Sys Rev Pharm 2020; 11(5): 335 – 346
A multifaceted review journal in the field of pharmacy
E-ISSN 0976-2779 P-ISSN 0975-8453

Comparative Characteristics of Osteofixators in Treatment of Dogs with Cranial Cruciate Ligament Rupture

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Article History: *Submitted: 10.02.2020* *Revised: 14.04.2020* *Accepted: 05.05.2020*

ABSTRACT
Cranial cruciate ligament rupture is one of the most common pathologies of the knee joint in dogs. It leads to greater knee flexion and subluxation of the tibia throughout the gait cycle, as well as to excessive internal rotation of the tibia during the standing phase. There are many works in domestic and foreign literature on the criteria for choosing the place of osteotomy and the angle of rotation of the osteotomized segment. However, information on the comparative assessment of fixation devices is not provided enough and there is no reliable information on the advantages and disadvantages of blocked compression and dynamic compression plates for osteofixation when performing rotary osteotomy. The process of remodeling of the proximal part of the tibia is completed in subgroup B2 by 45 days. In subgroup A2, in 50% of cases, and in subgroup B2 in 83.3% of cases, the 1st degree of lameness was noted 45 days after surgery. 60 days after surgery, no significant differences between the subgroups were found. The use of proximal tibia metaepiphysis in rotary osteotomy for dogs of medium and giant breeds of Synthes LCP clover leaf allows optimal osteofixation and stabilization of bone fragments, as well as reduction of rehabilitation time.
Keywords: Cranial Cruciate Ligament, Dogs, Rotary Osteotomy, Rupture, Surgery.
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DOI: 10.31838/srp.2020.5.49

INTRODUCTION
Cranial cruciate ligament rupture (CCLR) is one of the most common pathologies of the knee joint in dogs, which is characterized by the development of subluxation of the knee joint and lameness as the resting limb. The available literature widely reflects the issues of biomechanics of the knee joint, as well as methods for diagnosing pathology. The cranial cruciate ligament (CCL) is the main stabilizer of the knee joint. Natural rupture of the CCL leads to greater bending of the knee joint and subluxation of the tibia throughout the gait cycle, as well as to excessive internal rotation of the tibia during the standing phase. Joint kinematics leads to lameness, the development of osteoarthritis (OA) and, in some cases, meniscus injury [1].
There is evidence of pathomorphological changes in the knee joint that predispose to cranial cruciate ligament rupture, as well as post-traumatic transformations. At the same time, changes in the composition of synovial fluid have not been sufficiently studied as a marker for the development of post-traumatic changes in the joint [2, 3, 4, 5].
Despite the available data on the structure of orthopedic pathologies in dogs in general [6, 7, 8, 9], they require clarification of the features of injuring the knee joint in particular. Of scientific and practical interest are the relationships between the rupture of the cranial cruciate ligament in dogs with other pathologies.
The modern concept of treating dogs with cranial cruciate ligament rupture is reduced to performing intraarticular stabilization or reconstructive surgery based on the use of corrective osteotomy methods to normalize the biomechanics of the knee joint. To date, the main methodology for the correction of CCLR is a tibial plateau leveling osteotomy (TPLO), which includes an osteotomy of the proximal metaepiphysis of the tibia with subsequent rotation of this segment to normalize the angle between the tibial plateau and its biomechanical axis with further fixation of the plates [10, 11, 12].
Tibial plateau leveling osteotomy is one of the most commonly performed procedures for dogs with CCL rupture. An osteotomy is theoretically designed to alleviate the mechanical dependence of the knee joint on CCL by reducing the caudodistal inclination of the articular surface of the proximal tibia, thereby ensuring the stability of the knee joint in the absence of CCL. In static studies of CCL - ex vivo, as a rule, it was shown that TPLO leads to the conversion of the cranial subluxation of the tibia to the tail subluxation of the lower leg, as well as the altered mechanics of articular contact [8, 13].
There are many works in the scientific literature on the criteria for choosing the place of osteotomy and the angle of rotation of the osteotomized segment, however, information on a comparative assessment of osteo-fixators is insufficient [14]. There is no reliable information about the advantages and disadvantages of lockable compression plates (LCP) and dynamic compression (DCP) plates for osteofixation during

TPLO. A few studies comparing the plates indicate that complications after TPLO are found in 18.8% - 28%, which causes repeated surgery in 1.6 - 8.2% of cases [15, 16, 17, 18, 19, 20]. This problem was the purpose of this study.
The aim of the study is to conduct a comparative analysis of the plates in the treatment of dogs with cranial cruciate ligament rupture.

