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Treatment of fractures of the distal radius and ulna in toy breed dogs with circular external skeletal fixation: a retrospective study

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Keywords

Radius, fracture, circular external skeletal fixation, dog

Summary

Objective: To evaluate the effectiveness of circular external skeletal fixation (CESF) in treating fractures of the distal radius and ulna in toy breed dogs, and to document the type and frequency of complications associated with this technique.

Methods: The medical records of small breed dogs with fractures of the distal radius and ulna admitted to the University of Turin and to the Clinica Ferretti between 2002 and 2009 were retrospectively reviewed. The criteria for inclusion of cases in the study were: body weight of 5 kg or less, transverse or short oblique fracture of the distal third of the radius and ulna, no previous repair attempts, and treatment with CESF as the sole method of fixation.

Results: Twenty fractures in 16 dogs satisfied the criteria for inclusion into this study. No signs of infection or failure of fixation were detected in any case. Mean frontal plane alignment was $4.7^\circ \pm 2.7^\circ$ and mean sagittal plane alignment was $12.7^\circ \pm 7.2^\circ$. Postoperative complications occurred in one patient. All fractures achieved union. Mean time until radiographic evidence of a bridging callus and subsequent implant removal was 71 days (range: 30–120).

Conclusions: The results of this study support the use of CESF for treatment of fractures of the distal radius and ulna in toy breed dogs as an alternative to other methods of fracture fixation. However, this technique requires a series of follow-up examinations to evaluate the stability of the apparatus, the soundness of the wires and to determine the appropriate time for implant removal.

Introduction

Small and toy breed dogs have a high incidence of fractures of the radius and ulna, and these fractures are often a result of minor trauma (1–11; Ljunggren G 1969, Personal Communication). Fractures of the radius and ulna in toy and small breed dogs have a higher risk for delayed union or nonunion than similar fractures in large

breed dogs (1, 3, 5, 6, 8, 9, 12–19). The reasons for impaired healing appear to be both biomechanical and vascular (2, 3, 14, 16–19). Distal radial fractures often

have minimal bone surface contact after reduction because of the small size of the bones, as well as the short oblique or transverse orientation of the fracture (2, 14, 16). Anatomical alignment is further impeded by the tendency of the carpal and digital flexor

muscles to create caudo-lateral displacement of the distal bone fragment (5, 8, 16, 20). Furthermore, the limited soft tissue coverage and intraosseous circulation of the radius and ulna in toy and small breed dogs may contribute to a higher frequency of nonunion (11).

Success in obtaining fracture union is dependent on the method of treatment. Coaptation of radial and ulnar fractures in small or toy breed dogs is reported to result in up to 83% of the malunions and nonunions in these animals (5, 8, 21). Intra-medullary pinning of the radius is feasible, but not recommended because pin insertion requires invasion of either the carpal or elbow joint, and the round shape of the intramedullary pin leads to poor interference fit due to the elliptical shape of the medullary cavity of the radius. Furthermore, intramedullary pins only counteract bending forces. The incidence of major complications after repair of radial fractures ranges from 27 to 80% (6, 10). External skeletal fixation has been used to manage distal radial fractures in small breed dogs, with an incidence of complications ranging between four percent to 50% (6, 10, 21–24). Plate fixation is also considered to be a successful treatment option, but occurrence of major complications has been reported in 18% of cases (8, 25, 26). Osteopenia secondary to stress protection is a frequent finding after external skeletal fixation and plate osteosynthesis in fracture treatment of toy breed dogs (8, 25). Stress protection and refracture could be a source of possible concern in case of early plate removal once fracture union is complete (27). To avoid this problem, absorbable self-reinforced polylactide plates with metallic mini-screws have been successfully used in combination with light external splinting (28).

To our knowledge, there are not any reports regarding the treatment of distal radial and ulnar fractures with circular external skeletal fixation (CESF) in toy and small breed dogs. This treatment modality could represent an attractive surgical option for a variety of orthopaedic problems in dogs because these systems are versatile, can be applied in a minimally invasive fashion, and stability is provided from the use of small-diameter wires (29–34). Circular external skeletal fixation is an accepted method for fracture management in dogs (35–39). The CESF frame allows for axial micromotion at the fracture site during weight bearing while preventing bending, translation, rotation, and shear of the stabilized bone segments. These factors are purported to provide an environment conducive to optimal fracture union (40, 41).

