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Acrylic and Epoxy-pin External Skeletal Fixation Systems for Fracture Management in Dogs

Surbhi Kuldeep Tyagi[2], Hari Prasad Aithal[1], Prakash Kinjavdekar, Amarpal, Abhijit Motiram Pawde, Abhishek Kumar Saxena

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ABSTRACT

Background: The metallic ESF systems are not easily available in the field and have fixed frames leading to less versatility in size and direction. Free forms of external skeletal fixators (acrylic and epoxy-pin) have advantages as they can be customized. Both acrylic and epoxy-pin ESF systems have been evaluated biomechanically in earlier studies; in the present study both are compared clinically.

Methods: Twenty four dogs presented with 27 fractures of long bones, were randomly divided into 4 groups, according to the bones involved, group A was divided into A-I (radius-ulna) and A-II (tibia-fibula) sub-groups and group B was divided into B-I (radius-ulna) and B-II (tibia-fibula) sub-groups.

Result: The mean ± SE fracture healing time in animals was 48.85 ± 2.56 days with no significant difference between two groups.The early presented cases and the ones with less soft tissue trauma showed better gait scores during the follow up period. Both acrylic and epoxy-pin fixators provided stable fixation and the technique can be practiced at field conditions with minimal facilities. Epoxy-pin ESF owing to better handling characteristics of epoxy resin is easier to construct than the acrylic ESF.

Key words: Acrylic, Epoxy-pin, ESF, External skeletal fixators, Fracture, Minimally invasive fixation.

INTRODUCTION

External skeletal fixation (ESF) is a method of minimally invasive fracture fixation, using percutaneous pins that are connected outside the body to form a rigid frame or scaffold (Van- EE and Geasling, 1992). Generally the components of the external skeletal fixators were made of a metal, most commonly stainless steel and are called fixed frame ESF with a major limitation of their fixed frames which offer less versatility in shape, size and direction. The free form of fixators are light weight, less expensive, the pin direction and size need not be influenced by the direction and size of the connecting bar.

Various biomechanical studies have been conducted on acrylic and epoxy polymers as component of ESF (Willer *et al.*, 1991; Roe and Keo, 1997; Tyagi *et al.*, 2014a). When compared biomechanically, Multiplanar and Circular designs of acrylic and epoxy-pin ESF have been described superior to uniplanar designs (Tyagi *et al.*, 2014b; Tyagi *et al.*, 2015). Also, under compression loading both acrylic and epoxy-pin ESF systems showed no significant difference in the mechanical strength (Tyagi *et al.*, 2014a).

MATERIALS AND METHODS

Twenty four dogs reported with the fractures of radius-ulna or tibia-fibula presented to the referral polyclinics of Indian Veterinary Research Institute (2010-2011), were selected as the subject of the study. Group A was treated with acrylic ESF and was further divided into A-I (radius-ulna) (n=7) and A-II (tibia –fibula) (n=5) sub groups. Similarly, group B was treated with Epoxy-pin ESF and was divided into B-I (radius-ulna) (n=10) and B-II (tibia –fibula) (n=5) sub groups.

Indian Veterinary Research Institute, Izatnagar-243 122, Uttar Pradesh, India.

[1]Training and Education Centre, Indian Veterinary Research Institute, Pune-411 001, Maharashtra, India.

[2]COVAS, Sardar Vallabhbhai Patel University of Agriculture and Technology, Modipuram, Meerut-250 110, Uttar Pradesh, India.

Corresponding Author: Hari Prasad Aithal, Training and Education Centre, Indian Veterinary Research Institute, Pune-411 001, Maharashtra, India. Email: hpaithal@rediffmail.com

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Preoperative observations

History

Anamnesis regarding the breed, age and sex of the animal, cause of fracture, time since fracture, limb involved and primary treatment given if any, were recorded.

