Stifle arthrodesis using a locking plate system in six dogs

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Arthrodesis, stifle, locking plate, Fixin, dog

Summary
Objectives: To describe the use of the Fixin locking plate system for stifle arthrodesis in dogs and to retrospectively report the clinical and radiographic outcomes in six cases.

Materials and methods: Medical records of dogs that had arthrodesis with the Fixin locking plate system were reviewed. For each patient, data pertaining to signalment and implant used were recorded. Plate series and thickness, number of screws placed, number of cortices engaged, and screw diameters were also recorded. The outcome was determined from clinical and radiographic follow-ups. Radiographic outcomes assessed included the measurement of the postoperative femoral-tibial angle in the sagittal plane.

Results: Six dogs met the inclusion criteria for the study. Mean body weight was 13 kg (range: 3 - 34 kg). Radiographic follow-up (mean: 32 weeks, range: 3 - 52 weeks) was available for all dogs. In one case, an intraoperative complication occurred. In another case, a tibial fracture occurred 20 days after surgery. All arthrodeses healed and no implant complication was detected although all cases had mechanical lameness.

Clinical significance: Stifle arthrodesis can be performed successfully using a Fixin locking plate system.

Introduction
Arthrodesis is a surgical procedure carried out in cases where it is not feasible to restore functionality of a joint and where joint replacement options to maintain motion are not available. There are several indications for stifle arthrodesis, including complex joint fractures, complications due to sepsis, gunshot fractures, severe osteoarthritis, joint instability due to chronic ligament damage or immune-mediated arthritis, limb-sparing procedures for malignant tumours involving the joint, and following removal of failed prosthetic implants (1-7).

In veterinary medicine, there are several publications describing carpal, tarsal, elbow and shoulder arthrodesis, including success rates and possible complications (4, 8-13). However, there are to the best of our knowledge, only a few cases of stifle arthrodesis in dogs which have been reported to date, and none concerning the use of locking plate fixation (3, 7, 14-16).

The Fixin® system belongs to the category of locking plate systems (17, 18). A distinguishing feature is the screw-plate locking system, which allows for a tapered fit between the conical head of the screw and the conical hole of the bushing-insert screwed into the plate (17, 18).

The aim of this retrospective study was to report our experience and the results obtained using the Fixin locking plate system for stifle arthrodesis in the dog.

Materials and methods
The medical records of dogs that were presented at three surgical referral centres between April 2008 and June 2014 for severe stifle damage, and treated with arthrodesis stabilized solely with the Fixin locking plate system were reviewed.

Inclusion criteria
Inclusion criteria comprised availability of complete clinical records, and preoperative, immediate postoperative, and later than 12 week follow-up radiographic assessment. Cases with follow-up time periods shorter than 12 weeks were reported only if a complication had arisen. With reference to the radiographic follow-up until bone healing, cases were included if at least the medial-lateral projection was obtained.

Patient description
Information relative to the patient history and diagnosis was obtained from medical records. Information related to breed, age (months) and weight (kilograms) was recorded.

Surgical technique
The patients were positioned in dorsal recumbency for surgery. A medial parapatellar approach and stifle o. arthrodesis were performed as previously described (1). Fixin locking plates and screws of appropriate...
length were employed using a previously described technique (17). The plate in each case was contoured to fit the cranial bone surfaces and the screws were placed with a minimum of three proximal and three distal to the stifle. Following plate positioning, the tibial tuberosity was reattached using cerclage wire, compression screws or metric 3.5 polydioxanone sutures anchored to the soft tissues in the proximity of the stifle.

Cephalixin\(^b\) (20 mg/kg b.i.d. for 10 days), carprofen\(^c\) (2 mg/kg b.i.d. for 7 days) and tramadol\(^d\) (2-3 mg/kg b.i.d. for 10 days) were prescribed for all patients. Cage rest and short daily leash walks were recommended until there was documented radiographic evidence of bone union at the arthrodesis site.

**Implant data**

The following parameters associated with the implant were recorded during surgery: bone plate code and series (large or mini), plate length, plate thickness (mm), number of screws placed, number of cortices engaged, screw diameter (mm), and tibial tuberosity fixation method.

**Outcome evaluation**

The clinical and radiographic evaluations were performed by the same three surgeons who performed the surgical procedures.

Clinical and radiographic re-examinations were not scheduled at fixed regular intervals for all patients. The timing of the clinical and radiographic re-examinations was recorded in weeks.

**Radiographic outcome**

Orthogonal radiographic views of the treated stifle were obtained immediately after surgery. The arthrodesis angle in the sagittal plane was measured radiographically using commercial software\(^e\). In some cases, radiography was performed without sedation. Arthrodeses were considered healed when radiographic evidence of bone union was observed. Evidence of bone union was considered to be satisfactory when the radiolucent line between the two bone segments viewed mediolaterally was no longer visible. Radiographic evaluations after bone healing (greater than 12 weeks) were performed to monitor any signs of bone reabsorption in the screw-bone region (19, 20).

