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Evaluation of aluminium based circular external skeletal fixator for long bone fracture fixation in dogs

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The present study was conducted on nine clinical cases of radius-ulna (n=3) or tibial (n=6) fractures (either closed or open) in dogs of either sex, weighing 5-21 kg. The fracture was reduced and stabilized by transfixation of pins using aluminium based ring fixator. The main component of fixator, the aluminium rings, was designed locally using 4 mm aluminium sheets. The complete assembly was prepared with aluminium rings (n=2/3) weighing 21.22g each, 4.5 mm diameter with standard 75 mm length iron based connecting rods (n=4) weighing 7.56 g each and stainless-steel transcortical pins (n=4/6). Specialised wire fixation bolt (iron based, weighing 5.5 g) was designed for pin-ring articulation. The parameters studied during the postoperative period were weight bearing on the operated limb, stability of the assembly, pin tract discharge, pin loosening, bending/breakage of any fixator component, infection/osteolysis and radiographic healing. Based on the results, it was concluded that aluminium based circular ESF was a feasible and cost-effective technique, and was well tolerated by dogs leading to complete fracture healing.

Key words: *Aluminium rings, Circular External Skeletal Fixator, Circular rings, Dog, Fracture fixation, Radius-Ulna, Tibia*

External skeletal fixation (ESF) is a most versatile, affordable and acceptable technique in veterinary orthopaedics especially for management of comminuted, open or infected fractures (Egger *et al*., 1998), and can be used with variety of configurations (Beever *et al*., 2018). Circular external skeletal fixation (CEF) system can be used successfully in the management of severely comminuted fractures, non-union, open fractures, osteomyelitis, limb lengthening and it is the choice of technique for correction of angular deformities (Feretti *et al*., 1987).

Radius-ulna and tibia bones possess less surrounding soft tissues as compared to other long bones in dogs and for this reason these bones suffer more with traumatic injuries and clinically presented as open fracture (Rudd and Whitehair, 1992; Boone, 1996). In open fractures, internal fixation technique or any metal implant at the fracture site should be avoided. Linear ESF frames are simpler to use than circular (Marcellin-Little, 1999), but CEF systems have biomechanical advantage over linear systems (Jiménez-Heras *et al*., 2014). The present study was undertaken to evaluate CEF system developed locally using aluminium rings for treatment of closed and open radial or tibial fractures in dogs.

Materials and Methods

Nine dogs of different age, breed and sex referred for treatment of radial/tibial fracture were used in this study. All the dogs were evaluated clinically and radiographically (orthogonal views) to ascertain the type and location of fracture. Clinical signs like non-weight bearing on the affected limb, soft tissue swelling, pain and crepitus on palpation at the site of fracture were observed in all the cases, with no neurological deficit in any case. All the animals were examined and safe corridors were determined for pin placement (Marti and Miller, 1994a & b; Bilgili *et al*., 2007).

The animals were secured in lateral recumbency with medial or lateral surface facing towards the surgeon as per suitability and zone of comfort for surgical approach. The fractured bone along with the surrounding joints was shaved and prepared for aseptic surgery. The dogs were premedicated with atropine (0.04 mg/kg body wt) and xylazine (1 mg/kg body wt) administered intramuscularly. General anaesthesia was induced with a mixture of ketamine HCl (5 mg/kg) and diazepam (0.5 mg/kg) injected intravenously and was maintained on isoflurane in 100% oxygen.

The fixator assembly was composed of aluminium rings, and threaded connecting rods, nuts and fixation bolts made of iron. In seven cases, 80 mm (inner diameter) rings and in two cases, 50 mm rings were used. The threaded connecting rods were 4.5 mm in diameter. The spanner size was selected according to size of nuts and bolts. Transcortical pins (1.5, 2.0, 2.5 or 3 mm) were used and drilled into the bone through a high torque and low rpm electric drill. The limb was positioned at the centre of the ring. In four cases, the frame was assembled during surgery, whereas in five cases the frame was preassembled based on preoperative radiographs. For the application of the fixator, following steps were followed. First, the transcortical pins were drilled perpendicular to the bone (cross pins - mediolateral), in the same plane in proximal and distal fracture fragments, followed by fixation of proximal and distal rings by tightening the fixation bolts. Subsequently

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divergent pins were passed and tightened completely. Tensioning of pins was not done in the present study because of the use of relatively large diameter transcortical pins. Usually K-wires up to 1.5 mm used in CEF constructs can be tensioned easily and effectively to increase the fixation strength.

