RESEARCH ARTICLE Indian Journal of Animal Research, Volume 54 Issue 5: 578-592 (May 2020)

Prognostic Factors Associated with Successful Outcome of Metacarpal and Metatarsal Fractures Repaired Using External Coaptation in Bovines

Ganga Prasad Yadav, Vandana Sangwan, Ashwani Kumar, Shashi Kant Mahajan, Anuradha Gupta[1]

10.18805/ijar.B-3828

ABSTRACT

The objective of this study was to evaluate the various prognostic factors affecting outcome of metacarpal and metatarsal fracture repaired using external coaptation (straight or 'U' shaped aluminium splints and fibreglass cast) in bovine. The study investigated 100 bovines (37 buffaloes and 63 cattle) with 103 fractures (3 cattle with bilateral metacarpal fracture) presented during one year of study. Out of these, 10 were euthanized prior to the treatment, 23 died during the course of treatment and 7 were lost to follow up. Thus, out of the remaining 60 bovines with 61 fractures; 35 cattle with 36 fractures (10 metacarpal and 26 metatarsal) and 25 buffaloes (19 metacarpal and 6 metatarsal) were evaluated for the survival outcome of fractures. Cattle with metacarpal or metatarsal fractures were found to be about two times more prone to become open leading to unfavourable outcome (recumbency and death) as compared to that of buffaloes. The survival outcome as healed fracture of closed metacarpal and metatarsal, irrespective of species, was 100% and it was 33% more than that of the open fractures. In conclusion, the aluminium 'U' shaped splint with fiberglass cast was found to be suitable and economical method for the management of metacarpal /metatarsal fractures in adult cattle and buffaloes; whereas for the young and light weight bovines side splints with fiberglass cast involving hoof was recommended. The age and weight of animal, duration and cause of fracture, quality of first aid provided and radiographic type of fracture influenced the occurrence of open fractures, mortality and the survival outcome of metacarpal and metatarsal fractures repaired using external coaptation in bovines.

Key words: Buffaloes, Cattle, Metacarpal/Metatarsal fractures, Prognostic factors, Splint-Cast, Survival outcome.

INTRODUCTION

Livestock plays an important role in Indian economy. Long bone fractures are common in cattle resulting from a self-inflicted or external trauma (Tulleners, 1986a). The metacarpal and metatarsal are the most frequently encountered appendicular fractures in cattle and these are prone to become open because of lack of soft tissue (Tulleners, 1986a). Open fractures have guarded prognosis in cattle (Adams and Fessler, 1983; Tulleners, 1986b) and may require limb amputation or euthanasia (Jean and Anderson, 2014). The prognosis of fracture in cattle depends on the severity of injury (open or closed fracture, soft tissue or neurovascular damage), location and type of fractures (articular or non-articular) (Jean and Anderson, 2014). For the stabilization and treatment of fractures in cattle, different internal fracture fixation techniques have been described with variable success (Mulon and Desrochers, 2014). But, most of these techniques are impractical in field settings, rendering the use of external coaptation (splints and casts) being still accurate and affordable for the treatment of long bone fracture fixation in bovine (Mulon and Desrochers, 2014).

A few published reports are available on the repair and long term outcome of metatarsal and metacarpal fractures in cattle using conservative or external coaptation casts; however, a few sporadic case reports are available on buffaloes (Prabhakar *et al.* 2012; Velavan *et al.* 2014). As per author's knowledge there is no published report on the comparative outcome of metacarpal and metatarsal fractures repaired using external coaptation with particular reference to prognostic factors in cattle and buffaloes. The cattle and buffaloes are two different species, which though appear similar morphologically, but have different behaviour. Therefore, this study was designed with the objective to evaluate the various prognostic factors affecting the outcome of metacarpal and metatarsal fractures repaired using

Department of Veterinary Surgery and Radiology, College of Veterinary Science, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana-141 004, Punjab, India.
[1]Department of Veterinary Anatomy, College of Veterinary Science, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana-141 004, Punjab, India.

