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CRANIAL CRUCIATE LIGAMENT INJURIES –SURGICAL MANAGEMENT

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Introduction:
Tibial plateau adjustment techniques have become very popular amongst referral surgeons for the treatment of cranial cruciate ligament (CrCL) injuries in dogs. The concept was first introduced by Slocum and Devine in 1984 with the tibial wedge osteotomy (TWO), and this was further refined by Slocum and Slocum to the tibial plateau leveling osteotomy (TPLO) in 1993.

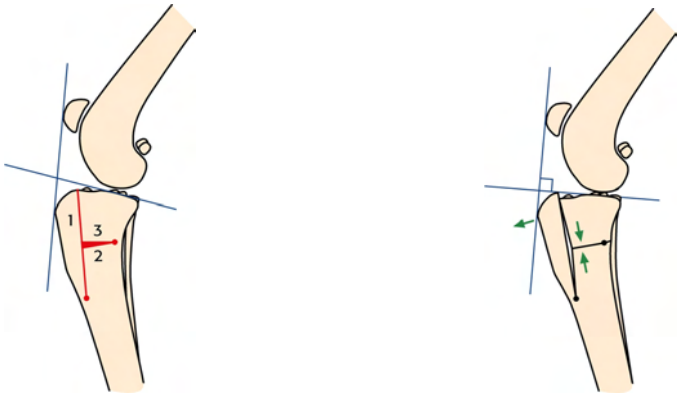
The rationale behind tibial plateau adjustment techniques is to provide functional stifle stability during the stance phase of the gait by eliminating cranial tibial thrust, i.e. the cranially directed force resulting from tibial compression generated during weight bearing. In normal stifles, cranial tibial thrust is opposed by the intact cranial cruciate ligament. In cruciate deficient stifles, cranial subluxation occurs spontaneously. The magnitude of cranial tibial thrust is dependant on the degree of compression during weight bearing and the slope of the tibial plateau. Thus, it has been theorized that leveling the tibial plateau eliminates the cranial tibial thrust, which in turn provides functional stability to the cruciate deficient stifle during weight bearing (Slocum and Slocum 1993).

Clinically, cranial tibial thrust can be elicited by performing the tibial compression test (Henderson and Milton 1978). In this test, the femur is held in a static position to fix the stifle joint and pressure is applied to foot to flex the hock joint. By holding the stifle in a fixed position and loading the foot in this way, there is increased loading of the stifle joint with a total joint force nearly parallel to the Achilles mechanism (Tepic and others 2002), which is approximately parallel to the functional axis of the tibia as defined by Slocum and Devine (1983). Slocum and Slocum (1993) proposed that the cranial tibial thrust could be eliminated by performing a radial osteotomy in the proximal tibia and rotating the proximal fragment so that the tibial plateau becomes perpendicular to the functional axis of the tibia. This theory was recently supported by a 3-D, 3-segment mathematical model of the canine stifle however the results of this analysis also showed excessive loading of the caudal cruciate ligament occurred following TPLO (Shahar and Milgram, 2006).

Warzee and others (2001) designed an *in vitro* biomechanical model in an attempt to simulate loading of the stifle joint. Their findings showed that the resultant force through the stifle on loading was directed 6.5 degrees more cranially than the functional axis. They concluded that, in order to prevent excessive caudal tibial thrust, the tibial plateau should only be adjusted to an angle of 6.5 degrees. However, this study did not fully duplicate all the muscle forces acting upon the stifle. A biomechanical analysis performed by Tepic and others (2002), concluded that the resultant force acting through the load bearing

stifle was in a direction more parallel to the patellar ligament and reasoned that shear force on the CrCL can be eliminated by making the tibial plateau perpendicular to the patellar ligament. This can be achieved in two ways, either by altering the position of the patellar ligament insertion relative to the tibial plateau, which is the basis of the Tibial Tuberosity Advancement technique (TTA) described by Montavon and others (2002), or by altering the alignment of the tibial plateau to the patellar ligament (a modification of the Slocum TPLO technique).

Triple Tibial Osteotomy (TTO):
In this lecture I would like to present the results of 64 cases of CrCL rupture treated by Triple Tibial Osteotomy (TTO), which is a new technique designed to combine the features of both the TTA and TWO techniques to achieve the same outcome, but with less radicle angular changes. The aim of the TTO technique is to reduce the tibial plateau slope to an angle perpendicular to the patellar ligament. Three cuts are made in the proximal tibia to create a partial wedge osteotomy caudal to a partial tibial crest osteotomy (Figure 1a and 1b). The tibial plateau is made perpendicular to the patellar ligament by rotating the proximal tibial fragment to close the wedge osteotomy and simultaneously advancing the tibial tuberosity.



