B-4262
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RESEARCH ARTICLE Indian Journal of Animal Research, Volume Issue : ()

Outcome of Open Long Bone Fractures in Dogs Stabilized with Linear External Skeletal Fixator

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10.18805/IJAR.B-4262

ABSTRACT

Background: External skeletal fixator (ESF) has been recommended as biological method to stabilize open fracture as it does not involves the wound site, besides protecting adjacent soft tissue structures. Considering the advantages of ESF, this study was envisaged with an objective to study the outcome of open fractures of radius-ulna and tibia-fibula stabilized with linear ESF in dogs.

Methods: This study included 17 dogs suffering from open long bone fractures of radius-ulna and tibia-fibula, divided into three groups; linear ESF type I or II (group I, n=8) and type III (group II, n=3). In group III (n=6), open fractures were initially treated using conservative methods *i.e* management of open wound till complete healing followed by delayed internal fixation using intramedullary pin or bone plating.

Result: Majority of the open fractures of radius-ulna and tibia-fibula were transverse (64.71%), involving distal third diaphysis (47.06%) in heavy weight (54.55%), 1-3 year old (64.71%), non-descript (35.29%), male (88.23%) dogs due to automobile accidents (58.82%). Neutrophilic (81.47±4.45%) leukocytosis (24610±2461.88 per cumm) and elevated levels of alkaline phosphatase and creatine kinase were observed. *Staphylococcus* spp. was the common isolated bacteria sensitive to Gentamicin, Cefotaxime, Tobramycin, Amikacin and Neomycin. High per cent fractures (83.33%) in group III had acceptable functional outcome as compared to fractures treated with linear ESF (55.55%) in groups I and II. Osteomyelitis due to pin tract infections was the major complication (8/11; 72.7%) recorded in ESF groups (Group I and II) that lead to delayed and/or nonunion. Weight bearing score improved markedly after removal of the ESF frame. In conclusions, immediate fixation of the long bone fracture using linear ESF in the presence of open contaminated / infected wounds leads to unacceptable outcome. Poor animal compliance, pin tract discharge, osteomyelitis, delayed union and nonunion are major complications associated with linear ESF. Conservative management of the open fracture wound using standard treatment for 2-3 weeks till complete wound healing followed by internal fixation with intramedullary pin or bone plate is recommended for open long bone fractures in dogs.

Key words: Canine, Linear external skeletal fixator, Open fracture, Osteomyelitis, Orthopaedic surgery.

INTRODUCTION

Management of open fractures is challenging for the small animal surgeons as these are unsuitable for internal fixation. Early stabilization of open fractures, without disturbing wound site, protects soft tissues around the fracture site by preventing further damage associated with mobility of bone fragments (Cross and Swinontkowski, 2008). In routine clinical practice, open fractures in dogs are managed conservatively (daily flushing, dressing and bandaging of wound) till cutaneous wound heals by healthy granulation tissue followed by external support bandaging. Conservative management of open fractures is associated with high expenditure on medication, prolonged recovery time and pain associated with unstable fracture.

External skeletal fixator (ESF) is a biological fracture fixation technique (Kumar *et al.,* 2020) which is indicated for the stabilization of grossly contaminated open fractures with extensive soft tissue compromise or when immediate fixation is needed for physiologically unstable patients (Cross and Swinontkowski, 2008). Considering the advantages of external skeletal fixator and paucity of Indian veterinary literature on the clinical use of linear ESF, this study was envisaged with an objective to study the outcome of open fractures of radius-ulna and tibia-fibula stabilized with linear ESF in dogs.

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How to cite this article: Singh, T., Kumar, A., Udehiya, R.K., Gill, K.K., Rai, T.S. and Mahajan, S.K. (2021). Outcome of Open Long Bone Fractures in Dogs Stabilized with Linear External Skeletal Fixator. Indian Journal of Animal Research. DOI: 10.18805/IJAR.B-4262.

