Comparison of Tibial Plateau Angle Changes after Tibial Plateau Leveling Osteotomy Fixation with Conventional or Locking Screw Technology

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Objective: To compare the effects of locking and conventional screws on postoperative tibial plateau angle (TPA), osteotomy healing, and complication rate after tibial plateau leveling osteotomy (TPLO) in dogs treated for naturally occurring cranial cruciate ligament (CCL) rupture.

Study Design: Prospective clinical study.

Study Population: Dogs (n = 118) with CCL rupture.

Methods: Dogs (≥ 20 kg) with unilateral CCL rupture and sufficient bone stock for TPLO and use of a 3.5-mm-broad or -narrow TPLO plate were sequentially allocated to have plate fixation with locking or conventional screws. Data analyzed included breed, age, sex, body weight, body condition score, limb operated, implants used, meniscal status, operative time, and days to recheck. Preoperative, immediate postoperative, and 8-week recheck mediolateral radiographs were reviewed, and TPA, complications, and healing status were evaluated.

Results: Stifles in the locking screw group had significantly less change in postoperative TPA than stifles in the conventional screw group. Locking screw fixation also had significantly higher grades of osteotomy healing, assessed on a mediolateral radiographic view.

Conclusions: TPLO plates secured with locking screws are acceptable when compared with those secured with conventional screws; osteotomy healing is improved and TPA better conserved when using locking screws.

Clinical Relevance: Locking screw fixation serves to increase stabilization of TPA during TPLO healing and provides improved radiographic evidence of osteotomy healing.

Rupture of the cranial cruciate ligament (CCL) is one of the most common causes of pelvic limb lameness in dogs with pet owners spending an estimated US$1.3 billion on treatment annually.¹ One of the most common surgical treatments for CCL deficiency is tibial plateau leveling osteotomy (TPA).²-⁴ Calculation of tibial plateau angle (TPA) is a critical step in presurgical planning to determine required rotation of the osteomized segment to achieve a predetermined TPA. The currently recommended postoperative TPA is 6.5° to resolve cranial tibial thrust while minimizing the stress placed on the caudal cruciate ligament,⁵ although others have found no statistical difference in ground reaction forces of dogs with postoperative TPA ranging from 0° to 14°.⁶ TPA can also change by 1.5° (mean) between immediate postoperative and 6.5-week recheck radiographs.⁷ The actual change in TPA may be higher than reported, because only 73.2% of the evaluated TPLOs were healed at the time of evaluation.

Our purpose was to evaluate the use of locking screw technology compared with conventional screw technology in TPLO performed for naturally occurring CCL deficiency. We hypothesized that locking screws would result in a less significant change in TPA measured on postoperative radiographs when compared with conventional screws. We also hypothesized that less change in TPA would result in improved osteotomy healing assessed radiographically and a decrease in the incidence of postoperative complications, including tibial tuberosity (TT) avulsion fracture.

MATERIALS AND METHODS

Inclusion Criteria

Dogs admitted for TPLO were considered for inclusion in the study. Dogs were included if they were of sufficient size and bone stock to allow use of a 3.5-mm-narrow or -broad
Unity Cruciate Plate (UCP, New Generation Devices, Glen Rock, NJ) as determined by 1 surgeon (R.M.D.) at the time of surgery.

**Study Design**

Dogs were sequentially allocated into 2 groups: in Group 1, 3.5 mm cortical screws were inserted distal to the osteotomy and cancellous fully threaded 4.0 mm screws proximal to the osteotomy (Fig 1), whereas in Group 2, only 3.5 mm locking cortical screws (Fig 2) were used. In addition, the “nose” screw of the locking screw implantations was drilled and placed to, but not through, the trans cortex of the tibial plateau. These were the only differences between surgical procedures, all of which were performed by the same surgeon (R.M.D.). Orthogonal radiographs were taken immediately postoperatively with the dog anesthetized and at 8 weeks with the dog heavily sedated (butorphanol and medetomidine).

