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Treatment of extremity fractures in 20 wild birds with a modified Meynard external fixator and clinical assessment of the results

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Abstract: The aim of this study is to evaluate the outcome of the treatment on twenty wild birds presenting with fractures that were stabilised with modified Meynard external fixators. The study material consisted of a total of twenty birds of eight different species, six white storks (*Ciconia ciconia*), one eastern imperial eagle (*Aquila heliaca*), one European honey buzzard (*Pernis apivorus*), one long-legged buzzard (*Buteo rufinus*), three common buzzard (*Buteo buteo*), one northern goshawk (*Accipiter gentilis*), one Armenian gull (*Larus armenicus*), and six yellow-legged gulls (*Larus michahellis*), which were diagnosed with fractures in their extremity bones following clinical and radiological examinations. The lesions of the twenty cases evaluated in the study were diagnosed as humerus fractures in nine cases, ulna fractures in three cases, tibiotarsus fractures in seven cases and a femur fracture in one case. The external fixators were removed between weeks five and nine postoperatively. While healing was seen in twelve of the twenty evaluated cases, the complete functional recovery occurred in six of these and they were released into nature. It was concluded that modified Meynard external fixator, which was made applicable for fractures in birds, could be an alternative method for fracture treatments in wild birds.

Keywords: avian; fracture assessment; orthopedic surgery; osteosynthesis

As a result of recently conducted evaluations, it has been found that extremity fractures are the most frequent injuries in wild birds brought to animal hospitals and rehabilitations centres (Rodriguez et al. 2010; Choi et al. 2016; Aslan et al. 2018). The treatment of extremity fractures has a vital significance for wild birds. Choosing the correct osteosynthesis method so that they can return back to nature, using suitable materials and a dedicated process of rehabilitation are complementary factors (Degernes et al. 1998; Pollock 2002).

Small animal orthopaedics and osteosynthesis techniques used in human medicine can also be used for birds (Bennet and Kuzma 1992; Tully 2002; Tunio et al. 2014). However, due to the birds' bone structure, feathers, flight dynamics and functional differences in their extremities, some modifications are needed in the materials used (Hatt et al. 2007; Bueno et al. 2015; Carrasco and Schimizu 2018). Most of the time, distal extremity bones are surrounded by skin and tendons only and have insufficient soft tissue support. These factors result in consequences such as failure in supporting the fractured ends and frequent fragmented fractures and open fractures (Bennet and Kuzma 1992).

In the bones of poultry, the extracellular bone matrix predominantly consists of mineral compounds as hydroxyapatite crystals (85% calcium phosphate, 10% calcium carbonate) (Konig et al. 2016; Sullivan et al. 2017). Due to this high hydroxyapatite con-

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tent, the bones of poultry are much more fragile when compared with mammals and they are more prone to fragmented fractures (Tully 2002).

For the optimal stabilisation of a fracture, the forces which are effective on the fracture should be neutralised. An intramedullary pin application alone is not enough to prevent rotation rather it also requires a bandage or cross pin application (Harcourt-Brown 2002; Perez et al. 2008). On the other hand, external fixation provides good stabilisation for the shear, rotation and bending movements, does not harm the joint and causes a minimum damage to the blood vessels and the soft tissue (Perez et al. 2008).

In treatments with an external fixation, bone healing occurs with the formation of an endosteal callus to a great extent. This provides a great advantage in bone healing in birds for which the endosteal blood support and endosteal callus are important for bone healing (Hatt et al. 2007).

The most important factor restricting the usage area of an external fixator in birds is the weight of the fixator (Hatt et al. 2007; Carrasco and Schimizu 2018). The clamps of many commercial external fixators are too heavy to use in birds, especially in birds weighing less than 1 kg. In addition, they are not compatible to hold the thin pins that need to be used in birds (Hatt et al. 2007; Arias et al. 2015).

This study presents the treatments of fractures in wild birds with a Meynard external fixator and the results of the treatments.

MATERIAL AND METHODS

The study was conducted with the 12/04/2017 dated and 141196 numbered ethical board approval of İstanbul University Animal Experiments Local Ethics Committee (İ.Ü. HADYEK) Commission Chair.