Submitted: 24-07-2020 **Accepted:** 04-03-2021 **Online:** 02-04-2021

MATERIALS AND METHODS

Animals

This study included 17 dogs, aged 3.11±0.51-year (1-7 year)

suffering from open fractures of radius-ulna and tibia-fibula since 4.64 ± 2.21 days (range 1-30 days), divided into three groups. In Group I (n=8) fractures were stabilized with linear ESF type I or II using half pins with 5 cancellous negative profile threads or full pin with central cortical positive profile threads. In Group II (n=3) fracture were stabilized with type III ESF, using full pin with central cortical positive profile threads combined with half pin with 5 cancellous negative threads. However, in Group III (n=6), fractures were initially treated using conservative methods *i.e* management of open wound till its complete healing followed by internal fixation with intramedullary pinning or bone plating. This study was conducted at the department of Veterinary surgery and Radiology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, India, from April 2018 to March 2019.

Classification of Wounds

Based on extent of tissue trauma (wound size, degree of contamination, soft tissue/muscle/vascular damage, periosteal striping and coverage of bone), open fractures were classified as type I, type II and type III (IIIA, IIIB and IIIC) as described by Gustilo *et al.* (1984).

Laboratory Investigation

A blood sample (3ml) was collected, preoperatively, under aseptic conditions and divided into 2 vials; first sample (1 ml) in EDTA for hematology and second sample (2 ml) for serum biochemistry {calcium (Ca), phosphorus (P), alkaline phosphatase (ALP) and creatine kinase (CK)}. A sample of sterile swab was collected from the wound site for CST using standard procedure.

Radiography

Preoperative radiographs of the affected limb/bone were obtained in craniocaudal and mediolateral views to assess the location and configuration of fracture. Immediate postoperative radiographs were evaluated to grade for fracture reduction as grade 0 (anatomical reduction), grade 1 (minimal < 1 mm malreduction), grade 2 (moderate 1-3 mm malreduction) and Grade 3 (severe > 3 mm malreduction) as described by Cook *et al.* (1999). Subsequent, radiographic examination was carried out at various intervals to assess the fracture healing. Fracture healing was scored based on callus formation and/or elimination of the fracture line or gap and was graded as 0 (complete radiographic healing); 1 (Appropriate progression towards healing, but not completely healed); 2 (Inappropriate progression towards healing); 3 (No evidence of healing, failure) as recommended by Cook *et al.* (1999).

Positioning of the animal and limb

Under general anaesthesia using standard protocol, the dogs were positioned in dorsal or lateral recumbency with the fractured limb tied at a higher point so as to achieve fracture reduction with its own weight (Kaur *et al.,* 2015) with 'hanging limb method'. Surgical area was scrubbed with Chlorhexidine solution followed by 5% povidone iodine and the limb was draped for aseptic surgery.

Surgical procedure and implants

In groups I and II, a stab incision was made over the proposed pin insertion site. Haemostatic forceps was used to bluntly dissect through the soft tissue from the skin up to the bone to create a soft tissue tunnel from skin to bone surface. A hole at the proposed site of pin insertion was drilled using a bit 0.5 mm diameter less than the fixation pin diameter.

Fixation pins were pierced both the near and far cortices/skin surface depending upon the type of fixator type used. Proximal most and the distal most pins were first inserted in the respective metaphyses of the bone. The fracture was reduced either by closed manipulation of the fragments or by making a small incision (open reduction). Two pins were connected to the clamps at the ends of external connecting bar. Clamps were preplaced over the connecting bar so as to accommodate placement of subsequent fixation pins. The remaining half pins were placed directly through the open clamps at a distance of approximately 1 cm proximal and distal to the fracture line. After the placement of all pins, the clamps were tightened.