MATERIALS AND RESEARCH METHODS

The work was performed on the basis of the Moscow State Academy of Veterinary Medicine and Biotechnology-MVA named after K.I. Scriabin and Peoples' Friendship University of Russia (RUDN University).
42 dogs with cranial cruciate ligament rupture of the knee joint served as research material. 19 animals at the age of 1 to 3 years underwent a TPLO with various types of plates for fixing bone fragments. For differential diagnosis, all animals underwent clinical examination and radiography. Clinical examination of animals was carried out according to standard methods. In all animals, concomitant pathologies were not detected.
Standard orthopedic examination was performed in all animals. The type of lameness was determined by palpation followed by special orthopedic tests to detect cranial cruciate ligament rupture: anterior drawer test and Henderson's compression test.
For anterior drawer test, we laid the dog on the floor on the opposite side of the affected limb, which was pulled. Then we took a limb, fixed the femur with one hand, and the lower leg with the other and tried to move the lower leg in the cranial direction. If its displacement occurred, then we confirmed that there was a cranial cruciate ligament rupture.
Henderson's compression test was performed according to a generally accepted technique. After completing the tests, lameness in dogs at rest and movement was re-evaluated.
Mediolateral radiographs of the knee joint (n = 42); performed in all animals in a lateral projection with a 90 ° angle of the knee and wrist joint, with the hock bent to accurately measure the tibial plateau angle (TPA). Radiography is, first of all, necessary for calculating the angle of inclination of the tibial plateau, which is measured on a mediolateral x-ray image. For correct calculations, we ensured that the condyles of the thigh were one above the other. The discrepancy between the center of the condyle of the femur and the center of the articular surface of the tibia was a diagnostic criterion for the cranial cruciate ligament rupture on the radiograph. Postoperative radiography was performed after surgery 30, 45, 60 days after surgery for evaluation to control the remodeling process.
The main pathology of the CCL rupture is the formation of the angle of the tibial plateau. The TPA is the ratio between the slope of its plateau and the line drawn along the biomechanical axis. TPA is a major determinant of the forces acting on CCL in dogs. An increase in TPA can increase the load on the CCL, which in turn will increase the risk of CCL rupture.
Studies have shown that maximum TPA was associated with higher incidence rates at an early age. Other studies have not established the effect of TPA on the presence or progression of the disease. The average TPA in large dogs varies from 20.5° to 28.0° [21]. In case of caudal deformity of the lower leg, an excessive angle of the plateau of the lower leg leads to cranial displacement of the lower leg and re-loading on the CCL. In dogs with TPA ≥ 35°, the angle may contribute to the rupture of the CCL. If the tilt of the lower leg reaches 60°, this case requires surgical intervention [1, 22].

Method For Determining The Tibial Plateau Angle
To measure the angle of the tibial plateau angle in the X-ray image, we drew a line of the surface of the tibial plateau from the cranial to the caudal edge. A line was drawn of the biomechanical axis of the tibia, which runs from the center of the talus to the intercondylar elevation on a tibial plateau. Actually, the angle of inclination of the plateau is the angle between the line drawn along the surface of the plateau and the line that is perpendicular to the mechanical axis of the lower leg. In the postoperative period, TPA was measured only on the day of surgery.
After the mediolateral image, a radiography was performed in a craniocaudal projection. We did these studies in order to determine whether there is deformation of the lower leg, as well as for the correct selection of plates, saws and screw lengths, with which we performed an operation to level the osteotomy of the tibial plateau.
To perform the clinical part of the studies, two groups of animals were formed. In group A, DCP TPLO dynamic plates (n = 14) were used for surgery. Animals of this group were divided into two subgroups: A1, where they used Slocum TPLO plates (n = 10), and subgroup A2, which used standard T-shaped plates for TPLO (n = 4), fixed with ordinary screws.
Group B (n = 22) included animals that were placed on locking compression plates (LCP). Group B was divided into two subgroups: B1, where Synthes LCP plates (n = 16) were used, and B2, Y-shaped LCP plates (n = 6) (Table 1).