The samples consisted of a total of twenty individual birds of eight different species that were enrolled into the study, including six white storks (*Ciconia ciconia*), one eastern imperial eagle (*Aquila heliaca*), one European honey buzzard (*Pernis apivorus*), one long-legged buzzard (*Buteo rufinus*), three common buzzard (*Buteo buteo*), one northern goshawk (*Accipiter gentilis*), one Armenian gull (*Larus armenicus*), and six yellow-legged gulls (*Larus michahellis*), which were brought to Istanbul University – Cerrahpaşa, Veterinary Faculty, Department of Surgery with a complaint of a fracture.

A physical examination, blood tests and faecal examinations to assess for parasites were performed first in each patient brought to our clinic and their general conditions were evaluated. Radiographs were taken of the related extremity in ventrodorsal (VD) and caudocranial (CuCr) positions for the wing fractures, while mediolateral (ML) and craniocaudal (CrCu) radiographs were taken for pelvic limb fractures. Antebrachial and distal tibiotarsus fractures were bandaged until the operation to avoid becoming a compound fracture and to reduce the pain associated with having a non-stabilised fracture. A figure of eight bandage technique was used for the antebrachial fractures. The fractures were classified from 0 to 5 degrees according to Tscherne and Oestern (1982). In patients which arrived with compound fractures, an antibiotic therapy was started with 100 mg/kg ceftriaxone (Unacefine©; Yavuz İlaç, Istanbul, Turkey) before any operation.

After the patients that were going to be operated on were given 1 mg/kg Butorphanol tartrate (Butomidor©; Richter Pharma, Wels, Austria) intramuscularly (i.m.) as the premedication, they were also given 2–3% isoflurane (Forane©; USP, Deerfield, USA) with a mask for induction and they were intubated with a cuffless tube and placed under general anaesthesia. Each patient was given sodium chloride (Polifleks©; Polifarma, Tekirdag, Turkey) at a speed of 10 ml/kg/h intravenously (i.v.), through the medial metatarsal vein during the operation and ceftriaxone (Unacefine©; Yavuz İlaç, Istanbul, Turkey) was given 100 mg/kg i.v. as an antibiotic. As a pre-emptive analgesia, meloxicam (Maxicam©; Sanovel, Istanbul, Turkey) was given at 0.5 mg/kg subcutaneously (s.c.) following induction.

After cleaning the operation area with Povidone-iodine (Biokadin©; Biokan, Kayseri, Turkey), the humerus and antebrachium were approached dorsally, the femur was approached laterally and the tibiotarsus was approached medially as described by Orosz et al. (1992). The fixation procedure was carried out using the open or limited open method. In all of the cases, the tie-in method was applied and, in the old fractures with muscle contracture, an intramedullary pin was first placed to position to bone ends. The intramedullary pin was first placed retrograde to the medulla of the bone and then normograde in all the cases (Figure 1A). After the external pins were placed with the help of a low-speed drill, the clamps were tightened with an allen wrench and the system was secured (Figure 1B

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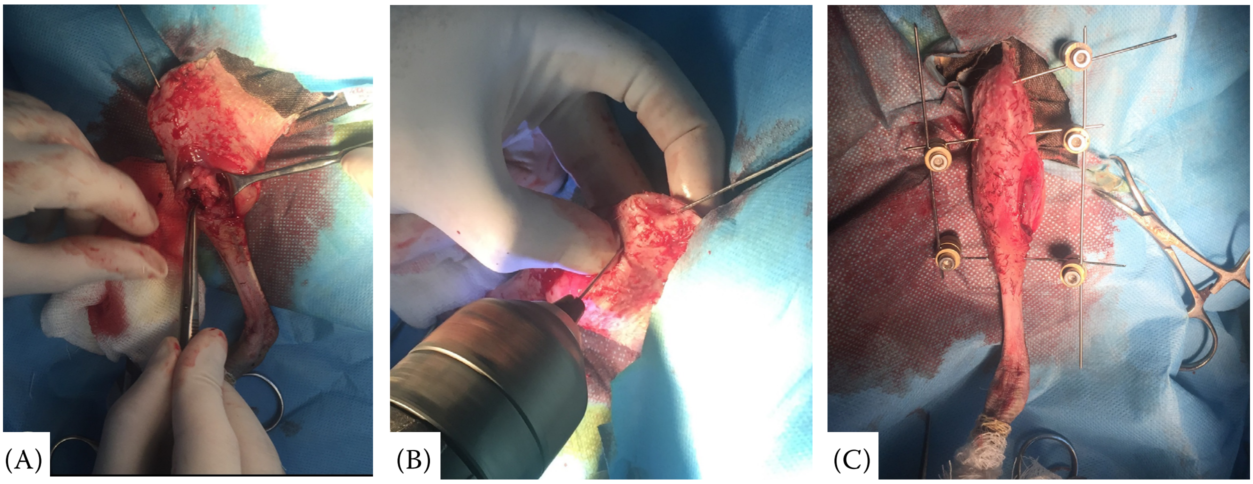

