SURGICAL MANAGEMENT OF *LIGAMENTUM CRUCIATUM CRANIALE* RUPTURES IN DOGS BY TRIPLE TIBIAL OSTEOTOMY (TTO) AND ADDITIONAL K-WIRE SUPPORT

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Abstract. The cranial cruciatum ligament rupture is a common orthopedic disease in dogs. Authors of article present the modified version of original Triple Tibial Osteotomy technique. Both techniques were assessed in 8 dogs treated surgically using the original TTO technique, and in 8 dogs were operated by modified TTO method. As modification authors added a Kirschner wire across the osteotomy line of the proximal tibial to prevent tibial tuberosity displacement which is complication during the original TTO procedure. Clinical results shown that stifle restoration time was similar in both groups, but in 3 dogs operated in original version this complications were noted. No complications were observed in patients treated by modified procedure with k-wire during one year after surgery. Triple tibial osteotomy as an alternative management to another surgical techniques is widely recommended, however author's modified original version to prevent tibial tuberosty detachment.

Keywords: TTO, dog, cranial cruciate ligament rupture, stifle joint

Introduction. Rupture of the cranial cruciate ligament (CCL) is a common disease of the stifle joint in dogs. The cranial cruciate ligament counteracts biomechanical forces in knee named cranial tibial thrust. Ruptured ligament leads to a cranial translation movement of the tibia during weight bearing. It causes permanent instability of the stifle joint, hind limb lameness and secondary osteoarthritis (Schmerbach et al., 2007). To prevent secondary progression of osteoarthritis and obtain functional restoration only surgical management is recommended (Adamiak, 2002; Ledecky et al.,2012). Since 1952, revolutionary progress was made in surgical techniques for knee joint stabilization and the treatment of cranial cruciate ligament ruptures. There are a few surgical techniques which aim neutralizing the tibiofemoral share forces in knee by the osteotomy of the proximal epiphysis of a tibia. One of them is the tibial plateau leveling osteotomy (TPLO). The stability of the stifle joint focuses on neutralizing the tibiofemora share forces in a cruciatum cranial ligament deficient knee dynamically which is achieved by the tibila plateau angle reduction. Another surgical technique is tibial tuberosity advancement (TTA). The mechanism of this technique is to alter the direction of the patellar tendon force, to gain a neutral or caudally directed tibiofemoral shear forces during weight bearing by changing the patellar tendon angle (Apelt et al., 2007; Lafaver et al., 2007). Triple tibial osteotomy is an alternative to surgical techniques for stabilizing proximal tibial epiphyseal fractures: Cranial Tibial Wedge Osteotomy- CTWO, Tibial Plateau Leveling Osteotomy- TPLO, Tibial Tuberosity advancement- TTA (Pozzi et al., 2006). The aim of the performed study is to show if additional Kirschner wire support of the tibial tuberosity osteotomy line will improve stabilization of the osteotomized bone.

Material and methods. The Triple Tibial Osteotomy (TTO) technique was assessed during surgical procedures of knee joints with ruptured cruciate ligaments in 16 dogs of both sexes and various breeds, aged 4 to 10 years, with body weight of 28 kg to 80 kg. The patients were divided into two groups. The first group consisted in 8 dogs (8 stifle joints) treated surgically with the involvement of the original TTO technique, whereas the second group comprised 8 dogs (8 stifle joints) operated by the modified TTO method. All patients were diagnosed based on the results of clinical, orthopedic and radiological examinations. Radiographic images were obtained in two projections: the posterior-anterior sagittal plane and the medial-lateral plane to determine the inclination angle of the tibial plateau and the incision line along the proximal tibial metaphysis. The dogs were premedicated with xylazine at 0.15 mg/kg BW and butorphanol at 0.2 mg/kg BW. The patients were intubated, and inhalation anesthesia was induced with isoflurane at initial gas concentration of 3–5 % and maintained at 0.5–1.5 %. Cephalosporins were administered intravenously at 22 mg/kg BW to prevent perioperative infection. Perioperative analgesia was induced with intravenous fentanyl.