The purposes of this retrospective study were to evaluate the effectiveness of CESF for the treatment of distal radial and ulnar fractures in toy and small breed dogs, and to document the type and frequency of complications associated with this technique.

Materials and methods

Inclusion criteria

The medical records of toy and small breed dogs with fractures of the distal radius and ulna admitted to the Department of Animal Pathology of the University of Turin and to the Clinica Ferretti between 2002 and 2009 were retrospectively reviewed. The criteria for inclusion of cases in the study were: body weight of 5 kg or less, having transverse or short oblique fracture of the distal third of the radius and ulna without previous repair attempts, and the use of CESF as the sole method of fixation. Information obtained from the medical records and preoperative radiographs included: breed, gender, age, body weight, affected limb, previous fractures of the same limb segment, time from injury to surgery, traumatic stress intensity, and fracture configuration. Patients were included in the study only if radiographic and clinical outcome could be determined until the time of CESF frame removal.

Instrumentation

The smallest diameter ring that could be placed around the dog's antebrachium, while still leaving at least 1 cm of space between the skin and the inner margin of the ring was chosen. Frames were constructed using components from one of two CESF component systems a, b.

The frame was pre-assembled, with a double-ring block configuration for the proximal segment, consisting of a proximally positioned arch and a distally positioned complete ring, and a single complete ring for the distal segment. An arch with the open portion oriented cranially was used proximally to avoid interference with elbow flexion. The rings were connected using three threaded rods: two cranially positioned rods placed at 10 o'clock and two o'clock, and a caudally positioned rod placed at six o'clock. We inserted slotted wire fixation washers under the nut that secured the ring to the rods when pre-assembled. In order to achieve adequate stabilization of the distal segment, either an oblique transosseous wire or a threaded half-pin splintaged, e was secured to the distal ring in addition to two transosseous wires. Transosseous wire diameter was selected according to established guidelines (33). Threaded pin diameter was selected to be approximately 25% of the craniocaudal radial width. The threaded pins used were Miniature Interface Fixation Half-pins^d or Hoffmann pins. Ring, wire and threaded pin diameters were entered as data into the study.

Surgical technique

Methadone^f (0.2 mg/kg, IM) was administered for pre-medication. General anaesthesia was induced by administration of propofol^g (1–2 mg/kg, IV) and maintained with 1.5–2% isoflurane^h in oxygen. The limb was prepared for aseptic surgery in a routine fashion. Cefazolin sodiumⁱ (20 mg/kg, IV) was administered to all dogs 30 minutes prior to surgery. A standard hanging limb preparation was performed with the dog in dorsal recumbency, in such a way to retain the possibility of attaching and detaching the limb from its support.

The first transosseous wire was placed in the proximal radius, parallel to medio-lateral axis of the elbow joint and perpendicular to the longitudinal axis of the proximal segment. The pre-assembled frame was passed over the limb, positioned close to

the proximal wire and supported by an assistant. The distal transosseous wire was inserted in a direction that was parallel to the antebrachio-carpal joint and perpendicular to the longitudinal axis of the distal segment. The proper placement of the wires was confirmed through intra-operative radiographs or fluoroscopy. The fracture was reduced manually in a closed fashion or, if necessary, through a medial mini-approach. The two wires were connected to the proximal arch and the distal ring respectively. The wires were not tensioned. If needed, fracture reduction was improved by distracting the distal fracture segment by adjusting the position of the distal ring on the threaded connecting rods. Limb alignment was assessed visually and, if acceptable, the remaining fixation wires were inserted. Two wires were placed on each ring at angles ranging from 30° to 90° (42–44), depending on the regional anatomy (45).

Stabilization of the small distal fracture segment was further improved by inserting an oblique transosseous wire or a small threaded half pin, at the surgeon's discretion, which was then connected to a post mounted on the distal ring (33).

Radiographic and clinical evaluation

Medio-lateral and cranio-caudal postoperative radiographic images were evaluated for fracture reduction and limb alignment. Fracture reduction was judged based on translation, overlap, and gap between bone segments.

Translational malalignment, either as mediolateral or craniocaudal displacement, of the distal bone segment relative to the proximal bone segment, was determined as a ratio between the maximal displacement and the width of the diaphysis. Percentages were grouped as <10%, 10 to 25%, 26 to 50%, 51 to 75%, and 76 to 100%. Overlap and fracture gap measurements between the major proximal and distal segments were recorded in millimetres.