Figure 1. Bone reduction with an intramedullary pin (A), insertion of external pins (B), after placement of the pins, the system fixed with Meynard clamps (C)

and C). The skin incision was closed with simple separate sutures with 3/0 or 4/0 absorbable sutures (Vicryl; Johnson & Johnson, New Jersey, USA).

In the treatment of the fractures, a Meynard modified external fixator was used and the tie-in method was applied in five of the cases, while a Type I external fixation was applied in eleven a Type II external fixation was applied in one and an intramedullary pin with a Type I external fixation was applied in three.

For the external fixation, a partially grooved titanium alloy and straight pins with a diameter of 1.2–2.5 mm were used. Meynard clamps with a diameter between 8 and 13 mm were used to fixate the pin and bar (Table 1).

Table 1. Type of fixation and description of the osteosynthesis materials

Case No.	Type of external fixation	Number of pins proximal/medial/distal	Description of pins (size of pin, threaded or non-threaded)	Instruments/body mass ratio (%)
1	Type I	4/4	2.5 mm, threaded	1.90
2	Type I	2/3	2.5 mm, threaded	1.12
3	Type I	2/2	2.5 mm, threaded	1.20
4	Type I	2/2	1.5 mm, threaded	1.05
5	Type I	2/3	1.5 mm, threaded	1.40
6	Type I	2/2	2.5 mm, threaded	1.80
7	Type I	2/2	1.5 mm, threaded	0.97
8	Type I	2/2	1.5 mm, threaded	1.29
9	Type I	2/2	1.5 mm, threaded	1.08
10	Type I	2/2	1.2 and 1.5 mm, threaded	0.93
11	Type I	2/2	2.5 mm, threaded	1.30
12	Type I + IM pin	2/2	2.5 mm, threaded	1.46
13	Type I + IM pin	2/2	1.5 mm, non-threaded	1.05
14	Type II	2/1/2	2.5 mm, non-threaded	2.30
15	Type I + IM pin	2/2/2	1.5 mm, non-threaded	1.30
16	Tie-in	1/1	1.2 mm, non-threaded	1.93
17	Tie-in	1/1	1.2 mm, non-threaded	1.98
18	Tie-in	2/2	1.2 mm, non-threaded	1.85
19	Tie-in	2/1	1.2 mm, non-threaded	1.90
20	Tie-in	1/1	1.2 mm, non-threaded	1.30

IM = intramedullary

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Ceftriaxone (Unacefine©; Yavuz İlaç, Istanbul, Turkey) 100 mg/kg i.m. q12h was used for a week postoperatively, meloxicam (Metacam©; Boehringer-Ingelheim, Ingelheim am Rhein, Germany) 0.5 mg/kg orally q24h was used as an analgesia for 3–5 days after evaluating the patient's condition, and undiluted Povidone-iodine (Biokadin©; Biokan, Kayseri, Turkey) was used for 5 days to clean the suture line and each pin site. In order to prevent the contamination of the wound line, the sutures were covered with a sterile gauze. In the birds that were aggressive and that tried to dismantle the external fixator system, cohesive bandage wraps were applied to cover the whole system. Radiographs were taken postoperatively and each week until the external fixator was removed after a sufficient callus formation was seen radiologically. Ultrasound therapy (Physiomed©, Schnaittach, Germany) of 0.2–0.3 W/cm^2 for 2 min was performed on the patients as a physiotherapy in order to prevent muscle contracture and ankylosis and to speed up the healing process.

Following the treatment of the pelvic limb fractures, the patients' lameness was scored from 0 to 5 (Kestin et al. 1992; Choi et al. 2016).

RESULTS

The patients were found to weigh between 500–2 500 grams. Of the twenty cases which received osteosynthesis, twelve were found to have thoracic limb fractures, eight were found to have pelvic limb fractures and of these fractures, nine of the thoracic limb fractures were the humerus, while three were ulna fractures and seven of the pelvic limb fractures were tibiotarsus and one was a femur fracture (Table 2).