The patients were placed in dorsal recumbency with the operated leg extended backwards to allow for free limb motion and to create free access to the anteromedial knee joint. Skin and subcutaneous tissue was incised from the tibial tuberosity to 3–4 cm above the patella. After muscle separation, the medial articular capsule was incised with an electrocauter to rinse the joint, remove detritus and inspect the meniscus. Damaged menisci were removed. The opened joint was rinsed with 500 ml of lactated Ringer's solution, and articular capsule was closed with a single suture using PDS 2/0 or 1/0 absorbable monofilament. The proximal tibial metaphysis was exposed medially to perform the TTO procedure and stabilize fragments of cut bone with a dedicated bone plate. The first osteotomy was performed by cutting the tibial crest. The length of the patellar ligament was measured with a protractor from the tibial tuberosity, parallel to the tibial crest. The saw blade was continuously cooled during the procedure. After osteotomy, the dissected bone wedge was removed with forceps, and fragments of the proximal end of the tibia were grasped with bone holding forceps. After the removal of bone fragments, the plate was set into place and adjusted.

Bone plates (Mikromed) were selected in view of the patient's size, body weight and tibia thickness. Six-hole plates, 40 mm long, 2.5 mm thick, 16 mm and 8 mm wide in the upper and lower part, were used in patients weighing less than 20 kg. Six- or seven-hole plates, 55 mm or 75 mm long, 2.5 mm or 4 mm thick, 22 mm and 10 mm wide in the upper and lower part, were applied in dogs weighing up to 35 kg. Seven-hole plates, 90 mm long, 5 mm thick, 30 mm and 14 mm wide in the upper and lower part, respectively were used in patients heavier than 35 kg. Tibial osteotomies were stabilized with cortex screws (Mikromed).

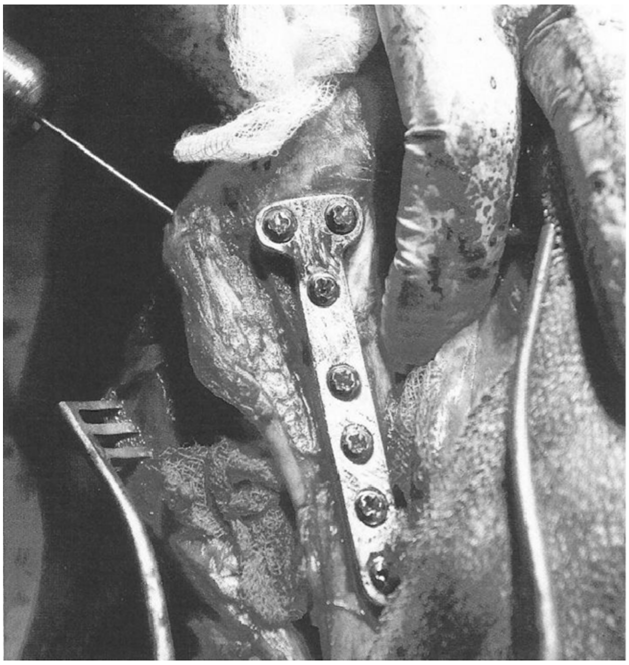

Fig.1. **Guiding the Kirschner wire across the osteotomy line after implanting the bone plate**

Plates with 3.5 mm screw openings were used in dogs with body weight of 20 to 35 kg, and plates with 4.5 mm screw openings were applied in patients heavier than 35 kg. The length of cortex screws ranged from 24 mm to 74 mm. An autograft comprising the removed bone wedge or its parts was used to stabilize the cut bone. In 8 dogs, the TTO technique was modified. Openings were drilled to obliquely insert a Kirschner wire from the upper part of the tibial tuberosity towards the lower posterior region of the tibia. The K-wire was guided across the osteotomy line of the proximal tibial metaphysis and the cephalad aspect of the cortex, bypassing the inserted screws (Figs 1. and 2.). The wire was cut to length. The fascia and subcutaneous tissue were closed with interrupted suture using absorbable material. Non-absorbable 3/0 or 2/0 monofilament was used to close skin wounds with running suture. Towards the end of the procedure, the patients were subjected to radiological examination in the medial-lateral plane and the sagittal plane. Meloxicam was administered intravenously for pain relief at 0.4 ml/10 kg BW. Sutures were removed 10–14 days after surgery. The animals were subjected to clinical observation for 30 days, and restricted movement was advised.