Position of CEF construct, reduction and alignment of bone fragments, and bone healing were evaluated through postoperative radiography. The pin-skin interfaces and the surgical wound were cleaned with 5% povidone iodine and bandage applied. Postoperatively, either ceftriaxone (15-30 mg/kg body wt, i.m.) or cefpodoximeproxetil (5-10 mg/kg body wt, orally) were used b.i.d for 5-10 days and meloxicam (0.2-0.5 mg/kg body wt, i.m.) administered o.d. for 3 days. Calcium-phosphorus and multi-vitamin preparation was administered orally during the postoperative period. The skin sutures were removed after 10-15 days of surgical fixation.

The animal owners were advised to restrict the movement or walking of dogs for 2-3 weeks, and afterwards passive exercise on joints and massage from top to bottom along the fractured bone for 5 min twice a day were recommended. The fixator assembly was covered with a bandage to prevent the invasion of dust and direct contact with external environment. Lameness grading was done (up to 6th postoperative week) as described by Larin *et al.* (2001) with slight modifications.

Once the fracture healing was evident on radiographic examination (bridging callus), and clinical improvement of limb function, the fixator assembly was removed under xylazine sedation by cutting the transfixation pins at one side using a pin cutter and pulling the pin using a plier after cleaning the cut ends. The fixator was also removed in case of fixator instability due to loosening of pins or injury to the skin and soft tissues due to the fixator assembly. After removal of the fixator assembly, the pin tracts were cleaned and flushed using sterile saline solution containing povidone-iodine, and bandage applied.

Results and Discussion

In the present study, three cases of radius-ulna fractures and six cases of tibial fractures were treated with CEF system (Table 1 and 2). The mean diameter of transcortical pins used in the proximal fragments was 2.54±0.09 mm (range 2-3 mm), while the mean diameter of pins applied in the distal fragments was 2.44±0.10 mm (range 2-3 mm). Pin size is one of the factors influencing the strength and stiffness of the fixator and its ability to resist the axial loading, bending and rotation associated with the weight bearing of the animal (Fossum, 2019). Fragomen *et al.* (2007) stated that the fixator stability increases with increasing the pin diameter and increasing tension placed across the pin. Frame stability can also be enhanced by using more pins per ring, placing pins

Table 1: Detailed history and clinical findings in different cases

Case No.	Age (months)	Sex	Body weight (kg)	Breed	Aetiology of fracture	Limb involved	Bone affected	Open or closed	Fracture location	Fracture type	Fixation method
C1	12	M	11.2	Non-descript	Automobile accident	RF	Radius-ulna	Open	Proximal 1/3rd	Slight-oblique	Open
C2	24	F	14.5	Non-descript	Automobile accident	LF	Radius-ulna	Open	Distal 1/3rd	Slight-oblique	Open
C3	3	M	5.3	Non-descript	Automobile accident	RF	Radius-ulna	Closed	Distal 1/3rd	Transverse	Closed
C4	4	F	8	Non-descript	Automobile accident	LH	Tibia	Closed	Proximal 1/3rd	Comminuted	Closed
C5	18	M	17	Non-descript	Automobile accident	RH	Tibia	Closed	Mid-shaft	Comminuted	Closed
C6	8	F	7	Non-descript	Automobile accident	LH	Tibia	Open	Distal 1/3rd	Transverse	Open
C7	4	M	5	Non-descript	Automobile accident	RH	Tibia	Closed	Proximal 1/3rd	Slight-oblique	Open
C8	42	M	21	Pit-Bull	Fall	RH	Tibia	Open	Mid-shaft	Slight-oblique	Open
C9	2	M	2.8	Non-descript	Dog-Fight	RH	Tibia	Closed	Distal 1/3rd	Comminuted	Open
Mean ±SE	13± 4.40	Male: 6	10.2 ±2.05	ND: 8Other: 1	Automobile accidents: 7 Other: 2	RF:2 LF:1 RH:4 LH:2	Radius-ulna:3 Tibia: 6	Open: 4 Closed: 5	Proximal 1/3rd :3 Mid-shaft:2 Distal 1/3rd:4	Slight-Female: 3 oblique: 4 Transverse: 2 Comminuted: 3	Open:6 Closed:3

Table 2: The procedure, apparatus configuration, limb status, fixator removal time, complications and functional outcome in cases treated with CEF.