Table 2. Findings of cases managed with the modified Meynard external skeletal fixators

Case No.	Signalment (species, age, weight in grams)	Fractures				Time[d] (wk)	Postoperative complications	Result[e]
		cause	side	bone[a], loc[b]	type[c]			
1	White stork, A, 2 300	gunshot	L	H, $^2/_3$	op, tr	–	–	ex
2	White stork, A, 2 500	unknown	R	H, $^2/_3$	cl, tr	–	–	ex
3	Imperial eagle, A, 2 000	pathological fracture	R	H, $^2/_3$	op, tr	–	–	ex
4	Honey buzzard, A, 900	unknown	L	U, $^1/_3$	cl, co	6	–	+
5	Long-legged buzzard, A, 700	unknown	L	U, $^2/_3$	op, tr	6	synostosis, malunion	-
6	White stork, A, 2 200	unknown	R	T, $^1/_3$	cl, tr	6	muscle contracture	+, 3
7	Buzzard, A, 700	gunshot	L	H, $^2/_3$	cl, co	6	–	+
8	Northern goshawk, A, 1 200	gunshot	L	H, $^3/_3$	cl, co	8	ankylosis	-
9	Buzzard, A, 900	gunshot	L	U, $^1/_3$	cl, co	7	patagial contracture, primary feathers damage	-
10	Common buzzard, A, 850	unknown	R	F, $^3/_3$	cl, tr	–	–	ex
11	White stork, A, 2 200	gunshot	R	H, $^2/_3$	cl, co	7	malunion	-
12	White stork, A, 2 300	unknown	L	H, $^2/_3$	op, tr	8	non-union	-
13	Armenian gull, A, 900	collision	R	H, $^3/_3$	op, co	9	material damage, ankylosis	-
14	White stork, A, 2 100	unknown	R	T, $^2/_3$	cl, se	–	material damage	ex
15	Yellow-legged gull, A, 930	collision	R	H, $^2/_3$	op, se	6	refracture	-
16	Yellow-legged gull, J, 580	falling from the nest	R	T, $^1/_3$	cl, tr	5	–	+, 0
17	Yellow-legged gull, J, 530	falling from the nest	L	T, $^2/_3$	op, tr	5	–	+, 0
18	Yellow-legged gull, J, 500	falling from the nest	R	T, $^2/_3$	op, tr	6	osteomyelitis	-, 5
19	Yellow-legged gull, J, 540	falling from the nest	L	T, $^3/_3$	op, ob	7	osteomyelitis, ankylosis	-, 5
20	Yellow-legged gull, I, 830	falling from the nest	R	T, $^2/_3$	op, tr	7	osteomyelitis	+, 0

A = adult; J = juvenile; I = immature; L = left; R = right

[a]Operated bone: H = humerus, U = ulna, T = tibiotarsus, F = femur; [b]Location of fracture: $^1/_3$ proximal third of bone, $^2/_3$ medial third of bone, $^3/_3$ distal third of bone; [c]Type of fracture: op = open, cl = closed, se = segmental, tr = transversal, co = comminuted, ob = oblique; [d]Removed time of fixator: wk = week; [e]Results: + = released, - = kept in captivity, ex = died, 0 to 5 lameness score

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Of the fractures determined before the operation, ten were compound fractures and ten were closed fractures. The forms of the fractures were simple transversal closed fractures in four cases and fragmented closed fractures in five cases. Of the open fractures, five were classified as a 1st degree, five as a 2nd degree and one was classified as a 3rd degree.

The removal time of the osteosynthesis materials was found to range between 5–9 weeks (Figure 2). In the postoperative period, the following complications were seen the patients: synostosis in one case, a mal-union (angular deformity) in two cases, a muscle contracture in one case, ankylosis in three patients, a patagial contracture in one case, primary feather loss in two cases, a non-union in one case, the fixator removal in three cases, a distal fragmented refracture in one case with a segmental fracture and osteomyelitis in three cases (Figures 3 and 4). Three cases that were found to have osteomyelitis (cases 18, 19 and 20) were also found to have pin loosening and the patients with osteomyelitis were treated with clindamycin (Klindan©; Bilim İlaç, Kocaeli, Turkey) 50 mg/kg i.v. therapy for 3 weeks. While two of the three cases were found to have function loss and 5/5 degree lameness, one was found to have 2/5 degree lameness (case 20). Case 20, which was found to have 2/5 degree lameness, was given ultrasound therapy for two weeks and the lameness degree was found to decrease to 0/5 degrees (Figure 5A–B).