Clinical Examination

All the dogs were examined for the degree of lameness, bone involved, location of the fracture, condition of the wound, if any and soft tissue injury at the fracture site. The degree of soft tissue injury was graded as slight (exposure of bone through a small opening in the skin with little contamination and soft tissue inflammation), moderate (relatively large skin wound with contamination or/and soft tissue inflammation) and severe (very large skin wound with gross contamination, soft tissue inflammation, necrosis and sometimes with vascular compromise).

Radiographic Examination

The fractured bone was subjected to radiographic examination in the orthogonal views.

Intraoperative observations

Surgical Fixation of Fractures

Food was withheld for 12 hour and water for 6 hour prior to surgery. The entire thoracic or pelvic limb was clipped and aseptically prepared. Fracture reduction and fixation was done under general anaesthesia. Atropine @ 0.04 mg/kg i.m., diazepam @ 0.5 mg/kg i.v. and pentazocine @ 1 mg/ kg i.v. were given as pre anaesthetics. Induction and maintenance of anaesthesia was done by using 5% thiopentone sodium (i.v. till effect). In general, 1.5 mm K-wires were used in radius/ulna and tibia/fibula, whereas in metacarpals and metatarsals, 1.2 mm K-wires were used.

After the fracture reduction, the K-wires were passed, avoiding major vessels, nerves and muscular attachments. The K-wires were introduced through the soft tissues up to the level of bone by hand, followed by bone drilling, which prevented the soft tissue wrapping around the pins. The pins were inserted through bone using a low speed (200 rpm) electric drill with continuous dropping of cold sterile normal saline solution to reduce thermal necrosis. The pins were crossed with each other at an angle of 70°-90° in such a way that they did not interfere with each other in medullary cavity and were directed from caudomedial to craniolateral and from craniomedial to caudolateral direction. In case of trans-articular fixation for the fractures at the distal end of R/U or T/F, single mediolateral pins were inserted in the metacarpals/metatarsals. A gap of about 1-2 cm was left in between skin and side bars.

Acrylic ESF

After passing the transcutaneous pins, a 20 mm diameter corrugated mouldable poly vinyl chloride (PVC) pipe of desired length was passed through the pins to construct the side bars and then the pins were bent. Acrylic powder was mixed with liquid in pre-cooled glass beaker in the ratio of 2:1 and was immediately poured into the hollow pipes with their cut/open ends facing upwards. Open ends of pipe were joined by cutting a small triangular piece from one end of the pipe so that the two ends of the pipe could fit into each other and was then secured with the help of an adhesive tape. To prevent damage to skin due to heat produced during polymerization, crushed ice was kept in between the fixator columns and skin. The acrylic columns were then allowed to harden; subsequently the remaining ice was removed (Fig 1a and Fig 1b).

Epoxy ESF

For epoxy fixator, after passing the pins, the pins in the same plane were bent at 2 cm from the skin towards the facture site and then joined with the help of adhesive tape to form a temporary scaffold. Using additional pins pieces, the two side bars of each side were joined at the proximal and distal ends. The epoxy hardener and resin were then mixed thoroughly for about 1-2 minute make uniform coloured dough. The epoxy putty was then hand moulded and applied along the temporary scaffold incorporating the bent pins within, making a near uniform side bars of appropriate diameter (15 to 20 mm). The epoxy fixator so formed was then allowed to harden (Fig 2a and Fig 2b).

Postoperative Observations

Postoperative Care and Management

Anti-inflammatory and antibiotic drugs were given in prescribed doses for five days. Regular cleaning and dressing of the wound and pin-skin interface was done with antiseptic solution 1% povidone iodine.

Clinical observations

Wound healing

The status of wound was assessed regularly and the total time required for wound healing was recorded in cases of open fractures and open fracture reduction cases.

Fig 1a: Surgical fixation of fracture with acrylic ESF, Pipe is passed through the pins to form temporary scaffold.

Fig 1b: Acrylic is poured in the pipe and ends sealed.

Status of the fixation device

Fixation device was evaluated regularly for any change in the position or deformation.