Breed, sex, age, weight, body condition score (BCS), preoperative TPA, limb operated, screw type used, meniscal damage, operative time, complications, and days to recheck were evaluated. Complications were categorized as major (requiring additional surgery) or minor (not requiring additional surgery). TPA was calculated from the immediate postoperative and 8-week postoperative mediolateral radiographs. Osteotomy healing was evaluated on the 8-week mediolateral radiographs.

**Surgical Procedure**

Dogs that had naturally occurring complete CCL tears, as indicated by a positive tibial compression test, had TPLO performed as described by Slocum and Slocum. The medial meniscus was evaluated through a limited caudomedial arthrotomy and classified as intact or torn. If the meniscus was intact, medial meniscal release was performed by midbody transaction. If there was visible damage to the meniscus, the damaged portion was removed with a #11 Bard-Parker scalpel blade in addition to midbody transaction. A 3.5 mm UCP was used for all TPLO with selection of a broad or narrow plate based on patient size.

Dogs that had clinical signs consistent with CCL tear (pelvic limb lameness, positive sit test, stifle effusion, discomfort to stifle flexion and extension, and presence of a medial buttress), as well as radiographic evidence (e.g. joint effusion), but negative tibial compression tests, had stifle arthroscopy before TPLO. After confirmation of partial CCL tears and arthroscopic debridement of the frayed portions, TPLO was performed. Arthroscopies were not performed after stifle arthroscopy.

A modified Robert Jones bandage was applied postoperatively to minimize swelling and removed the next day (19-22-hours postoperatively). Dogs were discharged 24-48 hours after surgery with instructions for administration of oral nonsteroidal antiinflammatory drugs, tramadol HCl (Apotex Inc., Weston, FL) and transdermal fentanyl patches (Fentanyl Transdermal System, Mylan Pharmaceuticals Inc., Morgantown, WV) as needed on an individual basis. All owners were given verbal and written instructions for postoperative monitoring and strict exercise restriction. Dogs were returned at 2 weeks for a clinical re-evaluation and skin staple removal and again at 8 weeks for a clinical re-evaluation and radiographs.

**Radiographic Method and TPA Determination**

Mediolateral radiographic projections were obtained with the stifle and hock joints at 90° flexion with the radiographic beam centered on the stifle and superimposition of

![Figure 1](image-url)  
Figure 1  Mediolateral and caudocranial radiographs of conventional screw TPLO immediately postoperatively.
the femoral condyles. Because digital radiography (DR) became available during the study, radiographs were taken with, or scanned into, DR format for TPA evaluation using a DICOM scanner (Radiographic Digital Converter, Logic Rad, Dallas, TX).

TPA was calculated as described by Slocum using standard digital radiographic viewing software (Eklin Medical Systems Inc., Santa Clara, CA). A single observer (R.M.D.) calculated all preoperative TPA. Three observers (R.M.D., A.L.C., and B.F.) calculated postoperative TPA for each set of radiographs to minimize inter-observer variability. During TPA measurement, observers were unaware of screw type by viewing only the mediolateral radiograph. In an attempt to eliminate TPA observer bias, both TPA line markers were placed to mark the medial tibial plateau and the long axis of the tibia. No angle measurements were visible during line placement. Angles were calculated by toggling a standard DR software angle tool (Eklin Medical Systems Inc.). In dogs where a particularly high tibial osteotomy and plate placement prevented TPA measurement by the standard method, the tangential method described by Reif et al. was used. Radiographs were critically assessed for adequately exposed tibial plateau to allow application of the tangential method or the cases were discarded from the study.

Osteotomies were evaluated using a subjective grading scale. The degree of bony bridging was classified as a percentage of complete bridging (4, 76–100%; 3, 51–75%; 2, 26–50%; 1, 1–25%; and 0, no bony bridging). This determination was made by a single board-certified radiologist (B.F.) based solely on the mediolateral radiographic projection. Caudocranial radiographs were not used to evaluate osteotomy healing as is typically done in a clinical setting to minimize bias between locking and conventional screw repairs because they can be differentiated by astute clinicians in this view. In addition, the surgeon and resident clinically evaluating the dog and orthogonal stifle radiographs at the time of re-evaluation did not assess osteotomy healing.

