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Factors Affecting the Healing of Radial Fractures Using Acrylic Pin External Fixation in Small Breed Dogs

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Abstract : Healing of 48 cases of radial fractures in small breed dogs treated with acrylic pin external fixation was evaluated retrospectively to investigate the factors affecting the healing of radial fractures. The mean age of the subjects was 15.02 months, the mean body weight was 3.48 kg, and the mean maximum length of the radius (MLR) was 90.77 mm. External skeletal fixation frames type 1a, 2a, and 3 were used; among them type 2a was used most frequently (75%). The mean time to clinical union (TCU) was 67.17 days, and the success rate was 95.8%. Age, bodyweight, MLR, and occurrence of complications increased TCU significantly. Among complications, pin loosening, swelling of the operated forelimb tissue for more than 2 weeks, and coexistence of two or more complications increased TCU significantly ($p < 0.05$). There was no relationship between location of the fracture and TCU. The results of this study may be useful to predict the prognosis of radial fractures in small dogs.

Key words : radial fracture, acrylic pin external fixation, small breed, time to clinical union.

Introduction

The radius is the main weight-bearing bone in animals. Radial and ulnar fractures account for 8.5 to 18% of all fractures in small animals (17), and radial and tibial fractures of dogs account for 23.1% of all fractures in Korea (12).

External skeletal fixation (ESF) is a common method of stabilization of radial fractures. ESF with an acrylic resin connecting bar is an alternative to the standard external fixation system. Because it is lighter, cheaper, and more convenient than the stainless steel configuration, the acrylic resin connecting bar is popular in local small animal clinics.

In fractures treated with ESF, bone healing is affected by the mechanical environment at the fracture site as well as the biological environment of the fracture. The mechanical environment is affected by the amount of motion allowed by the number of fixation pin and configuration of the frame. In ESF, the stiffness of the fixator is increased by increasing the number of pins and bars. Adding from two to four fixation pins to each bone segment increases the stiffness of the bone fixation construct (7). Type 1a, 1b, and 2b frames have significantly lower stiffness than types 2a and 3(1), and the pin diameter should not exceed 20 percent of the bone diameter (14). The biological environment of the fracture is reflected by the condition of the surrounding soft tissue and the vascularity of fracture fragments. It will affect the bone's ability to respond to injury and the speed of its response (8). Vascular

density is decreased in the distal one-third of the diaphysis of the radius (19), and the radius is surrounded by less soft tissue than are other bones. For this reason, bone healing can be delayed at distal radius compared to other site.

This study was carried out to investigate factors affecting the healing of radial fractures using acrylic pin external fixation in small breed dogs.

Materials and Methods

The medical records of 48 cases of 39 dogs with radius fractures treated at the Lee Seoung Jin Animal Medical Center between January 2013 and July 2016 were reviewed. All subjects were treated with external fixation pins and acrylic resin connecting bars in various configurations of the frame according to variables of the fracture, such as the diameter of the radius, body weight, and location of the fracture line. Comminuted fractures were excluded from this study.

Factors and variables obtained from the medical and radiographic records of the 48 cases were classified according to physical characteristics, fracture characteristics, surgical characteristics, and complications (Table 1). Anteroposterior and lateral postoperative radiographic images were evaluated for fracture reduction and limb alignment, maximum length of the radius (MLR), distance of the fracture line from the styloid process (FLS), and transverse diameter at midshaft (TDM) (Fig 1). The subjects were re-evaluated radiographically and clinically approximately 2 weeks after surgery, and at 2 to 4 week intervals thereafter until final removal of the frame. Follow-up radiographs were evaluated to assess healing and complications. The time to clinical union (TCU) was defined

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Table 1. Factors and variables obtained from records of 48 cases of radial fractures in small breed dogs treated with acrylic pin external fixation

Category
Physical characteristics
Breed, sex, limb fractured, age, body weight, MLR, and TDM of the radius (TDM)
Fracture characteristics
Fracture type (transverse, oblique, or spiral), FLS, FLS/MLR ratio
Surgical characteristics
Surgical approach (open or closed), temporary stabilization (K-wire or cerclage wire), bone graft (yes or no), frame configuration, destabilization (yes or no), number of transfixation pins, diameter of transfixation pins, diameter of transfixation pins/TDM
Complications
Swelling of operated forelimb tissue for more than 2 weeks, osteomyelitis, PTD

MLR; Maximum length of the radius, TDM; Transverse diameter at midshaft, FLS; Distance of the fracture line from the styloid process, PTD; Pin tract discharge.

