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Long bone fracture management using epoxy-pin as external skeletal fixator in 12 dogs

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Abstract
The study was conducted for management of long bone fracture using epoxy-pin as external skeletal fixator in 12 dogs. Physical examination and Radiography aided in diagnosis. In all the cases, the fracture was stabilized by application of free-form external skeletal fixation using epoxy connecting bars under general anaesthesia. Fixation wires in the same plane were bent and joined using adhesive tape and connecting bars were constructed using additional wires scaffolds. Thoroughly mixed epoxy putty was applied over the scaffold to create permanent connecting bars and rings. All the animals were evaluated clinically and radiographically at regular time intervals until healing. Haematological parameters were within normal range in all the dogs. Significant increase in serum calcium level; whereas non-significant increase in serum alkaline phosphatase values were observed during post-operative period. The construct involving fixation pins and sidebars remained stable throughout the study period. Breakage, bending or loosening of the pins in the fixators was not observed in any animal except for one. Gait analysis revealed higher standing gait scores than walking and running throughout the period of study significantly.

Keywords: Dog, epoxy-pin fixation, external skeletal fixation, fracture, long bone

1. Introduction
External Skeletal Fixation (ESF) is a means of stabilizing fractures or joint using percutaneous pins that penetrate the bone cortices internally and are connected together externally to form a rigid frame (Van and Geasling, 1992; Piermattei *et al.*, 2006) [25, 19]. External skeletal fixators of various designs and types have been used for fracture treatment. They can be divided into fixed form and free form of ESF. In fix form they can be of linear, circular and hybrid designs. The components of the external skeletal fixators were made of a metal, most commonly stainless steel also from aluminum and carbon fibers. The major disadvantage associated with ESF made of metal is their high cost, heavy weight and in addition their fixed frames which offer less versatility in shape and direction comparatively (Lewis *et al.*, 2001) [10]. Free-form external skeletal fixators have advantages of being light in weight, less expensive and the pin/wire direction need not be influenced by the direction and location of the connecting bar/ring. (Okrasinski *et al.*, 1991) [15]. Roe and Keo (1997) [20] suggested that epoxy putty can be a suitable material for connecting pins in free form external skeletal fixators. It is easy to handle, inexpensive and has suitable setting times and mechanical properties. More recently, epoxy pin fixator constructs have been used successfully for treatment of compound fractures in both dogs and small ruminants (Kumar, 2007; Aithal *et al.*, 2009, Aithal *et al.*, 2019) [8, 1, 2]. In the present study management of long bone fractures in dog by free-form external skeletal fixation using epoxy connecting bars was discussed.

2. Materials and Methods
The present study was carried out in 12 dogs with radius-ulna or tibia-fibula fractures. History regarding the age, breed, sex and body weight of the animal, cause of the fracture, duration and primary treatment given; if any. All the dogs were examined to rule out the degree of lameness, bone/s involved in fracture, location of the fracture and condition of the wound; if any. Orthogonal radiographs were taken pre-operatively to confirm the type and location of the fracture.
The blood samples was collected pre-operatively and thereafter, on 12th and 30th days, post-operatively for haematological and biochemical examination in all the animals. Hematological parameters viz.; haemoglobin (g %), packed cell volume (%), total leukocyte count (10^3/cu mm) and differential leukocyte count (%) were analysed using hematology auto analyzer.

Serum biochemical parameters viz.; alkaline phosphatase (ALP) and serum calcium were estimated using serum biochemical analyzer.

2.1 Fracture Management

2.1.1 Patient preparation and anaesthesia

Overnight fasting was allowed in all the animals prior to surgery. The whole length of the bone was prepared for aseptic surgery. Fracture reduction and fixation was performed under general anaesthesia using atropine sulphate @ 0.04 mg/kg IM, butorphanol @ 0.2 mg/kg IM, diazepam @ 0.5 mg/kg IV as pre-anaesthetics, 2.5 % thiopentone sodium @ 5 mg/kg IV as induction agent and maintained on isoflurane @ 1.5-2.0%.