Table 1: Group experiment characterization (n=36)

Group A (n = 14)		Group B (n = 22)	
Subgroup A1	Subgroup A2	Subgroup B1	Subgroup B2
Number of animals in the subgroup			
10	4	16	6
Type of plate used			
«Slocum» TPLO DCP plates	Standard T-shaped DCP plates	«Synthes» LCP Plates «Clover leaf»	Y-shaped LCP plates

Preparing for the Operation

Premedication was performed according to the generally accepted technique. Introduction was performed with zoletil, at a dose of 4-6 mg / kg. For basic anesthesia, isoflurane inhalation anesthesia with 3% maximum alveolar concentration was used.

Arthrotomy Technique

At the first stage of the operation, we carried out an inspection of the knee joint for meniscus rupture, as well as the presence of arthrosis. Lateral parapatellar arthrotomy was performed as an access to revise the meniscus and remove the remains of torn cruciate ligaments or to determine the presence of arthritis or arthrosis. After dissection of all layers, a capsule of the knee joint was opened for its revision. For better visualization, a knee expander or retractor was used.

The infrapatellar fat pad was removed for better visualization of intraarticular structures, including the remains of a torn cruciate ligament and menisci. In the event of a complete rupture, we removed all fragments of the cruciate ligament. With a partial rupture of the cruciate ligament, intact ligament residues were preserved, which had a great influence on the function and stability of the knee joint. In addition, a partial or complete medial meniscectomy was performed if the meniscus was damaged.

After the joint revision was completed, we proceeded to the second stage of the operation. For this, the medial surface of the lower leg was prepared. The incision was performed on the medial side. Skeletonization of the medial surface of the tibia was performed until a clearly visible medial collateral ligament appeared. The Honman retractor or the Farabef retractor was used to isolate during the cut, trying to minimize bleeding resulting from a tibia osteotomy (Fig. 1,2,3).

Figure 1: Stage of the operation for tibial plateau leveling osteotomy: lateral parapatellar arthrotomy

Figure 2: Revision of the cranial cruciate ligament and removal of residues in the first stage (standard lateral arthrotomy and meniscus revision)

Figure 3: Rotary osteotomy with an oscillating saw

Before osteotomy, articular surfaces were labeled with a needle inserted into the intraarticular space. The quadriceps tendon was mobilized cranially from the proposed osteotomy line. To avoid a postoperative fracture of the tibial crest, we left a sufficient amount of bone tissue in the area of the osteotomy line.

The osteotomy line was chosen below the attachment point of the medial collateral ligament. For cooling, a 0.5% pharmacoxidine solution was used. After osteotomy, a tibial plateau was rotated depending on the measured preoperative TPA angle. A certified table of different TPA angles and the corresponding required rotation in millimeters, expressed in relation to several sizes of saw blades used for TPLO, were used. In our study, we used three main sizes of cutting saws for TPLO: 24, 27 and 30 in diameter.

Method For Fixing Bone Fragments

To fix the tibia after an osteotomy, as mentioned earlier, two types of plates were used: TPLO DCP dynamic plates and LCP lockable compression plates. In group A, in some cases we used an additional screw or Kirschner needle, especially in dogs with a large body weight or a TPA angle deviation of more than 30º, while in group B we did not use additional implants (Figs. 4, 5). The surgical wound after standard lateral arthrotomy was sutured with a four-story suture. The capsule of the knee joint was sutured into two floors, using simple interrupted and horizontal "U-shaped" seams. The skin and subcutaneous layers were closed with a simple intermittent suture using PGA suture material or titanium clips. At the end of the operation, radiography was performed (Fig. 6).

Fixation of the limb was provided by a modified Robert - Jones bandage, which was removed on the 14th day after the operation).

