Study of the Protective Effect of Tibial Plateau Leveling Osteotomy on Ligament Degeneration in Canine Cranial Cruciate Ligament Disease

Summary of Doctoral Thesis

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Canine cranial cruciate ligament rupture (CrCLR) is a common cause of hind limb lameness in small animal orthopedics. Moreover, joint instability associated with CrCLR probably causes secondary osteoarthritis (OA) and medial meniscus damage. Canine CrCLR develops as a result of chronic degenerative changes with chondrometaplasia in the ligament, which is called "cranial cruciate ligament disease (CCLD)." Tibial plateau leveling osteotomy (TPLO) as functional stabilization is a useful treatment of the stifle joints with CrCLR and widely used procedure because it achieves early restoration of weight-bearing function. However, even with TPLO, OA has been reported to progress in long-term outcomes in radiological evaluation. Recently, particular attention has been paid to the TPLO at the early stage of CCLD to inhibit the progression of postoperative OA and reduce mechanical stress on the cranial cruciate ligament (CrCL). Although a protective effect of TPLO on CrCL has been observed macroscopically, it is unclear whether CrCL degeneration has been suppressed histologically. This study aimed to evaluate the usefulness of early intervention of TPLO for CrCLR by analyzing whether TPLO has a protective effect on degenerated CrCL. In Chapter 2, we assessed long-term outcomes through weight-bearing function and OA in CrCLR cases depending on the extent of CrCLR and presence of medial meniscus damage and verified the usefulness of TPLO during partial CrCL tears. In Chapter 3, since the progression of OA after TPLO contributed to the instability in non-weight bearing associated with TPLO, the effect of TPLO on stifle joint stability was examined using a robot system. In Chapter 4, the effects of TPLO on the tensile force in the ligaments, such as CrCL, caudal cruciate ligament, medial collateral ligament, and lateral collateral ligament, were analyzed under not only compressive loading but also cranial, caudal, internal rotational, and external rotational loading to examine the protective effect on the CrCL and

its effects on other ligaments. In Chapter 5, based on previous studies, we created a model of CrCL degeneration by increasing the tibial plateau angle (TPA) and subsequently adopting TPLO to evaluate its effect on CrCL degeneration histologically.

Chapter 2

Although there have been many studies on the outcome of TPLO for CrCLR in the past, it is unclear how the degree of CrCL damage or presence of medial meniscus damage affects the long-term outcome. Therefore, in this chapter, we evaluated how CrCL and medial meniscus conditions affect long-term weight-bearing function and radiographic OA scores and whether the progression of OA affects the recovery of weight-bearing function. The results confirmed that, regardless of the condition of the stifle joint, TPLO could improve weight-bearing function from as early as 3 months postoperatively and maintain it for as long as 36 months postoperatively. Furthermore, the progression of OA over time after TPLO was observed, but the postoperative progression of OA had only a minor effect on weight-bearing function. The progression of OA was also observed early in stifle joints with complete CrCLR. In contrast, the progression of OA was slower in stifle joints with functional partial tears of the CrCL. The progression of OA may be a risk factor for low quality of life, such as limited range of motion and chronic pain, even if the weight-bearing function recovers after TPLO. Therefore, these data suggest that TPLO may be the preferred treatment in the early stages of CCLD in dogs.

Chapter 3

In Chapter 2, it was found that OA progression was slow in cases of functional

partial CrCL tears, but this effect may also have various biological and biomechanical backgrounds. In this chapter, we aimed to determine the biomechanical effects of TPLO on stifle joint stability by performing craniocaudal drawer and axial rotational and proximal compression tests in control and TPLO-treated stifles, with and without the CrCL, using a robotic system. As in previous studies, TPLO was effective in preventing cranial displacement during the proximal–distal compression test in the CrCL transected stifle joint. However, TPLO promoted instability under craniocaudal and internal–external rotation test conditions following CrCL transection. Thus, TPLO in cases of complete CrCLR may induce additional instability of the stifle joint in non-weight bearing and may be a risk factor for the rapid progression of OA after TPLO in cases of complete CrCLR as presented in Chapter 2.

Chapter 4

The effect of TPLO on ligament tension in the stifle joint was evaluated. TPLO is known to reduce CrCL strain, especially during compressive loading, as previously reported. However, there are no studies evaluating ligaments other than CrCL, although TPLO was expected to cause changes in the tension of other ligaments to compensate for CrCL tension. It was also unclear whether the tension on the CrCL was reduced except for the compression load. To clarify this, we analyzed the CrCL, caudal cruciate ligament, medial collateral ligament, and lateral collateral ligament and the total ligament tension of normal and TPLO-treated stifle joints under cranial, caudal, compressive, internal, and external rotational loads using a robotic system. The results showed that TPLO decreased the CrCL tension under compressive load, as previously reported. However, under a compressive load, TPLO reduced the total tested ligament tension. Thus, the

shear force associated with compressive load was reduced. This suggested that the cartilage contact position was changed and the load generated on the cartilage was increased. In the caudal loading, TPLO reduced CrCL tension. The fact that the total tested ligament tension decreased with TPLO, especially for caudal and internal rotational loads, also suggested that other soft tissues, such as the medial meniscus and meniscofemoral ligament, might be affected. Thus, TPLO in the presence of CrCL had biomechanical effects on the surrounding soft tissues, including alteration in tension in each ligament under various loads along with anatomical conformation changes. It was found that TPLO decreased the CrCL tension, especially under compressive and caudal loading, which may have a protective effect on CrCL. Therefore, it may be useful to perform TPLO as a preventive method against CrCLR.

Chapter 5

The biomechanical protective effect of TPLO on CrCL is demonstrated in Chapter 4. It is also expected that such an effect may lead to improved macroscopic findings of the CrCL on arthroscopy after TPLO of the stifle joints with partial CrCL tears. However, it is unclear whether the macroscopic improvement in CrCL associated with this TPLO reflects the prevention of histological degeneration. Therefore, this chapter evaluated the histological effect of reducing the biomechanical loading of CrCL. Based on previous studies, we experimentally increased the bilateral TPA and created an excessive TPA (eTPA) stifle joint model and induced CrCL degeneration with an 11-month waiting period. Then, one side was treated with TPLO to reduce TPA (TPLO group), and the other side was subjected to sham operation to maintain TPA (eTPA group). Macroscopic findings of the CrCL at the time of euthanasia were

normal in both groups. Histological evaluation showed more progressive degeneration at the tibial attachments than the other regions in both groups. Compared to the eTPA group, the TPLO group showed a higher value for the positive region of collagen 1 immunohistochemistry and lower values for the positive region of mucopolysaccharide stained by Alcian blue and the elastic fiber region stained by Elastica–eosin. The degree of degeneration in the TPLO group was milder than that in the eTPA group. These results suggest that reducing the biomechanical load on the CrCL inhibits eTPA-induced degeneration of the CrCL. Thus, reducing the biomechanical load on the CrCL could delay or prevent chondrometaplasia of the CrCL.

In summary, the present study determined the benefits of early surgical intervention of TPLO for CCLD through long-term outcome, biomechanical, and biological effects. Through the present study, it was suggested that early surgical intervention could reduce the biomechanical stress of the CrCL, inhibit CrCL degeneration, and preserve CrCL function. The preservation of CrCL function is expected to minimize the instability associated with TPLO and inhibit the progression of postoperative OA.