2.1.2 Surgical technique

After restraining the animal in lateral recumbency with affected limb on upper side, the surgical site was scrubbed with 7.5% povidone iodine solution. Fracture reduction was achieved either by closed or semi-open method. Subsequently, by keeping the bone fragments in alignment, the K-wires (1.5 mm) were introduced perpendicular to the long axis of the bone, from caudo-medial to cranio-lateral and craniomedial to caudo-lateral directions using a low speed electric drill avoiding the major vessels, nerves and muscular attachments. To reduce the possibilities of thermal necrosis, pouring of cold normal saline solution was continued throughout the bone drilling. The K-wires were first inserted close to fracture site into the smaller fragment followed by larger fragment and subsequently the procedure was repeated excentrically in both the segments. The K-wires were crossed with each other at an angle of 70^{o} to 90^{o} in a way that they did not interfere with each other in the medullary cavity. In the cases of distal radius-ulna fracture, inspite of placing k-wires in the lower segment one additional k-wire (1.2 mm) was also inserted in the metacarpals in mediolateral direction for trans-articular fixation.

Finally, the K-wires in the same plane were bent 2 cm away from the skin towards the facture site. Then the side bars for both proximal and distal sites were prepared by using an additional K-wires. The bent K-wires along with side bars were then joined with the help of adhesive tape or fish net thread to form a temporary scaffold. The epoxy putty was prepared by mixing the epoxy hardener and resin for 2 minutes and then evenly applied it over the temporary scaffold and the side bars. The epoxy fixator so formed was then allowed to harden for a period of 20 minutes.

Fig 1-4: Technique of epoxy-pin external skeletal fixation

2.1.3 Intra-operative observations

Intra-operatively, the total number of K-wires used for the fixation and time taken for fixator application were recorded. Complications if any, were also observed during the application of fixator.

2.1.4 Post-operative care and management

Post-operatively, enrofloxacin @ 5 mg/kg and meloxicam @ 0.2 mg/kg were given orally for 5 days besides administration of Vitamin D3 @ 20,000 IU, intramuscularly once in a week for 4 weeks along with oral administration of calcium. Regular cleaning and dressing of the surgical wounds was performed with 5% povidone iodine solution till the removal of fixators.

Orthogonal radiographs were taken immediately after application of fixator to determine the level of fracture reduction and the placement of K-wires and also on 12th, 30th and/or 45th days, post-operatively to evaluate the fracture healing, status of fixation, fixator and complications; if any.

Gait of the animals was evaluated on the day of presentation and thereafter on 12th, 30th and/or 45th days, post-operatively. Scores were given for standing, walking and running. Weight bearing (WB) on the affected limb was graded as: 1= No weight bearing, 2= Slight weight bearing, 3= Moderate weight bearing, 4= Full weight bearing.

The status of the fixation device for bending/breaking/loosening of connecting bars and/or K-wires etc. was evaluated until its removal.

The fixator was removed by cutting the K-wires with a pin cutter on radiographic conformation of fracture healing. The cut wires were then pulled out and the wire tracts were cleaned and flushed with povidone iodine. Oral administration of meloxicam @ 0.2 mg/kg body weight and daily dressing of wire tracts was advised for 5 days after fixator removal.

2.1.5 Statistical analysis

Analysis of variance (ANOVA) and Duncan Multiple New Range Test (DNMRT) were used to compare the means at different intervals. The analysis was performed using SPSS 20.0.

3. Results and Discussion

Epoxy pin was used as external skeletal fixator in 12 animals presented with radius-ulna and tibia-fibula fractures. Most dogs (06) were aged between 6 months to 1 year. There were 09 non-descript dogs, 01 Labrador Retriever, 01 Doberman

Pinscher and 01 German Shepherd. males (08) were more affected than females (04). The most common causes of fracture were automobile accidents (09) followed by entanglement in objects (02) and dog fighting (01). Body weight of the dogs suffered with fracture ranged from 4.5 to 24.5 kg with a mean weight of 12.18 ± 0.58 kg. The duration of occurrence of fracture and presentation to clinic was 1-7 days.

Tibia-fibula fractures were more (08) as compared to radius-ulna (04) fractures whereas; the equal number of cases were observed in right and left fore (02) and hind limbs (04). All the cases were of close fractures. Most fractures were complete transverse (07) followed by complete oblique (03) and the overriding and multiple fractures (01). Location wise proximal one third (05) portion of the bone was more commonly fractured than the midshaft (04) and distal third (03) parts.