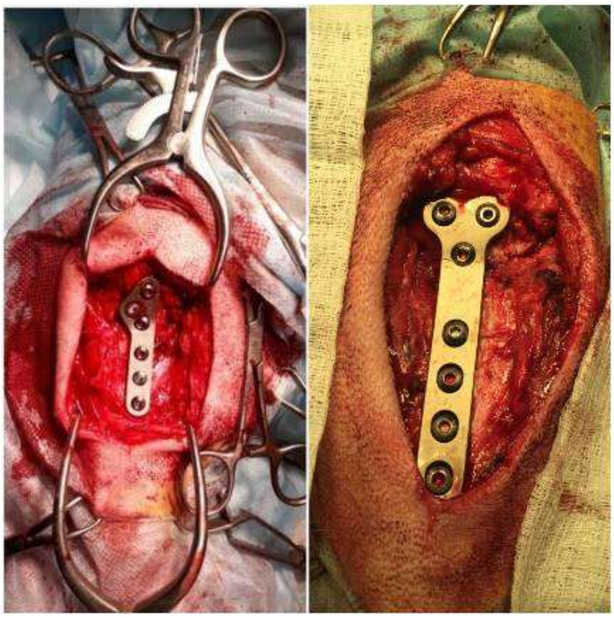

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Figure 4: Types of plates for TPLO in group A: a) the Slocum plate for TPLO, b) the standard T-shaped plate for TPLO

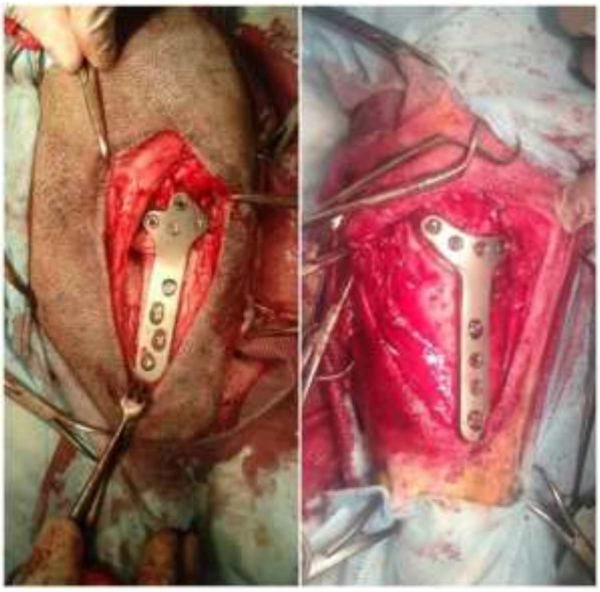

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Figure 5: Types of plates for TPLO in group B: a) the Synthes LCP plate, b) the Y-shaped LCP plate

a b c

Figure 6: Corrective osteotomy technique applied to all animals: a) before surgery, b) after performing osteotomy in direct projection, after performing osteotomy in lateral projection

Method of Postoperative Treatment

Interspectin (1 ml per 5 kg body weight, once a day / m / 5 days) and flexoprofen 2.5% (2 mg / kg body weight for 7 days) were administered to all dogs. Glucosamine chondroitin complex was used 30 days (1 capsule / 1 time per day / 30 days) after surgery.

Statistical processing of results

The reliability of the results relative to each other and relative to the norm was evaluated by the standard student criterion. Values of P <0.05 were considered significant. All analyzes were performed using SPSS software for Windows version 20.

RESULTS OF THE STUDY

A new approach to rupture of CCL was introduced using the TPLO leveling osteotomy plateau technique [23, 24]. Unlike extra- and intra-articular techniques that restore the stability of the knee joint over the entire range of movements, the rationale for the TPLO procedure is to ensure the functional stability of the knee joint during the standing phase, in the gait cycle by eliminating cranial tibial displacement. Duerr et al. (2014) noted that TPLO and extracapsular stabilization are the most common methods for surgical correction of CCLR [1].

The effects of TPLO on stifle biomechanics have been assessed in several studies, including cadaver experiments, computer modeling, and in vivo analyses.6-11 Most studies have focused on the femorotibial joint, because the procedure primarily aims to restore stability to this particular articulation. While TPLO can eliminate cranial tibial subluxation, the pro- cedure may also have some unintended biomechanical effects. In particular, it has been suggested that TPLO may alter patellofemoral joint mechanics [25, 26].