Of the twelve cases which were operated on for thoracic limb fractures, three died, one had a non-union, one had a refracture and seven were found to have a union; however, only two of these gained

Figure 2. Anteroposterior (AP; left) and mediolateral (ML; right) radiograph image of the tibiotarsus in the yellow-legged gull osteosynthesis material which was removed in postoperative week 5 (case 16)

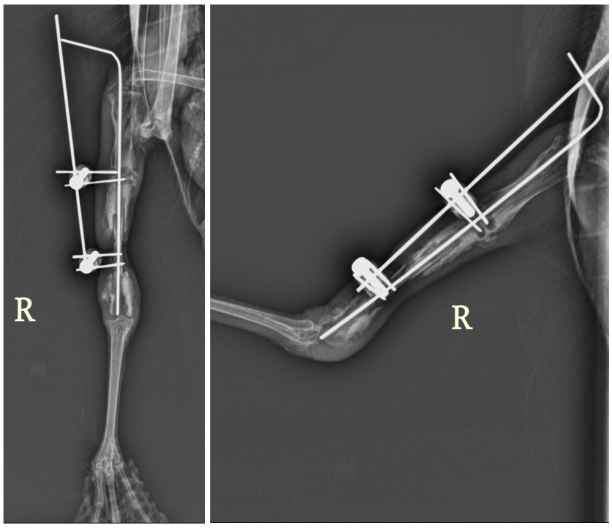

Figure 3. Postoperatively osteomyelitis in a yellow-legged gull which was applied tibiotarsus osteosynthesis (case 18)

Figure 4. Non-union in a white stork which received a humerus osteosynthesis (case 12)

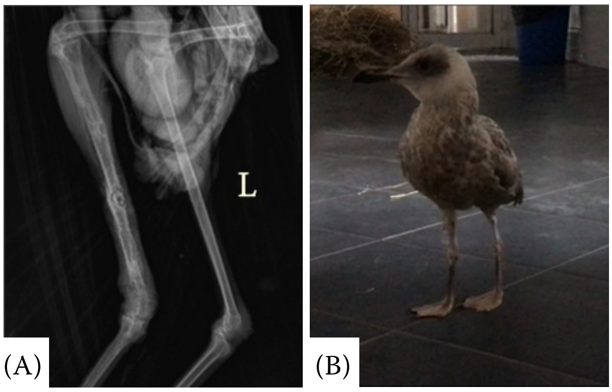

Figure 5. Radiography (A) and feet down image (B) of case 20, post clindamycin therapy and ultrasound therapy

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Figure 6. A common buzzard during the goniometric measurements

their physiological functions and could return to nature. After the removal of the osteosynthesis materials, goniometric measurements were performed and the wing angles were measured (Figure 6). In the two cases in which the birds could return to nature, when the intact wing and the wing with osteosynthesis were compared, the difference was found to be not greater than 5 degrees.

Of the eight cases which were operated on for pelvic limb fractures, two died, in the remaining six, the postoperative lameness degrees were found to be 0/5 in three cases, 3/5 in one case and 5/5 in two cases. Four of these cases were released back into nature. Of the five patients that died postoperatively, one died at day nine, one died at day ten, two died on day 14 and one died on day 28.

The ratio of the materials used for each patient to body weight was calculated and these ratios were found to be between 0.93–2.3% of the patient's body weight. No complications were seen, such as dropped wing which can occur in the postoperative period depending on the weight of the material.

DISCUSSION

In wild birds, trauma, forearm injuries, infections, nutritional deficiencies, other animals' attacks and metabolic disorders have been reported as the most frequent reasons for extremity fractures (Rodriguez et al. 2010). In seven of the twenty cases evaluated in our study; we could not find the aetiology of the fracture. Of the thirteen remaining cases in which the aetiologies were known, the pathological fractures were found to occur as a result of a forearm injury in five cases, as a result of falling from the nest in five cases, as a result of a car crash in two cases and as a result of malnutrition under captivity for a long time in one case, the results obtained were found to be in parallel with the results of previously conducted studies (Aslan et al. 2018).

