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Bone Fractures in Raptors in the Daegu-Gyeongbuk Region: A Retrospective Study

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Abstract : The purpose of this study was to perform retrospective data collection of the sites and types of fracture in raptors in order to enable wildlife veterinarians to manage cases of fracture more effectively. This study included raptors with fracture, rescued between January 2013 and August 2015 in the Daegu-Gyeongbuk region in Republic of Korea. The data were collected from the medical reports and radiographic findings acquired from designated animal hospitals for wild animals, the Dongin Animal Hospital and the Kyungpook wildlife rescue center. The distribution, sites, and types of fracture, and outcomes of rescue and fracture management of the raptors included in this study were analyzed. Among the 31 birds included in this study, *Falco tinnunculus* was the most common species. Of the 42 sites of fracture, the diaphysis of the humerus was the most common site of fracture, and comminuted fracture was the most common type. Of the 31 birds, 13 were treated surgically. Intramedullary pinning with bandaging was the most common method of surgical treatment. While 7 of the 13 birds died, 2 were reintroduced into the wild, and 4 were kept captive. This study presents the evaluation of the data on the species, sites, and types of fracture, and treatment procedures and outcomes in raptors with fractures, rescued in the Daegu-Gyeongbuk region. The findings of this study could serve as a basic database for the treatment of fracture in raptors.

Key words **:** avian, bone fracture, raptor, rehabilitation.

Introduction

Raptors are invaluable sentinels of environmental changes because of their position at the top of the ecological food chain and widespread distribution across large geographical areas. In addition, they are particularly sensitive to ecological changes (14,26). Over the past few decades, urbanization has progressed rapidly in Korea. With the expansion of space for human habitation throughout the country, the areas for foraging and reproduction of wild animals have shrunk correspondingly (31). The decrease in forest cover because of urbanization has also affected the habitat and population of free-living birds (15). Consequently, some of the species of free-living raptors have become endangered around the world (3). In addition, the construction of artificial structures has increased the rate of injuries to wild animals (9,17). Most of the free-living birds injured by gunshot or crashing into artificial structures experience bone fractures (4,6,8). According to previous studies on raptors, fracture is the most common cause of admission for treatment (50% of all cases of admission), followed by soft-tissue trauma (11%), head trauma (7%), starvation (5%), and suspected toxicosis (3%) (6,25).

Not all wildlife veterinarians are able to respond effectively to the need for treatment of injured animals (30). Most of the pioneering techniques in avian orthopedics have been adapted from small-animal practices (22,23). Unlike other small animals, however, birds have a unique skeletal system adapted for the reduction of weight for flight, including the loss or fusion of bones, reduction in cortical bone thickness, and pneumatization of the medullary cavities (12). The thin and brittle bone cortices complicate avian fracture repair because of their poor pin or screw-holding power as well as the possibility of iatrogenic fracture (1). Other issues encountered in avian orthopedics include the small size of the patients, scarce soft-tissue coverage of the distal extremities, and fractures near joints, which often lead to limited joint mobility (16).

Several studies have reported on the classification of fracture types in small animals, which has proven useful for the effective treatment of fracture (11,18). In avian orthopedics, many studies have reported the morbidity and mortality rates of fracture in other countries such as the USA, Greece, and Spain (5,13,19,20,24). However, studies regarding the classification of fracture in birds are scarce, and none have been reported in Korea.

This retrospective study involved the evaluation of injured raptors rescued between January 2013 and August 2015, in the Daegu-Gyeongbuk region. We evaluated the distribution of raptors, sites and types of fractures, distribution of fracture sites according to the species, and outcomes of rescue and fracture management.

Materials and Methods

This study included raptors with fracture, rescued between January 2013 and August 2015 in the Daegu-Gyeongbuk region in Republic of Korea. The data were collected from

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medical reports and radiographs of 31 raptors with fractures treated at designated wildlife clinics in the Daegu metropolitan city, the Dongin Animal Hospital, and the Gyeongsangbuk-do wildlife rescue center in Republic of Korea.

All of the birds evaluated in study were often species of raptors belonging to one of three orders. In cases with multiple fractures, the different fracture sites were categorized into their respective types for analysis. The categories of fracture sites, such as the humerus, radius, ulna, metacarpus, femur, and tibiotarsus, were the same as previously described (13). Additionally, the vertebrae were included as an additional site of fracture in this study. In addition, the fracture sites on long bones such as the humerus, radius, ulna, metacarpus, femur, and tibiotarsus were further categorized into the distal epiphysis, diaphysis, or proximal epiphysis sites, as described in a study on the classification of long-bone fractures of small animals (18). The types of fracture were categorized based on the direction and number of fracture lines as transverse, oblique, or comminuted fractures (27). The distribution of the sites of fracture was evaluated according to the species.

