Improving surgical reduction in radial fractures using a ‘dowel’ pinning technique in miniature and toy breed dogs

J. Yu1; C. E. DeCamp2; R. Rooks3

1VCA – Douglas County Animal Hospital, Castle Rock, Colorado, USA; 2Department of Small Animal Clinical Sciences, College of Veterinary Medicine, Michigan State University, East Lansing, Michigan, USA; 3VCA – All Care, Fountain Valley, California, USA

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Dowel pinning, radius, fracture, canine, external skeletal fixation

Summary
Objectives: A retrospective approach was used to detail and evaluate a ‘dowel’ pinning technique in distal radial fractures in miniature and toy breed dogs.

Methods: Medical records and radiographs from 2003–2009 of miniature and toy breed dog radial fractures were examined. Sixty cases were divided into two groups: 51 radial fractures repaired with a ‘dowel’ pinning and external skeletal fixation (ESF) and nine radial fractures repaired with closed reduction and ESF. Each dog was evaluated and radiographic images were obtained at presentation, postoperatively, and at 1, 2, 4, 8, and 12 weeks postoperatively. Signalement, reduction, alignment, time to clinical bone healing and ESF removal, and implant morbidity were determined for each group.

Results: Radial fractures repaired with a ‘dowel’ pin and ESF had improved reduction compared to closed reduction and ESF alone (p < 0.0001 as evaluated with lateral radiographs and p < 0.0004 with cranial/caudal radiographs). Both surgical groups resulted in good clinical outcome with low morbidity, however it was observed that the time to clinical union and ESF removal was an average of 2.5 weeks less with closed reduction technique compared to the open reduction and ‘dowel’ pinning technique (p < 0.031).

Clinical Significance: Incorporating a ‘dowel’ pin to the surgical repair enhances the reduction of distal radial fractures in miniature and toy breed dogs and results in excellent clinical outcomes but causes a small delay in bone healing.

Correspondence to:
Jeff Yu
VCA – Douglas County Animal Hospital
531 Jerry St
Castle Rock, CO 80104
United States
Phone: +1 303 688 2480
Fax: +1 303 688 3975
E-mail: badgerveterinarian@hotmail.com

Introduction
Radial and ulnar fractures represent approximately 18% of the fractures seen in dogs and cats (1). Furthermore, it has been documented that fractures of the distal third of the radius and ulna represent the third most common fracture observed in dogs (2). For reasons completely yet unknown, miniature and toy breed dogs appear to have a higher incidence of distal radial and ulnar fractures (2). It has been hypothesised that these breeds of dogs have low antebrachial failure loads in the distal diaphysis, which may predispose this location of the radius to injury (3).

Repairs of the radius and ulna in miniature and toy breeds can be difficult with several complications observed including delayed union, malunion, nonunion, severe bone atrophy and re-fracture, and osteomyelitis (2–9). Factors that have been identified to affect healing in miniature and toy breed dogs are inherent biomechanical instability, minimal bone surface contact after reduction due the small diameter of the bones, decreased soft tissue coverage, persistent formation of cartilage within the fracture site, and decreased vascular density at the distal diaphyseal-metaphyseal junction compared to large breed dogs (5, 10–11).

Several fixation techniques for radial and ulnar fractures in miniature and toy breed dogs are described and include external coaptation, external skeletal fixation (ESF) transfixation pins, and bone plating techniques, with and without autogenous cancellous graft (1–3, 6–8, 12–26). The use of a ‘dowel’ pin in radial fractures to improve end-to-end reduction has been described as an application of a short intramedullary pin alone, without any other surgical fixation (27). It was noted that the intramedullary pin alone was insufficient to neutralise all forces acting on the fracture site such as rotational and longitudinal stability and had inadequate bending stability (27). A recent publication described the use of the ‘dowel’ pin technique to help achieve improved reduction and alignment in feline metacarpal and metatarsal fractures with excellent outcomes (28).

The objective of this study was to evaluate the effectiveness of utilising a Kirschner wire (K-wire) as a ‘dowel’ pin to enhance fragment reduction and a Type IA ESF to...
enhance stability. Our hypothesis was that by combining the two repair methods, we would achieve improved reduction and alignment until clinical healing was achieved with minimal morbidity, compared to closed reduction and no ‘dowel’ pin with a Type IA ESF.