Frontal and sagittal alignment were determined using the centre of rotation and angulation (CORA) method (46). In the frontal plane, elbow and carpal reference lines were drawn. Intersecting anatomical axis and joint orientation lines yielded the medial proximal radial angle (MPRA) and lateral distal radial angle (LDRA). The absolute difference between the MPRA and LDRA was determined, yielding the angle of frontal plane alignment (FPA). In the sagittal plane, elbow and carpal reference lines were drawn. Because the canine radius has natural procurvatum, the anatomical axis was resolved into two separate straight mid-diaphyseal lines, one for the proximal

radius and one for the distal radius. The joint orientation angles of both elbow and carpus were determined, respectively, by measuring the angles from intersecting anatomical axes and joint lines, yielding the proximal cranial radial angle (PCRA) and distal caudal radial angle (DCRA). Because the radius does not possess a single anatomical axis in the sagittal plane, the angle of sagittal plane alignment (SPA) was calculated as the angular difference between the elbow and carpal joint lines. The data obtained were compared both with the normal reported values and with those from the normal contralateral limbs (46). Limb alignment was judged on both planes according to the following scale: excellent = normal values; good = less

than five degrees deviation from normal values; fair = five degrees to 20° deviation from normal values; poor = greater than 20° deviation from normal values.

Postoperative pain treatment consisted of administration of non-steroidal anti-inflammatory drugs for seven days. Postoperative management included wire and pin tract care, and restricted exercise under the direct supervision of the owner. The wire and pin tracts were cleaned daily with moist gauze sponges and then covered with povidone-iodine ointment and a cloth sleeve. Exercise was limited to short leash walks five times a day and owners were asked to perform carpal flexion and extension exercises in order to avoid a loss of carpal extension. All patients were re-evaluated clinically and radiographically at one month after surgery, and at approximately two weeks intervals thereafter until bone union was evident. On clinical evaluation, use of the limb, signs of pain, loss of carpal extension, wire and pin tract discharge, and wire breakage were recorded. The follow-up radiographs were evaluated to assess signs of callus formation, periosteal reaction, and bone lysis around the implants. Complications were considered minor if they were managed without additional surgery. Complications were considered major if they required additional surgery, or negatively influenced the expected outcome. Frame removal was performed as soon as the attending surgeon judged the fracture to be healed, based on its radiographic appearance. Determination of the number of cortices (0 to 4) bridged by callus was the method used for assessing progression of fracture healing: a fracture was considered healed when a bridging callus was present on at least three cortices (47). After implant removal, radiographic images were taken in order to assess: signs of ulnar resorption, radio-ulnar synostosis, and wire-hole dimension (Fig. 1). A light bandage was applied to the limb and cage rest was advised for two weeks if the wire tract diameter was found to be more than 40% larger than the diameter of the medullary canal. Limb alignment was also reassessed, as previously described, on the radiographs made at the time of union. The owner was asked to respect the instructions for exercise restriction for two more weeks, and to prevent or modulate excessive loads. Re-fracture after implant removal was diagnosed if a fracture line occurred at the level of the previous fracture site, or at the level of the wire or pin holes.

Long-term functional outcome was evaluated by phone interview with the owner at least six months after implant removal.

Statistical analysis

Statistical analysis was performed using a freeware statistical software package^j. The Shapiro-Wilk normality test suggested that the data were normally distributed. Metric data are presented as mean \pm standard deviation and nominal data are expressed as a percentage, frequency, or both. The mean fracture union time between fractures stabilized with a threaded half-pin or an additional transosseous wire secured to the distal ring was tested using unpaired Student's t-test. The relation between ulnar resorption for dogs treated with a threaded half-pin or a transosseous wire was tested using the χ^2 statistic. Results of analysis were considered significant when the value of p was <0.05 . Alignment measured from radiographs taken at the time of union was compared to the values measured on the initial postoperative radiographs using a Wilcoxon rank sum test.

Results

Twenty fractures in 16 dogs satisfied the criteria for inclusion into this study. The breeds of dogs included eight Italian Grey-hounds, four Miniature Pinschers, one Pomeranian, one Chihuahua, one Yorkshire Terrier, and one mixed-breed dog. Five dogs were males and 11 were females. Mean age was 14.7 ± 11.8 months (range: 4–50 months) and mean body weight was 3.2 ± 1.2 kg (range: 1.0–4.5 kg). There were 17 left antebrachial fractures and three were right antebrachial fractures.