**Clinical outcome**

Limb function, evaluated more than 60 days after surgery, was classified as painful lameness, mechanical lameness, non-weight-bearing lameness, or normal. Painful lameness was defined as an abnormal gait caused by pain, and required the localization of signs of pain at orthopaedic examination. Mechanical lameness was defined as an abnormal gait caused by a structural or anatomical modification of the locomotor system with no signs of pain elicited at orthopaedic examination.

**Complications**

Any complications related to the implants or the surgical procedure were analysed. Complications were classified as short-term if they developed within the first four weeks following surgery and long-term if they developed starting four weeks after surgery.

Complications were deemed as minor if they did not require revision surgery. If however revision surgery was required for bone healing, then complications were deemed as major. Complications were classified as “implant failures” or “other complications”. Implant failures included plate or screw breakage, plate bending, and screw pull-out. Other complications included problems not related to implant failures such as skin incision disruption, improper reduction with axial deviation, and osteomyelitis.

**Results**

**Patient description**

The medical records and postoperative radiographs of six dogs treated by arthrodesis with the Fixin locking plate system were reviewed. One Pomeranian, one Fox Terrier, one Toy Poodle, one German Shepherd, and two small sized cross-breed dogs met the criteria for inclusion in the study (Table 1). The mean age was 51 months (range: 9 to 107 months) and the mean

<table>
<thead>
<tr>
<th>Case</th>
<th>Breed</th>
<th>Age (months)</th>
<th>Weight (kg)</th>
<th>Radiographic follow-up (weeks)</th>
<th>Radiographic healing (weeks)</th>
<th>Clinical follow-up (weeks)</th>
<th>Arthrodesis angle (°)</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>Pomeranian</td>
<td>72</td>
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<tr>
<td>2</td>
<td>Fox Terrier</td>
<td>71</td>
<td>7</td>
<td>12</td>
<td>12</td>
<td>2 – 4 – 12 – 28</td>
<td>144</td>
</tr>
<tr>
<td>3</td>
<td>Mixed</td>
<td>107</td>
<td>12.8</td>
<td>6 – 16</td>
<td>16</td>
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<td>134</td>
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<tr>
<td>4</td>
<td>Toy Poodle</td>
<td>9</td>
<td>3.1</td>
<td>3 – 8 – 11 – 22</td>
<td>11</td>
<td>3 – 8 – 11 – 22 – 40</td>
<td>135</td>
</tr>
<tr>
<td>5</td>
<td>German Shepherd</td>
<td>12</td>
<td>34</td>
<td>7 – 20 – 32</td>
<td>32</td>
<td>2 – 7 – 20 – 32</td>
<td>118</td>
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<tr>
<td>6</td>
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<td>36</td>
<td>16</td>
<td>4 – 15</td>
<td>15</td>
<td>2 – 4 – 15 – 24</td>
<td>145</td>
</tr>
</tbody>
</table>

\(\) Data on patient signalment, timing of radiographic follow-up examinations (weeks), time until radiographic healing (weeks), timing of clinical follow-up examinations (weeks), and the measured femoral-tibial angles following surgery.
History and diagnosis

In all six patients, the preoperative radiographic views showed major abnormalities of the stifle joint which were the cause of clinical symptoms such as non-weight bearing lameness, decreased range-of-motion, and signs of pain on passive motion at stifle flexion and extension. In four cases out of six, stifle arthrodesis was necessary due to failure of a previous procedure. In case 1, the arthrodesis procedure was performed after traumatic and chronic stifle luxation involving collaterals and cruciate ligament rupture. The patient had severe cranial subluxation of the tibia, with total lack of contact between the femoral condyles and the tibial plateau. Dog 2 experienced a severe chronic patellar ligament rupture during a tibial tuberosity transposition procedure. The patellar ligament rupture was diagnosed by ultrasound examination. Arthroscopic evaluation showed osteoarthritic alterations and severe erosion of the joint cartilage over the femoral condyles. Two months after a tibial plateau levelling osteotomy procedure, dog 3 was run over by a car, suffering a rupture of the stifle lateral collateral ligament and fracture of the tibial tuberosity. Revision surgery failed and the patient experienced severe osteoarthritic changes and poor stifle range-of-motion. In case 4, lateral transposition of the tibial tuberosity was mistakenly performed on a dog with lateral patellar luxation. The patient was examined several months after surgery and displayed severe stifle osteoarthritis. Case 5 underwent osteosynthesis following distal femoral fracture. During surgery the screws were incorrectly positioned, thus causing serious and irreparable damage to the joint cartilage. Case 6 displayed a severely damaged stifle following distal femoral joint fracture that had never been treated, consequently the dog had not used the limb for two years.

