a stable joint during running and play. This ligament is the same as an anterior cruciate ligament (ACL) in humans. One of the important functions of the ligament is to prevent forward and backward sliding of the femur on the tibia bone (drawer motion). Cranial cruciate ligament rupture is the most common orthopedic problem. This problem affects all ages and breeds of dog. Frequently, cruciate ligament rupture is a gradual process and not simply due to a single traumatic injury (so called: partial tear). Most dogs have a predisposing factor such as age-related ligament degeneration, preexisting inflammation, anatomical abnormalities and excessive slope of the top of the tibial bone that may cause the ligament to rupture.
Cruciate ligament rupture, especially cranial cruciate ligament rupture, has long been a clinical problem observed in veterinary practice. First described by Carlin in 1926, it was not until 1952 that Paatsama, in his classic treatise on ligament injuries of the canine stifle, finally brought the clinical manifestations and surgical treatment of cruciate ligament rupture in the dog into focus. In the 30 years following that work, the diagnosis and surgical treatment of ruptured cruciate ligaments in the dog have received more attention in the veterinary orthopaedic literature than any other musculoskeletal problem, with the possible exception of hip dysplasia. In spite of all this information, the surgical treatment of cruciate ligament rupture continues to be a subject of discussion and investigation. (Charles D. Newton, David M. Nunamaker. 1985).

The cruciate rupture condition is progressive and degenerative. Stifle synovitis develops in the early phase of the disease before development of joint instability. Joint instability results from cruciate ligament sprain. Ligament sprains are defined biomechanically by structural damage and the degree of associated joint laxity:

- Grade I sprains are associated with mild fiber damage and no joint laxity.
- Grade II sprains are associated with moderate fiber damage and a stretch to the point of detectable joint laxity.

- Grade III sprains are associated with severe disruption of ligament fibers and obvious joint laxity. Consequently, an unstable stifle is the consequence of complete CR. (Susannah J. Sample et al, 2017).

Clinical signs of early cruciate disease include stiffness or very mild lameness. As the tear advances and the ligament progressively weaken, the lameness becomes more pronounced. Complete tears initially result in non-weight bearing on the limb, but as time goes on the pet will generally begin to gradually use the limb. It is unusual that the lameness will resolve to an acceptable level in a large breed dog without surgery. Numerous techniques have been described to address this condition. Among board-certified surgeons, the tibial plateau leveling osteotomy (TPLO) is one of the more popular techniques for treating cranial cruciate ligament rupture. (Can Vet J, 2014).

The rupture of the CCLR results in both translational and rotational instability of the stifle joint that leads to the development of osteoarthritis. TPLO has been reported to functionally stabilize the stifle joint during weight bearing, neutralizing the cranial tibiofemoral shear force (cranial tibial thrust [CrTT]) by reduction of tibial plateau angle (TPA). This is accomplished by radial osteotomy of the proximal aspect of the tibia and rotation of the proximal fragment. (Randy J. Boudrieau, 2009).

2. Literature review

2.1 The anatomy of the canine stifle joint

The stifle joint represents the movable link between the femur and the tibia. In anatomical terms, the stifle is classified as a di-arthrodial, condylar joint. Because of its complex motion and the presence of various intra-articular structures (cruciate ligaments and menisci), the stifle joint is, perhaps, the most complex joint in the body. (Charles D. Newton, David M. Nunamaker, 1985).

The canine stifle joint is a complex, synovial joint that allows motion in three planes. While the primary movement of the stifle joint is flexion-extension the anatomy of the joint also allows for cranial-caudal translation, internal-external rotation, varus-valgus angulation, medial-lateral translation and compression-distraction (Korvick DL et al, 1994).

It is composed of 3 long bones: distal femur, proximal tibia, proximal fibula; 4 sesamoid bones: popliteal, medial fabella, lateral fabella, patella; 2 menisci; 4 major ligaments: medial collateral, lateral collateral, cranial cruciate (CrCL), caudal cruciate; a joint capsule; and multiple muscles Each of these components works in concert to contribute to the dynamic stability of the stifle joint. (Carpenter DH, Jr., Cooper RC, 2000).

The cruciate ligaments are paired ligaments within the stifle and are named after their relative insertions into the tibial plateau (that is, the cranial ligament inserts cranially and vice versa). Together with the collateral ligaments, they provide stability to the joint. The paired action of the cranial and caudal cruciate ligaments act like a four-joint chain to allow both rolling and sliding of the femoral condyles over the tibial plateau. The CCL has four main functions within the joint: to oppose translation of the tibia with regard to the femur (“cranial draw”), to oppose internal rotation of the tibia, to oppose overextension of the femur and to provide a limited degree of varus-valgus support during stifle flexion. (Nick Wiliams, 2009).

The CCL is further divided into cranio-medial and caudolateral bands, which, during stifle flexion, twist around each other, thereby limiting the amount of internal rotation of the tibia. The craniomedial band is taut in all phases of stifle motion, but the caudo-lateral band is only taut during stifle extension, becoming relaxed during flexion. For this reason, stifle joints should be examined for cranial draw during both flexion and extension as partial tears of the ligament may otherwise be missed if performed only in extension. Mechanoreceptors within the ligament itself provide feedback to prevent excessive flexion and extension of the joint. Nutrition to both cruciate ligaments comes primarily from the synovium. The natural healing potential of the ligament is very limited. Another important structure to be aware of within the stifle is the meniscus – a fibrocartilaginous pad that acts as a "shock absorber" and compensates for incongruity between the tibial plateau and the femoral condyles. This pad is composed of two semilunar pads anchored to the tibia and femur by five ligaments, and to each other by the inter meniscal ligament. The medial menisci is further stabilized by an attachment to the medial collateral ligament – this makes it more immobile and hence more vulnerable to injury by the pinching and internal rotational forces of the CCL deficient stifle. Blood supply to the menisci is also poor, especially to the inner portions, meaning the chance of healing is also slim. The menisci have a good nerve supply to aid with proprioception but this, in turn, can cause an extremely painful stifle when damaged. (Nick Wiliams, 2009).

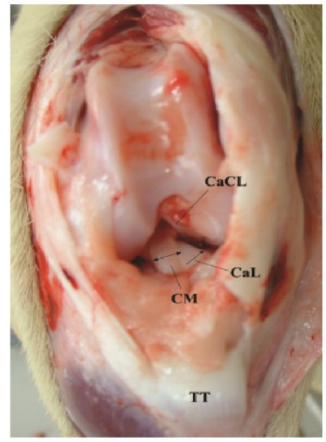

FIGURE 1: CRANIAL VIEW OF THE STIFLE JOINT. THE CRANIAL CRUCIATE LIGAMENT (CCL) IN THE DOG IS COMPOSED OF 2 SEPARATE BUNDLES. CM CRANIOMEDIAL BUNDLE OF THE CCL, CAL CAUDOLATERAL BUNDLE OF THE CCL, CACL CAUDAL CRUCIATE LIGAMENT, TT TIBIAL TUBERCLE. (DE ROOSTER, H. ET AL, 2006).

Stifle function is complemented by static support from a complex (passive) restraining system consisting of bony and musculotendinous structures, menisci, and several ligaments. (de Rooster, H. et al, 2006).

2.1.1 Ligaments of the stifle

The cruciate ligaments have specific functions that are directly related to their anatomic locations and orientations within the stifle joint. Although the main functions of other intra-articular and peri-articular structures and ligaments differ from those of the cruciate ligaments, they act complementary as constraints of stifle joint motion in various planes. (de Rooster, H. et al, 2006).

In subtle balance with the capsular structures, the collateral ligaments, muscles, the condylar geometry, and joint surface contact, the cruciate ligaments control and produce rotation of the tibia relative to the femur. (de Rooster, H. et al, 2006).

- ligament cranial meniscotibial 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.
- Ligament caudal meniscotibial 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.
- Ligament meniscifemorale – only on the lateral meniscus, extending from its caudal border to insert on the intercondylar area of the femur.
- Transverse ligament – connects the cranial aspects of the two menisci.
- Ligament 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.
- Ligament 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; Konig & Liebich, 2009).

2.2 Etiology

Canine cranial cruciate ligament (CrCL) rupture is one of the most common orthopedic conditions which can lead to degenerative joint disease (DJD) in case this ligament will be damage. (Elkins et al,1991). Unlike in people, where trauma is the most common etiology of the disease, CrCL rupture is multifactorial in origin. Regardless of cause, CrCL rupture results in stifle instability, which sets into motion a cascade of events including synovitis, articular cartilage degeneration, periarticular osteophyte development, capsular fibrosis, and medial meniscus injury. Progressive osteoarthritis is the end result after CrCL rupture regardless of treatment; however, the severity of osteoarthritis may be attenuated with early surgical intervention. (M. Isaka, 2014).

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).

Isolated traumatic injury to the CrCL has been reported in puppies. In puppies a traumatic event leads to avulsion of the ligament, most commonly at the tibial attachment site. While truly acute ruptures do occur, they are relatively rare. The chronic disease process far exceeds the number of acute ruptures. The clinical history at presentation may include an acute onset of lameness but physical examination findings and radiographic degenerative changes often support the chronic nature of the disease process. (Huss BLJ, 1994).

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).

A breed predisposition has been reported in certain breeds including the Rottweiler, Labrador retriever, Chesapeake Bay retriever, Newfoundland, Akita, Neopolitan mastiff, Saint Bernard and Staffordshire bull terrier. These breeds may have conformational characteristics that differ from dogs less prone to rupture. (Whitehair JG et al, 1993; Duval JM, 1999).

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).

2.3 Surgical Techniques

Surgical techniques of CrCL injury may be divided into two categories: extracapsular (outside of the joint) and intracapsular (inside the joint) techniques. The surgical treatment chosen is largely a matter of the surgeon's preference, as several retrospective studies have shown that the success rate of any technique is near 90%. (M. Isaka, 2014). Intracapsular and extracapsular techniques primarily aim to eliminate cranial tibial translation and stabilize the stifle to allow for periarticular fibrosis. Long term, this fibrosis becomes the primary restraint against cranial tibial translation (Vasseur PB, 2003).

Intracapsular techniques attempt to stabilize the knee by replacing the ruptured CrCL by passing an autologous tissue or synthetic graft through the joint. There are varieties of intracapsular techniques available, which differ only in the placement of the graft. Most surgeons performing an intracapsular technique will often augment the repair with an extracapsular reconstruction. Some of the most common intracapsular techniques are over-the-top procedure, under-and-over technique, Paatasama technique, and arthroscopic placement of the graft. (M. Isaka, 2014). This procedure is technically demanding, as it is very difficult to position the drill holes such that they exit exactly at the origin and insertion of the CrCL (McCurnin DM et al, 1971).

In contrast, extracapsular techniques usually involve the placement of sutures outside the joint or redirection of the lateral collateral ligament. Two other procedures, called the tibial plateau leveling osteotomy (TPLO) and the tibial tuberosity advancement (TTA), alter the biomechanics of the joint so that the animal can bear weight and walk without a cranial cruciate ligament. These procedures, in particular, have a steep learning curve and should only be performed by a veterinary surgeon with advanced training. (M. Isaka, 2014).

2.3.1 Osteotomy techniques

Osteotomy techniques, unlike the previous intra-articular and extracapsular techniques rely on changing the biomechanics of the stifle joint to effectively, remove the need for the CrCL thus repairing the problem of CrCL deficiency. The paradigm shift from incremental improvements in CrCL replacement to negating the need for a CrCL by altering the loading of the stifle joint started in the early 1980's with Slocum & Devine identifying cranial tibial thrust (CTT) as an important cause of rupture of the CrCL. Slocum & Devine further improved on their method and in 1993 published their seminal paper on the technique called *tibial plateau leveling osteotomy*, which has become perhaps the most widely used and studied osteotomy technique for CrCL deficiency. After the turn of the century, several other osteotomy techniques have been described. Some of these attempts to refine Slocum's original assumptions (e.g. TTO by Bruce 2007), some contest the assumptions and aim at remodeling the biomechanics of the stifle by altering a different site (e.g. TTA by Montavon et al, 2002).