Of the fractures in the study, ten were compound fractures and ten were closed fractures. Of the closed fractures, six were found to be comminuted fractures. While simple fractures mostly occur in caged birds, comminuted fractures are seen in wild birds (Meiners 2017). When compared with mammals, birds have comminuted fractures more frequently as a result of their pneumatised bone structure, thin cortex structure and calcium content (Meiners 2017). Wild birds mostly have old and open fractures (Bennet and Kuzma 1992; Meiners 2007; Sullivan et al. 2017)

Today, fracture treatments with external fixators in birds have shown different degrees of success. In a study conducted by Howard and Redig (1993), 38 of 81 birds were treated; however, functional healing was possible in 12 of the 38 cases. As a result, only 6 of the 12 cases which had bone healing could return to nature. Similar to the results of previously conducted studies, our results show that bone healing alone is not enough for wild birds to return to nature.

Passive exercises were performed on all of our patients following the first postoperative week. The fact that the physiotherapy and joint movements could be made without removing the material can be considered as another advantage of the external fixation in birds. In our study, in case 9, which developed a patagial contracture, the cubital angle was increased from 105° to 132° with the ultrasound therapy. In case 6 which received tibiotarsus osteosynthesis and which developed a postoperative muscle contracture, an ultrasound therapy and approximation were applied and the lameness degree was decreased from degree 5/5 to degree 3/5. Following the osteomyelitis treatment with clindamycin, the lameness regressed to degree 0/5 with the ultrasound therapy in case 20 which showed a second degree of lameness. Studies conducted have shown the necessity of physiotherapy practices with an appropriate treatment period and methods following the operative treatment of fractures which occur in the thoracic limb and

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pelvic limb bones (Pollock 2002). In our study, we achieved successful results in the functional healing of the extremities with an ultrasound therapy and passive exercise.

In pelvic limb fractures of birds, tibiotarsus fractures are the most frequent fractured bones (Harcourt-Brown 2002). The tie-in method is the preferred method in the treatment of tibiotarsus fractures (Harcourt-Brown 2002). The use of a tie-in fixator is a technique in fracture treatments which does not require a bandage, is low-cost, allows joint movement and can easily be removed from the extremity following healing (Harcourt-Brown 2002; Kubiak and Forbes 2011). In our study, eight of the twenty cases which received the osteosynthesis had pelvic limb fractures and in seven of these fractures, the fracture was in the tibiotarsus. In the treatment of tibiotarsus fractures, the tie-in method was applied to five of the cases, while a type I external skeletal fixator (ESF) was applied to one case and a type II ESF was applied to one case.

Of the patients in our study that had a successful osteosynthesis, 50% of the cases were able to be released to the wild, representing 30% of the total patients enrolled in the study. In experimental studies conducted about fracture treatment in birds, the rates of healing and returning to nature were found to be higher than our study (Hatt et al. 2007; Bennert et al. 2016). According to the osteosynthesis results conducted on twelve pigeons with external fixation following an ulna osteotomy, bone healing was observed in all of the birds (Tunio et al. 2014). According to these results, the prolongation of the time between the occurrence of the fracture and the operation has a negative effect on the clinical recovery. One of the most important factors that decreases the success of a return to nature is the time that passes from the occurrence of the fractures to the wild birds being taken to clinics and performing the operations (Slunsky et al. 2017). In complication-free cases, the period of time reported for bone healing is 4–6 weeks. It has been reported that this time can be longer in metacarpal and metatarsal fractures depending on the scarcity of soft tissue and decreased blood flow in the area (Pollock 2002; Dascalu et al. 2013). In our study, while the healing time was 5–6 weeks in the complication-free patients, this time period increased to 7–9 weeks in patients with complications.

A great number of methods used in small animal orthopaedic surgery and human medicine are also used successfully in birds. Commercially produced orthopaedic pins are generally designed for mammals (Perez et al. 2008). For this reason, some modifications are required in the osteosynthesis materials used according to the anatomic and physiological differences between birds and mammals. The most important necessity is the use of light materials for the birds which have a thinner bone cortex and lower body weight when compared with mammals (Bueno et al. 2015; Carrasco and Schimizu 2018).

A great number of studies conducted have emphasised the significance of the weight of the materials used in birds and special osteosynthesis materials that may be required. The weight of the external fixator is a factor that makes its usage difficult. Many commercial fixator clamps are too heavy to use in birds and they are also not compatible for holding the pins that need to be used in birds (Hatt et al. 2007; Arias et al. 2015). From the past to the present, a great number of materials have been used in fracture treatments in birds.