Having analyzed the data on the prevalence of cranial cruciate ligament rupture in dogs with a body weight of more than 30 kg by age category, we came to the conclusion that the peaks of the incidence of this pathology are observed in dogs 2 to 4 years and 6 years old. This is due, according to our data, with deformations of the tibia, namely an increase in the angle of the plateau by 23 or more degrees, as well as degenerative changes in the knee joint. We also came to the conclusion that peaks in the incidence of this pathology are observed in small dog breeds aged 6 to 9 years, which in our opinion is due to the degeneration of CCL by this time.

Based on the data obtained, when planning surgical correction of the anterior cruciate ligament rupture in dogs with body weight more than 40 kg, arthrotomy or arthroscopy should be used to revise and excise the affected part of the meniscus, while in dogs with body weight less than 20 kg this is not necessary. In dogs with body weight from 20 to 40 kg, it is necessary to exclude meniscus rupture by performing sonographic or tomographic examinations of the knee joint, as well as focusing on the degree of lameness, which will be 2 to 3 degrees when the meniscus ruptures.

When assessing the ease of insertion of plates, in subgroup A1 (osseous plates “Slocum” DCP) and subgroup B1 (clover leaf “Synthes” LCP), we determined an easier placement of osseous plates with an increased average time required from the beginning of the medial incision in the tibia before fixing the plate with tightening screws. The average time for subgroup A1 was 33.7 ± 2.06 minutes, and for subgroup B2, 30.9 ± 1.6 minutes.

The increased time spent on subgroup A1 more than on subgroup B2 can be explained by the need to simulate all types of DCP plates to the bone contour. In our opinion, a moderate degree of ease of placement of DCP plates is observed. In subgroup A2 (T-shaped bone plate DCP), the longest insertion time was 33.9 ± 4.8 minutes. Subgroup B2 (Y-shaped bone plate LCP) with an average time of 34.2 ± 3.1 minutes with the least ease in fixing the bone plate during the surgical procedure was in third place.

Comparative Characteristics of the Application of Various Fixation Methods for Rotary Osteotomy of the Tibia Plateau (TPLO) In Dogs

The degree of lameness after surgery was assessed, tests for RPKS and the performance of radiographic evaluation of bone healing were determined. To compare the effectiveness of the plates, cases of plate fracture, impaired healing of postoperative wounds were analyzed, the ease of the plate during installation was evaluated using a three-point system. Bone healing in the osteotomy zone was assessed by the degree of bone callus formation on a 3-point scale where the 3rd degree represents the best results, and the 1st degree is characterized by a violation of osseointegration of bone fragments (Table 2).

Table 2: Comparative evaluation of the application for osteofixation of various types of plates with TPLO

Types of plates		«Slocum» TPLO DCP	T-shaped DCP	«Synthes» LCP	Y-shaped LCP
Group		1A	2A	1B	2B
Number of animals		10	4	16	6
Number of plate fractures		0	0	0	1
Time of application		33,7 ±2.06	33,9 ±4.8	30,9 ± 1.6	34,2± 3,1
Dynamics of osseointegration	30 week	3	2	3	1
	45 week	3	2	3	2
	60 week	3	3	3	3

Orthopedic Assessment Of Operations Using Different Types Of Plates (Postoperative Degree Of Lameness)

According to the results of our study on the 30th, 45th, 60th day after the operation, in all cases we recorded a positive "drawer" test, but with a negative Henderson test. During the orthopedic examination of each animal, a 10-point evaluation methodology was used to determine the clinical degree of osteoarthritis. The lameness index was determined before treatment, on the 30th, 45th and 60th days of treatment.

Indicators were determined for each of the four evaluation criteria, after which the total score indicated the degree of clinical manifestation of lameness (max-10 points). Next, the orthopedic degree of lameness was established based on the number of points. In accordance with the previously described rating system, our experimental units were classified as shown in the following table (Table 3).

