Experiences using the Fixin locking plate system for the stabilization of appendicular fractures in dogs

A clinical and radiographic retrospective assessment

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Introduction

In conventional bone plating systems, stability is achieved by the compression between the plate and the bone generated by the screws (1). With the introduction of locking systems, the screw head is securely fixed to the plate, removing the need for the plate to be compressed to the bone (1, 2). This reduces insult to the periosteum and its vascularization (1-5). Due to the robust screw-plate junction and the fixed angle nature of the screw, perfect plate contouring becomes unnecessary. Consequently, from a mechanical perspective, locking plating systems are not dissimilar to external skeletal fixation; indeed these systems have been described as internal fixators (1, 2, 4, 6).

The Fixin system is divided into a ‘mini-implant series’ (plate thickness: 1.2 mm, 1.5 mm, or 2.0 mm; plate length: 25 mm to 100 mm) and a ‘large-implant series’ (plate thickness: 1.5 mm, 2 mm, 2.5 mm, or 3 mm; plate length: 44 mm to 192 mm). Whereas the former are applied using 1.9 mm or 2.5 mm diameter screws and are indicated for the treatment of fractures in cats and dogs up to 10 kg, the latter are applied using 3.0 mm or 3.5 mm diameter screws and are indicated for animals weighing more than 10 kg (6). The surgeon may select the implant using a body weight table provided by the manufacturer indicating the appropriate plate thickness based on patient body weight, fractured bone, type and location of bone fracture (7).

To the authors’ knowledge, there are currently no clinical reports of patient outcomes following application of the Fixin system for appendicular fractures in dogs.
The purpose of this study was to report our experiences using the Fixin system for the management of appendicular bone fractures in dogs.

### Materials and methods

The medical records of dogs with traumatic appendicular bone fractures that were stabilized solely using the Fixin bone plating system at three surgical referral centres in Italy (Clinica Veterinaria Dr Andrea Urizzi, Clinica Veterinaria Milano Sud, and Department of Veterinary Clinical Sciences, Padua University) between May 2005 and September 2010 were reviewed.

### Inclusion criteria

Inclusion criteria included the availability of complete clinical records and of immediate postoperative and follow-up radiographs. Only cases with follow-up radiographs taken at least 40 days postoperatively were included in the study. Cases with follow-up time periods shorter than 40 days were included only if a complication had arisen. Fractures were excluded if other primary or secondary methods of stabilization such as Kirschner wire, cerclage wire, intramedullary pin and screws had been used.

### Patient and fracture description

The information obtained from the medical records including breed, gender, age (months), body weight (kilograms), bone fractured (humerus, radius and ulna, pelvis, femur, tibia), and fracture type were recorded. The type of fracture was classified as transverse, oblique or comminuted (more than two cortical fragments in the fracture zone). In dogs that had more than one bone fractured, each bone was considered separately.

### Description of stabilization method

The implant was selected based on the indications of the body weight table and the opinion of individual surgeons. Fixin plates were applied as previously described (6). Briefly, the main steps included: direct reduction of the fracture using conventional methods, provisional stabilization of the implant to the bone using pins and pin-stoppers or reduction pliers, drilling using the appropriate drill guide and insertion of self-tapping locking screws after measuring (6). When necessary, the implants were contoured accordingly in order to reduce the distance between the bone and the implant, hence reducing the working length of the screws.

Postoperatively, all patients were administered antibiotic medications, non-steroidal anti-inflammatory drugs and an analgesic therapy using individualized dosage regimens.

### Implant data

Orthogonal radiographic projections of the fractured bone were obtained immediately after surgery.

The following parameters associated with the implant were recorded during surgery or measured on postoperative radiographs: bone plate series (large or mini), plate thickness (mm), number of screws placed proximal and distal to the fracture, number of cortices engaged, and screw diameter (mm). The use of either a single plate or double plating was recorded. The size of plates and screws used were compared with the patients’ weight. Patients were divided into groups according to their body weight: 0 to 10 Kg, >10 to 20 Kg, >20 to 30 Kg, and >30 to 40 Kg. For each group the plate thickness and screw diameter were recorded.

### Outcome evaluation

Outcomes were evaluated based on the information obtained from the medical records and follow-up radiographs. The timing of clinical and radiographic re-examinations was recorded in days.

### Radiographic outcome

Fractures were considered healed when radiographic evidence of a callus bridging at least one cortex in two radiographic planes of projection was observed (8). All three investigators had to fully agree before a fracture could be considered healed.