2.3.2 Cranial tibial wedge osteotomy (CTWO)

In 1983 Slocum & Devine identified cranial tibial thrust (CTT) as being an important cause of CrCL rupture and cranial drawer motion in dogs. They claimed that then current methods only aimed at eliminating cranial drawer motion, and a new technique was needed to also combat the CTT. A year later they proposed their first technique aimed at eliminating the CTT, called the CTWO. (Slocum & Devine, 1984). The CTWO technique is based on removing a wedge-shaped fragment of bone from the proximal tibia to change the position of the proximal head of the tibia in relation to the femur. This also results in a change in the tibial axis, moving it cranially. The technique utilizes a steel jig and an osteotomy guide to direct the osteotomy. The resulting wedge, which was between 18° and 30° wide in the 1984 study, is then closed with a compression plate. (Slocum & Devine, 1984). However, this procedure results in a cranial shift of the functional axis of the tibia leading to inadequate leveling of the tibial plateau. As a result, "over rotation" of the tibial plateau is necessary to achieve functional stability using this procedure. (Macias et al, 2002). The CTWO requires the use of another technique to eliminate the cranial drawer motion. In the 1984 paper the most commonly used technique was advancement of m. biceps femoris laterally and m. gracilis and m. semitendinosus medially. (Slocum & Devine, 1984).

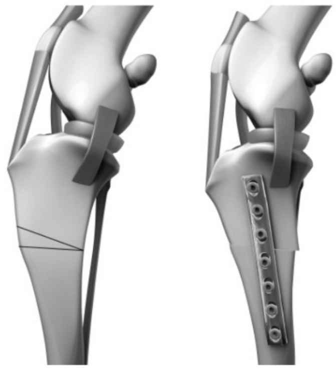

FIGURE 2: - THE CRANIAL TIBIAL WEDGE OSTEOTOMY INVOLVES REMOVING A WEDGE FROM THE TIBIA (LEFT) AND FUSING THE REMAINING PROXIMAL AND DISTAL PORTIONS OF THE TIBIA (RIGHT) (KIM, POZZI ET AL, 2008).

2.3.3 Tibial plateau leveling osteotomy (TPLO)

In their 1993 paper of the stifle surgery compilation of the Veterinary Clinics of North America Small Animal Practice series, Slocum & Devine methodically detail the short comings of the then current intra-articular and extracapsular techniques. They propose a new osteotomy-based technique, the tibial plateau leveling osteotomy. The TPLO is an evolution from CTWO, proposed nearly a decade prior. Like the CTWO, it aims not at replacing or substituting the failed CrCL, but instead on changing the biomechanics of the stifle joint to neutralize the CTT and thus negate the need for the CrCL. This is achieved by leveling the tibial plateau hence the name for the originally patented technique.

The leveling is performed by creating a radial osteotomy, with the help of a custom jig and custom radial saw, into the caudal edge of the proximal tibia. This fragment is then rotated so that the tibial plateau is perpendicular with the functional axis of the tibia. Once the fragment is in optimal position it is secured with a custom TPLO compression plate and the surgical site closed routinely. (Slocum & Devine, 1984).

FIGURE 3 - THE TIBIAL PLATEAU LEVELING OSTEOTOMY ROTATES THE PROXIMAL PORTION OF THE TIBIA SO THAT THE SLOPE IS PERPENDICULAR TO THE FUNCTIONAL AXIS OF THE TIBIA. A PLATE SECURES THE ROTATED TIBIA FOR FUSION OF THE TWO TIBIA PIECES (KIM, POZZI ET AL, 2008).

2.3.4 Tibial tuberosity advancement (TTA)

Advancement of the tibial tuberosity for treatment of CrCL deficiency was first published as a lecture during the 1st World Orthopaedic Veterinary Congress in Munich, 2002, by Montavon, Damur and Tepic. They propose that CrCL injury is due to a tibiofemoral shear force (Montavon et al, 2002). They also contend that the total joint force of the stifle is parallel to the patellar ligament, unlike Slocum, who maintains that it is parallel to the functional axis of the tibia (Montavon & Tepic, 2006). The principal concept of the TTA technique is to advance the tibial tuberosity to such an extent that the tibial plateau is perpendicular with the patellar ligament. This would reduce the tibiofemoral shear force to zero. The surgery involves sawing apart the cranial edge of the tibial tuberosity, placing a customized spacer (a cage) of appropriate size between the tibial body and osteotomy piece and then securing the pieces with a custom metallic plate or “tension band” (Montavon et al, 2002). To accelerate healing the open wedge osteotomy can be filled with autogeneous or allogeneic cancellous bone graft before standard closure of the surgical site (Montavon & Tepic, 2006).

FIGURE 4: TIBIAL TUBEROSITY ADVANCEMENT INVOLVES CUTTING THE CRANIAL ASPECT OF THE TIBIA ALONG THE CUT LINE, LEFT, AND FIXING THE CUT PORTION MORE CRANIALLY TO ALTER THE INSERTION DIRECTION OF THE PATELLAR LIGAMENT, RIGHT (KIM, POZZI ET AL, 2008).

2.3.5 Proximal tibial osteotomy (PTIO)

Damur et al. (2003) suggested an alternative technique to the TPLO called the proximal tibial osteotomy or PTIO. The technique attempted to accomplish the same end result as the TPLO technique, neutralizing CTT by changing the tibial plateau angle (TPA), but with the added benefit of not requiring custom tools. The procedure is performed from a medial parapatellar approach. Two linear osteotomies are made to create a wedge necessary for turning the tibial plateau. The pivot point of the wedge being at the level of the caudodistal end of the medial collateral ligament. A horizontal corticotomy is then made from the distal end of the wedge to the caudal edge of the tibia to enable rotation of the caudoproximal fragment. (Damur et al, 2003) The fragment is attached with two positional screws. The distal screw is placed perpendicular to the fragment and the proximal directed through the osteotomy plane in a caudolateral direction to the tibial tuberosity. The arthrotomy is then closed and the medial and lateral fasciae around the stifle and the femoral condyles imbricated with horizontal mattress sutures. (Damur et al, 2003).

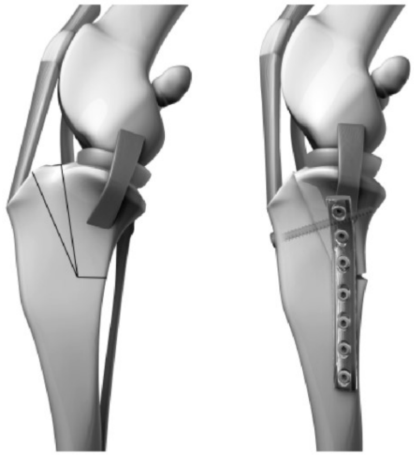

FIGURE 5: PROXIMAL TIBIAL OSTEOTOMY INVOLVES MAKING A WEDGE OSTECTOMY WITH THE BASE OF THE WEDGE LOCATED BETWEEN THE BURSA OF THE PATELLAR TENDON AND THE CRANIAL ASPECT OF THE MENISCI. (KIM, POZZI ET AL, 2008).

2.3.6 Triple tibial osteotomy (TTO)

Bruce et al. proposed in 2007 a technique combining a TTA and a CTWO for the treatment of CrCL deficiency. The technique is called the triple tibial osteotomy due to the three osteotomies performed: a partial tibial crest osteotomy like in the TTA and two osteotomies to create a partial tibial wedge as in the CTWO. The final result is similar to the TTA with the tibial plateau made perpendicular to the patellar ligament. (Bruce et al, 2007). The surgery is performed from a medial parapatellar approach. The osteotomies are made with the help of a custom saw guide and osteometer. The tibial crest osteotomy (TCO) is performed first with the wedge osteotomy, which in some early cases was a complete ostectomy, but refined in later cases to a partial osteotomy, performed second. The osteotomies are performed by first drilling a transverse 2 mm hole on the tibia from which the osteotomies are started and proceeding distally and cranially or proximally as necessary. The wedge osteotomy is reduced with the help of forceps and the site secured with a TPLO compression plate. Autogeneous cancellous bone graft harvested from the wedge osteotomy is used to fill the TCO gap before routine closure of the surgical site. (Bruce et al, 2007).

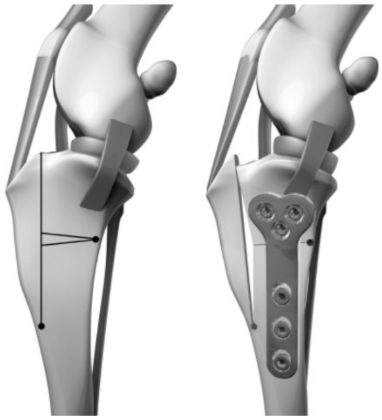

FIGURE 6: THE TRIPLE OSTEOTOMY COMBINES THE CTWO WITH THE TTA BY PERFORMING THREE OSTEOTOMIES IN THE TIBIA (KIM, POZZI ET AL, 2008).

2.3.7 Circular tibial tuberosity advancement (cTTA)

Verdonck & Petazzoni (2009) proposed the cTTA technique as a combination of the TPLO and TTA techniques. The key disadvantage of TTA is the opening osteotomy, which creates a bone defect as well as requiring a predetermined sized spacer (cage) for the correction of the advancement of the tibial tuberosity (Petazzoni, 2010). The cTTA combines the radial osteotomy of the TPLO with the TTA by performing the radial osteotomy not on the caudal edge of the distal tibia like in the TPLO, but on the tibial tuberosity. After radial osteotomy, the tibial tuberosity is rotated cranially and proximally until the tuberosity advances to a TTA type position with the tibial plateau slope perpendicular to the patellar ligament. The displaced tuberosity is secured with a custom T-shaped locking plate and the surgery site closed routinely. (Petazzoni, 2010).

2.3.8 Modified Maquet technique (MMT)

Etchepareborde et al. (2011) proposed the use of a modified Maquet technique previously used in human stifle surgery as a modification of the TTA procedure. The technique involves a tibial crest osteotomy similar to the TTA procedure with a TTA cage used for advancing the crista tibiae. Unlike TTA, no tension band implant is placed to secure the cranially displaced crista tibiae. Instead the distal tibial crest is either secured in place with a wire or as not secured at all. Also, since the crista tibiae is not detached distally and thus not displaced proximally, the patellar ligament is distended and patella may slide distally in the trochlear groove possibly causing patella baja. (Etchepareborde et al, 2011).

FIGURE 7: ILLUSTRATION OF MMT. LONG OSTEOTOMY (UP TO AROUND 23 LENGTH OF TIBIAL CREST): LENGTH OF OSTEOTOMY; B (BLACK LINE): ANGLE OF OPENING (A); C (BETWEEN BLACK ARROWS): CORTICAL HINGE. (MICHAEL D. LEFEBVRE ET AL, 2017).

2.4 How does the TPLO operates?

The objective of the Tibial Plateau Leveling Osteotomy (TPLO) is to redesign the stifle so the cranial cruciate is unnecessary for joint stability. By eliminating the slope of the tibia, thrust is eliminated. This is kind of "biomechanical" fixation. The 'new' design of the dog's knee, then begins to rely on the other ligaments within the knee to stabilize the knee over time. (Randy J. Boudrieau, 2009).

Basically, a curvilinear cut is made to the upper portion of the tibia. This cut portion of the tibia is then rotated on the order of about 20-30 degrees thereby creating a more level plane or surface on the top of the tibia upon which the femur can rest. The cut and repositioned portion of the tibia is then secured to the lower portion of the tibia. (Horan et al, 2013).

The success of the TPLO procedure has been based on the return to full flexion of the stifle, muscle mass and limb function, and the apparent lack of joint inflammation and slowing of progressive degenerative joint disease within the joint. The TPLO is designed to eliminate tibial thrust. This procedure has provided performance dogs with the ability to return to normal function while handling the highly competitive demands of their sport or work. Thus, a family pet is even better able to participate in normal daily activities without restriction of activities or residual lameness that can frequently be seen with other types of repair. The TPLO involves making a curved cut in the tibia bone at the level of the tibial plateau. The tibial plateais then rotated in order to flatten the slope. A plate and screws are used to hold the tibial plateau in place so that the bone can heal. (Randy J. Boudrieau, 2009).