Care was exercised to ensure that the trocar point of the fixation pins exit the far cortex. The connecting rod was positioned close to the skin surface, ensuring that neither the clamps nor the connecting bar impinged upon onto the skin surface. Small surgical incisions made to facilitate reduction were sutured. Wound associated with open fracture was allowed to heal by secondary intention. Extra pin ends were cut short close to the connecting bar and covered with m-seal to provide additional support to prevent loosening of ESF assembly.

Postoperative care and management

The pin-skin interface was cleaned with povidone iodine solution and covered with sterile gauze. E-collar was applied to prevent self-mutilation of the surgical wound or ESF assembly. Dogs were administered inj. Cefotaxime @ 20 mg/kg I.M. bid, inj. Amikacin @ 10 mg/kg I.M. od and inj. Meloxicam @ 0.2 mg/kg I.M OD for 7, 5 and 3 days, respectively. Syp. Osteopet was adivsed orally BID for 30 days. Besides, Clindamycin @ 11 mg/kg orally, OD, was prescribed in cases suspected and diagnosed for osteomyelitis for 10 days along with daily flushing the wound and restricting the movement for 2 weeks.

Weight bearing score

Postoperative weight bearing score was evaluated while standing and walking (Gill *et al.,* 2018a) at day 20, 45, 60 days and at final follow up. While standing, weight bearing was scored as 0 (carrying the limb), 1 (touching the toe) and 2 (touching the paw). While walking and running, weight bearing was scored as 0 (carrying the limb), 1 (occasional touching of toe/paw), 2 (frequent touching of toe/paw), 3 (touching the toe on every step with partial weight bearing

and 4 (touching the paw on every step with complete weight bearing).

Complications

Postoperative complications were recorded at various intervals to record status of wound healing, implant stability and implant related major/minor complications.

Implant removal

Following severe complications or evidence of radiographic bone union or satisfactory weight bearing, ESF assembly was removed under sedation.

Functional outcome

Functional outcome was classified as full (restoration to preinjury status), acceptable (restoration to preinjury status that was limited in level, duration, or required medication to achieve), or unacceptable (applied to all animals that did not exhibit full or acceptable function) as defined by Cook *et al.* (2010).

Statistical analysis

The data was analyzed using Microsoft Excel 2016. Objective preoperative parameters related to hematology (Hb, TLC, DLC, Platelets), serum biochemistry (ALP, Ca and P, Creatine kinase) were processed for mean and standard error and correlated with the duration of fractures, complications or outcome.

Results and Discussion

Haemato-biochemical Results

Majority of the clinico-haematological parameters were within normal range except neutrophilic (81.47±4.45%) leukocytosis (24610±2461.88 per cumm) which could be associated with open fracture and infection. Mean preoperative serum Ca (9.81 ± 0.24 mg / dL) and P (4.4 ± 0.25 mg / dL) levels were within normal range suggesting normal cortical bone health but the mean serum levels of ALP (191.52 ± 27.34 IU / L) and CK (512.14 ± 114.7IU / L) were increased on day 0 which could be attributed to proliferation of osteogenic cells and soft tissue / muscle damage. The ALP has been reported to increase in delayed cases of fracture (Gill *et al.,* 2018b).

Wound type and haemato-biochemical alterations

Type II (35.30%) wound was the most common type followed by type IIIA and type IIIB (29.40% each) and type IIIC (5.90%). Contradictory findings were observed by Aggarwal (2017) who recorded that Type IIIA were the most common followed by Type I in open radius-ulna fracture in dogs. Millard and Weng (2014) reported that heavy group of dogs were 4-5 times more likely to have an open fracture.

In this study, both TLC and CK were observed high in Type III B wounds (Table 1) but these could not be correlated to the extent of the open fracture wound which could be due to variation in the duration and cause of trauma. However, serum ALP showed consistent increase with the increasing severity of wound. Nordmann *et al.* (2009) found that continued rise in the CK was a sensitive marker for poor wound debridement and ongoing muscle death. Similarly, Larsson and Linden (1981) recommended that serum CK determinations could be useful to quantify muscle injury associated with fracture. Gill *et al.* (2018b) observed a significant leukocytosis and thrombocytosis in dogs suffering from fracture presented within 24 hours of trauma along with neutrophilia and corresponding lymphopenia.