Figures 1a & b
Figure 1a illustrates the three osteotomies of the TTO (1 = tibial crest osteotomy, 2 & 3 = wedge ostectomy). Figure 1b shows advancement of the tibial tuberosity with reduction of the wedge ostectomy and the tibial plateau becoming perpendicular to the straight patellar ligament.

Materials and Methods:
This prospective study consisted of 64 consecutive cases of CrCL injury in 52 dogs, referred to the Adelaide Veterinary Specialist and Referral Centre, Adelaide, South Australia, and treated by TTO during the period October 2002 to April 2004.

Clinical parameters including degree of lameness, cranial draw sign, cranial tibial thrust, thigh circumference, stifle joint range of motion (ROM), and radiographic osteoarthritis scores were assessed. Pre-operative radiographs were used to determine the tibial plateau slope angle (TPA) and the correction angle, which was defined as the angle between the straight patellar ligament and a line perpendicular to the TPA. In this series of cases, the wedge ostectomy angle was calculated as being 2/3rds of the correction angle.

A partial closing wedge ostectomy was performed caudal to a partial tibial crest osteotomy in the proximal tibia. The wedge ostectomy site was stabilized by applying a pre-contoured 3.5 T-plate[a]. Specialized TTO instrumentation was used to facilitate accurate bone cuts and cranial retraction of the tibial crest during wedge ostectomy[b].

The clinical parameters assessed at the time of surgery were reassessed at long-term follow-up. Owner assessment of their dog's ability to perform seven different physical activities and general owner satisfaction was recorded by means of a questionnaire at long-term follow-up.

[a, b] Veterinary Instrumentation, Broadfield Road, Sheffield, S80XL, UK.

Results:
Dogs were aged between 1 and 11 years (mean, 4.82 ± 2.51 years; median, 4 years) and weighed 17.5 to 84.5 kg (mean, 40.96 ± 3.67 kg; median 40 kg). Thirty-one dogs (60 %) were neutered females and 21 (40 %) were neutered males. A variety of breeds were represented, the most common being the Rottweiler and Rottweiler-types (29%). Pre-operative lameness scores ranged from 3/10 to 10/10 (mean, 5.5; median, 5). A cranial draw sign was present in all dogs; the tibial compression test was positive in 51 cases (79.6%).

Seven post-operative complications were encountered (11%). There were two fractures through the tibial tuberosity, one joint infection, one plate infection, one case of suspect bone neoplasia, and two meniscal injuries.

Forty-three dogs (55 stifles) returned for long-term evaluation from 11 to 26 months post-operatively (mean, 14.5 ± 3.2 months). Lameness scores ranged from 0 to 1/10 (median, 0/10), cranial draw signs were present in all cases and the tibial compression test was positive in 50 stifles (91%). There was a significant increase in thigh circumference ($P < 0.05$) and a significant increase in stifle ROM ($P < 0.05$). There was no statistically significant increase in osteoarthritis scores from pre-operative to long-term post-operative values ($P < 0.001$).

Owners completed questionnaires for 48 dogs (92%) at long-term follow-up. Dogs were assessed as being normal or near normal for all of the physical activities surveyed except sitting and standing, where 2% and 4% of owners

respectively judged their dogs as being mildly abnormal. All owners reported the procedure had resulted in a marked improvement in their dog's quality of life and all indicated they would have the procedure performed again if they had another dog with the same condition.

Conclusion:
Analysis of the outcomes in this prospective study, in which a significant number of the patients completed the long-term follow-up, reveals an outstanding result in a very high percentage of cases. The TTO technique is relatively easy to learn and does not require expensive additional instrumentation. Performing a partial tibial crest osteotomy and stabilizing the partial wedge ostectomy with a strong T-plate results in a very stable repair and the low incidence of implant failure is a testament to this fact.

This technique has the advantage of removing only a small wedge, thereby minimising any alteration in the relationship between the femur and tibial plateau. Advancing the tibial tuberosity reduces retro-patellar forces, which may lessen post-operative femoro-patellar chondromalacia and osteoarthritis (Montavon et al 2002). In addition, this technique allows the surgeon to make adjustments to accommodate other deformities of the stifle such as genu varum, genu valgum, excessive tibial plateau slope angle, tibial torsional deformities, and medial patellar luxation.

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