Abstract. The objective of this study was to evaluate the bone uptake of the bone-seeking radionuclide $^{99m}$Tc-methylene diphosphonate ($^{99m}$Tc-MDP) in order to examine and compare the clinical efficacies of tibial plateau leveling osteotomy (TPLO) and cranial tibial wedge osteotomy (CTWO) for the correction of experimentally induced cranial cruciate ligament (CrCL) transected stifle. Fifteen healthy adult beagle dogs, weighing between 10 and 15 kg, were used for this study. Dogs were assigned to TPLO (n=5), CTWO (n=5) or a control sham group (n=5) and screened with both physical and complete orthopedic examinations. Left CrCLs were transected and two of the three groups were stabilized using TPLO and CTWO. Scintigraphic evaluation of the stifle was performed before TPLO or CTWO surgical repair of the left limb and again at 4, 8 and 12 weeks after surgery. Bone uptake values at 8 and 12 weeks for the TPLO and CTWO groups were not significantly different from their preoperative values, but these differed significantly from the control group at 4, 8 and 12 weeks (p<0.01). No significant differences were found between TPLO and CTWO values. In summary, the relative efficacy of CTWO approximately equals that of TPLO. Moreover, the results of this study confirmed that TPLO and CTWO inhibited the progression of osteoarthritis in CrCL-deficient dogs.

Cranial cruciate ligament (CrCL) injury is one of the most common joint diseases in the canine hind limb, often progressing to secondary osteoarthritis (OA) (1). The CrCL is a vital stabilizer of the stifle joint, limiting cranial displacement of the tibia relative to the femur, preventing stifle hyperextension and limiting internal rotation of the tibia on the femur during stifle flexion (2-5). When acute CrCL rupture does occur, it is thought that repeated stresses are responsible for the progressive degenerative joint disease and secondary OA of the stifle that are typically seen (6, 7). Many intra- or extra-capsular surgical techniques have been employed for CrCL deficient stifle, but degenerative joint disease usually results, irrespective of treatment (7-11). Tibial plateau leveling osteotomy (TPLO) is a new surgical treatment for restoring functional stability to the CrCL-deficient stifle. TPLO has previously been demonstrated to prevent OA and restore limb function induced by CrCL rupture (12, 13). Cranial tibial wedge osteotomy (CTWO) is a simpler version of the TPLO technique (14, 15), but the effect of this procedure has yet to be determined objectively, and the relative effectiveness of CTWO versus TPLO has not been reported.

Scintigraphic changes have been described in OA resulting from CrCL transected stifle (16-19). These changes occur in subchondral bone as well as in articular cartilage in CrCL transected stifle and a marked increase in uptake of $^{99m}$Tc-MDP is seen in the CrCL transected stifle, with no significant increase found in uptake in the contralateral stifle (16).

There are no objective data detailing with scintigraphic changes resulting from the TPLO and CTWO procedures. We employed bony scintigraphy, using the bone-seeking radionuclide $^{99m}$Tc-MDP, to examine the clinical efficacy of TPLO and CTWO correction of experimentally induced CrCL transected stifle. In particular, we sought to answer the question of whether TPLO and CTWO alter the abnormal bony scan patterns found in the CrCL-deficient dog.

Materials and Methods

Animals. Fifteen healthy adult beagle dogs, weighing between 10 and 15 kg, were used for this study. Dogs were assigned to TPLO (n=5), CTWO (n=5) or control groups (n=5) and were screened by both physical and complete orthopedic examinations. After
examination, preoperative stifle joint scintigraphic and radiographic data were collected 7 days before surgery. CrCL transections were performed on the left hind limb of all animals.

Each dog was administered atropine (0.05 mg/kg) subcutaneously and acepromazine (0.05 mg/kg) intramuscularly (i.m.) 30 minutes before induction. Anesthesia was induced by intravenous (i.v.) administration of thiopental (12 mg/kg) and was maintained with isoflurane and oxygen. Lactated Ringer’s solution (12 ml/kg/hr, i.v.) was administered during surgery. Meloxicam (0.2 mg/kg, i.m.) was administered for analgesia before surgery, and cefazolin (22 mg/kg, i.v.) was administered both at the time of induction and 2 hours later.

Surgery was performed as follows, each dog was positioned in dorsal recumbency, the medial arthrotomy was performed and the left CrCL was excised. The tibia was subluxated cranially and a meniscal release was performed by completely incising the caudal horn of the medial meniscus just medial to its lateral attachment on the intercondylar eminence. The joint capsule was sutured and TPLO or CTWO was performed. Both TPLO and CTWO were performed by the same surgeon. Control dogs received CrCL transection and meniscal release only.