Based on the outcome of rescue and treatment, the birds were categorized as dead on arrival, euthanized, death during hospitalization or surgery, kept captive, or reintroduced into the wild. In addition, the methods of management of fracture as well as the outcomes were delineated. Four types of surgical treatments were recorded — intramedullary (IM) pinning and bandaging, IM pinning and external skeletal fixation (ESF), IM pinning and wire fixation, and amputation. According to the outcome of surgical treatment, the birds were recorded as dead, kept captive, or reintroduced into the wild. The surgical method, postoperative treatment, and outcomes of the two birds that were reintroduced into the wild and the one that was kept captive were also recorded.

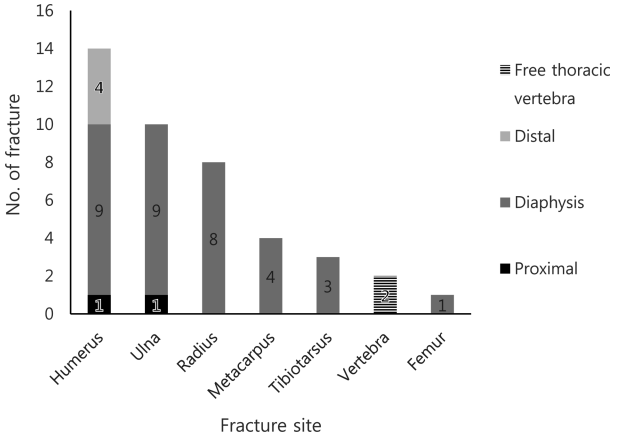

Fig 1. Distribution of sites of fracture in raptors (n = 42).

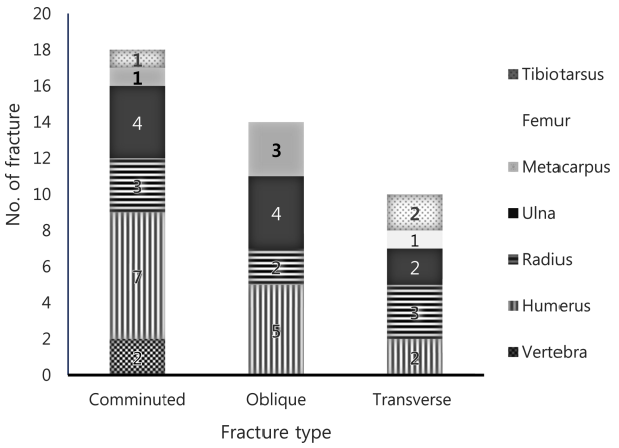

Fig 2. Distribution of types of fracture in raptors, classified according to the direction and number of fracture lines (n = 42).

Results

Distribution of the raptors

A total of 31 birds belonging to 10 species of the orders Strigiformes (5 species), Accipitriformes (4 species), and Falconiformes (1 species) were evaluated. The species-wise distribution of the birds was as follows: *Falco tinnunculus* (n = 10; 32.3%), *Ninox scutulata* (n = 5; 16.1%), *Aegypius monachus* (n = 3; 9.7%), *Bubo bubo* (n = 3; 9.7%), *Accipiter gentilis* (n = 2; 6.5%), *Buteo buteo* (n = 2; 6.5%), *Otus scops* (n = 2; 6.5%), *Strix aluco* (n = 2; 6.5%), *Asio otus* (n = 1; 3.2%), and *Accipiter soloensis*) (n = 1; 3.2%; Table 1).

Sites of fracture

A total of 42 fracture sites were categorized. The humerus (14 cases; 33.3%) was the most common site of fracture, fol-

Table 1. Distribution of the raptors admitted to the Dongin Animal Hospital and Gyeongsangbuk-do wildlife rescue center

Order	Family	Latin name	No. of birds, n	Proportion (%)
Strigiformes	Strigidae	*Ninox scutulata*	5	16.1
		Bubo bubo	3	9.7
		Otus scops	2	6.5
		Strix aluco	2	6.5
		Asio otus	1	3.2
Falconiformes	Falconidae	*Falco tinnunculus*	10	32.3
Accipitriformes	Accipitridae	*Aegypius monachus*	3	9.7
		Buteo buteo	2	6.5
		Accipiter gentilis	2	6.5
		Accipiter soloenesis	1	3.2
Total			31	100

Table 2. Distribution of fracture sites according to species*

Species	Humerus	Ulna	Radius	Metacarpus	Tibiotarsus	Vertebra	Femur	Total	Proportion (%)
Falco tinnunculus	5	4	2	1	1			13	31.0
Ninox scutulata	2	2	2		1			7	16.7
Buteo buteo	2	2	1		1			6	14.3
Aegypius monachus		2	2	1				5	11.9
Bubo bubo	1		1			1		3	7.1
Accipiter gentilis	1			1				2	4.8
Otus scops	2							2	4.8
Strix aluco	1			1				2	4.8
Accipiter soloenesis						1		1	2.4
Asio otus							1	1	2.4
Total	14	10	8	4	3	2	1	42	
Rate (%)	33.3	23.8	19.0	9.5	7.1	4.8	2.4		100