All fractures were caused by minor trauma. Only one fracture was open. Eleven fractures were transverse and nine fractures were short oblique. The mean time from injury to surgery was three days (range: 1–15 days). Three dogs had a history of previous fracture of the same antebrachium, which had been treated by external coaptation. The prior fractures had obtained union but with residual deformity in the frontal plane in two dogs, and in the sagittal plane in the third dog.

Reduction was achieved in a closed fashion in 18 fractures. In two malunited fractures, affected by pre-existing frontal plane deformity, a medial mini-approach and acute corrective osteotomy was performed. Because of the importance of

frontal alignment for limb function, we decided to only correct the angulation in the malunions with valgus deformities. A pre-assembled hinged frame was prepared based on preoperative radiographs of the malunion in both dogs. The hinges were placed at the level of the CORA, with the rings positioned at an angle corresponding to the amount of the deformity (31). The degree of the deformity had been previously determined by comparison with the opposite limb, according to the CORA method (46). After frame placement, a mini-approach was made to expose the deformity site. A closing wedge osteotomy was performed with a mini-oscillating saw^k. An acute deformity correction was performed by straightening the hinges and moving the rings in a parallel position. The hinged connecting rods were then replaced with threaded rods, to improve frame stability (Fig. 2).

Rings of the following diameters were used: 35mm (n=2), 40mm (n=14), 45 mm (n=3), and 60mm (n=1). The transosseous wire diameter was 1.0 mm (n = 20). The diameter of the threaded pin, inserted in the distal fragment was 1.2 mm (n =4), 1.6mm (n=3) or 2.0mm (n=2). In the remaining 11 fractures an oblique 1.0 mm transosseous wire was used. On post-operative radiographs, 13 fractures had <10% of translational malalignment, three fractures had 10% to 25% of translational malalignment, three fractures had 26% to 50% of translational malalignment, and one fracture had 51% to 75% of translational malalignment. One fracture had overlapping of the fractures segments (1 mm), and two fractures had fracture gaps of 1.5 and 2 mm, respectively.

Mean immediate postoperative FPA was $4.1^\circ \pm 2.1^\circ$ (range: $1.0^\circ - 8.0^\circ$), and the mean SPA was $12.6^\circ \pm 7.3^\circ$ (range: $0^\circ - 34.0^\circ$). In nine dogs it was possible to measure FPA and SPA in the normal contralateral limb, yielding a mean FPA of $2.3^\circ \pm 1.0^\circ$ and a mean SPA of $14.5^\circ \pm 2.2^\circ$. Compared to values reported by Fox et al, alignment in the frontal plane was judged to be excellent in all fractures, while alignment in the sagittal plane was judged to be excellent in 14 fractures and good in six

fractures (46). Upon comparison with the values from the contralateral limbs, alignment in the frontal plane was judged to be excellent in 15 fractures and good in five, while alignment in the sagittal plane was judged excellent in nine fractures, good in eight fractures, and fair in three fractures. All dogs used the stabilized limb within two days after surgery with a moderate degree of lameness. Clinical re-evaluation during the convalescence time period showed a progressive improvement of limb function.

Postoperative complications occurred

in one dog three months after surgery; a proximal radial fracture occurred through a wire hole. On radiographic re-evaluation, the bridging callus was judged as being not satisfactory. The frame was removed 25 days later, and a partially healed fracture line was detected at the level of a proximal transosseous wire tract (Fig. 3). No additional treatment was required, other than the application of a soft bandage, because the patient was capable of weight bearing on the affected leg. There were not any signs of osteomyelitis involving the fracture site or implant failure detected in any case. Postoperative minor complications included wire and pin tract discharge ($n = 8$). In three of these cases, there was also sudden lameness. All of these minor complications were successfully managed with administration of non-steroidal anti-inflammatory drugs and local cleansing of pin tracts. A loss of carpal extension was never observed. All fractures obtained radiographic union. Mean time until radiographic evidence of a bridging callus and subsequent implant removal was 71.0 ± 28.6 days (range: 30–120 days). Signs of ulnar resorption ($n = 7$) and radio-ulnar synostosis ($n = 10$) were observed on radiographs after implant removal. There was a significant difference ($p = 0.04$) for the time to union between fractures in which a threaded half-pin was used (53.9 ± 22.9),

and fractures in which an additional transosseous wire was used (79.1 ± 28.6). Ulnar resorption was more frequently associated with the use of an additional transosseous wire on the distal ring (6/11) than the use of threaded half-pin (1/9), ($p = 0.04$).