TPLO was performed using a small jig that was applied to the sagittal plane and parallel to the straight patellar tendon. A biradial saw blade was used to create a cylindrical cut in the proximal tibia. The proximal fragment was rotated until the tibial plateau angle was 5°-10° and was temporarily stabilized with the appropriate pin. The two portions of the osteotomy were positioned with a TPLO plate (Slocumenterprises, Eugene, USA).

CTWO was performed using a sagittal bony saw. TPLO was performed up to the positioning of the tibial plateau at the angle of 5°-10°, and the tibial fragments were temporarily stabilized with a wire in the cranial aspect of the tibial crest. The two portions of the osteotomy were positioned with a CTWO plate (Veterinary Instrumentation, Sheffield, UK).

After surgery, dogs were administered meloxicam (2.2 mg/kg) orally for 7 days and cefazolin (22 mg/kg, i.m.) for 3 days. Cage exercise was carried out for the first 3 weeks after surgery, followed by a gradual increase in the level of exercise from 10 to 30 minutes daily by the third month. Use of the limb commenced 10 days postoperatively. The protocols employed in this study were approved by the Animal Care Committee of Chungbuk National University, Korea.

**Scintigraphic evaluation.** Dogs were anesthetized with thiopental sodium (20 mg/kg, i.v.) and bony scintigraphy was performed 7 days prior to surgery and again at 4, 8 and 12 weeks post-operatively. Images were acquired using a parallel-hole collimator with x 1.6 magnification and a 20% energy window over the 140 keV photopeak of 99mTc with 256 x 256 matrices. Scintigraphy of both stifle joints was performed 3 hours after an intravenous injection of 10 mCi 99mTc-MDP (Daiichi, Japan) by means of a large-field gamma camera (SX-300 Picker, USA) with a face-up low energy general purpose (LEGP) collimator. A stifle joint image was collected for a set number of counts (100k counts).

Regions of interest (ROI) were drawn around the left and right stifles, with all ROI using boxes of the same size as the cranial border of the stifle ROI for the caudal border. The cranial and caudal borders for the stifle ROI were just above the tibial plateau and at the junction of the femoral condyle. The widths extended laterally to a point at which radioactivity faded to the background level. Total counts for each ROI were recorded for each study of each experimental dog. Ratios were calculated by comparing the percentage for ROI evaluated for the left stifle joint against the ROI for the contralateral normal right stifle joint (Figure 1).

**Radiographic evaluation.** Under general anesthesia, radiographs of the stifle joints were obtained, flexed mediolaterally and caudocranially, using a high-resolution film screen combination (Kodak, Japan). The radiographs were scored only for osteophytosis on a five-point scale.

The radiography was performed within 7 days before surgery and again 4, 8 and 12 weeks later. Osteophytosis scores were classified on a five-point scale.

**Statistical analysis.** Data were analyzed using a repeated measures ANOVA with repeated measurements for time and stifle condition. Data are reported as mean±SD, and \( p<0.05 \) was considered statistically significant.

**Results**

Surgical complications did not occur and all osteotomy sites had healed by 8 weeks after TPLO or CTWO surgery. Tibial plateau angles after TPLO and CTWO varied from 6° to 9° and TPLO and CTWO surgical groups had negative tibial compression tests. The control group, by contrast, had a positive tibial compression test.
The first 15 dogs entered in this study were examined scintigraphically. Table I shows the results of normal stifle scintigraphy for the 15 dogs that subsequently underwent transection of the left CrCL, with the results expressed as the ratio of counts of the left stifle to that of the contralateral stifle. The radionuclide uptakes of the normal dogs’ stifles were initially not significantly different. Four weeks after CrCL transection, though, the control group showed changes in uptake of 1.6-fold greater than their preoperative values. By contrast, the TPLO and CTWO groups showed lesser increases in uptake of 1.3-fold greater than preoperative values (p > 0.05); these increases were attenuated at 8 and 12 weeks (Figure 2). TPLO and CTWO groups had significantly less uptake at 8 and 12 weeks than the control group (p < 0.01), which at 8 and 12 weeks post-operatively showed even further increases in radioactive uptake relative to pre-operative values (Figure 1). As shown in Table I, there were no significant differences in scintigraphic findings between the TPLO and CTWO groups.

As scintigraphic counts increased in the control group from four weeks on, the radiographic scores of the stifle joint tended to increase (Table II). Beginning at 8 weeks post-operatively, mild osteophytosis was detected in TPLO and CTWO groups. However, the differences between these data were not statistically significant.