Pins tract sepsis

The degree of discharge, sepsis was recorded in each of the pins tracts and graded as: 1-slight = the pins-skin interface is moist with slight oozing of serous/ fibrinous exudate on pressing, 2-moderate = seropurulent exudation from the point of pin insertion on pressing the site and 3-severe = spontaneous exudation or excessive exudation on pressing.

Gait analysis

For analysis of gait, the animals were evaluated while standing, walking and running to observe weight bearing on the affected limb, on days 3, 7, 15, 30 and 45 postoperatively. Various scores were given for standing, walking and running as detailed below

Fig 2a: Surgical fixation of an open fracture with epoxy ESF, Pins passed through the skin and bone then bent and joined to form temporary scaffold.

Fig 2b: Epoxy putty applied to form the frame.

1- no weight bearing, 2- slight weight bearing (animal mostly keeps the limb lifted and keeps down *i.e.,* limb lifted mostly), 3: Moderate weight bearing (keeping the limb on ground but lifting in between *i.e*., limb on ground mostly) and 4: full/ good weight bearing (touching the ground during each step with full weight bearing).

Radiographic observations

Orthogonal radiographs were made immediately after the application of fixator and then at days 15, 30, 45 and 60. Once the fracture healing was evident on radiographic examination (bridging callus), the fixator was removed.

Fixator removal

Using a pin cutter the pins were cut and then pulled out with the help of pliers. Pins tracts were cleaned and flushed with povidone iodine and then bandaged. Owners were advised to regularly clean and dress the pin tracts, restrict animal movement for 1 week and give analgesics for 2-3 days.

Functional recovery

Functional recovery of the animal was graded as very good (VG), good (G), satisfactory (S) and unsatisfactory (US) (Kumar *et al*. 2012).

Statistical analysis

The data was analyzed using ANOVA and mean differences were tested for statistical significance by Duncan's multiple range test (DMRT) using software (Statistical Package for Social Sciences version 15.0). Significance was recorded at $P<0.05$.

Results and Discussion

Pre operative observations

A total number of 24 dogs were presented (among them, 3 dogs were having with bilateral R/U fracture) with 27 fractures (Table 1(a) and Table 1 (b)). Relatively more number of Radius/Ulna fracture cases were recorded (n=17) than tibia/fibula fractures (n=10) with males were more affected than females. Among different breeds, maximum cases presented were non-descript dogs, in addition to Labrador, Spitz and German shepherd. Road traffic accident (RTA) has been reported to be the major cause of fracture among animals (Braden *et al*., 1995; Aithal and Singh, 1999, Harasen, 2003). However, in the present study, fall from the height was the major cause along with RTA.

Intra operative Observations

High speed drilling has been shown to produce heat and thermal necrosis, whereas very low speed leads to wobbling and pin loosening (Egger *et al.*, 1986; Clary and Roe, 1995). For that reason, the pins were inserted using a low speed (200 rpm) electric drill along with continuous dropping of cold sterile normal saline solution with povidone iodine, to minimize the possible thermal necrosis and was found satisfactory.

Use of small diameter pins has been used in ring fixators and free form of fixators. In dogs and cats, 1-1.6 mm K-

Table 1 (a): Clinical and Pre-operative observations of animals of Acrylic ESF group.