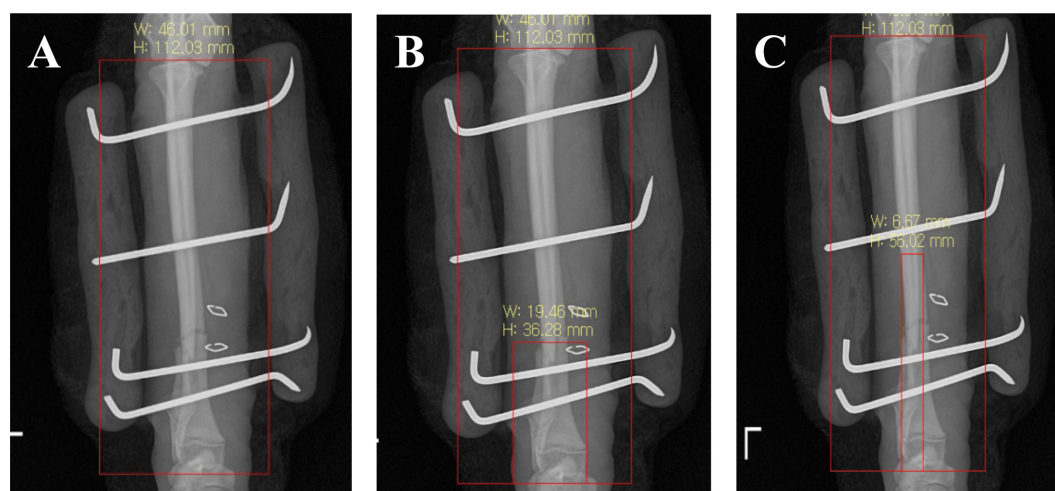


Fig 1. Measurement of morphometry of the radius and location of the fracture line in radiographs. (A) Anteroposterior postoperative radiographic images were used. The maximum length of the radius (MLR) is measured from the most proximal end on the radial head to the tip of the styloid process (112.03 mm). (B) The distance of the fracture line from the styloid process (FLS) is measured from the tip of the styloid process to the most distal fracture line (36.28 mm). (C) The transverse diameter at midshaft (TDM) is the distance from the medial to the lateral surface of the midshaft (6.67 mm).

as the time from surgical stabilization to final removal of the frame.

The statistical Package for the Social Sciences (SPSS version 22.0, IBM, Armonk, NY, USA) was used for statistical analyses. One-way analysis of variance, Student's t-test, and Pearson's correlation were performed to analyze the relationship between factors and TCU. Statistical significance was based on a *p*-value of 0.05 or less. The Pearson correlation coefficient indicates a distinct linear relationship when *r* is between 0.3 and 0.7 and a strong linear relationship when *r* is between 0.7 and 1.0.

Results

The most common breeds were Pomeranian (37.5%) and Toy Poodle (35.4%). The distribution of sexes was as follows: castrated male (43.8%), intact female (27.1%), intact male (22.9%), and spayed female (6.36%). The mean weight was 3.48 kg; the mean age was 15.02 months; the mean

MLR was 90.77 mm; the mean TDM was 6.13 mm; the mean FLS was 27.00 mm; the mean FLS/MLR ratio was 0.30; the mean ratio of pin diameter to TDM was 0.23; and the mean TCU was 67.17 days. Of the total 48 cases, treatment was discontinued in 1 case, 1 case had a refracture after removal of the ESF, and 46 cases were successfully treated, resulting in a 95.8% success rate (Table 2). Postoperative complications occurred in 45.8% of cases, including osteomyelitis, pin loosening, pin tract discharge, and swelling of the forelimb tissue for more than 2 weeks. The most common complication was pin tract discharge (27.1%), but there was no significant difference in TCU between subjects with and without pin tract discharge. TCU was significantly longer in subjects that experienced complications, especially swelling of the operated forelimb tissue for more than 2 weeks, pin loosening, and coexistence of two or more complications (*p* < 0.05). Among the complications that increased TCU, swelling of the operated forelimb tissue for more than 2 weeks had the greatest effect on TCU (Fig 2). Age, body weight, and MLR