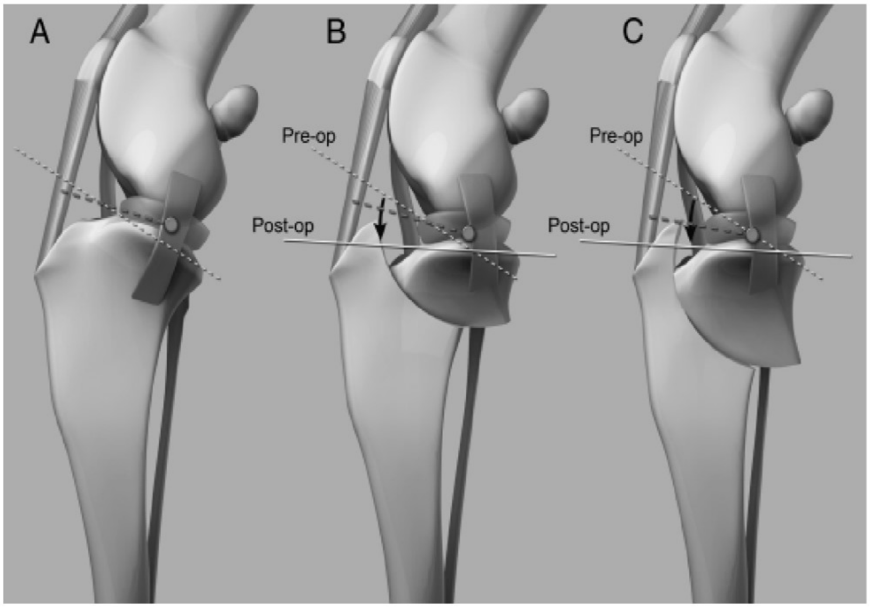

FIGURE 8: SCHEMATIC REPRESENTATION OF THE LEVER ARM IN THE STIFLE JOINT BEFORE (A) AND AFTER (B AND C) TIBIAL PLATEAU LEVELING OSTEOTOMY (TPLO). (A) PATELLAR TENDON LEVER ARM (BENDING MOMENT) IN THE STIFLE JOINT EXTENDS FROM THE PATELLAR TENDON TO THE FEMOROTIBIAL CONTACT POINT (HEAVY DOTTED LINE). (B) AFTER TPLO, THE PATELLAR TENDON LEVER ARM (HEAVY DOTTED LINE) SHORTENS MARGINALLY PROVIDED THAT THE OSTEOTOMY IS CENTERED ON THE INTERCONDYLAR TUBERCLES (BECAUSE OF THE LOSS OF BONE REMOVED BY THE KERF OF THE SAW BLADE). (C) POSITIONING OF THE OSTEOTOMY MORE OFTEN IS CENTERED JUST BELOW THE JOINT SURFACE AND CAUDAL TO THE MEDIAL COLLATERAL LIGAMENT; FURTHERMORE, ANY ADDITIONAL PLACEMENT OF THE OSTEOTOMY MORE DISTAL OF THE TIBIA RESULTS IN FURTHER SHORTENING OF THE PATELLAR TENDON LEVER ARM WITH ROTATION OF THE TIBIAL PLATEAU (HEAVY DOTTED LINE; COMPARE WITH PART [B]. (RANDY J. BOUDRIEAU, 2009).

The stability with conventional plates is connected with the pressure of the plate to the bone, caused by the traction force of the screws. Locking systems function as internal fixators achieving stability by locking the screw to the plate. The conic coupling consists of coupling of a conic male and a female part that are complementary. The grip, the friction and the micro-welding between the two surfaces into contact and the elastic deformation accomplish the stable union of the two elements (Fig. 8). Characteristics of this way of coupling are described in all common books of mechanics. In order to “weld” the male and female surfaces of a cone, an axial force Fa is needed. The axial force Fa induces a tangential force Ft that resists against slipping and gliding between the surfaces. A little axial force is needed with a small conic angle to get a very strong bond. The background of this study comes from the human experience in orthopedics and traumatology. The internal fixator Fixing, is a veterinary orthopedic implant for internal fixation with angular stability. The locking mechanism of the Fixing device is based on a conical coupling system where the conic head of the screw is locked in the corresponding conic hole of a titanium alloy insert that is screwed into the plate. Fixing device consists of: a support, with threaded holes where inserts can be screwed in. The support is made of orthopedic stainless steel. Inserts are made of titanium alloy, externally threaded, that can be screwed into the supports (Fig. 8) The insert hole is conical, to lodge, the head of the screw. The grooves on the edge of the insert couple with the “extractor-device”, the instrument used to screw and unscrew them from the support (Fig. 8). The support plus the inserts give what we usually call “the plate”. The screw is a self-threading, self-locking steel screw. The conical head of the screw perfectly fits with the conical hole of the insert. The conical coupling occurs between the head of the screw and the insert. The plate plus the screws give the implant. Despite to the appearance of a plate the Fixing system works like an external fixator and has to be compared with an external fixator to better understand its mechanism of action and its function. The aim of this retrospective investigation was to evaluate the outcome of TPLO stabilized by means of a conic coupling fixed-angle device. (M. Petazzoni, 2008).

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2.5 TPLO models

Tibial plateau leveling osteotomy (TPLO) was introduced in 1993 for treatment of the cranial cruciate ligament (CrCL) deficient canine stifle joint. (Kowaleski et al, 2013).

Various means have been used to fix and secure the cut portion of the tibia to the remaining portion of the tibia. Initially, screws and wire were used for this purpose. Later, those in the art used metal plates that were anchored into the tibia in both the bottom portion and upper, cut portion by way of bone screws. (Horan et al, 2013).

A variety of plating designs from different manufacturers have become available for use in the TPLO procedure. All of them are made of blocks of solid rigid polyurethane foam component. The size of the plates is playing an important rule. 60mm x 40mm x 68mm blocks uses for stimulating the proximal portion of the tibial diaphysis, while 60mm x 40mm x 58mm blocks uses for stimulate the tibial plateau. (Jude Thaddeus Bordelon, 2010).

Various TPLO plate constructs have been biomechanically compared. One study compared the stiffness of three commonly manufactured TPLO plates: Slocum, Securos and Synthes plates (kloc PA et al, 2009). The study found the Slocum and Securos plates to have similar stiffness. The Synthes plate was significantly stiffer than the Slocum plate. Modes of failure for the similarly stiff Slocum and Securos plates were confined to plastic deformation. The majority of the Synthes plates underwent elastic deformation. A similar subsequent study using a gap model evaluated the properties **of** other TPLO plate designs. (Bordelon J. et al, 2009).

Nowadays, the most common plates versions are the standard TPLO plate (SP), the low profile TPLO plate (Lop), the locking TPLO plate (LocP) and the broad locking TPLO plate (bLocP) (Jude Thaddeus Bordelon, 2010).

2.5.1 Orthomed TPLO plates

Orthomed company (Veterinary instrumentation, implants & training for surgeons of all levels) were designed TPLO plates which are available in 3 sizes; 2.7mm, 3.5mm and 3.5mm Broad. All the plate pre-contoured to the top of the tibia with minimal further contouring to achieve a perfect fit. The proximal hole configuration of the 3.5mm Broad plate has been updated to minimize the risk of crossing screws, which reduces surgery time and considerably simplifies the procedure. The plates are precision engineered from medical-grade stainless steel and laser cut. (Orthomed. Catalogue, 2018).

Figure 9: Standard TPLO plate. Designed with 3 different sizes:
Plate number 1: 2.7mm left and 2.7mm right.
Plate number 2: 3.5mm left and 3.5mm right.
Plate number 3: 3.5mm broad left and 3.5mm broad right. (Orthomed. Catalogue, 2018).

Figure 10: Pre-Bent TPLO plate. Designed with 3 different sizes:
Plate number 1: 2.7mm Pre-Bent left and 2.7mm Pre-Bent right.
Plate number 2: 3.5mm Pre-Bent left and 3.5mm Pre-Bent right.
Plate number 3: 3.5mm Pre-Bent broad left and 3.5mm Pre-Bent broad right.
(Orthomed. Catalogue, 2018).

FIGURE 11: SOP™ TPLO PLATE. DESIGNED WITH 3 DIFFERENT SIZES: PLATE NUMBER 1: 2.7MM.
PLATE NUMBER 2: 3.5MM.
PLATE NUMBER 3: 3.5MM BROAD.
(ORTHOMED. CATALOGUE, 2018).

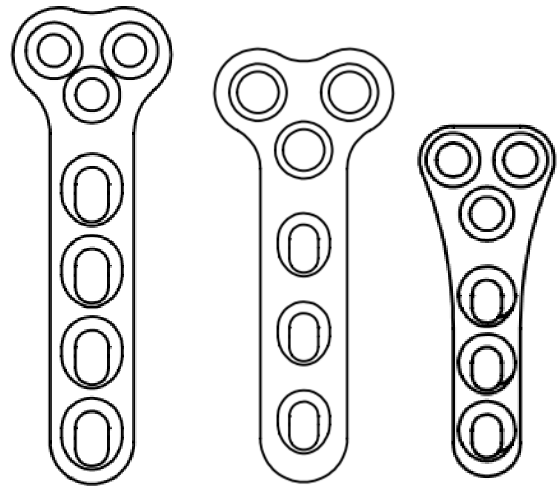


FIGURE 12: CLOVERLEAF TTO/TPLO PLATES. DESIGNED WITH 8 DIFFERENT VERSIONS: 2.0MM, 2.4MM, 2.7 AND 3.5MM SIZES. (VETERINARY INSTRUMENTATION, CATALOGUE, 2015).

2.5.2 Cloverleaf TTO/TPLO Plates

The Standard TTO Plate is a cloverleaf TPLO Plate. Being positioned over the caudal 2/3 of the tibia. the plate selected is typically a little smaller than is the case with a wedge TPLO. (Veterinary Instrumentation, catalogue, 2015).

2.5.3 pre-contoured and locking TPLO plates

TPLO locking plates use locking screws in the proximal tibial plateau segment and the plate is pre-contoured to match the shape of the proximal tibia. The plate does not need to be contoured to the shape of the proximal tibia during surgery, which saves time and avoids potential plate weakening by doing so. All the screws are set to avoid the joint space and allow for optimal load sharing. Locking holes are all stacked so will accept a cortical screw if necessary, and there are 2 compression holes in the plate shaft. (Veterinary Instrumentation, catalogue, 2015).

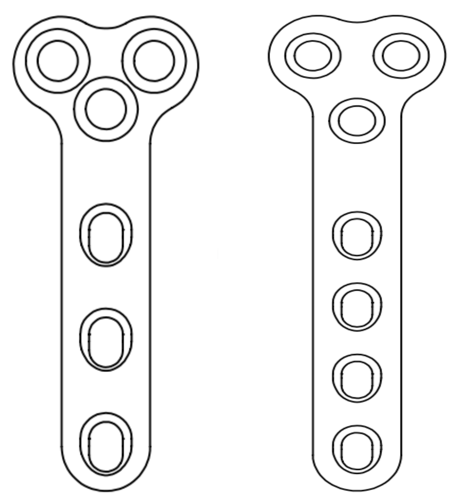


FIGURE 13: PRE-CONTOURED AND LOCKING TPLO PLATES. DESIGNED WITH 11 DIFFERENT VERSIONS: 3.0MM, 3.5MM, 3.5MM BROAD, 4.5MM, 4.5MM BROAD AND 6.5MM SIZES. (VETERINARY INSTRUMENTATION, CATALOGUE, 2015).

2.5.4 Slocum Style TPLO Plates

The plate was originally developed by Barclay Slocum in the 1980s.

The aim is to achieve a Tibial Plateau Angle (TPA) of 5 to 7 degrees. Once rotated, the tibial plateau segment is temporarily held in position by a single K-wire, or fracture reduction forceps. Then the plate and screws are applied for definitive stabilization. (Veterinary Instrumentation, catalogue, 2015).

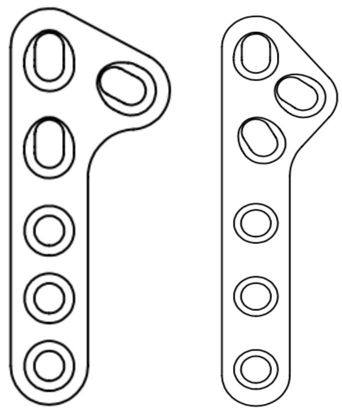


FIGURE 14: SLOCUM STYLE TPLO PLATES. DESIGNED WITH 6 DIFFERENT VERSIONS:
TPLO PLATE BROAD SLOCUM STYLE 3.5MM LEFT AND RIGHT.
TPLO PLATE SLOCUM STYLE 3.5MM LEFT AND RIGHT.
TPLO PLATE BROAD SLOCUM STYLE 2.7MM LEFT AND RIGHT.
TPLO PLATE SLOCUM STYLE 2.7MM LEFT AND RIGHT.
TPLO PLATE SLOCUM STYLE 2.4MM LEFT AND RIGHT.
TPLO PLATE SLOCUM STYLE 2.0MM LEFT AND RIGHT.
(VETERINARY INSTRUMENTATION, CATALOGUE, 2015).