*A total of 42 fracture sites were analyzed in 31 raptors. The data are presented as the number of birds unless otherwise specified.

lowed by the ulna (10 cases; 23.8%), radius (8 cases; 19%), and metacarpus (4 cases; 9.5%). The frequencies of fractures on the tibiotarsus (3 cases), vertebrae (2 cases), and femur (1 case) were low. Fracture sites on the humerus included the proximal epiphysis (1 case), diaphysis (9 cases), and distal epiphysis (4 cases). Fractures on the ulna were present at the proximal epiphysis (1 case) and diaphysis (9 cases), while those on the radius, metacarpus, femur, and tibiotarsus were present on the diaphysis only (Fig 1).

Types of fracture

Fractures at a total of 42 sites were categorized into the comminuted (n = 18), oblique (n = 24), and transverse (n = 10) types. The humerus exhibited fractures of all three types — comminuted (7 cases), oblique (5 cases), and transverse (2 cases). Comminuted and oblique fractures (4 cases each) were the most common types of fracture at the ulna, followed by transverse fracture (2 cases). The radius exhibited 3 cases of comminuted and transverse fractures and 2 cases of oblique fracture. The metacarpus exhibited oblique (3 cases) and comminuted (1 case) fractures. Tibiotarsal fractures included 1 case of comminuted fracture and 2 of the transverse type. Both cases of vertebral fracture were of the comminuted type, while the lone case of femoral fracture was of the transverse type (Fig 2).

Fracture site according to the species

The most common site of bone fracture in *Falco tinnunculus* was the humerus (5 cases), followed by the ulna (4 cases), radius (2 cases), metacarpus (1 case), and tibiotarsus (1 case). In *Ninox scutulata*, fractures were observed on the humerus (2 cases), radius (2 cases), ulna (2 cases), and tibiotarsus (1 case). In *Buteo buteo*, fractures were observed on the humerus (2 cases), ulna (2 cases), radius (1 case), and tibiotarsus (1 case). In *Aegypius monachus*, fractures were observed on the radius (2 cases), ulna (2 cases), and metacarpus (1 case). Fractures in *Bubo bubo* were present on the vertebrae (1 case), humerus (1 case), and radius (1 case). *Strix aluco* and *Accipiter gentilis* both exhibited a case each of humerus and metacarpal fractures. The humerus (2 cases) was the only fracture site in *Otus scops*. A case of femoral fracture in *Asio otus* and one of vertebral fracture in *Accipiter soloensis* were also observed (Table 2).

Outcomes of rescue and fracture management

Of the 31 birds included in the present study, 2 were found to be dead on arrival, 6 were euthanized, 16 died during hospitalization or surgery, 2 were released into the wild, and 5 were kept captive (Table 3).

Fracture management was performed in 23 cases, which excluded the 8 cases of dead on arrival and euthanasia. Of

Table 3. Outcome of bone fracture in raptors

	No. of birds, n	Rate, (%)
Death[a]	16	51
Euthanized	6	19
Captivity	5	16
Dead on arrival	2	7
Released	2	7
Total	31	100

[a]Death during hospitalization or surgery.

Table 4. Outcome of fracture management in raptors

Treatment	Died	Released	Captivity	Total
Medical treatment	9			9
Bandaging			1	1
IM pinning with bandaging	4	2	1	7
IM pinning with ESF	2			2
IM pinning with wire	1			1
Amputation			3	3
Total	16	2	5	23

The data are presented as the number of birds. IM, intramedullary; ESF, external skeletal fixation.

the 23 cases, 9 were managed by medical treatment and stabilization, 1 by figure-of-eight bandaging (metacarpal fracture), and 13 by surgical treatment. Of the 13 cases that underwent surgical treatment, 7 cases (humerus fracture, 2; radius and ulnar fractures, 4; and metacarpal fracture, 1) were treated by IM pinning and figure-of-eight bandaging; 2 (humerus and tibiotarsal fracture, 1 each) by IM pinning and ESF; 1 (humerus fracture) by IM pinning and wire fixation; and 3 (humerus fracture) by amputation .

Regarding the outcome of fracture management, 9 of the birds died during medical treatment and stabilization, and one of the birds that were treated by bandaging was kept in captivity because of its inability of flight. Among the birds that were treated surgically, 7 died either because of the inability to recover from anesthesia or from unknown causes, 2 were released into the wild, and 4 were kept in captivity (Table 4). The 5 birds that were kept captive because of inability of flight were used for conservational and educational purposes.