Immediate post-operative radiographs revealed satisfactory fracture reduction in all the cases except in one case of overriding fracture. Anterio-posterior radiographs revealed clear view of the fracture fragments as compared to lateral view in the present study. Basith (2015) [4] concluded that post-operative radiographs could be taken only in the anterio-posterior view as the epoxy connecting bar obscured the bone due to its superimposition in the lateral view. Immediate post-operative radiograph revealed good alignment of the fracture fragments with proper placement of fixator pins in all the cases except in one case where fracture was not properly reduced. Radiographic healing was evident on 30th and 45th post-operative days in eight and four cases respectively in the present study. Johnson *et al.* (1996) [6] reported 11.4 weeks mean time for bone union or bridging of comminuted fractures with callus treated by using external fixation. Julie (2005) [7] found that fracture gap was progressively filled up with callus from day seven to 45th day post-operative in all the dogs. Kumar *et al.* (2012) [9] reported that within a period of 30-45 days radiographic healing was evident in twenty three cases with delayed healing in seven dogs and malunion in one case. Bending of the pins/fixator or any other complication were not observed on radiography in any of the case.

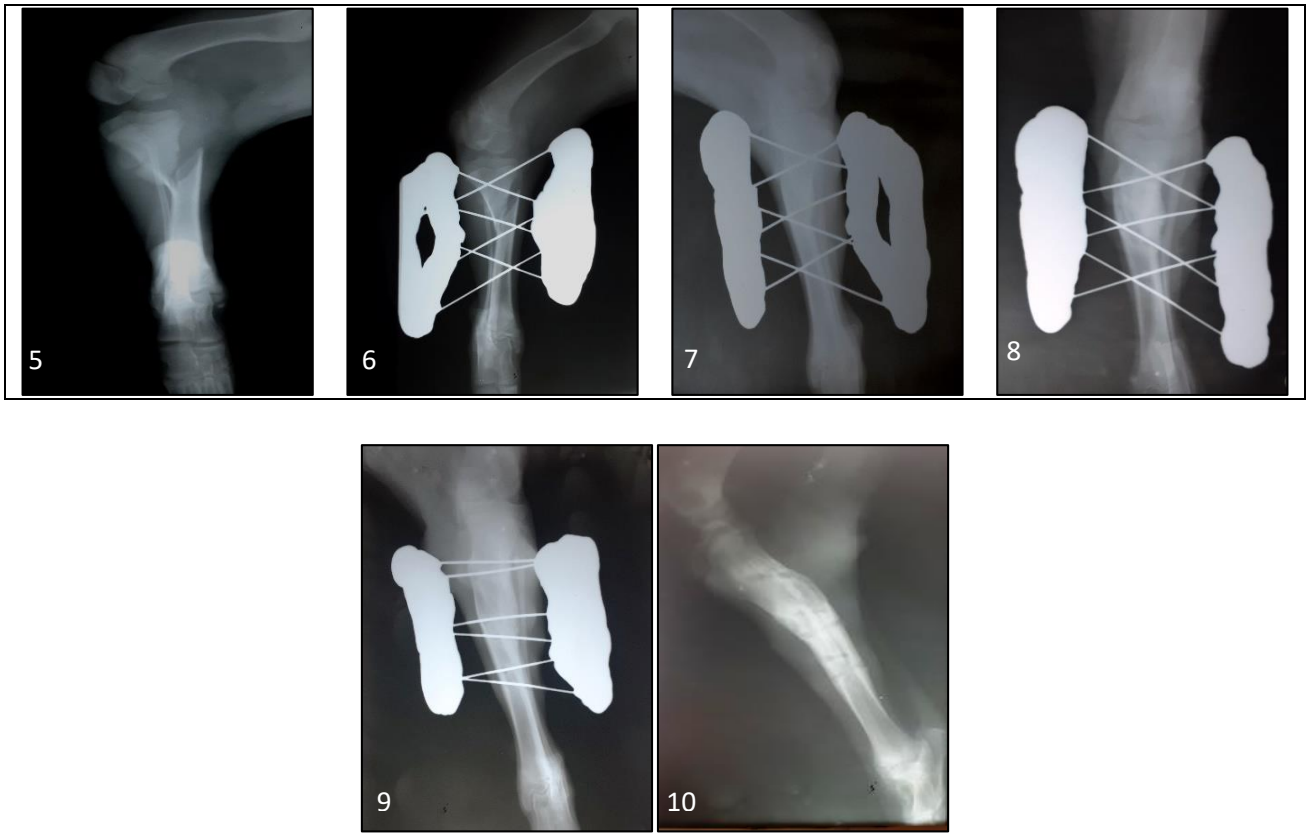

Fig 5-10: Radiographic evaluation of radius-ulna fracture treated with epoxy external skeletal fixation in a dog