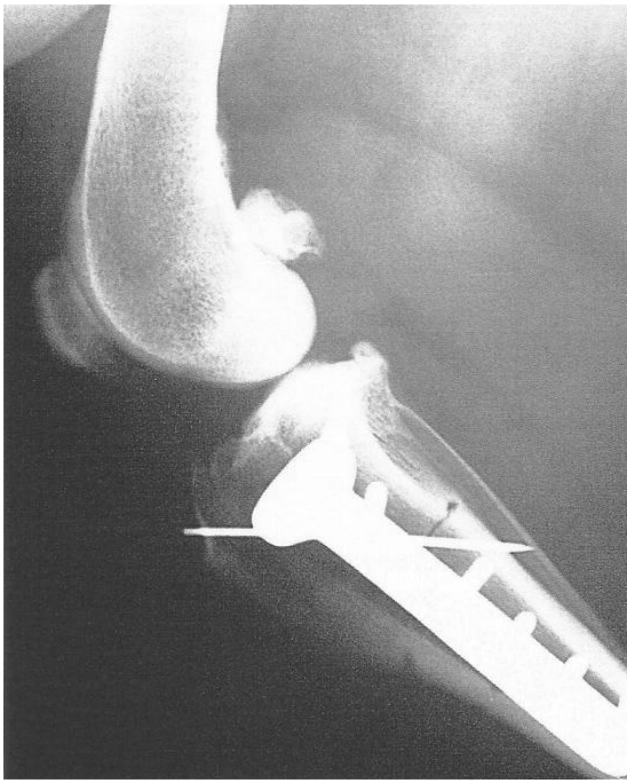

Fig. 2. **Postoperative radiogram**

The range of motion in stifle joint, including extension and flexion angle were compared between pre-operative and post- operative dogs using the Student's T- test. Statistic test was used to determine if two sets of data are significantly different from each other. The threshold chosen for statistical significance was 0.05. Goniometric measurements were performed in all dogs prior to the treatment, and the same measurements were performed again after surgical procedure. By comparing the same patient before and after the treatment we were effectively using each patient as their own control.

Results and discussion. According to the author's observations, movement was completely restored in both groups of dogs two to three months after surgery. No significant differences between groups were noted during recovery. The test statistic follows a normal distribution. In 13 dogs pre- operative goniometric measurements showed that the mean extension angle was 149,5^{o}, with a range of 147–152^{o}, and in post-operative measurements the mean extension angle was 156,5^{o}, with a range 155–

158°. The range of stifle extension was found to be significantly larger after surgery. Therefore, surgery revealed an improvement in range of motion in stifle joint. In 3 dogs, the extension angle was within the norm at 155–162° pre and postoperative.

In 13 patients, the angle of flexion was determined at 27–30° before surgery, and it exceeded the norm of 15–25°. Angles in the range of 15–23° were noted in the remaining 3 dogs. Post-operative goniometric measurements revealed flexion angles of 22–25° (average of 24.2°) in the group of 13 dogs, and 18.7° on average in the remaining 3 animals. The range of stifle flexion was found to be significantly improved after surgery (Table 1.).