Table 3: Comparative characteristics of TPLO osseous plates by degree of lameness

Subgroup	Days	Lack of lameness	Lameness I degree (1-3 points)	Lameness II degree (3-6 points)	Lameness III degree (6-8 points)	Lameness IV degree (9-10 points)
Subgroup A1 (n=10)	30	-	2	6	2	-
	45	2	4	4	-	-
	60	5	4	1	-	
Subgroup A2 (n=4)	30	-	-	3	1	-
	45	-	2	2	-	-
	60	3	1	-	-	-
Subgroup B1 (n=16)	30	-	8	7	1	-
	45	7	6	3	-	-
	60	10	6	-	-	-
Subgroup B2 (n=6)	30	-	2	2	1	1
	45	2	3	1	1	-
	60	4	1	1	-	-

Lack of support on the limb in a standing position and lack of support on the limb and soreness with passive movements in the joint and the presence of crepitus in the joint. X-ray confirmed that the patient had a fracture of the implant and reoperation was performed. 30 days after surgery, in 20% of cases (n = 2) in subgroup A, the 1st degree of lameness was observed, and in 60% (n = 6) - in the 2nd degree. While 50% of cases (n = 8) and 44% (n = 7) of subgroup B1 showed the 1st and 2nd degree of lameness, respectively.

On the 45th day after surgery, 60% of cases (n = 6) in subgroup A1 were distributed between the category of lameness of the 1st degree and the group without lameness. While 81% of cases (n = 13) in subgroup B1 were distributed between the category of lameness of the 1st degree and without the category of lameness. Dogs were seen touching the ground with their fingers or touching the ground with their fingers without transferring the load on the limb with / without the presence of crepitus in the joint.

In 50% of cases in subgroup A2 and in 83% of cases in subgroup B2, the 1st degree of lameness was observed 45 days after surgery. 60 days after surgery, no significant differences were found between the subgroups of one group and between the four subgroups. In most cases, there were no signs of lameness or lameness of the first degree.

Surgical stabilization continues to be considered the best interventional option for CCL-deficient stifle joints. Among the many methods available for stabilization, TPLO remains one of the most commonly performed surgical procedures. TPLO uses the rotation of the proximal tibia to reduce TPA. Reducing the TPA neutralizes subluxation of the cranial aspect of the tibia, thus providing a dynamically stable stifle joint. Reports of TPLO in dogs are numerous, and studies18–22 with radiography and ultrasonography have detected an increased incidence of patellar ligament thickening after surgery [27, 28, 29, 30].

Based on previous results, we found that the best types of TPLO plates associated with a decrease in the degree of lameness in the postoperative period are the "Synthes" LCP plates (Subgroup B1) in first place, then the standard "Slocum" DCP plates (Subgroup A1) and then a Y-shaped LCP plate (Subgroup B2) and, finally, standard T-shaped DCP plates (Subgroup A2).

During postoperative radiography, short-term results in this group were worse than other types of plates. After 8 weeks, the results of using these plates were better and were characterized by the formation of primary bone marrow. According to the results of our study, we conclude that there is a significant relationship between weight gain and the possibility of primary meniscus damage [9]. According to our results, dogs with a body weight of more than 40 kg were associated with a more pronounced degree of preoperative OA and lameness, agreeing with the fact that Heffron published in 1979 [31]. This was not observed in dogs weighing less than 20 kg. While the degree of preoperative degree of OA was significantly affected by primary damage to the meniscus, especially with those animals weighing more than 40 kg [32].

Postoperative evaluation of the effectiveness of the use of different types of bone plates was performed at various times after surgery. The degree of lameness after surgery was assessed, tests for CCLR and the X-ray of bone healing were determined (Fig. 7, 8, 9, 10)

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Figure 7: Radiograph of the dog's knee joint after surgery in group A: a) the Slocum TPLO plate, b) the standard T-shaped TPLO plate

a b

Figure 8: Radiograph of the dog's knee joint after surgery in group B: a) the Slocum TPLO plate, b) the standard T-shaped TPLO plate

a b c

Figure 9: X-ray of the knee in the dynamics of repair. Subgroups B1: a) before surgery, b) on days 30 after TPLO, c) on days 45 after TPLO