The mean FPA after implant removal was $4.7^\circ \pm 2.7^\circ$ (range: 1–10) and mean SPA was $12.7^\circ \pm 7.2^\circ$ (range: 3.0–32.0). These values for limb alignment measured in the initial postoperative radiographs and after implant removal did not differ statistically. Compared to values reported by Fox et al, alignment in the frontal plane was judged to be excellent in 18 fractures and good in two fractures (46). Alignment in the sagittal plane was judged to be excellent in 16 fractures and good in four fractures. Upon comparison with the values from the contralateral limbs, alignment in the frontal plane was judged excellent in eleven fractures and good in nine fractures, while alignment in the sagittal plane was judged excellent in ten fractures, good in four fractures, and fair in six fractures.

Three dogs sustained a fracture of the ipsilateral antebrachium 32, 44, and 50 days after frame removal, respectively. These cases were not considered to be refractured because the new fracture line was not at the same site as the previous one, nor was it at the level of any of the previous wire holes. These fractures were

treated in two cases with CESF, and in one case with a 2.0 dynamic compression plate^l.

Owners of 13 of the 16 dogs were contacted by telephone to obtain long-term follow-up evaluation: 10 of the dogs did not have any residual lameness and three dogs had a mild residual lameness.

Discussion

This retrospective clinical study evaluated the use of the CESF technique as treatment of distal radial and ulnar fractures in toy and small breed dogs. Different techniques for treatment of distal radial and ulnar fractures in toy and small breed dogs have been reported, with varying union and complication rates (5, 6, 8, 10, 21–26). Bone healing rates of 89% to 100% were reported for bone plates, 93% for external skeletal fixation, 50% for intramedullary pins, and 43% for external coaptation (5, 8, 10, 21–26). In our study, union was achieved in all fractures, validating the applicability and effectiveness of CESF for the treatment of distal radial and ulnar fractures in toy and small breed dogs. Bone plating and intramedullary pinning require open reduction of the fracture, therefore increasing the damage to soft tissues and blood supply. Closed reduction preserves the local blood supply and minimizes iatrogenic soft tissue damage. The CESF frames are compression-distraction systems that facilitate indirect closed reduction. If the fracture reduction, as obtained by manual distraction of the distal ring, is not satisfactory, an arched wire or olive wire can be employed to improve it, allowing distal fragment translation with minimal damage to bone and soft tissues (33). The use of external skeletal fixation has proved to be successful in the treatment of these fractures, as has the modified technique of using transfixation pins and acrylic bone cement (5, 10, 23). However, in small breed dogs the radius is a very narrow bone with a slight cranial bow. This, coupled with the oval shaped cross section of the radius, makes proper placement of the ESF transosseous pins in a mediolateral direction particularly challenging. Due to the small dimensions of radius and ulna in small breed dogs, availability of implants for fracture fixation is limited. The use of the 1.5/2.0 mm veterinary T-plate^m, 2.0 mm dynamic compression plate, and a poly-L-lactide plateⁿ has been recommended (8, 25, 28). However, the use of oversized implants could interfere with blood supply and increase the risk of nonunion.

The commercially available ring diameters of 35, 40 and 45 mm allow the use of this apparatus in small breed dogs. The ring dimension should be as close as possible to the bone, increasing the stability of the construct without interference with the soft tissues (40, 41). The use of an arch ring however, reduces the number of holes where transosseous wire could be inserted. We felt that pre-assembling the frame before surgery, based on preoperative radiographs of the fractured and of the intact limb, decreased surgery time. If minor frame modifications were needed, they were performed quickly during surgery.

The 45 mm diameter rings pose a particular challenge when securing the wires to the rings; while these rings have a high density of holes, often two adjacent holes are used, making tightening of the nuts and bolts impractical. The wires are