Surgical technique

In cases 2, 4, 5, and 6, a jig\(^f\) was used to maintain segmental bone contact once the osteotomies were completed. The jig was also used to compress the two edges of the bones before fixation. The jig was anchored to each bone segment using smooth pins of \(3\) mm diameter or less. The diameter of each pin was 25% of the bone diameter at the pinning site. Then, through the lock-screw holes in each of the two jig arms, 1.5 mm cerclage wire was passed. The wire was locked at one end and the other end was tensioned using a wire twister against the other jig arm to compress the osteotomy site before locking the second arm screw (Figure 1).

Implant data

The type and size of the implants used in each case are summarized in Table 2. Six screws per plate were used in all cases except case 6. Case 6 required double plating (11 screws). The second implant used was a hybrid plate designed for tarsal panarthrodesis. This implant was positioned on the lateral side of the stifle which allowed the insertion of two 3.0 mm screws in the femur and three 1.9 mm screws in the tibial diaphysis. All the screws engaged two cortices.

The tibial tuberosity was stabilized with polydioxinone suture in dogs 4 and 6, tension band cerclage wire in dogs 1 and 3, and two compression screws in dogs 2 and 5 (Figure 2, Table 2).

Radiographic outcome

The arthrodesis angles measured in the postoperative radiographs ranged between 105° and 145° (mean: 130°, median: 135°) (Table 1). The radiographic follow-up examinations were carried out between three and 52 weeks after the procedure (mean: 32 weeks, median: 15 weeks) (Table 1).

All arthrodeses healed. Mean healing time was 18 weeks (Table 1).

Clinical outcome

The times of clinical follow-up examinations are reported in Table 1. All dogs had a mechanical lameness. Case 1 (arthrodesis angle = 105°) and case 5 (arthrodesis angle = 118°) were weight bearing while walking.

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\(\text{f US Patent No. 5,578,038: Slocum Enterprises*, Eugene, OR, USA}\)
Complications were reported in two cases. All complications were classified as short-term, major complications. No complications were classified as a fixation failure.

One intra-operative complication was a fissure fracture of the cranial cortex of the tibial diaphysis in case 6, during tightening of the distal screw. The complication was overcome by application of a second locking plate designed for lateral tarsal panarthrodesis \(^\text{((SEE FOOTNOTE)})\) with two 3.0 mm screws in the femur and three 1.9 mm screws in the tibial diaphysis. This implant was inserted without pre-contouring as it already comes with a 135° angle. The 135° angled plate was applied to a 145° arthrodesis without centring the distal longitudinal mid-bone axes of the femur and the proximal tibia in the sagittal plane. ((AUTHORS: Please verify this sentence - the meaning is not clear))

Dog 4 sustained a fracture of the tibial diaphysis, at the level of the distal screw, after being trampled by a runner 20 days after surgery (\(\text{Figure 3a and b})\). Revision surgery was performed using a 6-hole locking plate on the medial side of the tibia (\(\text{Figure 3c and d})\). Eighty days after the initial surgery (60 days after the second), the radiographic follow-up showed bone union.
Discussion

The results of this retrospective study suggest that the Fixin locking plate system allows bone healing following stifle arthrodesis in the dog. Use of the jig made it possible to compress the two cut ends of the bones during surgery and held the femur and tibia stable during plate application.

When using a traditional implant, the plate needs an ample contact surface with the bone. Therefore, flattening the cranial surface of the distal femur together with the osteotomy of the tibial tuberosity allows for better contact between the bone surfaces and the plate, thus reducing the risk of implant failure (21). When using angular stable locking implants, it is not essential for there to be full contact between the plate and the bone surface, or for the plate to be accurately shaped to fit the bone surface (17, 18). In all cases, although a locking implant was used, the surgeon opted to seek the largest possible contact surface between the bone and the plate.

It was suggested that at least four screws be used in the femur, and at least four screws in the tibia when using conventional implants (1, 2, 5, 19). In all the cases, except for case 6, we used only three screws per bone. The authors believed that these implants with six locked screws would provide satisfactory stability (18).

In the literature there are no descriptions of tibial tuberosity fixation using sutures. In our study, this technique was used in a small dog because the authors considered that the tibial crest might be too thin for fixation with pins, cerclage wire or screws. In the second case, the decision to use suture to stabilize the tibial tuberosity was secondary to the intra-operative complication in which a second plate to treat the iatrogenic fracture was applied to the lateral side of the limb. Since there was no proximal dislocation of the tibial tuberosity or patella during the postoperative period, suture stabilization was deemed to be a satisfactory choice for keeping the tibial crest in place until consolidation of the fracture. The authors speculate that stifle arthrodesis probably limits the traction stress exerted by the quadriceps muscle on the tibial tuberosity through the patellar ligament, thus protecting the suture.