Table 1. **Pre and postoperative goniometric measurements of stifle joints**

Number	Post-operative Extention angle	Preoperative Extension angle	Post-operative Flejdon angle	Preoperative Flexion angle
1	155	147	23	27
2	157	152	25	28
3	158	147	25	30
4	158	149	24	29
5	156	147	25	29
6	156	151	25	30
7	158	149	22	27
8	155	151	25	30
9	156	152	24	27
10	158	152	22	28
11	158	148	25	29
12	153	147	24	27
13	156	152	25	30
mean	156.5	149.5	24.2	28.5
14	161	155	20	23
15	162	157	18	15
16	161	156	18	22
mean	161.3	150.7	18.7	20

The discussed surgical technique was modified to eliminate the risk of complications which were observed in 3 dogs operated based on the original TTO concept. In those dogs, the tibial tuberosity was displaced during surgery.

In 13 dogs, degenerative joint changes like the presence of osteophytes on the lateral sides of the femoral crest and above the femoral trochlea were observed during surgery. Complete rupture was observed in all 16 dogs. Perioperative meniscus examinations revealed damage of the medial meniscus in 9 cases. In all dogs bone union in the osteotomy line was seen 2–3 months after surgery.

Surgical procedure times are similar in most techniques (TPLO, TTA, CWTO, TTO) from 1.2 to 2 hours (Pozzi et al., 2006). In this study, no significant differences were observed in the time of surgical procedures performed in line with the original TTO concept and the modified approach.

Postoperative complications involving the proximal tibial epiphysis are widely reported in connection with the most popular surgical techniques (TPLO, TTA, CWTO and TTO). Based on the author's experience, the main complications observed after TTO in original technique was tibial tuberosity fractures during surgical procedures too.

Tibial tubercle osteotomy should be performed in the proximity of the patellar ligament to prevent inflammation or fracture of the tibial tuberosity when strong pressure is applied to the quadriceps femoris muscle during knee stretching. Excessive loading on bone fragments may result in the sequestration of bone grafts, prolonged bone union, reduced knee angulation and fibula fracture (Boudrieau, 2009; Duerr et al., 2008; Marsolaris et al., 2002; Pozzi at al., 2006). The risk of tibial tuberosity fracture is relatively higher in TPLO than in TTO because the union of bone fractions may be incomplete and the flexing strength of the quadriceps femoris muscle may damage the tuberosity (Moore et al., 1995). In the performed study, 3 dogs suffered from the tibial tuberosity displacement during TTO original technique.

Tibial tuberosity fracture as a surgical complication prompted the author to modify the original TTO method and to introduce an additional Kirschner wire for improved stabilization of the tibial tuberosity which contributes to the prevention of secondary fractures. As a result of performed modification in the original TTO technique no tibial tuberosity fracture was noted. Radiological examinations performed 90 days after surgery revealed bone union in the osteotomy line in all treated dogs. Based on the author's observation, Kirschner wire turned out to be a reasonable alternative for secure surgical techniques with tibial tuberosity movement.

In the work of Duerr et al. (2008), knee joint stability was achieved at the slope angle of the tibial plateau of 14° or less. In this experiment, an effective angle of inclination was determined at approximately 5°. In the present study, the angle of inclination ranged from 3° to 8° in animals subjected to TTO and modify TTO. The above angle effectively prevents subluxation of the tibial head (Tallat et al., 2006; Moles et al., 2009). An excessive angle of the bone wedge may result in a small angle of inclination of the tibial plateau and knee hyperextension. Significant improvement in the angles of flexion and extension were also reported in patients subjected to knee stabilization by TTO (Tallat et al., 2006; Bruce et al., 2007).

Conclusion

In the performed study no, complications were observed in the group of dogs treated with TTO technique supported with Kirschner wire – 100 % of successful treatment. Worst statistic was noted in dogs operated with original technique. In three dogs (38 %) tibial tuberosity detachment was noticed. Based on above results it may ascertain that the modified TTO procedure minimizes the risk of surgical complication like tibial tuberosity detachment. This observation should be taken into consideration when surgical treatment is required for large dogs (> 30 kg of body weight).

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Received 27 October 2014
Accepted 4 February 2015