**Statistical Analysis**

Statistical analysis was performed using software (MedCalc Software, Mariakerke, Belgium). Continuous variables were summarized using mean (± SD) and compared using Student's t-test. Categorical variables were evaluated using a χ²-test. P ≤ .05 was considered significant.

**RESULTS**

**Signalement**

Between January 31, 2006 and September 12, 2007, TPLO (n = 187) was performed on 169 dogs of appropriate size. Thirty-three dogs (33 stifles) were excluded because dogs were not returned for 8-week postoperative radiographs or data were incomplete and 18 dogs (36 stifles) were excluded because of bilateral surgery. Thus, 118 stifles were analyzed.

Sex distribution was 63 spayed females (53.4%), 53 castrated males (44.9%), 2 intact males (1.7%), and 0 intact females. Breeds included 76 pure-bred dogs and 42 mixed breeds.

**TPLO**

Eleven stifles (9.3%) had arthroscopy to confirm partial CCL rupture before TPLO. Eighty-eight (74.6%) narrow UCPs and 30 (25.4%) broad UCPs were implanted. Sixty-three (53.4%) plates were secured with locking screws and
55 (46.6%) with conventional screws. TPLO was performed on 60 (50.8%) left and 58 (49.2%) right pelvic limbs. Sixty-nine menisci were intact (58.5%) and 49 were torn (41.5%). Mean days to radiographic recheck was 60.5 days (range, 31–105 days).

No differences (P > .05) were identified for sex, age, weight, BCS, surgical time, meniscal status, broad versus narrow plates, preoperative TPA, and days to recheck between groups (Table 1).

**TPA**

Mean (±SD) preoperative TPA was 28.3 ± 3.5° (range, 20–37°). Mean immediate postoperative TPA was 4.57 ± 2.10° (range, 0.67–12°). Mean 8-week TPA was 6.50 ± 0.25° (range, 6.67–14°). Mean postoperative TPA change was 1.90 ± 0.19° (range, –2 to 8.67°). Mean change in TPA using locking screws (1.29 ± 0.22°; range, –2 to 5°) was significantly (P = .008) less than mean change in TPA using conventional screws (2.59 ± 0.31°; range, –1 to 8.67°).

**Osteotomy Healing (Table 2)**

TPLO performed using locking screws had significantly more complete healing than TPLO with conventional screws (P = .0163).

**Complications**

Twenty-two (18.6%) complications were recorded (Table 3). There was no difference in frequency of complications between the conventional (13 complications, 23.6%) and locking screw group (nine complications; 14.3%; P = .3992).

One dog (0.008%) had a methicillin-resistant *Staphylococcus aureus* (MRSA) incisional infection that required debridement and drain placement. Minor complications included 6 (5.1%) delayed unions, 3 (2.5%) incisional self-traumas, 2 (1.7%) nondisplaced to minimally displaced TT fractures, and 10 (8.5%) other individual minor complications (Table 3). TT fractures occurred late and were incidentally detected a mean of 68 days postoperatively during scheduled radiographic re-evaluation. There was no significant difference in TT fracture frequency between groups (P = .4322).

**DISCUSSION**

In these dogs with naturally occurring CCL rupture, TPLO fixation with 3.5 mm UCP using locking screws provided more stable maintenance of TPA and better bony union (mediolateral radiograph) at 8 weeks than 3.5 mm UCP with conventional screws.

A distinct advantage of locking screws is their ability to function as an "internal fixator" and maintain accurate osteotomy reduction without having a perfectly contoured plate. With conventional screws, if the plate is not accurately contoured at the time of screw placement, osteotomy reduction can be disrupted as the screws are tightened to achieve bone-plate friction. Less initial tibial plateau disruption has been reported with locking screws compared with conventional screws. We made no attempt to assess tibial plateau disruption caused by screw tightening. All plates were contoured as accurately as possible to minimize variability between groups, but locking screws should better maintain initial rotation of the tibial plateau segment if small gaps occurred between bone and plate. Plate contouring was not found to affect placement of the locking drill guide because of deformation of the locking threads and thus screws inserted in locking fashion. If locking thread deformation was anticipated as a problem, it could potentially be avoided by use of precontoured plates (TPLO plate, Synthes Inc., Paoli, PA) or use of commercially available locking plugs to maintain hole integrity during contouring (locking plugs, New Generation Devices).