Case. no.	Group	Breed	Age	Sex	Weight (kg)	Cause of injury	Time since injury (days)	Open/ closed	Degree of soft tissue trauma	Bone involved, Type and location of fracture
1.	Group A- I (Acrylic-R/U)	Rottweiler	9 m	F	14	Fall	20	Closed	Slight	Rt Distal Epiphyseal fracture (Salter Harris Type II)
2.		Labrador	1.5 y	M	30	Fall	5	Closed	Slight	Lt Distal epiphyseal fracture (Salter Harris Type II)
3.		German Shepherd	4 y	M	25	RTA	11	Open	Moderate	Lt Transverse Distal 3rd diaphyseal fracture
4.		Mongrel	3m	M	7	Fall	2	Closed	Slight	Rt Slight oblique midshaft fracture
5.		Spitz	6 y	M	13	Fall	5	Closed	Slight	Lt Transverse Distal 3rd diaphyseal fracture
6.		Mongrel	2 y	M	14	Hit by stick	15	Closed	Slight	Lt Slight oblique Distal 3rd diaphyseal fracture
7.		Spitz	8 m	F	5	Fall	2	Open	Moderate	Rt Distal Epiphyseal comminuted fracture (Salter Harris Type II)
8.	Group A-I I(Acrylic-T/F)	Mongrel	9 m	F	12	Fall	17	Closed	Slight	Lt Transverse midshaft fracture T/F
9.		Mongrel	6 m	M	10	Fall	6	Closed	Slight	Rt Slight oblique Prox 3rd diaphyseal communited fracture
10.		Great Dane	1 y	M	35	RTA	5	Open	Slight	Lt Slight oblique midshaft fracture
11.		Mongrel	1 y	M	16	RTA	7	Closed	Slight	Lt Distal 3rd diaphyseal transverse fracture of Lt
12.		Mongrel	11 m	F	15	RTA	10	Closed	Slight	Lt Slight oblique distal 3rd diaphyseal fracture of Lt

wires were used most commonly (Kumar *et al*. 2012; Ferriti, 1991).They carry the advantage of creating smaller defects in soft tissue and bone; however, as they are bilateral, care must be taken while passing pins through the skin and soft tissues as there are chances of neuro-vascular bundles to get entrapped and cause complications (Behrens, 1989).

The time required in passing K-wires, applying fixator, hardening and total time for fixator application has been given in Table 2. The total time required for application (applying fixator and hardening) did not differ significantly between the groups.

There were certain detriments associated with acrylic fixators. First, the fumes were produced while mixing acrylic powder with liquid, as also reported by others (Anderson, 1988), which are very irritating to the eyes and upper respiratory tract. Thus, wearing of face mask and gloves during handling of acrylic is recommended. Secondly, while pouring the acrylic inside the pipe, there were chances of leakage from the sites of pin insertion which made the field dirty and wet. Thirdly, the exothermic reaction made direct handling of pipes very difficult. The setting/hardening time being very less (9-11min.), does not give time for minor adjustments required. Martinez *et al*. (1997) have suggested keeping a distance of at least 10 mm between the acrylic bars and skin to prevent tissue necrosis due to heat production. To prevent the possible damage by heat, we packed crushed ice in between the skin and fixator frame. Though cumbersome, it was found as none of the clinical case showed any complication.

On the contrary, handling of epoxy was easier due to its doughy nature with no fumes and negligible heat production and giving enough time (20-22 minutes hardening) for slight modifications, if necessary.

Postoperative observations

The postoperative observations have been summarized in Table 3(a) and Table 3(b).

Wound healing

In most of the animals wound healed within 10 and 15 days.

Status of the fixation device

The fixation was maintained in all cases except for two (one in each group; due to auto mutilation). In the animal with epoxy fixator, epoxy was reapplied to the re-construct side bars. This clearly indicates that the K-wires of 1.5 mm diameter and polymeric connecting bars (acrylic/epoxy) of 15-20 mm diameter are strong enough to carry the weight of the animal.

Pins tract sepsis

No pin tract sepsis was observed in 16 cases. In 11 cases transudation (slight in 6, moderate in 5) from pin-skin interfaces was observed. Transudation was mostly observed in most proximal and distal pins which subsided gradually by regular cleaning, dressing and antibiotic coverage.

Gait analysis

All the animals showed a variable degree of lameness in

Table 1 (b): Clinical and Pre-operative observations of animals of Epoxy-pin ESF group.