This might explain the healing that occurred in these two cases.

Some authors recommend bandaging the limb for two to four weeks postoperatively, while others advise bandaging and splinting on the lateral side of the limb for six weeks to protect the osteosynthesis implant until partial healing of the bone (1, 5, 19). None of our patients were bandaged or splinted following the procedure. The authors believe that the angle stable implants used ensure the necessary stability for the arthrodesis to heal without the need for bandaging. In some cases bandaging might be advisable for 24 to 48 hours post-surgery to minimize oedema.

When the arthrodesis procedure is performed as described, there is a large contact surface between the two osteotomies of the metaphyseal cancellous bone (1). We theorize that there would be continuous postoperative dynamic interfragmentary compression secondary to limb loading because the plate is positioned on the tension side (see Figure 4). The decision to use an angular stable implant was made because this type of implant provides more reliable and longer stability of fractures than a conventional implant (20-24). The recovery time is indicated as two to nine months; therefore the authors preferred an implant ensuring prolonged stability until the full healing of the arthrodesis (1, 5, 19).

Bone union of the osteotomies was radiographically noted at a mean of 18 weeks postoperatively, but since the radiographic follow-up examinations were not planned at regular intervals and were not the same for all patients, healing could have occurred earlier. On the other hand, radiographic signs of healing might not correspond to histological progression of healing. It has been reported in a study on humans that radiographic healing occurred before histological healing (25). This should be taken into consideration in the event of implant removal.

The angle for stifle arthrodesis recommended in the literature is 125–150° (1, 2, 19). According to Köstlin the suitable angle in the dog corresponds to the physiological angle plus 10% (14). Implant pre-bending increases the likelihood of achieving the intended angle of arthrodesis. In two of our cases (case 1 [105°] and 5 [118°]) the resulting angle of arthrodesis was more acute than expected, because during the procedure, it was not possible to extend the stifle any further. The authors suspect that it might have been due to a soft tissue impediment. In these cases, the angle of the plate was accordingly modified intra-operatively.

In case 6, it was necessary to remove a large portion of the distal femoral condyles, and the surgeon deemed it necessary to increase the angle between the femur and tibia by approximately five degrees intra-operatively in order to compensate for limb shortening.

In the authors’ opinion, fissure of the tibial diaphysis (case 6) may have occurred for two reasons. Firstly the patient had not...
used the limb for two years. The bone cortical thickness was severely reduced, particularly at the proximal tibial metaphysis and distal femoral metaphysis. The second reason could be that the screws were too large in diameter. The screws were 3.5 mm in diameter, although 3.0 mm screws could have been used for that particular plate. The surgeon preferred to use the larger diameter screws to increase the contact surface at the screw-bone interface and thus reduce the risk of screw cut-out from the bone.

The second complication of tibial fracture at the level of the last distal screw has been described previously and can be associated with poor contact between the bone and the implant and with the long lever arm attached to the plate (1, 2, 19).

With a conventional implant, it has been recommended to remove the implant once recovery is complete and to use long plates covering more than one half of the total length of the femur and tibia (1, 2, 19). In the four cases with no complications, the plate reached the proximal third of the tibia. In the case in which the fracture of the tibia occurred, the plate extended less than half-way along the tibial diaphysis. We cannot know whether it was the external trauma alone that caused the fracture, or a combination of the trauma plus the plate not reaching the middle of the tibia.

We opted to assess radiographic healing using the mediolateral view alone because with a caudocranial or craniocaudal view, it would be difficult to line up the x-ray beam with the osteotomy plane, even with the patient under general anaesthesia.

It has been suggested that the implants be removed six to nine months after arthrodesis and after healing (1, 2, 5, 19). When using Fixin angular stable implants, we recommend annual radiographic follow-up examinations to detect screw loosening or stress protection (20, 26-28). In regard to the stress protection phenomenon, the follow-up times in our study may not be long enough for the majority of cases to allow detection of such complications.

Our study has certain limitations, mainly stemming from its retrospective design involving multiple surgeons. Clinical and radiographic re-examinations were not scheduled at fixed regular intervals for all patients. In some circumstances, radiographs were performed without sedation. Our study may under-report postoperative complications because follow-up on all cases was less than one year.

In our study the Fixin implants had characteristics that make them satisfactory for stifle arthrodesis in the dog.

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Conflict of interest

M. Petazzoni designed the Fixin system, however he has no financial interest in the companies that manufacture or market the system. T. Nicetto is a consultant to the company that produces the Fixin system.

References