Results of CST

The CST results revealed *Staphylococcus* spp. growth in majority of the wounds (76.47%) followed by no bacterial growth (17.65%) and *E. Coli* (5.88%). Absence of growth could be due to previous use of antibiotics at field level. Highest sensitivity was observed for Amikacin (100%, n=2/2) followed by Gentamicin (85.71%, 12/14), Neomycin (80%, 4/5), Ceftriaxone (75%, 3/4), Ciprofloxacin (66.67%, 4/6), Cefotaxime (63.63%, 7/11), Enrofloxacin (62.5%, 5/8), Norfloxacin (60%, 3/5) and Tobramycin (54.54%, 6/11). The isolates showed high resistance to Pefloxacin (100%, 6/6), Penicillin (100%, 2/2), Streptomycin (80%, 4/5), Tetracycline (63.64%, 4/7), Kanamycin (62.5%, 5/8) and Amoxicillin (60%, 3/5). Cited literature reports Staphylococcus spp being the most common pathogenic organisms isolated from open fractures (Stevenson *et al.,* 1986; Aggarwal, 2017).

Intraoperative results

Mini surgical approach along with traction, in combination, lead to easy (n=7) or difficult (n=10) fracture reduction. Majority of the delayed cases (>5 days) had difficult surgical reduction (Table 2) which was probably associated with muscle contracture and formation of adhesions / fibrous callus with adjoining tissues. Similar findings were reported by Gill *et al.* (2018b) and Aggarwal, (2017) in delayed cases of supracondylar fractures and open radius-ulna fractures in dogs.

Radiographic findings

Transverse fractures were the most common (64.71 %) followed by oblique (23.52%) and comminuted (11.71%).

Table 1: Effect of various types of wounds on haemato-biochemical parameters.

Parameters (Mean±S.E.)	Type II (n=6)	Type IIIa (n=5)	Type IIIb (n=5)	Type IIIc (n=1)
TLC / cumm	24250 ± 4409.03	17768 ± 1809.94[a]	31608 ± 5047.07[a]	26490 ± 0.00
CK IU/L	269.33 ± 91.04[b]	352.28 ± 136.88	990 ± 256.73[b]	379 ± 0.00
ALP IU/L	118.66 ± 9.74	235.6 ± 61.36	203.2 ± 53.75	350 ± 0.00

Values with same superscript 'a' or 'b' indicate significant ($p \leq 0.05$) difference from each other.

Majority fractures involved distal third region (47.06%), followed by mid diaphyseal (41.71%) and proximal diaphysis (11.77%). Fracture reduction on immediate postoperative radiographs in linear ESF groups (Group I and II) revealed grade 0 (n=6), grade 1 (n=5), grade 2 (n=4) and grade 3 (n=2). At final follow up, only 4 out of 9 (44.44%) fractures that were treated with linear ESF (Group I and II) showed complete or appropriate progression of healing, radiographically, (Fig 1 a - d); whereas in group III, all (100%) fracture cases either showed complete or appropriate progression towards healing.

Implant stability

As compared to both ESF groups (group I and II) (54.55%), group III dogs had more per cent cases with stable implant (66.67%) (Table 3). Consequently, implant related complications were also high in both ESF treated groups (3 loose and 2 unstable) in comparison to group III (two unstable / proximal pin migration). Presence of open contaminated / infected wounds (in groups I and II) might be responsible for more implant related complications as also been reported by Kallianpur *et al.* (2017).