Haematological parameters revealed a non-significant difference in haemoglobin, packed cell volume, total erythrocytes count, total leukocytes count and differential leucocytes count at different time intervals in all dogs. Significant increase in the mean value of serum calcium on 12th and 30th post-operative day in comparison to day of operation was recorded. Chandy *et al.* (2000) [5] and Pardeshi (2007) [17] reported non-significant post-operative variation in serum calcium levels in dogs stabilized with external skeletal fixation for tibial fractures. Non-significant increase in serum alkaline phosphatase values was observed on day of surgery, which further kept on increasing significantly till day 30. Alkaline phosphatase (ALP) is one of the markers of new bone formation. Increased ALP level is associated with either skeletal or hepatobiliary diseases (Leroux and Perry, 1972) [26]. Similar findings were also reported by Mahendra *et al.*, (2007) [11]; Singh *et al.*, (2008) [23] and Patil (2017) [18].

Table 1: Mean ± SE values of haematological parameters

Sr. No.	Parameter	Pre-operative day			12th Post-operative day			30th Post-operative day			'P' value
1	Haemoglobin (g %)	9.49	±	0.17	9.80	±	0.25	11.00	±	0.24	0.168
2	Packed cell volume (%)	28.47	±	0.5	29.73	±	0.79	32.94	±	0.72	0.185
3	Total leucocyte count (10^3/cu mm)	20.05	±	5.07	17.73	±	5.19	18.44	±	7.20	0.578
4	Neutrophils (%)	69.17	±	1.20	66.33	±	0.76	67.92	±	1.07	0.803
5	Lymphocytes (%)	23.99	±	1.17	30.6	±	1.39	32.17	±	1.74	0.252
6	Monocytes (%)	4.00	±	0.15	5.25	±	0.23	4.75	±	0.26	0.483
7	Eosinophils (%)	3.25	±	0.22	2.67	±	0.17	2.08	±	0.13	0.182
8	Basophils (%)	0.00	±	0.00	0.00	±	0.00	0.00	±	0.00	-

Non-Significant ($p \geq 0.05$).

Table 2: Mean ± SE values of serum biochemical parameters

Sr. No.	Parameter	Pre-operative day			12th Post-operative day			30th Post-operative day			'P' value
1	Serum calcium (mg/dl)	9.01	±	0.14^{b}	10.42	±	0.18^{ab}	11.07	±	0.22^{a}	0.025
2	Alkaline phosphatase (IU/L)	360.50	±	19.79^{a}	390.42	±	18.53^{a}	497.17	±	20.33^{a}	0.185

Means bearing same subscripts differ non-significantly ($p>0.05$).
Means bearing different subscripts differ significantly ($p \leq 0.05$).

Patient preparation and the used anaesthetic protocol were found satisfactory in all the cases. Fracture reduction was satisfactory in all the cases except in one case of overriding fracture. Closed or semi-open technique used for fracture reduction limits soft tissue trauma, preserve vascular supply and adjacent supportive tissue (Ozsoy and Altunatamaz, 2003) [16]. The 1.5 mm diameter K-wires inserted in caudo-medial to cranio-lateral and cranio-medial to caudo-lateral directions at 70° - 90° angle served satisfactorily for fixator preparation in the present study. Insertion of the mm K-wire (1.2) in the metacarpal bone in mediolateral direction was without causing any iatrogenic fracture and provided additional support to the fixator in cases of distal radius-ulna fractures. Additional placement of pins in proximal and distal portion provided additional stability to scaffold. No thermal necrosis or bone sequestration was observed in any of the case. The size of the fixation pins used in external skeletal fixation depends on the type of fixator and the size of the bone fixed and the patient (Marcellin-Little, 1999) [12]. Surbhi (2011) [24], Kumar *et al.* (2012) [9]; and Basith (2015) [4] also reported that 1 to 1.8 mm K-wires were sufficient for epoxy skeletal fixator.