Case No.	Procedure	Apparatus configuration	Limb status (first use of limb/ weight bearing/)	Removal of implant (in days)	Complications	Functional outcomes
Case 1	Open fracture, open reduction	One 80-mm ring in proximal and one ring in distal fragment. Two 3-mm smooth pins in proximal ring and two end threaded half pins of 2.5 mm in distal fragment.	Day 1	23 days	One ancillary pin in distal fragment loosened on day 5	Excellent
Case 2	Open fracture, open reduction	One 80-mm ring in proximal and one ring in distal fragment. Two 2-mm pins each in proximal and distal rings.	Day 1	22 days	Osteomyeilitis, pin tract infection	Good
Case 3	Simple fracture, closed reduction	Two 50-mm rings, one each in proximal and distal fragment. Total of 4 smooth pins, 2 in each fragment.	Day 1	40 days	Minor pin tract infection	Excellent
Case 4	Simple fracture, closed reduction	Two 80-mm rings, one each in proximal and distal fragment. Total of 4 smooth pins of 2 mm diameter, 2 in each ring.	Day 1	55 days	Minor pin tract infection	Excellent
Case 5	Simple fracture, closed reduction	Three 80-mm rings, 2 rings in proximal and one ring in distal fragment. Total 6 smooth pins (3 mm), 4 in proximal and 2 in distal fragment.	Day 15	63 days	Minor pin tract infection	Excellent
Case 6	Open fracture, open reduction	Two 80-mm rings one in proximal and one in distal fragment. Two pins (2 mm) in proximal fragment and two in distal fragment.	Day 18	59 days	Minor pin tract infection	Good
Case 7	Open fracture, open reduction	Two 80-mm rings, one each in proximal and distal fragment. Two pins (2 mm) each in proximal and distal fragment.	Day 7	38 days	Minor pin tract infection	Excellent
Case 8	Open fracture, open reduction	Three 80-mm rings, 2 in proximal and one in distal fragment. Four pins (3 mm) in proximal fragment and 2 pins in distal fragment.	Day 1	123 days	Delayed union	Fair
Case 9	Closed fracture, open reduction	Two 50-mm rings, one each in proximal and distal fragment. Two pins (2 mm) in proximal fragment and 2 pins in distal fragment.	Day 15	40 days	Dragging of limb, minor pin tract infection	Good

on opposite sides of ring, securing pins directly to the ring, and by inserting pins in different planes. Krischner pins of 1.5-2.0 mm diameter have been used by Bilgili *et al.* (2007) for CEF in tibia and radius-ulna in dogs weighing 10-55 kg. In a retrospective study, Cappellari *et al.* (2019) recommended the use of pins having approximately 25% of the diameter of the bone segment for treatment of antebrachial and crural septic non-union fractures in dogs using CEF. Some researchers have recommended using pins of a maximum of 20% of the size of bone diameter (Egger, 1991; Aron and Dewey, 1992; Palmer *et al.*, 1992; Harari *et al.*, 1996).

In the present study in all the cases mostly smooth transcortical pins (n=40) were used except for one end-threaded pin (Schanz pin). Pin design is an important parameter affecting the stability of bone fixation (Anderson *et al.*, 1997). The number and size of pins placed per segment should be selected based on the support required, including the load-sharing capability of the bone, the dimensions of each segment, and the weight of the animals (Rovesti, 2016). In most of the frames in this study (n=7), CEF was constructed as 2-ring construct (1:1) and were found providing good stability till bone healing and fixator removal. Only in 2 cases (case 5 and 8) CEF was constructed using 3 rings, 2 rings in the proximal fragment and one in the distal fragment. Bilgili *et al.* (2007) used 2 complete circular rings and 1 partial ring for 3-ring construct in their study and found good stability. In another study of 6 cases, the fractures were stabilised with two full and one partial (5/8th) ring construct (Dwivedi *et al.*, 2009).