Weight bearing scores

The earliest weight bearing was seen on day 20 in group II (2.0±1.62) followed by Group III (1.0±0.25) whereas no weight bearing was seen at day 20 in Group I. On day 60, weight bearing scores in group I and II were non-significantly less that of the group III (Table 4). In group I, there was a marked improvement in the weight bearing score between the day 60 (at the time of ESF removal) and at final follow up which might be due to ESF assembly induced pain / irritation in soft tissue around the pin tracks which have been relieved after ESF removal.

Complications

Osteomyelitis was major complication (n=8) followed by delayed union (n=5), pin tract infection (n=4) and non-union (n=4) (Table 5). No case of pin breakage or occurrence of iatrogenic fracture at pin insertion site was recorded. Complications such as pin loosening, pin tract infection, pin breakage, nonunion or delayed union were frequently encountered in ESF applications (Johnson *et al.,* 1989; Ness, 2006). In comparison to close, healing of open fractures repaired with ESF was delayed (Johnson *et al.,* 1989) which corroborate to the findings of current study.

Implant removal

Complete removal of the linear ESF was done on mean period of 55.5±9.83 and 48.33±14.67 days in group I and II,

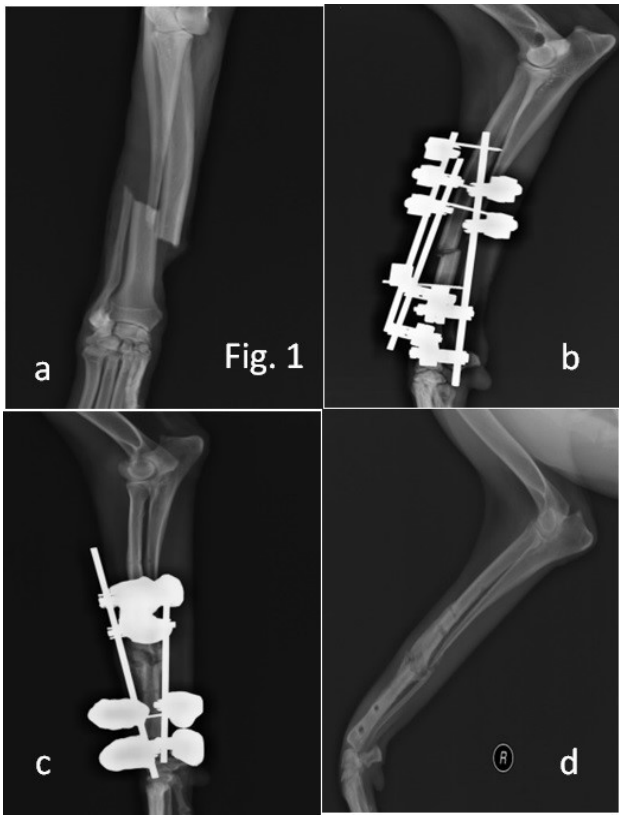

Fig 1: Sequential radiographs showing healing of Radius-ulna fracture (group II) repaired with Type III Linear ESF. (a) Preoperative, (b) Immediate postoperative, (c) At day 60, (d) After removal of ESF.

Table 2: Effect of duration of fracture on the ease of reduction.

Duration of fracture	Ease of fracture reduction			
(days)	Easy	%	Difficult	%
0-1	3	60	2	40
2 to 4	3	40	1	25
5 and above	1	12.5	7	87.5

Table 3: Implant stability and implant related complications in dogs with open long bone fracture.

Groups	Stable implant		Unstable implant	
	No.	%	No.	%
Group I (n=8)	4	50.00	4	50.00
Group II (n=3)	2	66.67	1	33.33
Overall ESF (Group I and II, n=11)	6	54.55	5	45.45
Group III (n=6)	4	66.67	2	33.33

Table 4: Weight bearing scores at various intervals in different groups.