2.5.5 Locking TPLO Plates

Plates are available in 2.7mm, 3.5mm and 3.5mmm broad, covering the vast majority of TPLO patients. The head section is both wider and shallower than any other locking design maximising the area of bone spanned to give very even force distribution across the whole of the proximal segment whilst also permitting a very proximal osteotomy. The locking holes are both convergent and divergent to maximize pull-out resistance and angled to avoid articular surfaces. (Veterinary Instrumentation, catalogue, 2015).

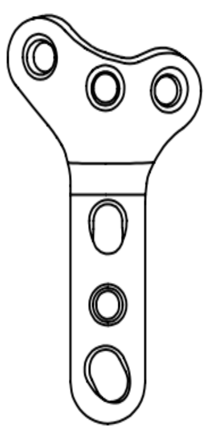


FIGURE 15: TPLO PLATES WITH LOCKING SCREW TECHNOLOGY. DESIGNED WITH 3 DIFFERENT VERSIONS:
TPLO PLATE LOCKING 2.7MM LEFT AND RIGHT
TPLO PLATE LOCKING 3.5MM LEFT AND RIGHT
TPLO PLATE BROAD LOCKING 3.5MM LEFT AND RIGHT
(VETERINARY INSTRUMENTATION, CATALOGUE, 2015).

2.5.6 TPLO plate examples according to the weight and the breed

FIGURE 16: Toy Poodle TPLO T-plate support. For 2.5kg. contain 4 holes. 23mm length. (Intrauma. Catalogue, 2018).

FIGURE 17: Mixed breed TPLO L-plate support. For 2.8kg. contain 4 holes. 25mm length. (Intrauma. Catalogue, 2018).

FIGURE 18: Scottish terrier TPLO T-plate support. For 8.4kg. contain 4 holes. 25mm length. (Intrauma. Catalogue, 2018).

FIGURE 19: Mixed breed TPLO T-plate support. For 11kg. contain 4 holes. 32mm length. (Intrauma. Catalogue, 2018).

FIGURE 20: Pointer TPLO T-plate support. For 17kg. contain 4 holes. 45mm length. (Intrauma. Catalogue, 2018).

FIGURE 21: Labrador TPLO T-plate support. For 33kg. contain 4 holes. 53mm length. (Intrauma. Catalogue, 2018).

FIGURE 22: Bernese TPLO T-plate support. For 44kg. contain 6 holes. 76mm length. (Intrauma. Catalogue, 2018).

FIGURE 23: Rottweiler TPLO T-plate support. For 53kg. contain 5 holes. 56mm length. (Intrauma. Catalogue, 2018).

FIGURE 24: Italian Masttif TPLO Large Breed. For 65kg. contain 6 holes. 86mm length. (Intrauma. Catalogue, 2018).

2.5.7 The standard TPLO plate (SP)

This plate which also called the Slocum TPLO plate was designed to accommodate 3 cortical screws in both the rotated proximal segment and in the diaphysis. In the head of the plate, the most proximal screw-hole was round (neutral) and the other 2 were oval (load) holes oriented radially so that they could potentially be aligned perpendicular to the radial cut. An additional 3 round screw-holes (neutral) were aligned with the long axis of the straight portion of the plate. This plate could be applied in a neutral fashion, or alternatively under compression using the proximal load holes; the design of the 2 proximal load holes was believed to be able to apply improved compression of the radial orientation of the 2 opposing bone surfaces. (Kowaleski et al, 2013). The Slocum idea was that most of the motives for rupture and fail to repair of CCL reside in the rear limb anatomical conformation, particularly represented by the excessive tibial plateau slope in respect with mechanical axis of the tibia. The tibial slope finally increases, during stance and moreover during motion, the cranial tibial trust (CTT) (Henderson and Milton, 1978).

FIGURE 25: SLOCUM TPLO PLATE. (KOWALESKI ET AL. 2013).

2.6 Features

The TPLO plate has many similarities to existing bone fixation plates, with a few important improvements. The technical innovation of locking screws and an anatomical contour provide the ability to create a fixed-angle construct. (DePuy Synthes vet, 2013).

There are six major cross-sectional area size plates and two basic hole types. It is important to choose a plate of correct length, also. When using a plate with a round-hole design, the proper size plate must be chosen so that the tension device can be used at the end of the plate. When using the dynamic compression system, the tension device need not be applied; therefore, a plate approximately one- or two-hole lengths longer can be used. (Charles D. Newton, David M. Nunamaker, 1985).

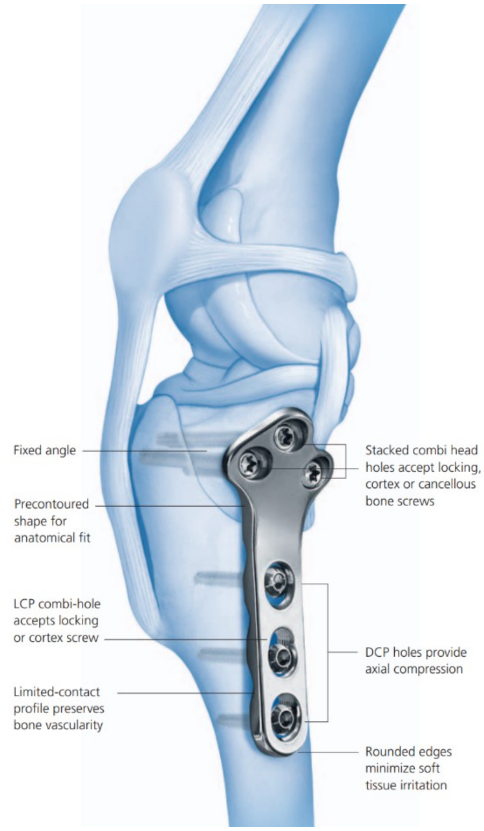


FIGURE 26: THE DIFFERENT HOLE CHARACTERISTICS OF THE TPLO PLATE (SYNTHES VETERINARY, 2013).

The arched surface of the cylinder that defines at least a part of the bone-contacting Surface for the proximal portion of the plate can have varying dimensions depending on the anatomy in which it is to be used. (Horan et al, 2013).

The most common TPLO plates are available in 2.7, 3.5 small, 3.5 and 3.5 broad versions and can be uses either with conventional or locking screws. In addition, the TPLO plates designed with pre-contoured for reaching anatomic fit of the bone and the screw trajectory in head holes is designed to minimize likelihood of penetrating articular surface and osteotomy (DePuy Synthes vet, 2013).

Although plate-and-screw techniques have been used sporadically in veterinary medicine for a long time, they have become a popular method only in the last decade. (Charles D. Newton, David M. Nunamaker, 1985).

2.6.1 holes

The common Vet TPLO plate is designed with three distinct screw-hole technologies to accommodate all plating modalities. (DePuy synthes, 2013).

2.6.2 Proximal holes

The proximal portion has at least three locking screw holes (Horan et al, 2013) which called stacked combi-holes (Synthes Veterinary, 2013) that arranged such that there is a superior, proximal Screw hole and a cranial and a caudal screw hole that are both distal from the superior screw hole. Preferably, the superior screw hole is designed such that the superior screw will be angled distally from the bone-contacting surface and also preferably caudally. Preferably, the cranial screw hole is designed such that the cranial screw will be angled caudally from the bone-contacting surface. Also preferably, the caudal screw hole is designed such that the caudal screw will be angled cranially from the bone-contacting Surface. (Horan et al, 2013).

The use of a hand drill or brace usually causes a large amount of drill bit wobble, which produces oval holes that will not allow maximal purchase by the screw, thereby weakening the internal fixation. Therefore, it is recommended that a power drill be used whenever possible. Even with a power drill it is helpful to use drill guides to prevent wobble and the formation of oval holes. A good drill bit should drill approximately 1 mm of bone per second. Drilling at rates slower than this can produce thermal damage in bone. (Charles D. Newton, David M. Nunamaker, 1985).

2.6.3 Distal holes

The distal portion is made of two dynamic compression plate (DCP) holes separated by one or two central locking compression plate (LCP) combi-holes. The DCP holes accept cortex screws that may be placed in either loaded or neutral positions, depending on whether or not interfragmentary compression is desired. The LCP combi-hole(s) in the center of the plate shaft accepts either cortex screws or locking screws. (DePuy synthes, 2013). The cortex screw should be placed in the unthreaded portion of the locking combi-hole in either a loaded or neutral position. Alternatively, a locking screw may be used in the threaded portion of the combi-hole when indicated. The three stacked combi-hole in the plate head accept either cortex, cancellous bone, or locking screws. If locking screws are to be used in conjunction with cortex or cancellous bone screws in the plate head, the cortex screws must be inserted and tightened first, before any locking screws are inserted. If cortex screws are used, the plate must be appropriately contoured to the bone. (DePuy synthes, 2013).

FIGURE 27: THE STANDARD TPLO PLAT WHICH DEMONSTRATE THE CHARACTERISTIC OF THE DIFFERENT HOLES TYPES.

2.6.4 Screws

Screws are inserted into the bone through drill holes. The process of drilling is an important one, since the interface between the screw and the bone should be complete. (Textbook of small animal orthopedics, 1985).

There are two basic types of screws the fully threaded cortical screw and the partially threaded cancellous screw. Both screws are available in a wide variety of sizes necessary for the varied problems that arise in small- animal orthopaedics. The efficacy of the various screws depends on the location where they are used and on the function that is expected of them. In general, canine bone is relatively hard and the use of a cancellous screw at any location is rarely necessary. Cortical screws are adequate for nearly all applications in the dog, except in some young, growing dogs and dogs with disuse osteoporosis, as well as those with metabolic bone disease. Cancellous screws should be used only when failure (stripping) of a cortical screw has occurred or in an animal in whom previous drill holes have indicated that failure of the cortical screw is likely to occur. (Charles D. Newton, David M. Nunamaker, 1985).

At the proximal portion, the bone plating system according to the present invention can implant with locking, cortex or cancellous bone screws (Synthes Veterinary 2013) which character as non-locking screws, and locking screws. (Weaver et al. 2006), while the distal screws, which located at the bone-containing surface are include locking or cortex screws (Synthes Veterinary, 2013).

The cancellous screw is a partially threaded screw that exerts its interfragmentary compression by having all its threads on one side of the fracture plane; these threads exert their force against the head of the screw, which rests on the other side of the fracture. they available in two diameters Ñ4 mm and 6.5 mm, and the large 6.5-mm screw is available in two thread lengths Ñ16 mm and 32 mm. On the other hand, the cortical screw is a fully threaded screw that produces interfragmentary compression by means of a large gliding hole in the ciscortex (near cortex) and a smaller threaded hole in the transcortex (far cortex). They are available in sizes that range from 1.5 mm to 4.5 mm thread diameter. (Charles D. Newton, David M. Nunamaker, 1985).

At least one first hole passing through the upper and bone-contacting Surfaces and having a thread, and at least one second hole passing through the upper and bone-contacting Surfaces. The bone plating system also includes a first screw having a shaft with a thread for engaging bone and a head with a thread configured and dimensioned to mate with the thread of the first hole, and a second screw having a shaft with a thread for engaging bone and a head. The first and second screws remain seated in their respective holes for substantially as long as the bone plate is implanted. Preferably, the bone plate includes a plurality of first and second holes, and a corresponding plurality of first and second screws are provided. (Synthes Veterinary, 2013).

In order to facilitate insertion, the first and second screws can be a self-tapping screws. These screws can also be self-drilling screws. Additionally, the first and second screws can be cannulated for insertion of a guide wire to guide screw placement. The first plate hole can have a Substantially conical shape with a double-lead thread. (Weaver et al, 2006).

The cortex screw should be placed in the unthreaded portion of the locking combi-hole in either a loaded or neutral position. Alternatively, a locking screw may be used in the threaded portion of the combi-hole when indicated. The three stacked combi-hole in the plate head accept either cortex, cancellous bone, or locking screws. If locking screws are to be used in conjunction with cortex or cancellous bone screws in the plate head, the cortex screws must be inserted and tightened first, before any locking screws are inserted. If cortex screws are used, the plate must be appropriately contoured to the bone. (Synthes Veterinary, 2013).

2.7 TPLO complications

Recently, patellar fracture has been described as a postoperative complication after tibial plateau levelling osteotomy procedure (Rutherford et al, 2012).