The mean distance between the skin and inner margins of rings in the present study was 23.19±3.04 mm. Marcellin-Little (1999) and Dwivedi *et al.* (2009) recommended a minimum of 10 mm distance between the skin and inner margins of rings for better stabilization. But in the present study slightly increased gap was kept to prevent ring-skin friction trauma, and observed good fixation stability without any complication. In a study of biomechanics of Ilizarov system (Calhoun *et al.*, 1991), researchers have found that compression stiffness increased by increasing bone compression, which was accomplished clinically through decreasing the distance between the rings. In this study, one case (C8) of tibial fracture was stabilised using 3-ring construct and in that the distance between the adjacent rings from the fracture site was more as compared to others, probably causing instability and delayed union (16th week).

In the present study, aluminium alloy was used to construct the circular rings. Similarly, Dwivedi *et al.* (2009) have used aluminium circular rings for management of compound radius-ulna and tibia fractures in dogs. Bilgili *et al*. (2007) have also used circular rings composed of ETAL-74 (94.5% aluminium, 1.5% magnesium, 4.5% copper) for the fixation of tibia and radius-ulna fractures in dogs.

In this study, total of 5 cases (compound fracture-4; simple fracture- 1) were treated by open method of fracture reduction and fixation, and rest 3 cases by closed method. The wound at the fracture site healed gradually with complete healing by 2-3 weeks post-fixation. Most of the dogs seemed to tolerate the fixator well and started bearing weight from the very next day of surgical fixation.

In all the dogs, partial weight bearing was recorded within 1-18 days, with the mean period of 6.67±2.43 days. The early weight bearing avoids complications like muscle atrophy. The major purpose of any fracture treatment is to obtain the quickest possible recovery and early functional limb use (Egger, 1992). Early limb use promotes fracture healing by allowing axial micromotion at the fracture site and also prevents muscle atrophy in patients with bone fractures (Lincolan, 1992; Radke *et al.*, 2006; Yardimci *et al.*, 2018). The weight bearing improved gradually and progressively, and by 6th week, 88.88% cases were showing good to excellent weight bearing on the operated limb. Dwivedi *et al.* (2009) have reported that from 3rd postoperative week onwards the dogs started bearing weight on the operated leg with minimal limping, and during the 8th week the dogs were able to bear full weight on the treated limbs.

Radiographic evaluation in the immediate postoperative period can help in studying the bone fragment apposition, alignment, angulation and positioning of the apparatus (Langley-Hobbs, 2003). In the present study, immediate postoperative radiographs revealed complete reduction with appropriate alignment of fractured fragments in 8 cases. However, many fractures were reduced with less than anatomical results, probably due to the severity of fracture and closed reduction of fracture (Johnson *et al.*, 1989; Rovesti, 2016). The fixator construct was maintained in position throughout the healing period in 4/9 cases. In the proximal fragment, all pins got loosened in 2 cases, loosening of one pin was seen in one case by 9-28 days. In the distal fragment, all the pins got loosened in one case only by 22-36 days. In one case, complete failure of ESF assembly was reported during the late postoperative period, but it did not interfere with the position of transcortical pins.

Fracture healing was assessed up to 8th week and graded 1 to 5 according to Hammer *et al.* (1985). The mean radiographic healing grades of all the 9 cases at 2nd, 4th, 6th and 8th week intervals were 3.66±0.33, 2.78±0.36, 2.22±0.36 and 1.78±0.36, respectively (Figs 1 and 2).

In the present study, pin tract infection was recorded (6/9 cases) more in later postoperative period (Fig. 3). Pin tract sepsis is caused by necrosis and infection of soft and osseous tissue around the pin.