Case. no.	Group	Breed	Age	Sex	Weight (kg)	Cause of injury	Time since injury(days)	Open/ Closed	Degree of soft tissue trauma	Bone, Type and location of fracture/luxation
1.	Group E-I (Epoxy R/U)	Mongrel	4 m	M	10	Hit by stick	4	Closed	Slight	Rt Distal 3rd transverse diaphyseal fracture
2.		Labrador	1 y	M	24	RTA	1	Open	Slight	Rt Transverse Distal 3rd communited diaphyseal fracture
3.		Rottweiler	9 m	F	14	Fall	20	Close	Slight	Lt Epiphyseal fracture (Salter Harris Type II)
4.		Labrador	9m	F	22	RTA	1 month	Closed	Slight	Lt Transverse Distal 3rd communited diaphyseal fracture
5.		Labrador	1.5 y	M	30	Fall	5	Closed	Slight	Rt Slight oblique Distal 3rd diaphyseal fracture
6.		German Shepherd	5 y	M	47	RTA	5	Closed	Severe	Rt Distal 3rd diaphyseal fracture of R/U and meta carpals 2,3 and 4
7.		Mongrel	4m	M	10	Fall	20	Closed	Slight	Lt wedge osteotomy of R/U (old fracture distal third diaphysis)
8.		Mongrel	11 yr	M	15	Fall	2	Closed	Slight	Rt Transverse midshaft
9.		Mongrel	2 y	M	14	Hit by stick	15	Closed	Slight	Rt Slight oblique Distal 3rd diaphyseal fracture
10.		Spitz	8 m	F	5	Fall	2	Open	Moderate	Lt Distal Epiphyseal comminuted fracture (Salter Harris Type II)
11.	Group E-II (Epoxy T/F)	Mongrel	4 y	F	12	Fall	1 month	Closed	Severe	Rt Mid.shaft transverse fracturte
12.		Spitz	5 y	F	12	Hit by stick	6	Closed	Slight	Rt Communited slight oblique distal third diaphyseal fracture
13.		Mongrel	2 y	M	13	RTA	2	Closed	Moderate	Lt Avulsion of Rt tibial tuberosity
14.		Doberman	8 m	M	15	RTA	4	Open	Severe	Lt Distal 3rd communited diaphyseal fracture
15.		Spitz	1.5 y	M	14	RTA	7	Open	Slight	Dislocation of left tibio-tarsal joint

Table 2: Mean ± SE of time required for passing wires, applying fixator, hardening and total time of application (min) in acrylic and epoxy-pin ESF group.

Parameters (min)	Acrylic (n=12)	Epoxy (n=15)	Overall mean (n=27)
Time Passing Wire	14.92 ± 1.00	15.20 ± 1.13	15.07 ± 0.75
Time applying fixators	29.58 ± 2.26[a]	19.67 ± 1.42[b]	24.07 ± 1.58
Time hardening	10.67 ± 0.41[a]	22.00 ± 0.52[b]	16.96 ± 1.15
Total time	59.17 ± 3.34	56.87 ± 2.28	57.89 ± 1.92

[a,b] Values with different superscripts differ significantly at $P<0.05$.

Table 3 (a): Post-operative observations of animals treated with acrylic ESF.

Case No.	Type of fixator design	Level of fixation	Time for healing (in days)	Complications (day)
1	Group I(Acrylic RU)	VG	30	_
2		VG	55	Filling defect, pin loosening most distal pin (3), moderate transudation from many pins
3		S	45	_
4		G	30	_
5		VG	45	Toe dragging (up to day 6)
6		G	60	Loosening with Slight transudation from one proximal pin (30)
7		G	58	Moderate transudation, proximal and distal pair (30)
8	Group II(Acrylic Tibia)	VG	35	Slight transudation of one proximal pin (3)
9		VG	28	_
10		G	65	Bar broken due to auto mutilation (15)
11		S	60	_
12		G	45	_

Table 3 (b): Post-operative observations of animals treated with epoxy-pin ESF.