Many reports of complications following TPLO have been published, most of these describe the early case experience at single institutions. Many alterations in the original description of the technique, particularly the emphasis that has been placed on osteotomy position, as well as the newly introduced array of fixation devices likely have resulted in the reduction in complication rate (BVOA, 2008). A study in 2004 reported radiographic findings in 40 dogs 6 months after being treated with TPLO. In this series 40% of dogs showed progressive osteoarthritic changes, 57.5% showed no progression and 2.5% showed a decreased in osteophytosis **(**Rayward RM. et al, 2004).

A complication rate ranging from 18.8% to 33.3% has been reported in association with the TPLO in the researches of Corr SA, Brown C. (2007), Stauffer KD et al (2006), Priddy NH et al (2003) and Pacchiana PD et al (2003). Complications include tibial crest fracture, fibular fracture, implant failure, joint infection, incisional infection, incisional edema, osteomyelitis, hemorrhage, meniscal injury, luxation of the long digital extensor tendon. Boudrieau RJ et al (2005) and Harasen GL, Simko E. (2008) Were reported on peri-implant sarcoma formation, distal patellar tendon thickening (Carey K at al, 2005) and patellar desmitis (Carey K et al 2005, Mattern KL et al, 2006).

Risk factors have been identified for a number of these complications in the researches of Wheeler JL et al (2003), Bergh MS et al (2008) and Kergosien DH et al (2004) that refer to simultaneous bilateral TPLO procedures, a thin tibial crest post-osteotomy, age, weight and location of the anti-rotational pin have been shown to predispose dogs to tibial crest fractures, and eventually, the higher body weight, magnitude of tibial plateau rotation and pre-operative TPA have been shown to increase the risk of fibular facture (Tuttle TA, Manley PA, 2009).

The problem with many plates currently in use is that they require the surgeon to manipulate the plate to conform to the tibia during the surgical procedure. This is often difficult because the plates are relatively thick and rigid, and thus are not easily bent into an acceptable shape. Furthermore, bending of the plate during the procedure can result in the screw holes becoming deformed. (Horan et al, 2013).

Another drawback with the TPLO plates currently available is that the screw holes in the plate for use with the upper, cut portion of the tibia are not designed for optimum fixation. (Horan et al, 2013).

2.7.1 Implant complications

Aiming errors that occur during surgical drilling procedures are a clinically important problem and includes errors which occurring during bone drilling, cutting and removal procedures. Specific veterinary examples include intra-articular screw placement (Fitzpatrick et al, 2010), creation of iatrogenic angular limb deformity during tibial plateau levelling osteotomy (Wheeler et al, 2003) and periprosthetic fracture during total joint arthroplasty (Liska, 2004).

Another veterinary examples include positioning errors occurring during placement of iliosacral screws or lumbosacral pedicle screws that occur at rates of 12.5% (Shales et al, 2010) and 33% (Smolders et al, 2012), respectively.

Small errors can be clinically important; for example, a 4° aiming error resulted in ventral exit of the drill from the sacral body in 58 per cent of feline sacral during an ex vivo study defining the safe corridor for sacral body screw placement (Shales et al, 2009). Even smaller margins of error may be encountered during trans-articular screw placement. For example, at atlantoaxial joint stabilisation, in which the available bone corridor can be 3 mm wide. Thus, although the reported mean aiming bias of 2°–2.2° might appear small, this degree of bias is sufficiently large to result in potentially important surgical errors in clinical practice. (Reves et al, 2013).

Plates and screws remain a popular means to manage many fractures; however, some fractures are sufficiently close to a joint, that they limit the amount of bone available to achieve a standard stable plate and screw fixation (Richard Meeson, 2017).

Implant-related complications are reported to occur in less than 10% of all TPLO procedures. Intra-articular placement of a jig pin, Kirschner wire, or screw can cause significant damage to the articular cartilage and may result in persistent or intermittent lameness, particularly if the problem is not immediately addressed. particular care should be taken when contouring bone plates with angle-stable screw fixation, as this may direct the screw proximally into the joint. Postoperative radiographs should be carefully evaluated and if a screw is suspected to be within the joint, the patient should be immediately returned to surgery to have the screw redirected or a shorter screw placed. Broken drill bits and Kirschner wires that do not violate the joint space typically do not prove to be problematical, and therefore do not need to be retrieved. A small number of anti-rotational Kirschner wires that are left in place are reported to loosen over time and subsequently require an additional surgery to remove the implant. Implants may fail postoperatively by bending, breaking, or loosening. Limb alignment and the degree of osteotomy healing should be carefully assessed at the time of diagnosis as not all implant failures necessitate re-operation. Aside from implant failure, indications for removal include implant-associated infection, local inflammation, and elective removal during subsequent treatment of meniscal tears or It has been postulated that it may be due to inadequate stabilization of the proximal plateau segment, improper osteotomy positioning, or a modulus mismatch between a rigid implant construct and relatively soft metaphyseal bone. If instability of the stifle and lameness result from resultant increase in the tibial plateau angle, additional stabilization of the stifle may be required to improve comfort and function in the patient. ‘Pivot shift’ may occur after TPLO due to uncontrolled internal rotation of the tibia during the stance phase of the gait. The cause of this complication has not been fully investigated, however, it has been hypothesized to be due to tibial torsion, angular deformity, excessive internal rotation of contralateral TPLO. (M. S. Bergh; B. Peirone, 2012).

Duane A. Robinson was claimed in his article that complications can occur during the recovery period following the TPLO procedure. This have a direct correlation with the patient comorbidities: advanced age, concomitant corticosteroid administration, and metabolic disease (eg, hyperadrenocorticism) which can play a role in fracture healing.

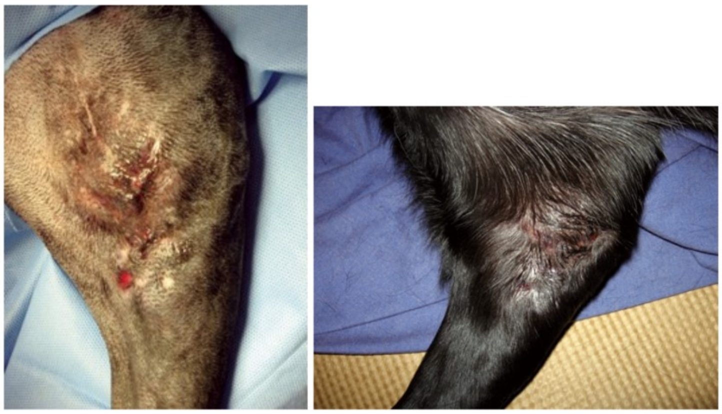


FIGURE 28: SURGICAL SITE IN DOG THAT HAS HEALED FROM TPLO, DEMONSTRATING DRAINAGE THAT COULD BE ASSOCIATED WITH IMPLANT-ASSOCIATED INFECTION. (DUANE A. ROBINSON).

Duane was mentioned that microbial infections involving TPLO screws implants often develop a bacterial biofilm, which confers resistance to systemic antimicrobial drugs. Thus, eradication of the infection necessitates removal of the implant once healing is complete. Of similar importance is the removal of any avascular bone and/or sequestrate that may be present. If a fracture or osteotomy is not healing in the expected amount of time, careful evaluation of implant construct and thorough patient evaluation are necessary.

FIGURE 29: POSTOPERATIVE TPLO PATIENT THAT DEVELOPED AN INFECTION AND SEQUESTRUM (DUANE A. ROBINSON).

Elective procedures such as TPLO long-term complications apparent on radiographs can include: Fracture of tibial tuberosity, Screw breakage or loosening, Patellar fracture, Septic arthritis, Tibial/fibular fracture. (Duane A. Robinson).

Bone-implant construct failure can occur due to a failure at the implant level, such as a broken screw or bent plate and it also can be associated with the bone, such as a tibial tuberosity fracture after TPLO. (Duane A. Robinson).

FIGURE 30: CATASTROPHIC FAILURE OF TPLO: NOTE THAT SCREWS IN PROXIMAL FRAGMENT HAVE PULLED OUT AND A FRACTURE OF PROXIMAL TIBIAL FRAGMENT IS PRESENT. THE FIBULA IS ALSO FRACTURED, WHICH ELIMINATES ITS FUNCTION AS AN INTERNAL SPLINT. (DUANE A. ROBINSON).

In the research of Alissa D. Gallagher and W. Daniel Mertens, TPLO was performed on 255 dogs and implant removal rat from infective dogs was evaluated.

According to the British Veterinary Orthopaedic Association (BVOA, 2008), one of the main complications following TPLO is associated with the patellar tendon, which can cause to patellar tendonitis (PTS) due to a lack of inflammatory cell infiltrate. In addition, Tibial tuberosity fractures can occur in case of fixation failure which leading to instability of the proximal tibial plateau segment with or without tibial tuberosity fracture. The BVOA claims that strict attention to principles of internal fixation, accurate apposition of the bone segment in both the sagittal and frontal planes as well as avoidance of single stage bilateral procedures should mitigate this complication. In addition, new, stiffer implants that feature angle stable, locking screws should provide superior fixation with less primary loss of reduction. Lastly, complications can be result with meniscal tears. These lesions can be tears missed at the initial surgical procedure, or tears that truly occurred following surgery which can lead to lameness.

Cancellous screws have two limitations for use in hard cancellous or cortical bone. If such a screw is placed in cortical bone, the cortical bone may grow around the shaft of the screw, thereby making it difficult or impossible to remove the screw following fracture healing. During removal, the screw will back out to a certain point and usually will break at the junction of the shaft and end thread. (Charles D. Newton, David M. Nunamaker, 1985).

Another problem with any partially threaded screw is that there is a stress concentration normally occurring at the junction of the thread and the shaft. Although one cannot presume that the screw will break during insertion in normal canine bone, it is possible for the threaded portion to fracture from the shaft, especially if the junction occurs just at the fracture line. In this case the threaded portion of the screw is difficult to remove. (Charles D. Newton, David M. Nunamaker, 1985).

2.7.2 Infection

G. Brown et al, were tried to evaluate the long-term functional outcome following surgical site infection (SSI) in 683 dogs that underwent TPLO (according to Slocum), and to identify predictive factors for infection development and management. The SSI cases were examined six weeks after either antibiotic administration or implant retrieval.

The results show complications after the procedures in 10-34% and 2–4% of the cases required surgery to resolve it, particularly when signs of SSI develop or are recognized later in the postoperative period. (G. Brown, T. Maddox, M. M. Baglietto Siles, 2016).

2.7.3 Suture complications

Although results with the TPLO procedure are usually good, complications can include delayed osseous union, nonunion, and mechanical failure with loss of reduction prior to attainment of osseous union. (Samuel P. Franklin1, Emily E. Burke, Shannon P. Holmes, 2017).

2.7. 4 Complications associated in small dogs

In a study that was performed by Rebekah Knight and Alan Danielski1 between January 2010 and July 2014, which were evaluated the rate and nature of complications after TPLO surgery in small dogs with TPAs>30° and investigated factors associated with increased complications of 129 dogs underwent TPLO using a 2.0 mm plate was found that the major complication rates following TPLO surgery have been reported between 3.1% and 7% and included TT avulsion/fracture, fracture of tibia or fibula, delayed meniscal tears, implant failure, patellar luxation and implant-associated sarcoma. They also founded that the main complications observed in this study were incisional complications and transient periods of lameness.

It has been suggested that small dogs may have steeper tibial plateau angles (TPAs) than large dogs, which has been associated with increased complication rates after TPLO such as patellar tendonitis, tibial tuberosity (TT) fracture and implant failure. (Rebekah Knight, Alan Danielski1, 2018).

In small dogs, Complication rates associated with TPLO have been reported between 9.7% and 39% which include incisional complications, TT fractures and implant failure/pin migration after TPLO surgery. (Rebekah Knight, Alan Danielski1, 2018).

3. Goal:

The goal of this discussion is to interduce a new model of TPLO plate which called ‘Locking Vision’ and to show its unique characteristics which provide a major advantages over the standard TPLO plates that exist today.

4. Methods:

By performing observation on 6 different cases of the Locking Vision TPLO that have been implanted, and by their radiography images analysing, we would be able to observe the differences between the state of the CCL rupture prior to the surgery, the effect of the TPLO plate right after the surgery and the success of the treatment refer to the healing process that can be evaluate thanks to the ‘window’ that provide in the plate.