Materials and methods

All medical records and radiographs of miniature and toy breed dogs with radial fractures that were repaired by three different surgeons during the period of 2003 to 2009 were obtained from the VCA-All Care hospital (California, USA). In total, 60 complete records were examined and divided into two groups: 51 radial fractures that were repaired with open reduction, ‘dowel’ pinning and Type IA ESF group, and nine radial fractures that were repaired with closed reduction and Type IA ESF group. The age, sex, weight, initial and postoperative radiographic measurements of reduction and alignment, size, number and type of ESF pins, and time to clinical union and ESF removal were recorded.

Orthogonal radiographs of the antebrachium (medial to lateral and cranial to caudal projections) were obtained for all dogs under general anaesthesia immediately postoperatively and through the healing process, was determined by measuring the normal angle of frontal plane alignment (FPA) and sagittal plane alignment (SPA) as described by Fox et al (29).

Surgical technique

All patients in the ‘dowel’ pinning and ESF group were anaesthetised and positioned in dorsal recumbency. The affected antebrachium was prepared for aseptic surgery. A standard medial surgical approach to the fracture site was performed (6). The proximal radial fragment was stabilised with a bone forcep while a K-wire was used to drill a guide hole approximately 4.0 mm in length into the medullary cavity. The size of the K-wire was determined by using a wire that filled the medullary cavity (range of K-wires used varied from 0.07 to 2.0 mm diameter). Next, a K-wire was advanced into the medullary cavity of the distal radial fragment until resistance was met. The distal end of the K-wire was cut to a blunted end prior to advancement to reduce the risk of penetrating the joint surface. The proximal end of the K-wire was cut so that approximately 4.0 mm was left extending from the distal radial fragment. The two radius fragments were then reduced, guiding the exposed portion of the K-wire into the previously drilled hole in the proximal radial fragment. Direct visual confirmation of interdigitation of the two fragments and ‘sighting’ down of the accessory carpal pad to the olecranon were used to assess reduction and correct limb alignment. A Type IA ESF was then placed using positive profile pins for the most proximal and distal pins, and non-threaded K-wires for the intermediate pins. Three to four fixation pins were used per segment. The non-threaded K-wires allowed the wires to bypass the dowel pin with minimal resistance. A single connecting bar was formed with polymethyl methacrylate and the incision was closed. Postoperative orthogonal radiographs were taken to evaluate reduction, alignment, and placement of the implants (Fig. 1).

All patients in the closed reduction group were anaesthetised and the affected antebrachium was prepared for aseptic surgery. Closed reduction was achieved with indirect manual manipulation of the fragment ends and a Type IA ESF was placed on the affected radius with three to four positive profile fixation pins per segment and a polymethyl methacrylate connecting bar. Postoperative radiographs were used to evaluate reduction, alignment, and placement of the ESF.

Following postoperative evaluations, dogs in both groups were discharged and re-evaluated at 1, 2, 4, 8, and 12 weeks (if needed). Any changes in reduction, frontal and sagittal alignment, implant loosening or migration, and the presence of any additional fractures were recorded. Once clinical union was determined, the ESF was removed under general anaesthesia and a soft padded bandage was applied to the antebrachium for additional support for a total of two weeks with instructions for gradual return to normal activity.
Data analysis

The two groups were compared to determine if there were any differences in the age, sex, weight, reduction, alignment, and time to clinical union and ESF removal. The Wilcoxon rank sum test (nonparametric) p-value was used to determine if there were any differences in the age, weight, reduction, and time to clinical union between the two groups. A chi-square analysis was used to evaluate for any sex predilection using Yates’s correction factor due to the small numbers in the closed reduction and ESF group. A split-plot repeated measures analysis of variance and post hoc t-test were used to evaluate comparisons of alignment over time. A value of $p \leq 0.05$ was considered significant for all comparisons.

Results

Fifty-one dogs (85%) in the study had surgical repair with an open reduction and ‘dowel’ pinning technique combined with a Type IA ESF. Breeds represented in the ‘dowel’ pin and ESF group included 12 breeds of which the most common were Pomeranians (31%), Chihuahuas (24%), Miniature Poodles (10%), and Miniature Pinchers (8%). The average age in this group was 1.05 years ± 0.60 with an average weight of 3.13 kg ± 1.58. Nine dogs (15%) had surgical repair with a closed reduction technique and a Type IA ESF. Breeds represented in this group included Pomeranians (55%), Miniature Pincher (11%), Yorkshire Terrier (11%), Japanese Chin (11%), and Italian Greyhound (11%), with an average age of 1.68 years ± 2.29 and weight of 2.81 kg ± 1.61. There were not any significant differences in age or weight between groups. There were 16 entire females, 14 entire males, 12 neutered males, and nine spayed females in the ‘dowel’ pinning group. In the closed reduction group, there were four entire males, three entire females, and two neutered males. There were not any differences in sex distribution between the two groups.