### Discussion

This study confirmed by scintigraphic assessment the similar effectiveness of CTWO compared with the TPLO procedure in halting the progression of OA in the CrCL transected dog. Multiple surgical techniques have been described for treatment of CrCL rupture in the canine stifle (9, 10, 20). Many in vitro and in vivo studies have confirmed the clinical efficacy of TPLO (3, 5, 13, 21-23), based on the technique described by Slocum and Devine (5). However, no studies of CTWO, which is a simpler surgical technique than the TPLO procedure, have been reported. This is the first study that scintigraphically evaluated short-term changes following TPLO and CTWO in experimentally induced CrCL transected stifle.

The CTWO and TPLO surgical procedures do not restore the CrCL, but act to functionally stabilize the stifle joint during weight bearing (5, 14). These procedures inhibit the progression of OA in a manner similar to that seen with lateral suture techniques (13, 24). Radiographic evaluation of OA should be used cautiously as a predictor of clinical efficacy (25). However, bony scintigraphy can be useful for monitoring the course of osteoarthrosis (16, 18) and objective scintigraphic evaluation of the TPLO and CTWO.

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**Table I. Bone uptakes of 99mTc-MDP after TPLO and CTWO (%).**

<table>
<thead>
<tr>
<th>Group</th>
<th>Time (weeks) after surgical procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>TPLO</td>
<td>100.58±4.29</td>
</tr>
<tr>
<td>CTWO</td>
<td>101.98±2.95</td>
</tr>
<tr>
<td>Control</td>
<td>99.89±1.17</td>
</tr>
</tbody>
</table>

**Table II. Mean osteophytosis scores after TPLO and CTWO.**

<table>
<thead>
<tr>
<th>Group</th>
<th>Time (weeks) after surgical procedure</th>
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<tr>
<td></td>
<td>0</td>
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<tr>
<td>TPLO</td>
<td>0</td>
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<tr>
<td>CTWO</td>
<td>0</td>
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<tr>
<td>Control</td>
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TPLO: Tibial plateau leveling osteotomy; CTWO: cranial tibial wedge osteotomy; Osteophytosis score: 0=none, 1=mild, 2=moderate, 3=severe and 4=most severe.

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Lee et al: Scintigraphy of TPLO and CTWO in Dogs

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Figure 2. Bone scintigraphs of stifle bone uptake 12 weeks after left cranial cruciate ligament transection in dogs. Similar bone uptakes (arrows) were observed in TPLO (A) and CTWO (B) dogs compared to normal right stifle. TPLO: Tibial plateau leveling osteotomy; CTWO: cranial tibial wedge osteotomy.
techniques following transection of the CrCL has not been reported. Bony scan findings are abnormal in the stifle with CrCL-deficiency and CrCL reconstruction procedures such as TPLO and CTWO can correct the abnormal bone scan patterns.

In this study, bone uptakes of the TPLO and CTWO groups were not significantly different from their preoperative values at 8 and 12 weeks, but were significantly different from the control group at 4, 8 and 12 weeks ($p<0.01$). Four weeks after surgery, bone uptakes of the TPLO and CTWO dogs were significantly different from that in the control group ($p<0.01$). The osteophyte score for the affected joint did not change significantly during the study (Table II). This may be explained by limited radiographical detection in the early stages of OA, by the small size and numbers of animals, or by lack of disease progression. Bone uptake changes, however, were significant. It would seem that scintigraphy is more sensitive than radiographic scores in the early stages of postoperative evaluation following CrCL rupture. Two stifle joints for TPLO and one stifle joint for CTWO showed slightly increased osteophyte scores and bone uptake during the period of the study. However, no evidences of osteophytosis or abnormal bone uptakes were noted in the majority of dogs. All of these osteophyte scores, however, employed a subjective scoring system to evaluate animal limb function. Using scintigraphic evaluation as an objective measure of outcome was more sensitive than the subjective osteophyte scores.

Unlike TPLO, CTWO alters the normal relationship of the femoropatellar joint, potentially causing a lowered patellar position relative to the femur, unless the stifle is hyperextended (26). For this reason, additional objective data is needed for comparison of TPLO versus CTWO, such as kinematic gait analysis and synovial fluid analysis. Specialized gait analysis techniques may enable surgeons to better resolve lameness issues and to accurately select the appropriate time for a return to normal activity of a dog after recovery from CrCL injury (27, 28).

Based on our scintigraphic evaluation results, no significant differences between TPLO and CTWO values were found. These results suggest that the relative efficacy of CTWO approximately equals that of TPLO. Moreover, the results of this study confirm that TPLO and CTWO both inhibit the progression of OA in early stages and demonstrate that scintigraphy is more sensitive than radiography for the post-operative evaluation of OA in CrCL-deficient dogs. This study had important limitations, however, most notably the use of small number of small-sized animals. Further long-term clinical trials may be necessary for a superior comparison of TPLO and CTWO with other traditional intra- or extra-capsular surgeries to confirm these preliminary results.

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References


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