Lewis *et al.* (2001) [10] reported that gap of 10-20 mm kept between fixator side bars and skin was adequate to allow the expected soft tissue swellings, facilitate pin tract care and cleaning of the wound. In the present study, a gap of 2 cm was kept between the skin and epoxy putty and it served well in almost all the cases. Similar observation were also recorded by Surbhi (2011) [24].

The total number of K-wires used for the fixator application ranged between 6 to 9. Average time taken for application of epoxy fixator was 49.58 ± 0.60 minutes. Basith (2015) [4] reported that the time required for application of epoxy fixator was 55.49 ± 5.43 minutes in goat.

Cleaning and dressing of the entry and exit points of the pins on the skin with 5% povidone-iodine was found effective in keeping the sites clean and dry in all the dog. Complications such as pin loosening, pin tract infection, pin breakage, non-union or delayed union were frequently encountered in external fixation applications (Anderson *et al.*, 1993, Lewis *et al.*, 2001; Ozsoy and Altunatmaz 2003 and Ness, 2006) [3, 10, 16, 14]. However, in the present study no post-operative infection or inflammation was observed in any of the case. The use of Vitamin D_3 and calcium give an additional benefit of early fracture healing in dogs. Fischer *et al.* (2018) stated that calcium and vitamin D_3 play pivotal roles in bone remodeling and mineralization, which helps in early of healing of the fracture bone.

Gait analysis revealed higher standing gait scores than walking and running throughout the period of study. However, standing, walking and running gait scores significantly increased during post-operative days. The above findings are in correlation with the findings of Surbhi (2011) [24] and Shah (2017) [22]. This could be due to the fact that ground reaction force is the opposite force exerted on the limbs when it is on ground which positively correlate with velocity and negatively correlate with the stance time (Rousch and McLaughlin, 1994) [21].

Table 3: Mean ± SE values of gait analysis

Sr. No	Parameter	Pre-operative day	12th post-operative day	30th post-operative day	'P' value
1	Standing	1.25 ± 0.04^{b}	2.67 ± 0.06^{a}	3.08 ± 0.08^{a}	1.05
2	Walking	1.00 ± 0.00^{b}	2.42 ± 0.10^{a}	2.92 ± 0.10^{a}	1.8
3	Running	1.00 ± 0.00^{b}	2.58 ± 0.10^{a}	2.83 ± 0.11^{a}	6.06

Means bearing same subscripts differ non-significantly ($p \geq 0.05$).
Means bearing different subscripts differ significantly ($p<0.05$).

The fixation pins and side bars maintained their structures throughout the study period. Translocatory movement of fixator assembly observed on 30th post-operative day in three cases. Breakage, bending and/or loosening of the pins in the fixators was not observed in any of the case except in one case where breakage of 1st upper most pin was observed on 12th post-operative day in the present studies. Premature pin loosening has been reported as a major problem in some earlier ESF study (Ness, 2006) [14]. Kumar *et al.* (2012) [9] also reported proximal wire breakage in one case which might be due to misaligned fracture fragment during fixation. Further, they also observed the pin loosening in four dogs without affecting the stability of the fixator.

Post-operatively, wound was observed at medial side of upper most pin in one case. It was dressed regularly with povidone-iodine but did not respond to the treatment hence in that case fixator was removed on 30th post-operative day followed by regular antiseptic dressing. Subsequently the wound healed in ten days period after fixator removal. Surbhi (2011) [24] stated

that ESF using acrylic or epoxy not only provide stable fixation of bone fragments but also allow early soft tissue and wound healing. Kumar *et al.* (2012) [9] observed mild wire tract sepsis in 6 cases and moderate to severe infection in one case each. Mathai (2012) [13] reported a case of pressure wound by epoxy connecting bar during healing period, which subsequently healed after fixator removal. He also reported post-operative swellings for 3-5 days in all the cases treated by external skeletal fixator.

The fixator was easily removed in all of the cases without any anaesthesia in the present study. Similarly, Surbhi (2011) [24], Kumar *et al.* (2012) [9]; Mathai (2012) [13]; Basith (2015) [4] and Aithal *et al.* (2019) [2] reported easy removal of the fixator assembly by cutting it with pin cutter and pulling out the fixator assembly.

4. Conclusion

It can be concluded that the technique of epoxy-pin external skeletal fixation is easy, economical, needs minimal instrumentation and hence can be practised by a field veterinarian in any remote place.

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