Improved fragment reduction was observed at the immediate postoperative radiographic evaluation for the ‘dowel’ pinning group compared to the closed reduction group on lateral (97% vs. 77%; $p <0.0001$) and cranial-caudal (95% vs. 90%; $p = 0.0004$) radiographic projections. Using a split plot ANOVA, there were not any differences in frontal plane limb alignment ($p = 0.69$) and sagittal plane alignment ($p = 0.96$) observed over time between the groups (Fig. 2 and 3). The time duration to clinical union and ESF removal was evaluated, and it was observed that the mean time duration to healing in the ‘dowel’ pinning group (9.7 weeks) was greater than that of the closed reduction group (7.2 weeks) ($p = 0.031$). Complications noted in the ‘dowel’ pinning group included three dogs with loose K-wires at the time of ESF removal and one dog that developed a fracture of the radius above the ‘dowel’ pin after the ESF had been removed. The dog with the additional radial fracture was repaired with another Type IA ESF with the previous dowel pin left in situ and the dog healed without any further complications. Two dogs in the closed reduction group had loose K-wires at the time of ESF removal. No other complications were observed.

Discussion

Anatomical reduction, adequate stabilization, and preservation of local blood supply must be obtained to ensure minimal complications in miniature and toy breed antebrachial fractures. Since the bone diameter and fracture segments are much smaller in these breeds, proper reduction of the segments can be technically challenging and may result in excessive manipulation of the fragments with increased damage to the blood supply of bone and surrounding soft tissues. Carpal and digital flexor muscles may also contribute to caudolateral displacement of the distal radial bone segment and add to reduction difficulty (2, 4). The incorporation of a K-wire as a ‘dowel’ pin to the fixation technique simplifies initial anatomic reduction and also maintains reduction until an ESF is applied.

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Fig. 2 Frontal plane alignment of ‘dowel’ pin with external skeletal fixation (ESF) and non-‘dowel’ pin with ESF over time with standard deviation (in degrees) from normal axis.
There were no significant differences in the age, sex, and weight between the groups, and limb alignment did not change during the healing process. The main difference observed was that measurement of the anatomical reduction was significantly improved in the ‘dowel’ pin and ESF group. Although it may be expected that improved reduction would improve healing time duration, it was observed that the time to clinical union was shorter in the closed reduction and ESF group. On average, the closed reduction and ESF group had their ESF removed 2.5 weeks earlier than the open reduction ‘dowel’ pin and ESF group. The cause of the shorter time to clinical union may be explained by the lack of disruption to the medullary blood supply, and thus as following a ‘biological fixation’ principle. Previous research has shown a decrease in the interosseous bloody supply of the distal radial of miniature and toy breed dogs compared to large breed dogs (11). Any manipulation through an open fixation technique could further disrupt the local vasculature at the fracture site resulting in delayed healing. When evaluating morbidity with a ‘dowel’ pinning fixation technique, there were not any observed increases in complications rates despite the longer time to clinical union. One dog did have a significant complication and re-fractured the radius and ulna a few months following ESF removal, however it healed without any complications following corrective surgery. Additional complications that were not observed in this study, but which could occur include migration of the ‘dowel’ pin or persistent medullary infection due to the presence of the pin.

As this was a retrospective study, there were limitations in our case selection, data collection, and patient evaluations. A prospective study would reduce bias by random selection of cases with uniform data collection. For example, a comparative study with similar sized small or toy breed dogs with an open reduction and ESF versus an open reduction and ‘dowel pin’ with ESF may provide additional information on the long-term consequences of a ‘dowel’ pinning technique. Furthermore, the addition of an autogenous cancellous bone graft at the fracture site could be evaluated to determine if its application was advantageous in reducing the time to clinical union and shortening the time to ESF removal.

In summary, the use of a ‘dowel’ pinning technique with an ESF results in excellent reduction and clinical outcome in miniature and toy breed dog radial fractures. It is a useful technique when reduction is difficult as when working with small bone segments. The surgeon must be aware that the improved reduction may come at the cost of some delay in the time duration to bone healing.

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