Discussion

According to a previous study on fractures in raptors, members of *Strix varia* exhibited the highest frequency of fractures, followed by members of *Buteo jamaicensis* and *Accipiter cooperii* (28). In the present study, the most common species of raptors with fractures was *Falco tinnunculus,* followed by *Ninox scutulata*. Members of these species are much smaller than the members of other species that are rescued in countries such as the USA, Greece, and Spain (5,13, 19,20,24,28).

It was previously reported that the humerus was the most common site of bone fracture in raptors, followed by the radius and ulna, while the carpus and metacarpus were reported to exhibit the lowest frequency of bone fractures (13). In another study, bone fractures were reported as occurring most frequently at the ulna, followed by the humerus and radius (28). In accordance with the results of these previous studies, the humerus, radius, and ulna were found to be the most frequent sites of fracture in the present study.

In a previous study, the percentages of fracture on the radius and ulna were both reported to be approximately 50% (2), similar to the results observed in the present study.

We confirmed 2 cases of free thoracic vertebral fracture in the present study. The avian vertebral column exhibits fused vertebrae such as the notarium, synsacrum, and pygostyle, which are all rigid (1). These rigid structural features could be the cause of vulnerability of the free thoracic vertebrae to fracture.

There have been no studies on the evaluation of fracture types in raptors till date. In the present study, a high percentage of comminuted fractures were observed in the long bones such as the humerus, radius, and ulna. According to the results of a previous study on small animal bone fracture, the number of bone fragments and extent of damage to the adjacent soft tissues are both affected by the velocities of the forces causing fracture. Low-velocity forces result in single fractures, with little energy dissipated into the adjacent soft tissue, while high-velocity forces result in comminuted fractures, with high amounts of energy dissipated in the forms of fracture propagation and injury to the adjacent soft tissues (27). Thus, high-velocity forces could be one of the reasons for the high percentage of comminuted fractures observed in this study.

In a previous study, patient reintroduction was reported to be the most frequent outcome of fracture management, followed by captivity; additionally, the rate of death was very low (13). In another study, the number of birds that were not released was higher compared to that of birds that were released (10), which corresponds to the results of the present study. The reasons for the low rate of reintroduction of raptors in the Daegu-Gyeongbuk region include delayed treatment because of the long interval between the time of injury and discovery as well as the method of rehabilitation.

The selection of appropriate surgical materials and methods for the treatment of fractures in raptors is challenging. The bodies of birds are adapted for flight (12). However, the brittleness of the bone cortices, which have poor pin or screw-holding power, often complicates the process of fracture repair in birds (1). In addition, small body size, scarce soft tissues, and fractures near joints, which limit joint mobility, are the other problems encountered in avian orthopedics (16). The possibility of failure of surgical repair of long-bone fractures because of the heavy weight of orthopedic appliances should also be considered (7). Lighter orthopedic appliances and less invasive techniques would enable better healing of long-bone fracture (29). Treatment of fracture in birds chiefly involves the use of IM pins and ESFs (21). Bone plating has received less attention in avian species for a variety of reasons, including the morbidity associated with the placement of bone plates, need for follow-up surgery for the removal of plates in cases of wild birds destined for release, and lack of demonstrated efficacy (7).

In the present study, IM pins were applied in 10 of the 13 surgically treated cases, excluding the 3 cases of amputation. Among the 10 cases, ESF was performed in 2 cases and wire fixation in 1 case. In a previous study on fractures in raptors with a mean body weight of 931 g, IM pinning with ESF was performed in 54% of the cases, while 48% of the cases were treated with IM pinning alone (28). The frequency of treatment with ESF as well as the mean body weight in this previous study were higher compared to those in the present study. The difficulty in performing ESF in small birds such as *Falco tinnunculus* and *Ninox scutulata* could be one of the reasons for the low frequency of treatment with ESF in the present study.

Of the 10 birds that were surgically treated in the present study, 3 exhibited recovery, while 7 died. However, because of the differences in physical status among these birds, it is difficult to correlate the mortality rates with the methods of surgical treatment of fracture.

Conclusion

The present study is the first retrospective evaluation of raptors in Korea. The study was conducted on raptors rescued between January 2013 and August 2015 in the Daegu-Gyeongbuk region. The most common species of raptors with fractures was *Falco tinnunculus*. The humerus was the most

frequent site of fracture, and humerus fractures were most often observed at the diaphysis. Comminuted fractures were the most frequent type of fracture. The most common method of surgical treatment was IM pinning with bandaging. The percentage of the rescued birds reintroduced into the wild was significantly low.

The findings of this study are expected to provide wildlife veterinarians information regarding the frequency and characteristics of fractures in raptors and could also serve as a basic database for the treatment of fracture in raptors.

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