The primary aim of fracture treatment is to achieve the fastest possible healing and enable the patient to function normally by allowing early walking (Aron, 1998; Shahar, 2000). For this, the aim is to produce anatomical unity between the joints above and below the fractured bone and functioning of the extremity (Piermatei and Flo, 1997). In the treatment of radius and tibia fractures in dogs, external fixation methods are primarily suggested (Johnson et al., 1989; Font et al., 1997; Palmer, 1999). External fixators are used either primarily or as a support for internal fixation and are frequently applied using a closed method (Foland and Egger, 1991; McLaughlin and Roush, 1999).

External fixators are used extensively in both human and veterinary orthopaedics as a treatment option in severely comminuted and open fractures, infected non-union cases, arthrodesis, for bone-lengthening and also correcting growth disorders (Harari, 1992; Aron et al., 1995; Altunatmaz and Yucel, 1999).

External fixators can be applied either with an open approach or closed reduction. In the fracture treatment with an open approach, manipulations necessary during the operation will cause secondary trauma in the injured region and the blood circulation of the bone will be damaged, causing a delay in the healing period (Dudley et al., 1997; Lauer et al., 2000).

In severely comminuted and dislocated diaphyseal fractures, reconstruction is known to be very difficult. However, during surgery, priority should be given to establishing anatomical structure and protecting vascularisation of the bone rather than to its reconstruction. This kind of an approach is the basis of biological osteosynthesis (Aron et al., 1995; Johnson et al., 1998; Palmer, 1999).

External fixation has advantages such as causing minimal damage to the injured region, maintaining bone length, minimising the atrophy forming in the bone and soft tissues, allowing complete weight-bearing on the healing bone and keeping soft tissue trauma at the fracture line at the lowest (Johnson and Decamp, 1992; Egger, 1998; Lewis et al., 2001).

Healing in fractures treated using external fixation occurs mainly via endostal callus rather than a periostal one (Harari et al., 1996). Some cases however, heal primarily. Researchers (Johnson et al., 1989; Harari et al., 1996; Egger, 1998) report that healing takes place in 3–12 weeks with this application. As well as healing, delayed healing and non-union cases have also been reported (Aron et al., 1986; Carmicheal, 1991; Harari, 1992; Rudd and
Whitehair, 1992). In fractures to which they applied external fixation, Johnson et al. (1989) observed that, bone healing or duration of union occurred at the same time or earlier compared to those treated with internal fixation.

In external fixation applications, complications such as pin loosening, pin-base infection, pin breaking, non-union or delayed union are frequently encountered (Johnson et al., 1989; Anderson et al., 1993; Lewis et al., 2001).

MATERIAL AND METHOD

The material for this study comprised of 30 dogs of different breed, age, gender and body weight, brought to the Istanbul University Veterinary Faculty Surgery Department with a complaint of lameness or inability to use the leg (Table 1).

In the clinical examination, cause of the fracture, location of the fractured bone, whether the fracture was open or closed and other injuries were determined. A 2-way (AP, ML) radiograph was taken of the area and the reduction technique (limited open or closed) to be applied was decided.

Patients were sedated and the operation site was shaved and disinfected. Following this the animals were put under general anaesthesia. A Type I external fixator (unilateral-uniplanar) was used in cases with a humerus fracture and a Type II external fixator (bilateral-biplanar) was used in cases with tibia-fibula and radius-ulna fractures. Straight Steinmann pins were used for fixation in all cases (Table 2).

Two different types of clamp (Meynard and handcuff clamps) were used to attach the pins to the fixator. Due to the small diameter of the bar, the handcuff clamp was only used in dogs weighing under 10 kg.

The fixation procedure was carried out using the limited open method in 6 fractures and via closed approach in 24. In 1 case where an external fixator was applied to the radius using the closed method, an intramedullary pin was placed in the ulna using an open approach. In 2 cases which had open fractures in the distal diaphysis of the tibia-fibula, the fixator was applied in transarticularly. In 1 case, which had been given an internal fixation but in which complications had developed due to osteomyelitis, an external fixator was applied using a closed approach. In one severely dislocated case (No. 9), distraction was used to bring the bone fragments closer together using the closed method. In one other case with an open fracture in the distal diaphysis of the tibia-fibula, the fixator was removed and plate osteosynthesis was carried out due to non-union.

In the cases to which an external fixator was applied using the limited open approach, the incision was kept minimal. The incision was closed after the bone fragments were aligned and fixation was complete.

In open and infected fractures, an external fixator was applied after debridement and thorough irrigation of the area using sterile saline solution. Postoperative antibiotics were given to all cases. The fixator was dressed using a large amount of cotton-wool and the area was covered.

Immediately after fixation, the fractured bone was radiographed and re-positioning was checked for alignment. Distances between the bone fragments were also recorded.

The condition of the callus was evaluated with radiographs taken regularly during the postoperative period. The fixator was removed in cases which showed sufficient callus formation.

RESULTS

Treatment with external fixation and results after the treatment were evaluated in a total of 30 dogs in which, after clinical and radiological examination, radius-ulna fractures were determined in 6, tibia-fibula fractures in 14 and humerus fractures in 3 (Tables 1 and 2).

Fourteen of the dogs, which had been diagnosed with a fracture and had been treated were adults and 9 had not yet completed their growth. The bodyweight of the cases ranged between 4–48 kg.

In the 6 cases with radius-ulna fractures, the fracture was in the mid-diaphysis in 3 cases and in the distal diaphysis in the remaining 3.

Of the tibia-fibula fractures 2 were located in the proximal diaphysis, 2 in the mid-diaphysis, 9 in the distal diaphysis and 1 in the distal epiphysis. All of the humerus fractures were located in the mid-diaphysis.