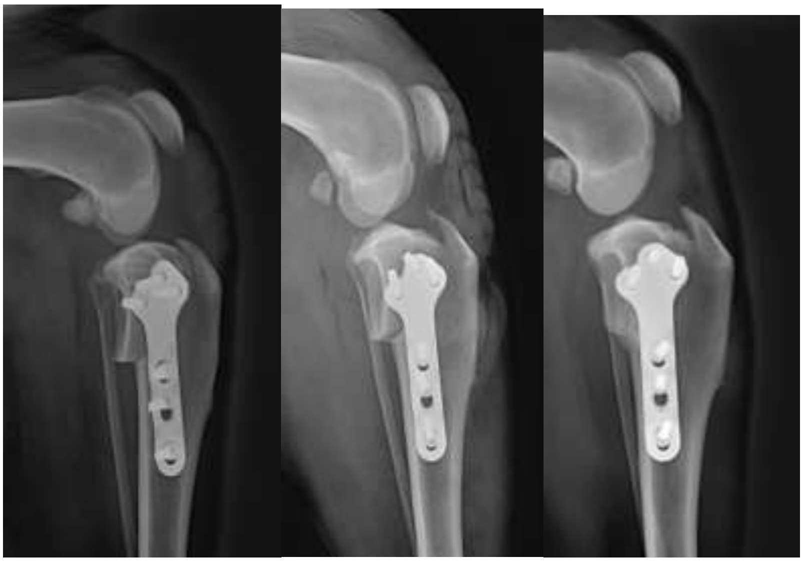

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Figure 10: X-ray patterns of the knee joint in the dynamics of repair. Subgroups B1: a) at 30 days after surgery, b) at 45 days after surgery, c) at 60 days after surgery. On day 45, the completed process of remodeling the proximal part of the tibia is determined

The best results were observed in animals in subgroup A1 in postoperative radiographic monitoring on the 30th, 45th, 60th day after surgery. Subgroup A2 had worse results than wafers using Slocum TPLO.

In subgroup B1, bone healing along the line of osteotomy was better compared to similar results obtained in subgroup A1. However, in our study, the presence of an osteotomy rupture was not always associated with the risk of bone fracture or implant failure.

As a result of the studies, it can be concluded that the choice of a particular type of wafer for TPLO depends on many factors. The surgeon's preference and familiarity with a particular plate type for TPLO play an important role in the choice of an osteofixator. According to the results of our research and clinical preferences in terms of ease of installation and reliability of fixation, we give Synthes LCP plates as clover leaf. This type provides easier placement of plates with other LCP plates and is slightly lighter than Slocum plates, which require modeling of the plate contours before placement.

The LCP Y-plate can be recommended for use on a wide tibial plateau. The likelihood of postoperative complications associated with plate displacement is significantly reduced when using LCP TPLO plates, which use both dynamic and compression screws, unlike Slocum plates and the standard T-plate, which are fixed only with dynamic screws.

The results of an intraoperative assessment of the anatomical, topographic and orthopedic adequacy of the installation of osteofixators for performing a tibial plateau leveling osteotomy allowed us to conclude that plates with angular stability are the most optimal according to the technique of implementation and ensuring stabilization of bone fragments.

Based on the results of x-ray studies, an orthopedic study of the features of the postoperative period in dogs after performing an osteotomy and the use of various types of plates, it was found that LCP plates of the clover leaf type, compared with other types of plates, provide early immobilization, shortening the radiographically visible bone consolidation time fragments.

CONCLUSION

Studies have established the completed process of remodeling the proximal part of the tibia in subgroup B2 by 45 days. In subgroup A2, in 50% of cases, and in subgroup B2 in 83% of cases, the 1st degree of lameness was noted 45 days after surgery. 60 days after surgery, no significant differences between the subgroups were found. The use of proximal tibia metaepiphysis in tibial plateau leveling osteotomy for dogs of medium and giant breeds of Synthes LCP clover leaf allows optimal osteofixation and stabilization of bone fragments, as well as reduction of rehabilitation time.

SOURCE OF FUNDING

The publication was prepared with the support of the "RUDN University Program 5-100" (the agreement number 02.a03.0008)

CONFLICT OF INTEREST

The authors have no conflict of interest.

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