necessarily placed close together because of the available safe, soft tissue corridors combined with the small size of the apparatus itself. Furthermore, the presence of the connecting rods on the medial and lateral side of the frame does not aid in this matter. Wire and pin dimensions should follow the published guidelines to avoid intra-operative or postoperative convalescent period iatrogenic fractures (33). It is mandatory to place fixation elements only in safe soft tissue corridors. Muscle belly transfixation will likely cause pain, wire and pin tract discharge and poor limb function during convalescence. Care must be taken before wire insertion in order to avoid multiple attempts that would increase the risk of iatrogenic fracture or bone necrosis. Careful attention to radiation safety protocol is mandatory, and surgeon exposure should be minimized, if intraoperative fluoroscopy is used. Due to the small body weight of dogs in the study, the wires were not tensioned because small diameter rings were used in these dogs. The small dimension of the distal segment does not allow the use of double ring block. In order to achieve adequate stabilization of the distal fragment, an additional oblique transosseous wire or a half-pin splintage threaded pin was connected to the distal ring, at the surgeon's discretion. The use of a threaded half-pin, without crossing both sides of the limb, reduces the risk of interference with anatomical structures in this region. Anecdotal reports suggest that the combination of a rigid fixation element (i.e. a half-pin splintage threaded pin) with flexible fixation elements (i.e. two transosseous wires) in the same bone segment is believed to predispose to premature loosening of the fixation pin (34). However, we did not find any radiographic signs of notable increase in pin-tract hole size in the distal segment after implant removal.

Closed reduction yielded acceptable ap position and limb alignment in 18 out of 20 fractures when compared with the data previously reported (46). The FPA obtained from our series had a restricted range when compared to normal values proposed by Fox et al, but our mean FPA was similar. However, our SPA range was narrower and with a lower mean. Alignment in the sagittal plane however is less relevant to the clinical outcome than FPA, due to the primary degree of freedom of the canine forelimb existing in the cranial-caudal direction (46).

Although postoperative radiographic assessment was performed with standard views, the small dimension of the bone segment and the superimposition of threaded connecting rods made the fracture healing evaluation sometimes difficult. We obtained oblique projection radiographic views to better evaluate reduction and alignment. These oblique projection views were also useful to evaluate the progression of bone healing. However the oblique projection views must be consistent during subsequent radiographic evaluations to judge and compare callus formation.

The complication of a proximal radial fracture in one case was possibly due to the long treatment duration and bone resorption around the wire. To avoid this complication, it may have been better to locate this wire in the head of the radius and not in the narrow portion of diaphysis below the radial head. Wire and pin tract discharge should be expected with CESF (38). Wire breakage is a reported complication with CESF in medium to large breed dogs (37, 38). This complication however did not occur in any of the dogs in this study, most likely attributable to the light body

weights. A loss of carpal extension, which is a complication reported when these fractures are treated by bone plating, was not observed (25). No major complications occurred in our series; this outcome compares favourably to previous reports (5, 8, 10, 24).

Although none of our patients had a re-fracture after implant removal, three patients experienced a fracture on the ipsilateral antebrachium at a later time, but in a position unrelated to the previous fracture or wire tracts. None of the three dogs were affected by malunion or ulnar and radial osteopenia. Therefore we suppose that these new fractures were due to a minor trauma. However, in our opinion, a wire tract found to exceed 40% of the diameter of the medullary cavity (Fig. 2) would constitute a risk factor for a fracture in that site. In patients where this occurred, a light bandage and cage rest for two weeks were recommended.

There are limitations to our study, mainly stemming from its retrospective design which in itself limits the conclusions that can be made from the results. Because of the retrospective nature of our study, we only had appropriately positioned radiographs of the contralateral normal antebrachii in nine dogs. A major limitation was the evaluation of long-term outcomes using a subjective phone interview with the owner. Kinetic gait analysis would have resulted in objective data, but was beyond the scope of this study. It was not available at our hospitals, and it would be difficult to accomplish with toy breeds dogs.

The results of this study support the feasibility of fixation through the use of the CESF frame for distal radial and ulnar fractures in toy breed dogs as an alternative to other methods of fracture fixation. However, this technique requires a series of follow-up examinations to evaluate the stability of the apparatus, the integrity of the wires, and to determine the right moment for implant removal; this requires more collaboration of the owner for a prolonged period of time. Overall, CESF when compared to other techniques performed well in terms of fracture healing and reported complication rates.

Conflict of interest

The author Antonio Ferretti is a consultant for Hoffmann S.a.S.