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**Figure 1** American Staffordshire terrier, nine-months-old, female, 24 kg. Left tibia and fibula diaphyseal fracture. Minimally invasive percutaneous osteosynthesis. Medio-lateral and caudo-cranial views: A) preoperative, B) postoperative, C) six-week follow-up, D) 12-week follow-up, E) two-year follow-up.
Clinical outcome

Limb function, evaluated between 40 days and 90 days postoperatively, was classified as being normal, mild lameness, severe weight bearing lameness, or non-weight bearing lameness. Telephone consultations were carried out in selected cases where clinical examination between 40 days and 90 days following surgery had not been performed. Owners of pets with minor and major complications were contacted by phone for long-term follow-up (minimum 6 months) of lameness.

Complications

Any complications related to the implant or the surgical procedure were recorded. Complications were classified as short-term if they developed within the first 30 days following surgery and long-term if they developed after 30 days following surgery. Complications were deemed as minor if they did not require a revision surgery, and major if revision surgery was required to achieve bone healing. Complications were further classified as ‘fixation failures’ or as ‘other complications’. Fixation failures included: plate or screw breakage, plate bending and screw pull-out. Other complications included problems not related to implant failures such as incisional complications, improper reduction with axial deviation and osteomyelitis.

Results

Patient and fracture description

The medical records and postoperative radiographs of 89 dogs that were presented for treatment of appendicular fractures were assessed. Among the cases examined, 14 dogs were excluded from the study. An additional implant was used in nine of these dogs (cerclage wire in 3 cases, Kirschner wire in 1 case, intramedullary pin in 3 cases, and compression screw in 2 cases), and duration of follow-up was less than 40 days in the other five dogs.

Seventy-five dogs (82 fractures) met the criteria for inclusion in the study. Within this population, 27 different breeds were represented by dogs of both genders (42 male, 33 female), aged between three months and 15 years (mean 31.5 months, median 42 months), and weighing between 1.3 kg and 40 kg (mean 11.5 Kg, median 16 Kg). The treated fractures involved the humerus (n = 5), radius-ulna (n = 35), pelvis (n = 6), femur (n = 18) and tibia (n = 18) (Figure 1). Fifty-six fractures were transverse, 12 oblique and 14 comminuted.

Implant data

An implant from the mini-series set was used in 44 fractures. In the remaining 38 fractures an implant from the large series was used.

For dogs weighing up to 10 kg, mini implants were used in 41 out of 53 fractures, and large implants were used 12. For dogs weighing >10 kg to 20 kg, mini implants were used in three out of 16 fractures, and large implants in 13 fractures. For all dogs weighing more than 20 kg, an implant of the large series set was used (Figure 2).

The thickness of the implants used was 1.2 mm (29%), 1.5 mm (33%), 2.0 mm (25%), 2.5 mm (9%), and 3 mm (4%) (Figure 3). The 1.9 mm screws were used in 18 fractures (22%), the 2.5 mm screws in 26 fractures (31.5%), the 3 mm screws in 14 fractures (17%), and the 3.5 mm screws in 24 fractures (29.5%) (Figure 2). Four

Figure 2
Graph representing the use of Fixin implants in the study animals, with respect to each plate thickness range (1.2 mm, 1.5 mm, 2 mm, 2.5 mm, 3 mm). Patients were divided into groups according to their body weight: 0 to 10 Kg, >10 to 20 Kg, >20 to 30 Kg, and >30 to 40 Kg. The blue colour was used to record cases presenting no complications involving the plate. Cases involving plate bending and plate breakage were marked in grey and black, respectively.
screws per plate were used in 40 fractures (49%), five screws in 12 fractures (14%), six screws in 23 fractures (29%), and eight screws in five fractures (6%). The remaining two percent were represented by two dogs treated using double plating. The screws engaged seven to 20 cortices (mean 10). 95% of the screws were inserted engaging two cortices. A range of two to five (mean 3) screws were inserted per bone fragment.

Double plating was performed in two cases to improve construct stability. The first case was a four-month-old, 4.5 kg female Dachshund with a transverse fracture of the proximal third of radius and the distal third of the ulna in the same limb. Due to the curvature of the bone in the frontal and sagittal plane, it was not possible to contour one single plate to achieve adequate numbers of screws per bone fragment. Therefore, two mini-series implants were used: one was 39 mm long and the second was 29 mm long. Four 1.9 mm diameter screws (2 distal and 2 proximal to the fracture) were used in the long plate and two 1.9 mm diameter screws were used in the second plate (one distal, one proximal). The two plates were placed on the diaphysis of the radius. Radiographic re-examination completed 42 days after the surgery showed healing of the bone.