Our study groups included a mixture of narrow and broad 3.5 mm UCP. One could argue that broad plates provide more stability to the TPLO repair regardless of screw type; however, stability of the osteotomy construct results from screw to plate (locking screw) and plate to bone (conventional screw) frictional forces. For this reason, the narrow and broad plates were evaluated together rather than analyzing them separately. Plate size is proportional to the size of the bone, although there was not an
Table 3  Tibial Plateau Leveling Osteotomy Complication Data for 22 Stifles

<table>
<thead>
<tr>
<th>Major complications</th>
<th>Minor complications</th>
<th>Breed</th>
<th>Screw Type</th>
<th>Complication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>Golden Retriever</td>
<td>Standard</td>
<td>Incisional infection with perroso placement*</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>Rottweiler Mix</td>
<td>Locking</td>
<td>Fluctuant mass</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>German Shepherd Mix</td>
<td>Standard</td>
<td>Delayed union</td>
</tr>
<tr>
<td>4</td>
<td>7.58</td>
<td>Labrador Retriever</td>
<td>Standard</td>
<td>Delayed union</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>Labrador Retriever</td>
<td>Standard</td>
<td>Delayed union</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>Deberman</td>
<td>Locking</td>
<td>Delayed union</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>Bullmastiff</td>
<td>Standard</td>
<td>Delayed union</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>Labrador Mix</td>
<td>Standard</td>
<td>Delayed union</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>Great Dane</td>
<td>Standard</td>
<td>Fibular fracture, Tibial plateau shift, slight valgaus</td>
</tr>
<tr>
<td>10</td>
<td>11</td>
<td>Akita Mix</td>
<td>Locking</td>
<td>Broken drill bit intraoperatively</td>
</tr>
<tr>
<td>11</td>
<td>11</td>
<td>Labrador Retriever</td>
<td>Standard</td>
<td>Periostitis</td>
</tr>
<tr>
<td>12</td>
<td>5</td>
<td>Pribull</td>
<td>Locking</td>
<td>Persistent nonweight bearing lameness</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>Labrador Mix</td>
<td>Locking</td>
<td>Pivot shift</td>
</tr>
<tr>
<td>14</td>
<td>8</td>
<td>Labrador Retriever</td>
<td>Locking</td>
<td>Incisional self-trauma</td>
</tr>
<tr>
<td>15</td>
<td>8</td>
<td>Labrador Retriever</td>
<td>Locking</td>
<td>Incisional self-trauma</td>
</tr>
<tr>
<td>16</td>
<td>8</td>
<td>Labrador Retriever</td>
<td>Locking</td>
<td>Incisional self-trauma</td>
</tr>
<tr>
<td>17</td>
<td>8</td>
<td>Mix</td>
<td>Standard</td>
<td>Incisional self-trauma, seroma</td>
</tr>
<tr>
<td>18</td>
<td>5.5</td>
<td>Alaskan Malamute</td>
<td>Standard</td>
<td>Tibial tuberosity avulsion fracture, delayed union</td>
</tr>
<tr>
<td>19</td>
<td>5.5</td>
<td>Chow Mix</td>
<td>Standard</td>
<td>Tibial tuberosity avulsion fracture, proximal screw fracture</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
<td>Mastiff</td>
<td>Locking</td>
<td>Traumatic stifle effusion, hemorrhage</td>
</tr>
</tbody>
</table>

*Previous failed lateral suture repair.  
†Arthroscopy and TPLO performed.  
TPLO: tibial plateau level osteotomy.

objective measure for plate selection in our study. Furthermore, because only locking screws or conventional screws (never both) were used in any UCP, we feel the study reasonably assesses the difference between the 2 screw technologies.