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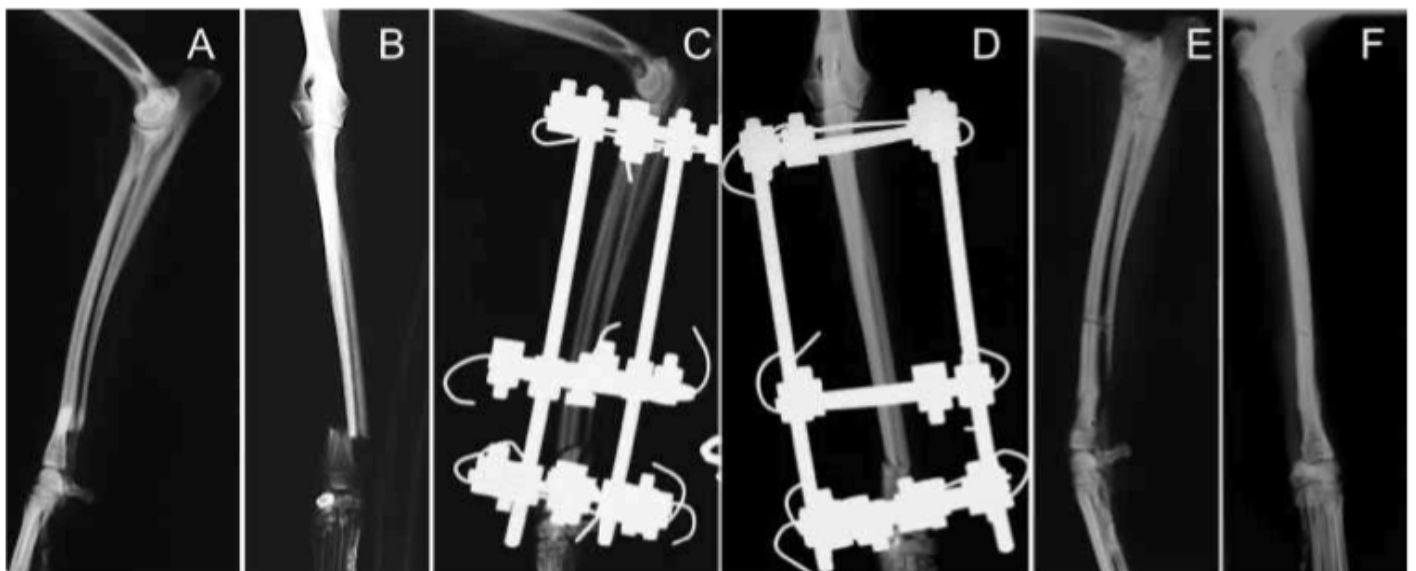


Fig. 1 Distal radial-ulnar fracture in a two-year-old Italian Greyhound: A) and B) Preoperative medio-lateral and cranio-caudal radiographs. C) and D) Immediate postoperative medio-lateral and cranio-caudal radiographs. E) and F) 65 days follow-up radiographs: radial fracture has obtained union. Note the resorption of the distal ulna.