The second double plated case was a three-year-old, 18 kg Springer Spaniel that had transverse bilateral fractures of the distal third of the radius-ulna (▶ Figure 4 A). The right fracture was stabilised using a 53 mm long, 1.5 mm thick mini-series plate with three 2.5 mm screws distally and three 2.5 mm screws proximally. The plate was applied medially. During application, the surgeon realized that the plate was not aligned with the bone in the sagittal plane, with the proximal screw not purchasing the centre of the bone (▶ Figure 4 B). For this reason, a second plate 39 mm long, 1.2 mm thick mini set plate with four 2.5 mm screws was applied cranially (▶ Figure 4 B). The fracture subsequently healed (▶ Figure 4 C, D).

**Outcome evaluation**

Clinical and radiographic re-examinations were not scheduled at regular intervals for all patients.

**Radiographic outcome**

Radiographic re-examinations were carried out between eight days to two years (median 60 days) following surgery with an average of two radiographic assessments for each patient. One radiographic re-examination was performed in 14 fractures, two re-examinations were performed in 45 fractures, three re-examinations were performed in 15 fractures, and more than three re-examinations were performed in eight fractures. The first radiographic re-examinations were performed as follows: 49 fractures were first seen within 30 days postoperatively, 27 fractures were first seen between 30 to 60 days after surgery, and six fractures were first seen between eight and 17 weeks postoperatively. The final radiographic follow-up examinations were performed as follows: four fractures were seen within 30 days postoperatively, 32 fractures were seen between 30 to 60 days after surgery, 20 fractures were seen between 60 and 90 days after surgery and 26 fractures were seen between 90 days and two years postoperatively. Seventy-three out of 82 fractures (89%) reached radiographic union without complications.

**Clinical outcome**

Clinical re-examinations were performed between three days and two years (mean 62 days) after surgery. During the long-term follow-up period from six months to two years after surgery, nine owners were contacted by phone regarding their pets’ complications. All owners except two reported a full use of the limb, and no fracture complications were reported.
required a third intervention. A mild lameness was occasionally observed in two dogs. Limb function was graded as normal in 73 (97%) dogs and ‘mild lameness’ in two (3%) cases.

Complications assessment

Complications occurred in nine out of 82 fractures (11%). All complications resolved after treatment. The complications involved the humerus (1 case), radius-ulna (5 cases), femur (2 cases) and tibia (1 case). Six short-term and three long-term complications were observed.

Minor complications reported in three cases included incidental breakage of one screw, osteomyelitis (resolved after antibiotic therapy), and moderate malreduction resulting in valgus deviation of the distal radius following the operation. Six major complications required surgical revision for plate breakage (4 cases), plate bending (1 case), and screw breakage (1 case). The major complications were diagnosed between eight and 60 days after surgery.

Seven complications were classified as fixation failures: breaking of the plate (4 cases), bending of the plate (1 case), and breaking of the screws (2 cases). Two complications were referred to as ‘other complications’: osteomyelitis in one case and postoperative valgus deviation of the distal radius in one other case.

Screw breakage (n = 2)

Screw breakage was diagnosed in a two-year-old, 8 kg female miniature poodle with a radius-ulna fracture. A 63 mm long, 1.5 mm thick implant was placed using six 1.9 mm screws. Six months after the operation the surgeon decided to remove the implant as there were radiographic signs of bone resorption at the screw-bone interface (Figure 5 A). No evidence of lameness was apparent at this time. Breakage of the second screw was observed at the time of plate removal (Figure 5 B, C).

In one case, the complication involved the breaking of two screws with total loss of stability of the fracture. This case consisted of an open comminuted fracture of the mid-third of the femoral diaphysis in a two-year-old, 8 kg male mixed-breed dog. A large-series, 6-holed, 92 mm long, 2 mm thick implant with five 3.5 mm screws, two proximal and three distal, was used (Figure 6 A). The screws failed fifty-six days following surgery (Figure 6 B). The surgical revision involved the removal of the two broken screws and replacement of the plate with another one of the same size util-
Characterizing three proximal screws (▶Figure 6C). No evidence of lameness was apparent at the time of clinical examinations. The owners declined further radiographic examinations.

**Plate breakage (n = 4)**

The first patient was a six-year-old, 7 kg male mixed-breed dog presented with a mid-diaphyseal transverse humeral fracture. A 6-holed ‘mini-series’ implant (57 mm long, 1.2 mm thick), with two proximal and three distal 2.5 mm screws, was used. Plate breakage was diagnosed nine days following surgery (▶Figure 7). Surgical revision was completed with the use of an external skeletal fixator that resulted in radiographic union of the fracture. Mild lameness was occasionally observed by the owner.