Of the fractures that were treated with external fixation, 3 were open fractures (tibia-fibula fractures). One of these cases (Case No. 11) was an old fracture and necrosis was present in a 3 cm-long part of the bone.

Type I external fixation was applied to cases with humerus fractures (Figure 1) and Type II external
fixation was used in those with radius-ulna and tibia-fibula fractures (Figure 2).

After the fracture was stabilised using a fixator, measurements showed the distance between the bone fragments to differ between 0.5–1.5 mm.

In postoperative radiographic check-ups (observation of sufficient mineralised callus formation) the fractures were observed to heal in between 16–40 days. Although there was no contact with external surroundings, the healing period in 3 humerus mid-diaphyseal fractures treated using a limited open approach was seen to be approximately the same as those treated using the closed method.
All the cases that were treated (except case No. 11) were seen to make slight ground contact with the leg 3–10 days after external fixation and to function close to normal within 20 days with full weight-bearing on the fractured leg.

The fixator was removed in cases which had sufficient mineralised callus formation and which could bear weight on the leg. While this period was approximately between 20–30 days, it was also delayed due to the late appearance of the patient owners (178 days).

In the radiographs taken 24 days later of case No. 8, in which a fixator was applied to the radius using the closed method and an intramedullary pin.
was placed in the ulna using an open approach, while there was sufficient healing in the radius, the union in the ulna was seen to be insufficient. Various complications were seen in the cases included in our study which were; pin loosening in 2, pin-base infection in 3, valgus deformation in 2, non-union in 1 and ankylosis in 1 case. Pin loosening and pin-base infection was usually seen in pins placed in the proximal fragment. In a case which had an open and infected fracture, the infection was seen to disappear after application of a fixator. However, as non-union was present, the fixator was removed and treatment was carried out with plate osteosynthesis.

**DISCUSSION**

When treating fractures in immature animals, it is very important to protect the growth plates and provide early return to function (Altunatmaz and Yucel, 1999; Lewis *et al.*, 2001). Ten cases, to which we applied external fixation, had not yet completed their development. During fixation utmost care was taken not to damage the growth plates and in the postoperative follow-ups no complications were encountered relating to obstruction of growth in these cases.

Type II external fixators can be applied to tibia-fibula or radius-ulna fracture cases of all ages and bodyweight (Aron *et al.*, 1995; Aron, 1998; Kraus *et al.*, 1998; Lewis *et al.*, 2001). Likewise in this study, location of the fracture did not cause any problems with respect to application of the fixator. The fact that 6 radius-ulna and 11 tibia-fibula fracture cases, to which a fixator was applied using the closed method, and 3 humerus fracture cases fixed using an open approach healed in a short period without complication, once again proved the significance of biological fixation (Toombs, 1992; Johnson *et al.*, 1998; Palmer, 1999).

The fact that the patients were able to walk by touching the fractured leg on the ground within 3–10 days after application of the fixator and that they could use their leg to a great extent within 20 days, are important developments with respect to
Figure 2. Radiography of mid-shaft *tibia-fibula* fracture belonging to a Siberian husky, using external fixator with closed reduction. a – before surgery, b – immediately after surgery, c – appearance 22 days after surgery showing problem-free healing.
avoiding possible complications, such as bone and muscle atrophy, by allowing early return to function of the extremity. Also easy application of the fixator, its low cost and re-useability are other significant advantages (Carnmicheal, 1991; Aron et al., 1995).

It was not a problem during the healing process that the bone fragments could not be aligned as well as with internal fixation. This result is clear proof that, when anatomical alignment is achieved healing can take place in a short time without the need for perfect positioning of the fragments.

External fixators can be removed after a postoperative period of approximately 3–5 weeks, when the callus tissue has reached the point where it prevents rotation of the bone fragments. However, in intramedullary fixation the pins are removed only after bone healing is completed. In a case to which external fixation had been applied to the radius and an intramedullary pin to the ulna, although sufficient callus formation was observed in the radiographs taken 24 days after fixation, union was not yet complete in the ulna. This is a clear example of early healing in closed treatment with external fixation.

While it had been reported (Johnson et al., 1989; Harari et al., 1996) that fractures treated with external fixators heal with endostral callus rather than periostal callus, in the fractures that were fixed using closed and limited open approaches, healing was observed to take place with the formation of a large callus (both periostal and endostal callus formation) (Figures 1 and 2).

In one clinical study (Aron et al., 1986), it was reported that fixation done using smooth pins only provided a trouble-free fixation for 2.2 months, that this period was 4.3 months for fixation done using smooth and threaded pins together and 4.8 months for fixation with threaded pins alone. However, in this study where only smooth pins were used, the pins were seen not to provide stability for more than 40 days and that pin loosening occurred especially in areas with a thick muscle layer.

Using the drill at high speed during the insertion of pins produces heat related necrosis in the bone and this in turn causes pin loosening and failure in fixation. To avoid this, the process of pin inserting should be done at low speed. A manual drill may be preferred but the oscillation produced is another cause of pin loosening (Anderson et al., 1996; McLaughlin and Roush, 1999). In 2 cases which showed pin loosening and 3 cases in which pin-base infection had developed, the fact that these complications occurred in the pins placed in the proximal fragments suggests that this may be a result of the area being covered with a thick muscle layer.

In one of the cases with an open fracture, although infection was treated, non-union was present, of which the reason was excessive loss of bone. Treating infection is one of the fields of use of external fixation (Harari, 1992; Lewis et al., 2001).

In this study, in which 2 different types of clamps and external fixators were used with a closed or limited open approach, very short healing period, sufficient stability, early return to function in the extremity, easy application and low cost conclude that external fixation with closed or limited open application should be preferred in appropriate cases.

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