In order to decrease the weight of the external fixator, polymethyl methacrylate (PMMA) or epoxy putty have been used as the connection rod. Using only PMMA can form a small contact surface between the fixator and pin surface and cause instability. In order to increase the contact surface, methods such as creating roughness on the smooth pins, bending the pins 90° and covering the pins with cerclage wire before covering with PMMA have been proposed (Arias et al. 2015).

In our study, different configurations were created by using titanium alloy Meynard clamps produced in special measurements (8 mm, 10 mm, 14 mm), with partially threaded or non-threaded pins (with 6 clamps of each length). The 14 mm Meynard system weighed 32 g, while the 10 mm Meynard system weighed 22 g and the 8 mm Meynard system weighed 11.1 grams. They were successfully implemented in twenty cases with a bird body weight of between 500 and 2 500 grams. No complications were seen such as a low wing which can occur in the postoperative period depending on the weight of the material.

In our study, in addition to the material weight calculated by Hatt et al. (2007), we also calculated the live weights of the material weight. To do this, we used the 5% rule of transmitter weights used in determining migration routes and migration strategies (Gaunt et al. 1997). According to this

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rule, for a bird to maintain its problem free physiological activities and to complete the migration without any extra energy loss, the material weight (transmitter) that can be added to its body should be about 5% of its maximum weight. In our study, we calculated the ratios of the weights of the materials used for each patient to the live weight and we found the ratio to be 0.93% at the minimum and 2.3% at the maximum. In patient 7, in which a humerus osteosynthesis was conducted, this rate was calculated as 0.97% and we observed that this patient could start flying with the external fixator on its wing during the second postoperative week. Our results showed that the 5% rule can also be used for the material selection in the fracture treatment.

Of the five patients that died postoperatively, one died at day 9, one died at day 10, two died on day 14 and one died on day 28. According to the necropsy, blood examination and microscopic examination performed on the patients that died, the causes of death were septicaemia, pneumonia, askaridosis and enteritis. As advocated by Dascalu (2013), these results bring to mind that the deaths could have possibly occurred as a result of the birds, which are brought in with a complaint of a fracture, having been exposed to the disease agent when they were in nature, as well as due to their weakened immune system due to being in captivity.

It is unclear if this could have occurred due to the disease state out in the wild, or as a result of the treatment within the hospital.

Threaded pins produced from a titanium alloy provide a bigger hold on the bone surface when compared with stainless steel non-threaded pins and they are more resistant to bending and breaking (Subasi and Karatas 2012). Threaded pins made from a titanium alloy were used in twelve cases in our study. While no pin breakage was found in these cases, we observed pin bending in two cases in which the bird tried to remove the external pins. These findings show that titanium alloys have a low resistance to bending.

Hatt et al. (2007) applied the tie-in method by using straight pins in two of the five cases on which they performed a tibiotarsus osteosynthesis and grooved pins in three and they did not show a significant difference in bone healing. They stated that using a grooved pin was not necessary with the tie-in technique in birds with less than a 1 000-gram live weight, while it was necessary for birds weighing more than 1 000 grams. We used the tie-in method with straight pins in the birds with a tibiotarsus fracture which were less than 1 000 g and we did not come across any complications. These results were found to be in parallel with other studies conducted (Hatt et al. 2007).

Postoperative complications for fracture treatments in birds have been reported as refractures, arthritis, synostosis, osteomyelitis, pododermatitis, pin breakage, pin loosening, neurological losses and non-unions (Bueno et al. 2015; Bennert et al. 2016; Gerbaga Ozsemir 2018). In the postoperative period, the complications seen in our study were synostosis, a malunion (angular deformity), muscle contracture, ankylosis, a patagial contracture, primary quill feather loss, a non-union, a fixator removal, a distal fragmented refracture and osteomyelitis (Table 2).

In the light of the references above about fracture treatments in birds, our results are in parallel with the results of studies which state that producing osteosynthesis materials from titanium alloys makes these materials stronger and decreasing the weight by producing specially-sized materials for birds provides a great number of advantages in the fracture treatment of birds.

As a result, we found that a modified Meynard external fixator can be used in the fracture treatment of wild birds, which provides advantages with its ease of application and material weight. In our study, when compared with other experimental studies, the success rate is low, but compared with the clinical assessments, our results are shown to be in parallel.

We concluded that in addition to the fracture treatment, factors such as the care, physiotherapy and rehabilitation are also important in the birds' returning to nature.

Conflict of interest

The authors declare no conflict of interest.

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