5. Discussion

5.1 Introduction

Cranial cruciate ligament disease is one of the most common orthopedic conditions of dogs has become a multibillion-dollar business in veterinary medicine. Despite the prevalence of disease and its economic impact, few, if any, studies directly compare the long-term safety and efficacy of the major surgical procedures used to manage disease in dogs. (Scott A. et al, 2011).
The Technique Guide of Tibial plateau leveling osteotomy in the canine proximal tibia, which was published by Synthes company, described the main advantages of the Synthes TPLO plates. It was mention that the TPLO Plate provides stable fixation of the canine proximal tibia to promote healing at the osteotomy site. When used with locking screws, the plate and screw construct provide a locked, fixed-angle construct. In addition, the rounded edges and the anatomical design of this plate assist in preservation of the blood supply by minimizing surface contact with the bone and disruption of soft tissue, and preserving bone vascularity. This plate also anatomically fit the proximomedial canine tibia, providing proper alignment and optimal function of the repaired stifle. The plate provides secure fixation which may contribute to pain reduction and permits early, active rehabilitation conducive to optimal recovery. (Synthes Veterinary, 2013).

In the initial tibial plateau leveling procedure described by Slocum, cranial closing wedge osteotomy was performed in 19 stifles (Slocum & Devine, 1984). Excellent outcome was reported in 9/9 dogs followed out to 1-year. Additionally, no cranial drawer motion was palpable nor was any progression of osteoarthritis noted on radiographs. Similar results were reported in a case series of 394 stifles repaired using the cranial closing wedge technique or TPLO (Slocum B, Slocum TD, 1998). Good to excellent functional results were reported in 94% of cases followed long term. Radiographic findings were not reported in this series.

The success rate of surgical treatment is multi-factorial and depends on surgeon experience and on the studied population. The subjectivity of the surgeon in assessing clinical and radiographic results influences the outcome as well. (Bennett D, May C, 1991). Most of the authors report a satisfactory functional recovery in 80 to 98 per cent of the dogs operated on. After successful surgery, the limb is fully functional within 8 to 12 weeks postoperatively. (Shires PK et al, 1984, Zahm H. 1966, Denny HR, Barr ARS, 1987).

Although TPLO has very good chance of healing the CCL, when we compare it to the other main methods such as the TTA, It seems that all the research that have been made on the subject can find small differences in the outcome of both TTA and TPLO , respect to the ability of the dog to walk normally as possible after the surgery. (Scott A. et al, 2011).
According to 8 different researches, the data shows that by using one of the three methods, 90 percent of the dogs will gain full movement recovery between 6-8 weeks. (Jan Mattila, 2012).

One point that most of the literature agrees on is that the biggest difference between each method is the complications that accord after the treatment. (Scott A. et al, 2011).

The most common current grouping of complications is division into three temporally separate groups: perioperative, short term post-operative and long-term post-operative. In the last 25 years the reporting of complications has improved significantly. Where the 1989 study on fibular head transposition by Mullen et al. only reports the most common perioperative and postoperative complication, studies from the last 5 years account in great detail the different complications encountered, which in some cases can get to a 49% chance for a major complication after surgery. (Jan Mattila, 2012).

Veterinarians understand today that the decision whether using TTA or TPLO is more based on the complication and neither on the success of the surgery. Therefore, companies try to find new models to treat CCL rupture every day.

5.2 Locking Vision TPLO Plate

In the past few years, a new model of TPLO plate has been designed and tested by Dr. Tamás Ipolyi from Szent Istvan university and the developing engineer from Scinova company, Mr. Mihaly Flaskay.

Dr Ipolyi Tamás completed his M.D. Studies at Szent Istvan university that located in Budapest, Hungary at 1999. and was subsequently trained in veterinary orthopedic medicine. Dr. Ipolyi is a member of the veterinary surgeon team in Szent Istvan university and an experienced TPLO professional. He has been performing TPLO surgeries for more than two decades.

From 2009 Dr Ipolyi Tamás and Mr. Mihaly Flaskay joined together to design a unique Tibial Plateau Leveling Osteotomy plate which its aim was to excel the common disadvantages that the TPLO have. They thought about a plate that can achieve faster and better healing to the bone and in addition to provide a way to obtain the healing process. The patent also takes into account the most suitable size of the plate according to the size and the weight of the dog, the type, the position and the angulation of the inserted screws.

At 2017 , the new TPLO plate was already being used during surgeons. Until today, this plate was implanted and examined on about more than 100 dogs with successfully outcomes refer to the healing process of the stifle joint and therefore, nowadays, Dr Tamás Ipolyi and Mr. Mihaly Flaskay working on improved version which contain low contact plate type that made of Titanium to achieve more resistant for septic complications.

5.3 Updates and advantages of the Locking Vision TPLO plate

The locking TPLO plate system (introduced in 2018 Barcelona ESVOT) is the result of research and development targeting to produce a TPLO system with the most up to date principles in surgery:

- minimal contact design to allow more blood supply to the bone
- stable, but not overly rigid fixation is ideal for osseointegration

- easier positioning and after check, is due to more visibility through the plate
- double threaded (on the head) locking -swiss style- screws
- highest quality implant steel with the purest chemical properties
- Anatomical contour and complex design of the plate would normally result in extremely high selling costs, but due to highly effective manufacturing, the cost is surprisingly competitive. (SCINOVA. Catalogue, 2019).

Unlike the common locking plates, the main advantage of Dr Ipolyi's plate is maintain by a 'window'. This is a big hole that located at the head of the plate which its purpose is to provide an overview about the healing process of the bone via radiography imaging. This 'windows' which found below the locking bone screw and above the proximal region of the plate neck cannot be found in any others locking plates that were designed so far and was added to Dr ipolyi plate due to the intention to decrease the usual problems that emerge during and after the operation procedure.

FIGURE 31: THE 'LOCKING VISION' TPLO PLATE (SCINOVA, 2019).

Dr Ipolyi claims that one of the biggest obstacle that orthopedists need to deal with, is the complication that show up after the operation procedure which cause due to wrong insertion during the drilling procedure of the screws that can lead to tibial crest fracture or fibula fracture, joint infection, incisional infection, incisional oedema, osteomyelitis, haemorrhage, meniscal injury, luxation of the long digital extensor tendon and suture complications. For his opinion, in case there is any complication that was developed after the surgery, the observation and the evaluation ability is limit due to the fact that the common plate is covering the bone surface and therefore the radiography imaging cannot provide reliable scene about what is actually occur under the plate, at the most critical area that was sutured.

At the level of the fracture, the bone necrosis and resorption caused delayed healing of the cortex immediately underneath the plate. The focal bone necrosis and the resulting delayed union underneath the plate was suggested to be the cause of refracture of the bone following plate removal (Matthew D. Barnhart, Karl C. Maritato, 2019).

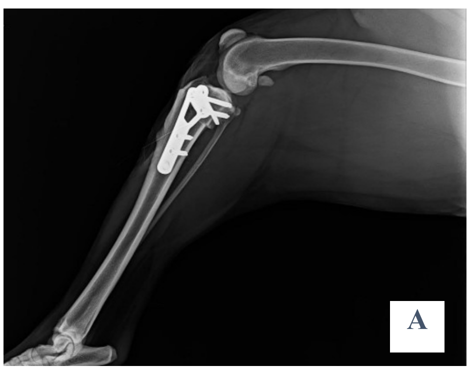
FIGURE 32: LOCKING 'VISION TPLO' PLATE

- BETTER VISIBILITY FOR POSITION AND CHECKING
- STABLE AND SAFE FIXATION WITH LOCKING SCREWS
- PRE-BENT SHAPE FOR SIMPLE AND QUICK FIXATION
- ANATOMICAL CONTOUR
- LEAVES MORE BLOOD SUPPLY TO THE BONE AT THE CUT FOR FASTER HEALING

(SCINOVA, 2019).

The 'windows' is also very important during the real time of the insertion procedure due to the fact that this wide hole can provide a benefit picture of what is the ultimate position that the surgeon need to insert the plate without to penetrate the bone and to avoid unrecommend position.

This vision plate was design as a Pre-bent shape for simple and quick fixation. The proximal region of the head design with three locking holes, (stacked combi-holes), which include the superior/proximal Screw hole, the cranial and a caudal screw hole that are suitable for 3.5 mm size screws.



The position in which we insert the screws in that region of the plate is very important and must be kept with 5 degree of angulation between the screws. This is provided by ventral composition of drilling to avoiding unnecessary penetration of the bone. This technique is true only for the proximal screws, while the insertion of the distal screws performed straightly. By this specific composition, the plate can provide stable and safe fixation to the bone.

FIGURE 33: RADIOGRAPHIC IMAGES OF THE LOCKING VISION TPLO PLATE (A) MEDIOLATERAL VIEW AND CAUDOCRANIAL VIEW(B)

This unique locking plate is suitable for dogs that are more than 5 kg of weight due to the vacuolation limitation that found in toy breeds, that can lead to common complications such as TT avulsion/fracture, fracture of tibia or fibula, delayed meniscal tears, implant failure, patellar luxation, implant-associated sarcoma and lameness. These complications deriving from the fact that small dogs may have steeper tibial plateau angles than large dogs. Therefore, the plate is available only in two size 2.7mm and 3.5mm which are respect the size and the weight of the dog.

5.4 The effect of the Locking Vision TPLO plate

As there are not enough case studies for a full research that shows the complete outcome of the Locking Vision TPLO, we can start to process the few dogs that has been treated by it.

I have collected the check-up x-ray pictures from 6 different dogs, that suffers from CCL rupture and was treated with the Locking Vision TPLO plate.

5.4.1 Case studies

<u>Roti</u>

In this set of radiography images, we can see the new TPLO plate ,8 weeks after getting inserted in a 1.5 years old Rottweiler on the 14.8.2019. the dog suffered from parapatellar arthrosis, and chronic total CCL rupture. in addition, the caudal horn of the medial meniscus found injured as well.

As we can see, the line of the osteotomy is well visible (which points on a good healing process) and the healing process can be observe due to the ‘window’ in the canter of the plate, which gives a big advantage over the regular TPLO plates.

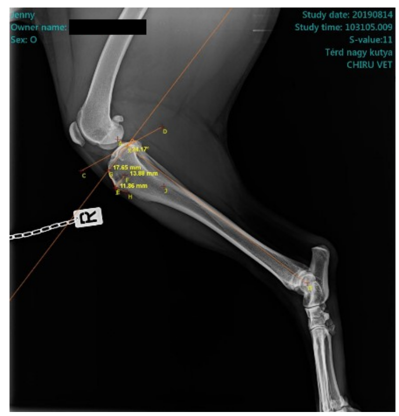


FIGURE 34: MEDIOLATERAL VIEW THAT WAS TAKEN PREOPERATIVE WHICH SHOWS TOTAL CCL RUPTURE AND PARAPATELLAR ARTHROSIS.

FIGURE 35: MEDIOLATERAL VIEW, TWO MONTHS AFTER THE OPERATION. WE CAN SEE THE LINE OF THE OSTEOTOMY WITH A PARTIAL HEALING PROCESS.

FIGURE 36: MEDIOLATERAL VIEW THAT WAS TAKEN RIGHT AFTER THE OPERATION. WE CAN SEE THAT THE LINE OF THE OSTEOTOMY IS WELL VISIBLE.

Bodza

In this sets of radiography images, we can see Bodza, a 6 years old Golden Retriever that was suffer from proliferative synovitis with total CCL rupture and partial caudal cruciate ligament rupture which is refer to a rare condition. In addition, there was injury of the medial meniscus and the lateral condyle of the left femur found with tendinopathy. In the photos, we can see the improvement of the knee that was operate through a period of six months.

FIGURE 37: MEDIOLATERAL VIEW THAT WAS TAKEN PREOPERATIVE WHICH SHOWS PROLIFERATIVE SYNOVITIS WITH TOTAL CCL RUPTURE, PARTIAL CAUDAL CRUCIATE LIGAMENT RUPTURE AND INJURY OF THE MEDIAL MENISCUS.

FIGURE 38: MEDIOLATERAL VIEW THAT WAS TAKEN RIGHT AFTER THE OPERATION. THE LINE OF THE OSTEOTOMY IS VISIBLE DUE TO THE 'WINDOW' OF THE PLATE.

FIGURE 39: MEDIOLATERAL VIEW THAT WAS TAKEN 7 MONTHS AFTER THE OPERATION. THE OSTEOTOMY LINE IS NOT VISIBLE ANYMORE DUE TO THE COMPLETE HEALING PROCESS.

Sally

Sally is a 10-year-old, female Border Collie that was suffered from chronic lameness and pain on her right hindlimb. The surgery was performed on the 29.10.2018. preoperative x-ray finding shows total CCL rupture, arthrosis and coxarthrosis. Intraoperative finding shows in addition to total CCL rupture, also rupture on the caudal part of the medial meniscus and severe arthrosis.