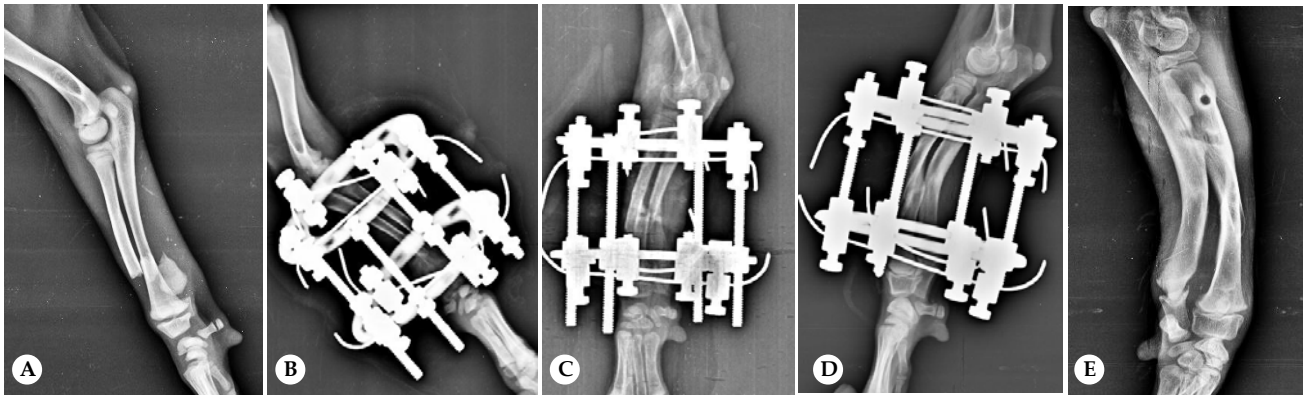

Fig. 1: Sequential radiographic evaluation in case No. 3; A-preoperative radiograph showing distal third radius-ulna fracture, B- radiograph made soon after fixation shows good reduction and alignment of bone fragments, C-2nd postoperative week radiograph shows initial signs of healing at the fracture site, D-4th postoperative week shows good healing between the fracture ends, and E-6th week after removal of fixator shows complete bone union with remodelling.

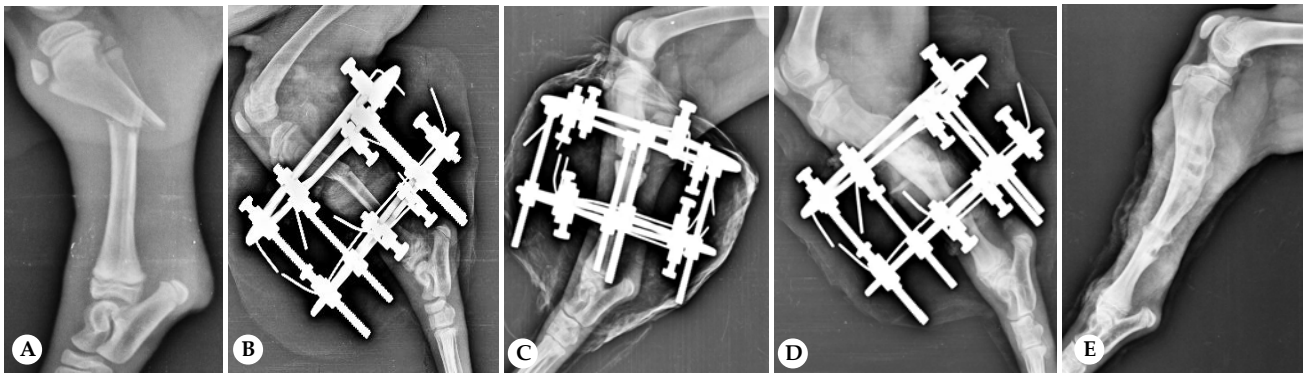

Fig. 2: Sequential radiography in case No. 7; A- preoperative radiograph showing oblique fracture at proximal diaphysis of tibia-fibula, B- radiograph made soon after fixation shows fracture reduction with slight malalignment, C- 2nd postoperative week radiograph shows callus reaction at the fracture site, D- 4th postoperative week complete radiographic union is seen at fracture site, and E- at 6th week, after removal of fixator, radiograph shows complete bone healing with slight malunion.

Fig. 3: Complications: A- fixator instability; B- pin tract sepsis.