Table 2. Characteristics of study subjects

Characteristic		N	%
Total <i>N</i>		48	100
Function of the limb	Good	46	95.8
	Bad	2	4.2
Complications	Yes	22	45.8
	No	26	54.2
Mean \pm SE			
Age (mo)		15.02 \pm 11.41	
Weight (kg)		3.48 \pm 1.53	
MLR (mm)		90.77 \pm 17.58	
TDM (mm)		6.13 \pm 1.23	
FLS (mm)		27.00 \pm 11.84	
FLS/MLR		0.30 \pm 0.13	
No. of transfixation pins		4.98 \pm 1.34	
Diameter of pins (mm)		1.40 \pm 0.23	
Diameter of pins/TDM		0.23 \pm 0.04	
TCU (days)		67.17 \pm 35.11	

MLR; Maximum length of the radius, TDM; Transverse diameter at midshaft, FLS; Distance of the fracture line from the styloid process, TCU; Time to clinical union.

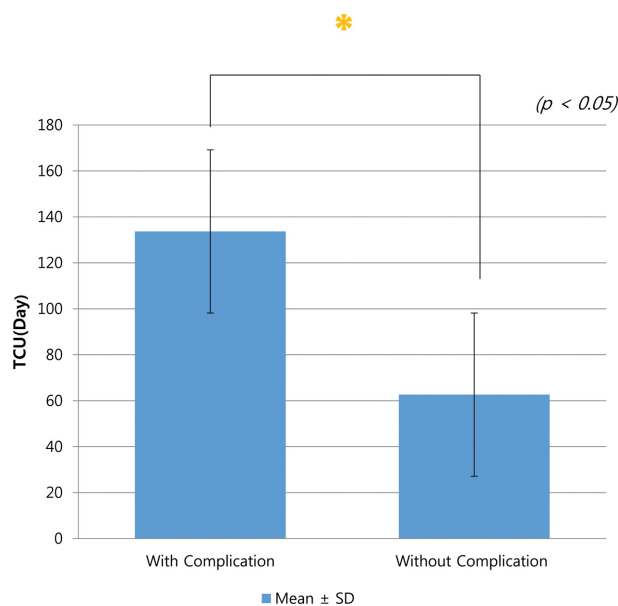


Fig 2. Time to clinical union (TCU) in subjects with and without swelling of the operated forelimb tissue for more than 2 weeks. TCU is significantly higher in subjects with swelling.

were significantly correlated with TCU significantly ($p < 0.05$), but the correlation was not strong ($0.3 < r < 0.7$). There was no significant relationship between TCU and location of the fracture.

Discussion

In this study, the most common breeds with radial fractures were Pomeranian and Toy Poodle. Considering that radial fractures are long-bone fractures, the results of this study are similar to those of Kim (11). There was no signifi-

cant difference between Pomeranians and Toy Poodles in the incidence of radial fracture. The high incidence of radial fracture among Pomeranians and Toy Poodles in this study may be due to the recent preference for these two breeds by Koreans.

The number of fractures was significantly lower in spayed female. However, the number of spayed females was only 6.3% of the total, so it may be difficult to prove that the significant relationship between sexes and occurrence of fractures. There were no significant differences between intact males, castrated males, intact females, and spayed females in weight, age, and MLR. Studies in humans have shown that sex hormones, sex hormone-binding globulin, body mass index, and age affect bone density (2,4,10). However, the effects of these factors on bone density have not been investigated in veterinary studies.

The mean TCU in this study was 67.17 ± 35.11 days, which is similar to the mean values of 65 days reported by Gemmill *et al.* (3) and 70 days reported by Johnson *et al.* (9). However, in the latter two studies, the ESF frames differed from those in the present study, most subjects were medium- and large-sized dogs, and tibia fractures were included. It is also relevant to the subject's visit to the hospital and the timing of the examinations. In the present study, seven subjects had a TCU of more than 100 days, and three were not treated regularly after surgery or were left in a contaminated environment where they developed inflammation and swelling. In this case, postoperative complications, such as swelling of the operated forelimb tissue for more than 2 weeks, and pin loosening were prominent, which appeared to prolong TCU. The other two cases had prolonged TCU despite strict follow-up of the general protocol or treatment of radial fractures, such as strict postoperative treatment and exercise restriction. In this cases there was a history of previous arthrodesis of the shoulder joint or history of refracture of the radial shaft. Axial micromotion at the fracture site stimulates callus formation and remodeling and leads to more rapid fracture healing (5). It seems that there was excessive restriction of exercise because of concern for refracture, which delayed healing. In the other two cases, TCU was prolonged because the owner delayed visiting the clinic.