The second and the third cases (a two-year-old, 8 kg female mongrel dog and a six-month-old, 38 kg male Bernese mountain dog, respectively) were patients with transverse fractures involving the distal third of the radius-ulna. A 6-holed, 63 mm long and 1.5 mm thick plate was used in the first case, and an 8-holed, 161 mm long, 2.5 mm thick plate in the second case. Plate breakage occurred 42 and 30 days after surgery, respectively. The mongrel dog was treated by means of a Robert-Jones bandage for four weeks and was then considered healed. The owner occasionally observed a mild lameness. The Bernese mountain dog was successfully treated by means of double plating using the Fixin system. Full use of the limb was reported by the owner at long-term follow-up.

In the fourth case, plate breakage occurred in a three-year-old, 18 kg Springer Spaniel presented with transverse bilateral fractures of the distal third of the radius-ulna (▶Figure 4A, ▶Figure 8A). The patient experienced a complication from the left antebrachial fracture which was repaired using a 59 mm long, 1.5 mm thick mini-series plate, with three 2.5 mm distal screws and three 2.5 mm proximal screws to the fracture (▶Figure 8B). Implant failure occurred 14 days after surgery (▶Figure 8C). Surgical revision using a large series plate resulted in fracture healing (▶Figure 8 D, E). Full use of the limb was reported by the owner at long-term follow-up.

**Plate bending**

Bending of the plate was seen in a 2.5-year-old, 8.2 kg male mixed breed dog with an open transverse diaphyseal tibial fracture. A 4-holed (59 mm long, 1.5 mm thick) plate with four 3.5 mm diameter screws was used. The plate failure occurred eight days after surgery when the owner reported that the dog had trapped its leg, prior to the acute onset of lameness. During the surgical revision, a 6-holed, 79 mm long, 2 mm thick implant was inserted using six screws, 3 mm in diameter, which resulted in complete healing of the fracture.

**Discussion**

In this study limb function at long-term follow-up was graded as normal in 73 out of 75 dogs (97%) and ‘mild lameness’ in two cases (3%). This is comparable to the results obtained by other authors for the evaluation of another locking plating system for long-bone fractures in small animals. Baroncelli et al. reported excellent results in 20 out of 25 cases (80%) and occasional mild lameness in five cases (20%) using locking compression plates

The data collected showed that 89% (73 out of 82) of the fractures achieved fracture healing without any complications. All complications resolved after treatment.

We observed an 11% overall complication rate with three minor complications (3.5%) and six major complications (7.5%). This is comparable to the results obtained by other authors for the evaluation of other locking plating systems for long-bone fractures in small animals. Haaland et al. reported an overall 12.8% complication rate (minor 4.3%, major 8.5%) when locking compression plates were used while Baroncelli et al. reported no major complications and 11.5% minor complication rate using the same plating system (9, 10). Voss et al reported a 19.7% complication rate (minor 12.2%, major 7.5%) when the Unilock locking plate system was used in long-bone fractures in cats and small dogs (11). The complication rate observed for this study was lower than that observed with different osteosynthesis systems (external fixators [30%], Mennen clamp-on plate [36%], interlocking nails [23%]) used in appendicular fracture repair (12-14).

Complication rates up to 66% are reported in the literature for the treatment of radius-ulna fractures with open reduction using conventional bone plates in small and miniature dogs (15, 16). Larsen et al. reported a 54% overall complication rate with catastrophic complications occurring in 18% of fractures and minor complications occurring in 36% of fractures (15). Conversely, Hamilton et al reported a 66% overall complication rate (ulna resorption) and no major complications using the AO plate.

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Figure 6
Mixed breed, two-years-old, male, 8 kg. Left Femur; diaphyseal comminuted fracture.
A) Postoperative cranio-caudal view.
B) Radiographic follow-up 56 days postoperatively demonstrating breakage of two screws.
C) Cranio-caudal view after revision.

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b Synthes, Solothurn, Switzerland
veterinary mini T-plate in 14 dogs (16). Other authors have identified nonunion and delayed union as frequent complications in the treatment of radius-ulna fractures in small dogs (17-19). In this study, we treated 53 dogs weighing 10 kg or less, 25 of which presenting with radius-ulna fractures. Two complications (8%) - one minor and one major complication - were observed in these dogs. Nonunion did not occur in any fracture. The complication rate in this case series was found to be lower compared to reported complication rates of other osteosynthesis techniques for radius and ulna fracture treatment. In our opinion, the Fixin system could have offered one substantial advantage related to conventional plating systems. The plates are not compressed to the bone, thus there is minimal disturbance to the periosteal vascularization of a region with decreased vascular supply in toy and small breed dogs (20).