Excessive pin motion directly contributes to the infection. It is characterised by persistent and excessive purulent drainage associated with soft tissue inflammation and patient discomfort. Pin tract infection can be minimized by reducing skin tension around the pin, avoiding the thermal necrosis of bone during pin insertion, and limiting pin-bone and pin-skin motions (Johnson *et al.*, 1989; Harari, 1992; Piermattei *et al.*, 2006; Rovesti, 2016). In one case of the present study, signs of osteomyelitis were noted radiographically. Clinically the limb was graded with good weight bearing score while radiographically the fracture healing was graded fair up to 10th postoperative week. Johnson *et al.* (1989) reported radiographic signs of osteomyelitis in 12 bones among the 28 cases of radial or tibial fractures treated by the use of linear ESF. As the radiographic signs of osteomyelitis resolved in all the dogs without the use of antibiotics, it was hypothesized that the responses noted radiographically may have resulted from stimulation other than bacterial infection. To reduce the risk of osteomyelitis with ESF immobilization, it has been advised that the animal be kept in a clean environment, the fixator be protected with a sleeve of fabric to avoid external contamination and signs of swelling and redness be effectively treated. In the present study also, till the implant removal, the fixator construct was kept protected from external environment by bandaging around the whole fixator assembly.

In one case (Case 8) having open fracture of tibia, delayed bone healing was observed (12 weeks). In that particular case, fracture reduction was not optimum with a large gap evident in the immediate postoperative radiograph. Yardimci *et al.* (2018) in their study using semicircular ESF and IM pin tie-in combination, reported delayed union in a case of humeral fracture due to a large fracture gap. Osteomyelitis (Case 2), delayed union (Case 8), dragging of limb (Case 9) and pin tract infection (most of the cases) were observed as postoperative complications (Table 2). In one case (Case 6) spontaneous dismantling of CESF construct was reported and it might be due to hyper-activity of the dog. During the fracture healing period, limb shortening (Case 6) and angular deformity (Case 7 and 9) were noted in one and two cases, respectively. Johnson *et al.* (1989) repaired radial and tibial fractures in 28 dogs using ESF and have noted valgus or rotational malalignment in 16 cases. Although angular deformity was evident in some cases, it did not seem to affect the limb function. The fixator assembly was removed between 22 and 123 days (average 51.44 days) after the surgical fixation. During the long term follow-up, the limb function was found excellent, good, fair and poor in 50%; 25%; 12.5% and 12.5% cases, respectively.

To conclude, aluminium based circular ESF is a feasible, light weight and cost-effective technique, which is readily tolerated by dogs, hence can be an option to treat certain fractures which may be difficult to treat by other conventional methods.

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OBITUARY

Dr Harpal Singh, Professor Surgery and former Dean College of Veterinary and Animal Sciences, GBPUAT Pantnagar left for heavenly abode on June 17, 2024. Born in Muzaffarnagar, U.P. on 15 July 1942, Dr Harpal Singh was educated at DAV Collge, Muzaffarnagar, 1956-60; GBPUAT, 1960-66; University of Illinois, USA, 1968-71. He did B.Sc. in 1960; B.V.Sc. & A.H. in 1964; M.V.Sc. in 1966; Ph.D. in 1971; and obtained Diploma in French Language in 1982.

He started his career as Assistant Professor in Veterinary Surgery at College of Veterinary Sciences, GBPUAT, Pantnagar and served till 2003 in various teaching and Administrative positions viz: Associate Professor, Professor Veterinary Surgery; and Head, Department of Surgery, Director, Training and Placement,, Dean, College of Post Graduate Studies, Dean, College of Veterinary Sciences, Dean, College of Fishery Science, and Director, Administration and Monitoring, GBPUAT, Pantnagar.

He also served as visiting professor of Veterinary Surgery & Radiology, at University of Constantine, Algeria, and Professor Surgery, Hawassa University, Ethiopia.

Dr Singh was the recipient of numerous awards and Honours from National and International organizations. He was President, Indian Society for Veterinary Surgery, and Indian Society of Veterinary Educators. He was Fellow of National Academy of Agricultural Sciences, National Academy of Veterinary Sciences; Indian Society for Veterinary Surgery and Association for Advancement of Veterinary Research. He was chairman/member of many National level councils, boards and committees.

Dr Harpal Singh is survived by his wife, son and daughter. Both Son and Daughter are well settled.

Indian Society for Veterinary Surgery pray Almighty to grant eternal peace to the departed noble soul.