Pin loosening, pin tract discharge, infection, delayed union, malunion and failure of fixation are known to be associated with ESF for fracture treatment (16). The most common complications reported in this study was pin tract discharge (27.1%). The complications that significantly increased TCU were swelling of the operated forelimb tissue for more than 2 weeks, pin loosening, and coexistence of two or more complications. The second most common complication was pin loosening. Pin loosening occurred because a K-wire or smooth pin was used as a transfixation pin in all subjects. When a K-wire or smooth pin is used, the pin cannot adhere to the bone, resulting in movement of the pin, and the bone tissue surrounding the pin may be converted into fibrous tissue. McCartney reported that the use of a K-wire as a transfixation pin was associated with loosening of the external pins in all subjects (13). However, in the present study, loosening of the external fixation pin occurred in only 25% of cases even though all transfixation pins were K-wires, because the weight

Table 3. Relationship between configuration of the frame and ratio of FLS to MLR

Configuration of frame	FLS/MLR (Mean \pm SE)	N	%
Total N		48	100
1a	0.38	1	2.1
2a	0.33 \pm 0.12	36	75.0
3	0.22 \pm 0.10	11	22.9

FLS; Distance of the fracture line from the styloid process, MLR; Maximum length of the radius.

of the subjects was less than that in report of McCartney. This is consistent with McCartney's report of the use of K-wires in cats with a low rate of external fixation pin loosening (13). Coexistence of two or more complications was also a factor that increased TCU significantly, but there was a significant increase in among subjects with swelling of the operated forelimb tissue for more than 2 weeks. Swelling of the operated forelimb tissue for more than 2 weeks had the greatest effect on TCU of all factors that significantly increased TCU.

The mean FLS/MLR was 0.30 in this study. FLS/MLR is the position of the fracture line with respect to the entire radial length. As this value decreases, the fracture line is located more distally, which means that it is difficult to repair the fracture because of the difficulty of inserting a sufficient number of external pins to stabilize the distal bone fragment (15,18). The soft tissue surrounding the radius and the metaphyseal artery, which supplies blood to the distal radius, also limit distribution in this site (3). For this reason, bone healing can be delayed at the distal radius. However, there was no statistically significant relationship between FLS/MLR and TCU. In this study, in order to increase the treatment success rate, more rigid frames were used for fractures located more distally (Table 3). As a result, the location of the radial fracture has no relationship with TCU if the stabilization is assumed.

TCU has been shown to be shorter in young dogs than in adult dogs. The periosteal blood supply is much greater in young dogs than in adult dogs, and the vascular supply and associated periosteum are atrophied in adult dogs. Platelet-derived growth factor (PDGF) released by platelets deposited at the fracture site may be more effective in young dogs. PDGF promote fibroblast proliferation and chemotaxis of inflammatory and mesenchymal cells and enhances collagen and cartilage synthesis to heal bone fractures (6).

This study has limitations due to its retrospective method. In order to clarify the factors that affect TCU, it will be necessary to change certain factors while keeping other factors fixed to determine which factors are related to TCU. It is also important that TCU can be changed according to the clinician's ability to read the radiological and clinical information and the visit period of the owner and the subject. The limited number of cases is also a limiting factor. In future studies, it will be necessary to clarify the cause and result relationship by designing an experiment that changes the factors affecting TCU independently and includes a larger num-

ber of cases.

Conclusion

This retrospective study was carried out to investigate the factors affecting the healing of radial fractures using acrylic pin external fixation in small breed dogs. Among the factors, age, body weight, MLR, and occurrence of complications significantly increased TCU. Among the complications, pin loosening, swelling of the operated forelimb tissue for more than 2 weeks, and coexistence two or more complications significantly increased TCU. There was no relationship between the location of the fracture and TCU.

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