In two out of four major complications involving plate breakage, the implant used was undersized compared to the recommendations of the manufacturer (7) (Figure 2 and 3). Furthermore, in one of these fractures, one unfilled plate hole was localized at the level of the comminuted fracture (Figure 7). The choice of screw positioning and plate thickness may have contributed to the breakage of the plate due to cyclic bending (21-23). A thicker plate of the mini set without holes at the level of the fracture would have been more appropriate. In the second case, plate breakage occurred in an 18 kg dog (Figure 8A). The implant was undersized with respect to the weight of the patient, as the mini-series implants are recommended for animals weighing up to 10 kg (6).

Surgical revision of the case with breakage of two screws involved the removal of the two broken screws and replacement of the plate with another one of the same size utilizing three proximal screws (Figure 6C). The plate served as a bridging plate. Therefore, the use of only two proximal screws was probably inadequate to withstand the forces acting upon it (Figure 6B).

From the analysis of the complications arisen, it is evident that three (two with broken plates and one with broken screws) out of the six (7%) fractures requiring surgical revision were caused by the incorrect choice of the implant. A considerable number of the cases included in this retrospective study involved the first patients treated with the Fixin system. As with the use of any type of implant, the learning curve may influence early study results. Experience is likely to improve surgical choices for implant selection and application, thus possibly reducing the risk of complication even further.

Various internal osteosynthesis systems have been tested for the resistance to bending and torsional stress in recent in vitro studies (24, 25). The Fixin system showed relatively low bending stiffness and strength when compared to other locking plate fixation systems (24). The clinical complication rate reported here with the Fixin system was consistent with other angular stable osteosynthesis systems (9-11). In this study, plate bending associated with a traumatic event was reported in one case.

Figure 7 Mixed-breed, six-years-old, male, 7 kg. Right humerus; diaphyseal fracture. A) Postoperative medio-lateral view. B) Radiographic image taken at the follow-up examination nine days post-surgery. Breakage of the plate.

Figure 8 Springer Spaniel, three-years-old, male, 18 kg. Left distal radius-ulna fracture. A) Preoperative medio-lateral view, B) postoperative medio-lateral and cranio-caudal views, C) cranio-caudal view at 14 days (implant failure), D) medio-lateral and cranio-caudal views after revision, E) cranio-caudal view taken 9.5 months after revision.
A minimum of three bicortical screws in each main fragment (6 cortices) is optimal for compression and neutralization plating and it is recommended for bridging plating in small animals using conventional systems (26). A minimum of three bicortical screws in each fracture segment was also recommended for fracture healing when Locking Compression Plates were used (21). A mean of three (median 2) screws per bone segment were used in this study and 49% of the fractures were treated successfully using only two bicortical screws per fracture segment. However, the vast majority of dogs were toy, small and medium breeds (mean weight 11.5 kg, median 16 kg) and no giant breeds were treated.

In this study, the surgeons used mainly bicortical screws (95%); the literature reports that bicortical locking screws improve torsional stability of the construct by more than 50% compared to unicortical locking screws (27).

In two cases, the use of two implants was deemed necessary to adequately stabilize the fracture. Double plating was described for the treatment of Y-T humeral condyle fractures in dogs (28). The use of two locking plates is a surgical solution that allows for the stabilization of the fracture while countering forces in a way that is similar to the application of biplanar external skeletal fixator configuration.

In our cases, no complications were observed in patients treated with double plating.

There are limitations to our study, mainly stemming from its retrospective design, which in itself limits the conclusions that can be derived from the results. Due to the retrospective nature of the study, clinical and radiographic re-examinations were not scheduled at fixed regular intervals for all patients. Hence it is possible that complications may have been missed because of limited radiographic re-examinations. In some circumstances, radiographic examinations were performed without sedation. However, radiographic positioning was adequate to permit evaluation of fracture healing in all cases. Furthermore, postoperative skin complications such as wound dehiscence, seromas and lesions caused by bandaging may not have been reported in the medical record. It would have been interesting to record data pertaining to surgical time and length of surgical approach in the patient medical record for comparison with other types of implants. These same study limitations are inherent to previous fractures treatment outcome studies (9-14).

Despite these limitations, this study has shown that radiographic healing and good clinical outcomes can be achieved in most cases. Therefore, the Fixin locking plate system appears to be an acceptable choice of implant for the stabilization of appendicular fractures in dogs.

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**Conflict of interest**

Massimo Petazzi and Andrea Urizzi are partners of Traumavet, the company which owns the patents on, produces and sells the Fixin system. Tommaso Nicetto is a consultant of Traumavet.

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