FIGURE 40: MEDIOLATERAL VIEW THAT WAS TAKEN PREOPERATIVE WHICH SHOWS TOTAL CCL RUPTURE AND ARTHROSIS.

FIGURE 41

FIGURE 42

FIGURE 41 AND FIGURE 42: MEDIOLATERAL (41) AND CAUDOCRANIAL (42) RADIOGRAPHIC VIEWS THAT WAS TAKEN POSTOPERATIVE, SHOWS THE OSTEOTOMY LINE (41) AND THE INSERTED SCREWS (42).

Nero

This following case example is belonging to 5 years old Rottweiler that was suffer chronically from pain and lameness on his right hindlimb. One week before the operation that was perform on the 30.10.2018, there was acute regression in his limb status, perhaps due to an act of jumping which cause total CCL rupture. Other diagnostic findings were including effusion of the stifle and mild coxarthrosis.

On the 6.5.2019 the implant was removed after good prognosis and complete healing process.

FIGURE 43: MEDIOLATERAL VIEW. RADIOGRAPHIC IMAGE THAT WAS TAKEN PREOPERATIVE WHICH DEMONSTRATE TOTAL CCL RUPTURE.

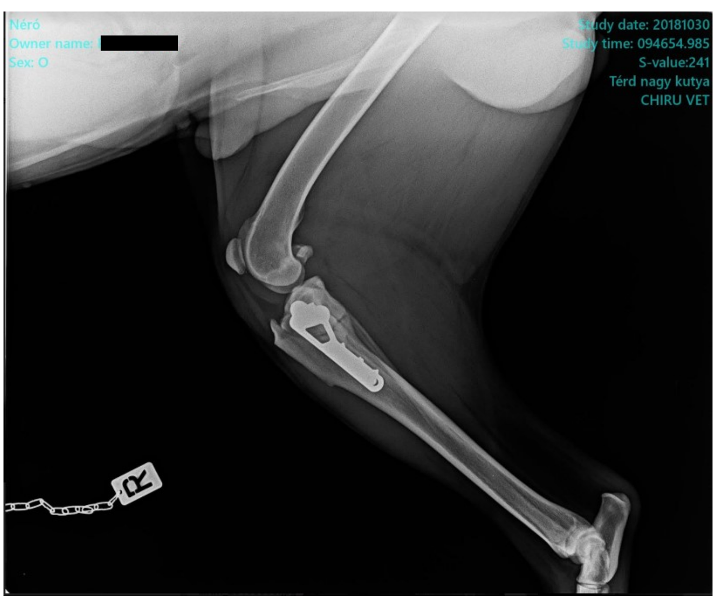


FIGURE 44: MEDIOLATERAL VIEW THAT WAS TAKEN POSTOPERATIVE WITH THE VISIBLE OSTEOTOMY LINE.

Rufusz

This case belongs to 5 months old border collie that was operated on the 26.11.2018 due to CCL problem that cause by unknow indoor trauma. The dog was first exanimated on the 7.11.2018 and found suffered from moderate pain in the hip joint during extension and moderate cranial draw signs that may develops due to anatomical deformities background which contains wide symphysis pelvis and open obturator foramen. In addition, it is important to mention that this case deal with young dog that still having epiphyseal growing plate, which can be easily damaged with other osteotomy procedure, but here, the use of the Locking Vision TPLO plate together with the CORA based, achieved a very good prognosis without any affect on the tibial proximal epiphyseal plate.

Intraoperative finding showed longer CCL but intact without knee stabilization ability.

First evaluation of the healing process was performed on the 4.1.2019 but the healing of the bone was diagnosed as 'not completed'.

The second evaluation was taking on the 4.2.2019. the finding showed complete bone healing and the implant was removed.

FIGURE 45: MEDIOLATERAL VIEW THAT WAS TAKEN PREOPERATIVE WITH INTACT, LONGER CCL THAT CANNOT STABILIZED THE KNEE.

FIGURE 46: MEDIOLATERAL VIEW THAT WAS TAKEN POSTOPERATIVE.

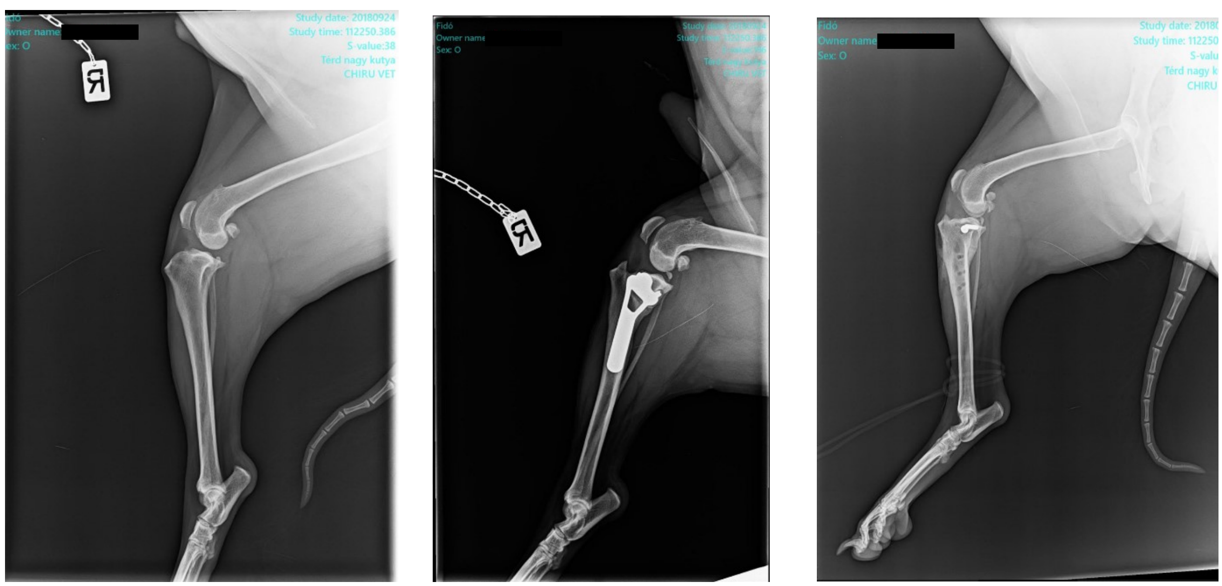
Fido

This case belongs to 6.5 years old, mix breed dog when first show pain and lameness signs both on the right and the left hindlimb on the 31.8.2018. symptoms of the right knee were knee effusion and osteophytes, while the left knee found painfully during stretch.

The left stifle was operated on the 24.9.2018. the intraoperative finding showed total CCL rupture with intact menisci.

The right stifle was operated on the 19.11.2018. the intraoperative finding showed the same finding as the right stifle.

On the 28.6.2019, after good prognosis of the healing process, the both implants have been removed.



A B C

FUGURE 47: MEDIOLATERAL VIEWS OF THE RIGHT STIFLE. (A) PREOPERATIVE; (B) POSTOPERATIVE; (C) COMPLETE HEALING AND IMPLANT REMOVING.

6. Conclusions:

TPLO is considered to be one of the best methods of surgery treatment for CCL rupture, alongside TTA. although each method has its advantages and disadvantages it seem that in many cases the decision of choosing one method over the other is based more on the complication chance rather on the chance for restore the knee to a full movement recovery. Therefore, finding a way to overcome and observe the complications of the implant is vital in order to choose the best option for the surgery. Although it's only been used for a few years, the implant procedure of the locking vision TPLO plate have proved to be simple and efficient such as the standard TPLO plate that exist today. From the 6 cases that this thesis examines, a considerable improvement can be seen from the radiographic images of the wounded legs.

The locking vision TPLO plate may be the best solution for a wide verity of complications that the other TPLO plates and other methods can't deal with. In order to really assessment whether this claim is true, a large data process has to accrue, but from the few observations that this thesis shows we can see that the successful healing process alongside the ability to observe the wounded area, makes the locking vision TPLO plate to the best choice.

7. Summary:

The goal of this thesis - 'Canine TPLO – the advantage of one-hole TPLO' is to examine and compare the different method of osteotomy technique for treating CCL rupture. The thesis is composed of 2 main parts: Part 1 review the written literature of the CCL rupture and its main characteristics, while part 2 discuss on the advantages of the 'Locking vision' TPLO plate.

Part 1 divided to 3 main chapters: chapter one explains what CCL injury is and its main characteristics and review the developments of the CCL treatment methods. Chapter two introduce the different osteotomy treatment techniques for the CCL rupture and chapter three describes about the TOPL, its characteristics and the complications that can occur after using it for treating CCL rupture.

Part two discuss the advantages of the locking vision TPLO plate over other versions of TPLO's and divided to two main chapters: chapter one introduce the locking vision TPLO plate and its advantages and chapter two examine 6 cases of dogs that have been treated by locking vision TPLO plate and analyse their radiographic images preoperative, intraoperative and postoperative.

The case study shows a high rate of successes for the locking vision TPLO plate for treating CCL rupture, and provide proof for the claim that the locking vision TPLO plate is better than the standard TPLO's.

For conclusion, the thesis achieves its main goal to provide essential information about the benefit of the locking vision TPLO plate with the intention of encouraging further research on the subject.

8. List of abbreviations

CrCL – Cranial Cruciate Ligament

CCLR – Cranial Cruciate Ligament Rupture

ACL – Anterior Cruciate Ligament

TPLO – Tibial Plateau Leveling Osteotomy

TPA – Tibial Plateau Angle

CrTT - Cranial Tibial Thrust

DJD - Degenerative Joint Disease

TTA - Tibial Tuberosity Advancement

CTT - Cranial Tibial Thrust

TTO – Tibial Triple Osteotomy

CTWO - Cranial Tibial Wedge Osteotomy

PTIO - Proximal Tibial Osteotomy

TCO - Tibial Crest Osteotomy

cTTA - Circular Tibial Tuberosity Advancement

MMT - Modified Maquet Technique

SP – standard TPLO plate

Lop - low profile TPLO plate

LocP - locking TPLO plate

bLocP - broad locking TPLO plate

DCP - Dynamic Compression Plate

LCP - Locking Compression Plate

SSI - Surgical Site Infection

PTS - Patellar Tendonitis

TT - Tibial Tuberosity

9. List of references

Coletti TJ et al. Can Vet J. (2014) Complications associated with tibial plateau leveling osteotomy: a retrospective of 1519 procedures. [online] - Can Vet J. 2014 Mar; 55(3): 249–254 - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3923481/

RANDY J. BOUDRIEAU, DVM, Diplomate ACVS & ECVS (2009) Tibial Plateau Leveling Osteotomy or Tibial Tuberosity Advancement [online] - Veterinary Surgery 38:1–22.
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.654.18&rep=rep1&type=pdf

Susannah J. Sample et al (2017) Radiographic and magnetic resonance imaging predicts severity of cruciate ligament fiber damage and synovitis in dogs with cranial cruciate ligament rupture [online] – PLoS One, 2017 Jun 2.
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5456057/

Nick Wiliams. Vet Times - The website for the veterinary profession (2009) - Cranial cruciate ligament rupture and tibial tuberosity advancement [online] - September 14, 2009 –
https://www.vettimes.co.uk/app/uploads/wp-post-to-pdf-enhanced-cache/1/cranial-cruciate-ligament-rupture-and-tibial-tuberosity-advancement.pdf

Mitsuhiro Isaka et al (2014)- Two-Hole Extracapsular Technique for the Repair of Canine Cranial Cruciate Ligament Rupture in Thirty-Eight Dogs [online] – Veterinary Science Development - Vol 4, No 2
http://www.pagepress.org/journals/index.php/vsd/article/view/5284/6360

Slocum, B., & Devine, T. (1984). Cranial tibial wedge osteotomy: a technique for eliminating cranial tibial thrust in cranial cruciate ligament repair. Journal of the American Veterinary Medical Association, 184(5), 564–569.

Montavon, P. M., Damur, D. M., & Tepic, S. (2002). Advancement of the tibial tuberosity for the treatment of cranial cruciate deficient canine stifle. ESVOTVOT 2002 proceedings, 152.

Montavon, P. M., & Tepic, S. (2006). Joint Surgery in Canine Hind Limb–Recent Contributions from the University of Zurich. European Companion Animal Health, 25–28.

Damur, D. M., Tepic, S., & Montavon, P. M. (2003). Proximal tibial osteotomy for the repair of cranial cruciate-deficient stifle joints in dogs. Veterinary and Comparative Orthopaedics and Traumatology, 16(4), 211–216.