Groups	Day 20	Day 45	Day 60	Final follow up
Group I (n=6)	0	0.33±0.21	0.66±0.2	3.66±1.20
Group II (n=3)	2.0±1.62	2.0±1.63	2.0±1.63	2.0±1.63
Group III (n=6)	1.0±0.25[a]	3.16±0.60[a]	4.0±0.73[a]	6±0

Values with same superscript show significant difference ($p \leq 0.05$) from each other.

Table 5: Radiographic and grossly apparent complications and/or combinations in open long bone fractures in dogs.

Complications	Group I	Group II	Group III	Total
Osteomyelitis	4	3	1	8
Pin tract infection	3	1	0	4
Implant failure	2	0	0	2
Non union	2	2	0	4
Malunion	1	0	0	1
Delayed Union	3	1	1	5
Open wound infection	2	1	2	5

Table 6: Assessment of final functional outcome in cases of open long bone fractures.

Groups	Full	Percent	Acceptable	Percent	Unacceptable	Percent	Total
Group I	3	50.00	1	16.67	2	33.33	6
Group II	1	33.33	0	0	2	66.67	3
Group III	5	83.33	1	16.67	0	0	6
Total	9	60.00	2	13.33	4	26.67	15

Table 7: Effect of type of open fracture on the functional outcome.

Functional Outcome	Type of open fracture							
	II		IIIA		IIIB		IIIC	
	No.	%	No.	%	No.	%	No.	%
Full	2	100	0	0	2	40	0	0
Acceptable	0	0	0	0	1	20	0	0
Unacceptable	0	0	1	100	2	40	1	100
Total	2	100	1	100	5	100	1	100

respectively, after appearance of cortical union or in case of complications. The weight bearing score increased markedly after removal of the linear ESF frame. Similarly, Sereda *et al*. (2009) removed ESF frames at 50-123 days after the correction of antebrachial deformities in dogs and noticed remodeling of cortices 5 weeks after surgery and the fixator removal.

Final Functional outcome

Evaluation of 15 fractures presented at final follow up revealed full (n=9, 60%), acceptable (n=2, 13.3%) or unacceptable (n=4, 26.7%) functional outcome. Two cases died during study, so had no follow-up evaluation. High per cent fractures (83.33%, n=5/6) in group III had acceptable functional outcome as compared to fractures treated with ESF (55.55%, n=5/9) in Groups I and II (Table 6). It was found that conservative management of open fracture wound by daily or alternative day dressing / bandaging till complete healing followed by delayed definitive stabilization (Group III) leads to better outcome as compared with immediate stabilization of open long bone fractures with ESF.

Type of Open Fracture and Functional Outcome

Majority dogs with type III open fracture progressed to unacceptable outcome (57.14%, 4/7) (Table 7). Similar findings were reported by Kallianpur *et al.,* (2017) who observed a significantly high frequency of major complications in fracture cases treated with ESF because it was commonly used to stabilize open fractures.

Conclusion

Non-descript, heavy weight, male dogs with distal third diaphyseal fractures of radius-ulna and tibia-fibula due to accidental trauma are prone to become open. *Staphylococcus* sp. is the most common bacterial infection of open long bone fracture sensitive to Gentamicin, Cefotaxime, Tobramycin, Amikacin and Neomycin. Linear ESF may be indicated for the management of early presented cases of open long bone fracture associated with small wound in dogs. Poor animal compliance, pin tract infection, osteomyelitis leading to delayed union, implant dislodgement and nonunion are major complications associated with management of open long bone fracture with linear ESF. Conservative management of the open fracture wound using standard treatment for 2-3 weeks till complete wound healing followed by delayed internal fracture fixation with intramedullary pin or bone plate is recommended over immediate use of linear ESF for the management of open long bone fractures in dogs.

Acknowledgement

Authors are highly thankful Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, India for providing research facilities and the Indian Council of Agricultural Research, New Delhi for providing financial support under 'All India Network Program on Diagnostic Imaging and Management of Surgical Conditions in Animals'.

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