Case No.	Type of fixator design	Level of fixation	Time for healing (days)	Complications (days)
1.	Group III(Epoxy RU)	G	30	_
2.		G	45	Moderate transudation, first pin (3), distal pin broken (45)
3.		VG	30	Slight transudation, first pin (30)
4.		G	45	Moderate transudation, proximal and distal(30,45)
5.		S	55	Moderate transudation, first pin (3)
6.		S	60	2 pins break (15), Bar broken, reapplied
7.		VG	60	_
8.		G	70 Delayed	Osteolysis and slight transudation, most distal pair (45),
9.		G	60	Slight transudation, proximal and distal (7)
10.		G	58	_
11.	Group IV(Epoxy Tibia)	G	60	on day 15-side bar broken, auto mutilated, fixator reapplied
12.		S	60	Slight transudation, proximal pair (7)
13.		VG	60	_
14.		G	35	_
15.		G	50	_

the immediate post- operative period with a gradual increase in weight bearing.

Radiographic observations

Healing occurred within 4-8 weeks, with a mean ± SE value of 48.85 ± 2.56 days. The mean ± SE of days for radiographic healing in group I were 46.14 ± 4.72 days (Fig 3 and Fig 4) and 46.6 ± 7.08 days in group II (Fig 5 and Fig 6). Fracture healing was significantly ($P<0.05$) faster in young animals (37.00 ± 7.68 days) as compared to animals of 1-2 years (56.67 ± 1.67 days) and above 2 years of age (56.67 ± 4.01days). Although the epoxy-pin external fixator components were radio-opaque, they did not interfere with radiographic evaluation of the fracture site. The cranio-caudal radiographs allowed better visualization of fracture site than the medio-lateral radiographs. Acrylic being radiolucent on radiograph offers an advantage over epoxy and stainless steel fixators (Lewis *et al*., 1998). In the present study, fracture healing occurred through external (periosteal) callus formation, *i.e*., by secondary healing.

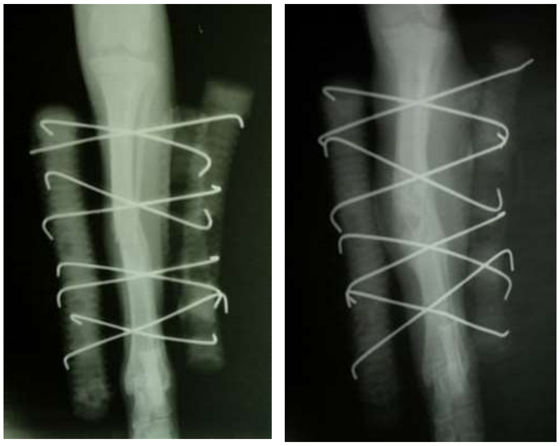

Fig 3: Immediate postoperative (3a) and follow up radiographs (3b) of case with tibia/fibula fracture treated with acrylic ESF (Group I).

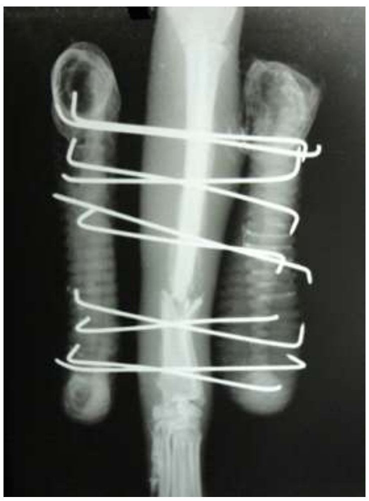

Fig 4: Postoperative radiograph of a case with radius/ulna fracture treated with acrylic ESF (Group I).

Fig 5: Postoperative radiograph of a case with tibia/fibula fracture treated with epoxy ESF.

Fig 6: Postoperative radiograph of a case with radius/ulna fracture treated with epoxy-pin ESF.

Functional recovery

92.59 % of the animals showed good to very good functional recovery after removal of fixator.

CONCLUSION

Different size of the ESF can be constructed using variable size K-wires and variable diameter side bars. In case of the acrylic ESF, different diameter PVC pipes or tubing can be used, whereas, epoxy polymer can be hand moulded to different diameters, *i.e.*, they can be tailored based on each case. Both fixators are equally effective in terms of stability and the technique is minimally invasive, needs minimal instrumentation and can be practised by field veterinarian. Though, epoxy-pin ESF was easier to construct because of better handling characters.

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