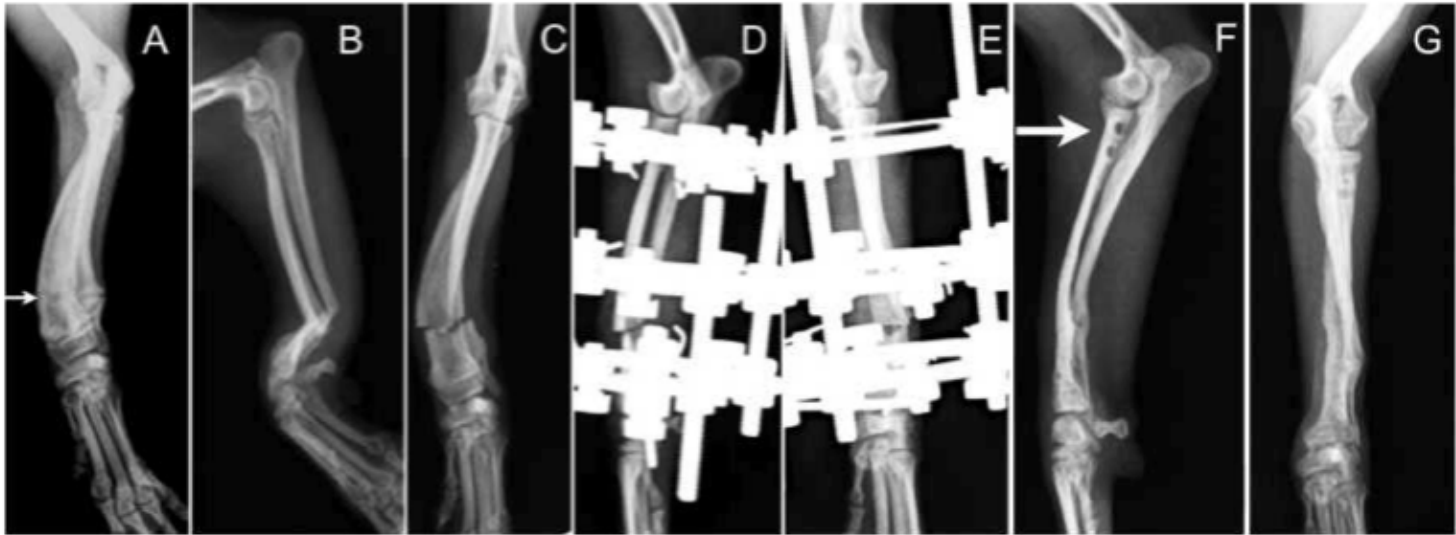


Fig. 2 A) Distal radial-ulnar malunion in an eight-month-old Chihuahua: the arrow indicates the healed fracture line. B) and C) Preoperative medio-lateral and cranio-caudal radiographs: the fracture occurred two months after the previous fracture malunion. D) and E) Immediate postoperative medio-lateral and cranio-caudal radiographs. F) and G) Follow-up radiographs at 80 days; the fracture has healed and the bold arrow indicates large empty holes after removal of the circular external skeletal fixation.

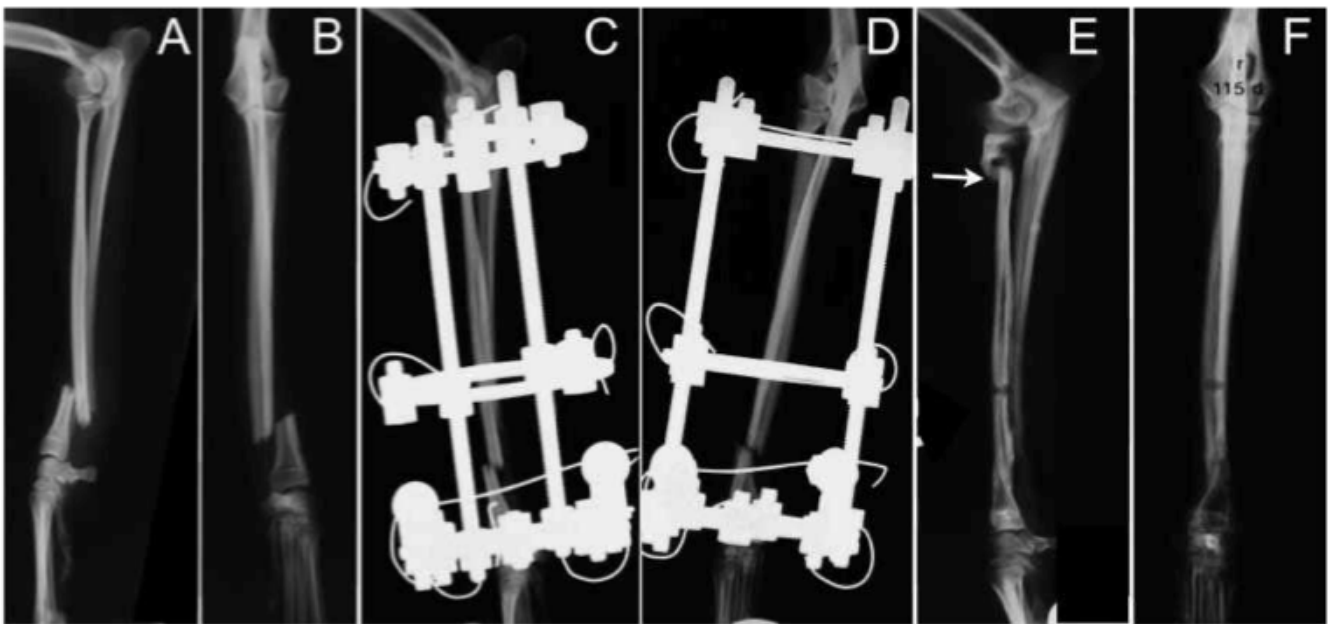


Fig. 3 Distal radial-ulnar fracture in a one-year-old Italian Greyhound: A) and B) Preoperative medio-lateral and cranio-caudal radiographs. C) and D) Immediate postoperative medio-lateral and cranio-caudal radiographs. E) and F) Follow-up radiographs at 115 days: radial fracture has healed; a proximal radial fracture (arrow) occurred at the level of the proximal transosseus wires.