The cranial–proximal "nose" screw was placed to, but not penetrating through, the trans cortex of the tibial plateau to minimize the risk of entering the stifle joint (a reported complication rate of 0.5–3%). Unintentional, intra-articular screw placement had occurred in a single case before this study, requiring immediate screw replacement under the same anesthetic episode with a shorter unicortical locking screw to prevent intra-articular interference. The locking drill guide and contoured plate combination directs the nose screw proximally and caudally, thus commonly directing it intra-articularly if completely drilled and used with full-length screws. This approach could arguably decrease mechanical stability of the construct because of the decreased number of cortices in the proximal, osteotomized segment; however, we have not observed this. Use of preconoured plates or a change to the New Generation Devices plate design could avoid this complication.

TPA

The change in TPA postoperatively was significantly different between groups when analyzing broad and narrow plates together. Given that mean radiographic recheck time was 60.5 days (8.6 weeks) further change is not likely. The mean TPA change (1.9°) is comparable with that reported by Moeller et al (1.5°); however, we had a longer recheck time than Moeller and colleagues (46 days) and only 73.2% of their osteotomies had healed at that time based solely on a radioucent line at the osteotomy. Ninety-seven stifles out of 118 (82.2%) were categorized as ≥50% healed in our patients. The single conventional TPLO categorized as Grade 1 healing in our study had a previously performed lateral suture extracapsular repair. The dog became nonweight bearing lame 11 days after TPLO and an incisional MRSA infection was diagnosed and treated. The infection, disuse, and prolonged recovery may have delayed osteotomy healing in this dog. The patient was lost to follow-up so ultimate radiographic healing is unknown.

Complications

Our overall complication rate was 18.6%, comparable with previous reports of 18.8–28%. The complication rate for the locking TPLO group was lower (14.3%). We excluded dogs that had single session or staged bilateral TPLO because the contralateral limb can potentially affect the results of the other limb. Interestingly, when we looked at outcome in these dogs, there were significantly more complications, and more major complications, and more so when conventional screws were used. Additional studies would be warranted to evaluate the benefit of locking screws in bilateral TPLO because the incidence of bilateral CCL ruptures has been reported to be between 18% and 61.3%.
TT Fractures

TT fractures have a reported incidence of 3.1–9% after TPLO.2-4,18,19 Our TT fracture incidence was 1.7%. Non-displaced TT fractures were typically detected incidentally at radiographic re-evaluation. Owners did not report a noticeable change in the dogs' clinical status at home, which is consistent with previous reports.18 TT fractures were successfully managed with additional exercise restriction without additional surgery.

Our clinical experience suggests that there may be a difference in pathogenesis of major versus minor TT fractures with early TT fractures having more clinical impact. Factors significantly associated with TT fractures include TT width, increase in TPA during the postoperative period and single session bilateral procedures.19 We made no attempt to evaluate TT width. TT fracture dogs in our study did have a mean TPA change of 4.5° from immediately postoperatively to 8-week radiographic re-evaluation, which was higher than the overall mean TPA change (1.9°) and consistent with higher TPA change being a risk factor. Both stifles with TT fractures had TPLO performed with conventional screws.

Limitations

A potential limitation of our study is that osteotomy healing was only evaluated using mediolateral radiographic view compared with orthogonal views in a typical clinical setting. Using the mediolateral view was a conscious choice because with close evaluation of the cranioventral view, one can determine whether locking or conventional screws were used and this could introduce bias into the study design. A second potential limitation was use of 2 different width plates. We are of the opinion that analyzing the locking and conventional screw breadth and narrow implants together rather than as 4 groups accurately reflects the difference between the 2 screw technologies; however, additional studies could be performed to evaluate other sized implants. Further studies are needed to determine the advantages of locking screw technology in other plated bone repairs and whether locking plates offer an advantage in high-risk dogs (e.g. morbidly obese, metabolically challenged, and single-session or staged-session bilateral CCL repair). Further work is needed to elucidate the correlation between TPA and clinical outcome.

We concluded that TPLO using UCP secured with locking screws are an acceptable method of stabilizing tibial plateau osteotomies. Locking screw technology resulted in improved radiographic healing on the mediolateral projection at ~8 weeks and TPA was better conserved when compared with similar fixation using conventional screw technology.

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