Massimo Petazzoni and Andrea Urizzi (2008). TPLO stabilized by means of fixin internal fixator: 184 cases. 14th ESVOT Congress, Munich, 10th - 14th September 2008, 309.

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

Petazzoni, M. (2010). cTTA (circular Tibial Tuberosity Advancement). ESVOTVOS proceedings 2010, 295–296.

Etchepareborde, S. Brunel, L., Bollen, G., & Balligand, M. (2011). Preliminary experience of a modified Maquet technique for repair of cranial cruciate ligament rupture in dogs. Veterinary and Comparative Orthopaedics and Traumatology, 24(3), 223–227.

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.

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

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

de Rooster H. (2001). Ghent University Academic Bibliography. [Online] Available at: https://biblio.ugent.be/publication/522123 [Accessed 2016]

de Rooster H. et al (2006). Morphologic and Functional Features of the Canine Cruciate Ligaments. Veterinary Surgery. 35:769-780.

Scott A. et al (2011). Comparison of Long-Term Outcomes Associated with Three Surgical Techniques of Cranial Cruciate Ligament Disease in Dogs. Laboratory University of Missouri.

Michael D. Lefebvre et al. (2017) Risk factors for tibial damage associated with the modified Maquet technique in 174 stifles [online] Available at: https://onlinelibrary.wiley.com/doi/pdf/10.1111/vsu.12707

Slocum B, Slocum TD (1998). Tibial plateau leveling osteotomy for cranial cruciate ligament In Current Techniques in Small Animal Surgery, 4th ed. Bojarab MJ (ed). Baltimore, MD: Williams and Wilkins. 1209-1215.

BVOA – British Veterinary Orthopedic Association (2008). Soft tissue of the pelvic limb/stifle joint. pp. 35

M. S. Bergh; B. Peirone (2012). Complications of tibial plateau levelling osteotomy in dogs. [online] Available at: https://www.orthovet.org/sites/default/files/vcot-full-paper/vcot_2012_25_5_17583.pdf

Duane A. Robinson. Recovery & Rehab | Orthopedic Follow-Up Evaluations | Identifying Complications. [online] Available at: https://todaysveterinarypractice.com/recovery-rehab-orthopedic-follow-up-evaluations-identifying-complications/

Kowaleski et al. (2013). Radiographic Outcome and Complications of Tibial Plateau Leveling Osteotomy Stabilized with an Anatomically Contoured Locking Bone Plate. 847-852.

Jude Thaddeus Bordelon (2010). An In Vitro Mechanical Compression of TPLO Plates. [Online] Available at: https://shareok.org/bitstream/handle/11244/9806/Bordelon_okstate_0664M_10836.pdf?sequence=1

Weaver et al. (2006). United States Patent. Bone Plating System. [online] Available at: https://patentimages.storage.googleapis.com/3e/e1/4c/fa7c4a179cc205/US7128744.pdf

Horan et al. (2013). United States Patent. Tibial Plateau Leveling Osteotomy Plates. [online] Available at: https://patentimages.storage.googleapis.com/38/87/2d/f54fe10fd200a4/US8523921.pdf

Synthes Veterinary (2013). TPLO Plate. Tibial plateau leveling osteotomie in the canine proximal tibia. [online] Available at: https://emea.depuysynthes.com/binary/org/DPY_SYN_EMEA/HCP/Veterinary/PrductLiterature/036.000.025.pdf

Kloc PA, 2nd, Kowaleski MP, Litsky AS, Brown NO, Johnson KA. (2009). Biomechanical comparison of two alternative tibial plateau leveling osteotomy plates with the original standard in an axially loaded gap model: an in vitro study. Vet Surg 38:40-48

Bordelon J, Coker D, Payton M, Rochat M. (2009). An in vitro mechanical comparison of tibial plateau levelling osteotomy plates. Vet Comp Orthop Traumatol 22:467-472

Rayward RM, Thomson DG, Davies JV, Innes JF, Whitelock RG. (2004) Progression of osteoarthritis following TPLO surgery: a prospective radiographic study of 40 dogs. J Small Anim Pract. 45:92-97

Corr SA, Brown C. (2007). A comparison of outcomes following tibial plateau levelling osteotomy and cranial tibial wedge osteotomy procedures. Vet Comp Orthop Traumatol 20:312-319

Stauffer KD, Tuttle TA, Elkins AD, Wehrenberg AP, Character BJ. (2006). Complications associated with 696 tibial plateau leveling osteotomies. 42:44-50

Priddy NH, 2nd, Tomlinson JL, Dodam JR, Hornbostel JE. (2003). Complications with and owner assessment of the outcome of tibial plateau leveling osteotomy for treatment of cranial cruciate ligament rupture in dogs: 193 cases (1997-2001). 222:1726-1732

Pacchiana PD, Morris E, Gillings SL, Jessen CR, Lipowitz AJ. (2003). Surgical and postoperative complications associated with tibial plateau leveling osteotomy in dogs with cranial cruciate ligament rupture: 397 cases (1998-2001). 222:184-193

Boudrieau RJ, McCarthy RJ, Sisson RD, Jr. (2005). Sarcoma of the proximal portion of the tibia in a dog 5.5 years after tibial plateau leveling osteotomy. J Am Vet Med Assoc 227:1613-1617, 1591

Harasen GL, Simko E. (2008). Histiocytic sarcoma of the stifle in a dog with cranial cruciate ligament failure and TPLO treatment. Vet Comp Orthop Traumatol 21:375-377

Carey K, Aiken SW, DiResta GR, Herr LG, Monette S. (2005). Radiographic and clinical changes of the patellar tendon after tibial plateau leveling osteotomy 94 cases (2000-2003). Vet Comp Orthop Traumatol. 18:235-242

Mattern KL, Berry CR, Peck JN, De Haan JJ. (2006). Radiographic and ultrasonographic evaluation of the patellar ligament following tibial plateau leveling osteotomy. Vet Radiol Ultrasound. 47:185-191

Wheeler JL, Cross AR, Gingrich W. (2003). In vitro effects of osteotomy angle and osteotomy reduction on tibial angulation and rotation during the tibial plateau-leveling osteotomy procedure. Vet Surg 32:371-377

Bergh MS, Rajala-Schultz P, Johnson KA. (2008). Risk factors for tibial tuberosity fracture after tibial plateau leveling osteotomy in dogs. Vet Surg 37:374-382

Kergosien DH, Barnhart MD, Kees CE, et al. (2004). Radiographic and clinical changes of the tibial tuberosity after tibial plateau leveling osteotomy. Vet Surg 33:468-474

Tuttle TA, Manley PA. (2009). Risk factors associated with fibular fracture after tibial plateau leveling osteotomy. Vet Surg 38:355-360

Korvick DL, Pijanowski GJ, Schaeffer DJ. (1994). Three-dimensional kinematics of the intact and cranial cruciate ligament-deficient stifle of dogs. J Biomech 27:77-87

Carpenter DH, Jr., Cooper RC. (2000). Mini review of canine stifle joint anatomy. Anat Histol Embryol 29:321-329

Huss BLJ. (1994). What's your diagnosis? Intra-articular avulsion fracture of the left tibia at the insertions site of the cranial cruciate ligament. Journal of the American Veterinary Medical Association 204:1017-1018

Whitehair JG, Vasseur PB, Willits NH. (1993). Epidemiology of cranial cruciate ligament rupture in dogs. J Am Vet Med Assoc 203:1016-1019

Duval JM, Budsberg SC, Flo GL, Sammarco JL. (1999). Breed, sex, and body weight as risk factors for rupture of the cranial cruciate ligament in young dogs. J Am Vet Med Assoc 215:811-814

Vasseur PB. (2003). Stifle Joint: Textbook of Small Animal Surgery. 3rd ed. Philadelphia: Elsevier Science; 2090-2133

McCurnin DM, Pearson PT, Wass WM. (1971). Clinical and pathologic evaluation of ruptured cranial cruciate ligament repair in the dog. Am J Vet Res; 32:1517-1524

Macias C, McKee WM, May C. (2002). Caudal proximal tibial deformity and cranial cruciate ligament rupture in small-breed dogs. J Small Anim Pract 43:433-438

HENDERSON R., MILTON J. (1978). The tibial compression mechanism: a diagnostic aid in stifle injuries. J.Am.Anim.Hosp.Assoc., 14: 474.

Bennett D, May C. (1991). An 'over-the-top with tibial tunnel' technique for repair of cranial cruciate ligament rupture in the dog. J Small Anim Pract 32:103-110.

Shires PK, Hulse DA, Liu W. (1984). The under-and-over fascial replacement technique for anterior cruciate ligament rupture in dogs: A retrospective study. J Am Anim Hosp Assoc; 20:69-77.

Zahm H. (1966). Operative treatment of crucial ligament injuries in dogs with synthetic material. Berl Munch Tierarztl Wochenschr 79:1-4.

Denny HR, Barr ARS. (1987) A further evaluation of the 'over the top' technique for anterior cruciate ligament replacement in the dog. J Small Anim Pract 28:681-686.

Orthomed, Product Catalogue. (2018). Veterinary instrumentation, implants & training for surgeons of all levels [online] Available at: https://www.orthomed.co.uk/eu/resources/

Veterinary Instrumentation, product catalogue. (2015). [online] Available at: http://www.veterinary-instrumentation.co.uk/pages.php?pageid=239

Intrauma S.P.A, product Catalogue. (2018). Trauma Locking Plates [online] Available at: https://www.intrauma.com/page.php?id=809&tipo=articoli&lang=EN

Charles D. Newton, David M. Nunamaker. (1985). Textbook of small animal orthopedics. Chapters 16, 30, 80.

Rebekah Knight,1,2 Alan Danielski1. (2018). Long-term complications following tibial plateau levelling osteotomy in small dogs with tibial plateau angles >30°. Veterinary Record. doi: 10.1136/vr.104491

Samuel P. Franklin1, Emily E. Burke, Shannon P. Holmes. (2017). The effect of platelet-rich plasma on osseous healing in dogs undergoing high tibial osteotomy. Plos One. [online] Available at: https://doi.org/10.1371/journal.pone.0177597

G. Brown, T. Maddox, M. M. Baglietto Siles. (2016). Client-assessed long-term outcome in dogs with surgical site infection following tibial plateau levelling osteotomy. Veterinary Record. doi: 10.1136/vr.103688

Richard Meeson. (2017). Making internal fixation work with limited bone stock. In Practice. Volume 39 | 98-106. doi: 10.1136/inp.j595.

Rutherford S., Bell J. C., Ness M. G. (2012). Fracture of the patella after TPLO in 6 dogs. Veterinary Surgery 41, 869–875

Fitzpatrick, N. & Solano, M. A. (2010). Predictive variables for complications after TPLO with stifle inspection by arthrotomy in 1000 consecutive dogs. Veterinary Surgery 39, 460–474

Liska, W. D. (2004). Femur fractures associated with canine total hip replacement. Veterinary Surgery 33, 164–172

Shales, C. J., White, L. & Langley-Hobbs, S. J. (2009). Sacroiliac luxation in the cat: defining a safe corridor in the dorsoventral plane for screw insertion in lag fashion. Veterinary Surgery 38, 343–348

Shales, C., Moores, A., Kulendra, E., White, C., Toscano, M. & Langley-Hobbs S. (2010). Stabilization of sacroiliac luxation in 40 cats using screws inserted in lag fashion. Veterinary Surgery 39, 696–700

Smolders, L. A., Voorhout, G., Van De Ven, R., Bergknut, N., Grinwis G., Hazewinkel H. A. & Meij B. P. (2012). Pedicle screw-rod fixation of the canine lumbosacral junction. Veterinary Surgery 41, 720–732.

Reves, N. V., Stahl, C., Stoffel, M., Bali, M., Forterre, F. (2013). CT scan based determination of optimal bone corridor for atlantoaxial ventral screw fixation in miniature breed dogs. Veterinary Surgery 42, 819–824

Matthew D. Barnhart, Karl C. Maritato. (2019). Locking Plates in Veterinary Orthopedics. Chapter 3: The Biology of Locking Plate Applications
SCINOVA (2019). Veterinary implants. [online] Available at: http://www.veterinaryimplant.com

Jan Mattila. (2012). Surgical treatment of canine cranial cruciate ligament deficiency. University of Helsinki, Faculty of Veterinary Medicine.

DePuy Synthes vet, product Catalogue. (2013). Standard Tibial Leveling Osteotomy (TPLO) system. [online] Available at: http://synthes.vo.llnwd.net

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