Corresponding Author: Vandana Sangwan, Department of Veterinary Surgery and Radiology, College of Veterinary Science, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana-141 004, Punjab, India. Email: drvandanasangwan@rediffmail.com

How to cite this article: Yadav, G.P., Sangwan, V., Kumar, A., Mahajan, S.K. and Gupta, A. (2020). Prognostic Factors Associated with Successful Outcome of Metacarpal and Metatarsal Fractures Repaired Using External Coaptation in Bovines. Indian Journal of Animal Research. 54(5): 578-592.

Submitted: 04-04-2019 **Accepted:** 18-09-2019 **Published:** 03-12-2019

external coaptation (straight or 'U' shaped aluminium splint incorporated Fiberglass) in bovines.

MATERIALS AND METHODS

This clinical study was conducted at the Referral University Veterinary Hospital for a period of one year (January to December 2017) and was duly approved by the Institutional Animal Ethics Committee.

All the metacarpal (MC) and metatarsal (MT) fractures in cattle and buffaloes presented during the one year study period were recorded, treated and evaluated for the outcome after treatment with external coaptation using aluminium splints and fiberglass cast. The species, age, gender and body weight of all the bovines were recorded. History of trauma and age of fracture, quality of the first aid provided and ambulating (recumbent or standing) status of bovine was also recorded. All the bovines were examined for the type of fracture (open or closed), site of the wound and general health status. All the bovine were subjected to radiography in lateral and dorso palmar or plantar views of MC and MT bones, to assess the site, type or configuration of fracture using Siemens portable X-ray machine of 160mA. Based on the survival outcome, various prognostic factors were derived.

Method of treatment using external coaptation

All the closed and open fractures of MC and MT in cattle and buffaloes were treated using external coaptation. Fracture was stabilized using aluminium splints (6 mm thick and 24 mm wide), cotton, bandages, thick cotton string (it a braided cotton string approximately 1.5-2 cm in diameter and 5 meter in length) and commercially available fiberglass cast roll (5 inches and 3.6 meters long). The aluminium splints were used in 2 shapes; 'U' shaped and straight (Fig 1) depending upon the size of the bovine or the inter-digital gap in the hoof. The 'U' shaped aluminium splint was made using hammer on an iron angle, so as it sets in the inter-digital space of the hoof in the saggital plane of the limb. The U' splint was used in adult bovine having larger inter-digital space. Since, the 'U' part of the aluminium splint fits in the inter-digital space, so if the space is less, it puts undue pressure on the third phalanx. In small hoofed or young bovines, instead of 'U' shaped, straight aluminium splints of required length were used on the anterior and posterior surfaces of the limb. In heavy weight animals (more than 350 Kg), in addition to 'U' shaped splint, medial and/or lateral straight splints were also used.

The 'U' splint for the MC bone was made by moulding the straight aluminium splint into a 'U' shape with both arms straight. For the MT fractures, the arms of the U' splint were moulded in the shape of the hock at that level (Fig 1). The length of the arms was kept from the mid/proximal tibial/ radius region to the heel of the hoof. The arms of the U splint were doubled in heavy weight bovines, so as to avoid bending at carpal/tarsal joint. The arm length of the straight splint was same as that of U splint.

Steps for the application of external coaptation (Fig 2)

The bovine was restrained on comfortable bedding with the affected limb up. Usually, no sedation or anaesthesia was administered unless the bovine was very excited, where sedation using inj. xylazine @0.02mg/kg, or inj. midazolam @0.02mg/kg, intravenously, was given.

1. A piece of thick cotton string (approximately 70cm) was tied with a half slip knot just above the hoof for traction. The knot was kept on the lateral aspect of the hoof for alignment and traction. The other end of the string was tied to a piece of splint or wood for proper traction. Counter traction was applied by tying ropes placed underneath the humerus or femoral region to the other side of the casting bed. Fractured fragments were manipulated to attempt reduction before application of traction and counter traction.

2. Powder zinc oxide was generously applied all around the

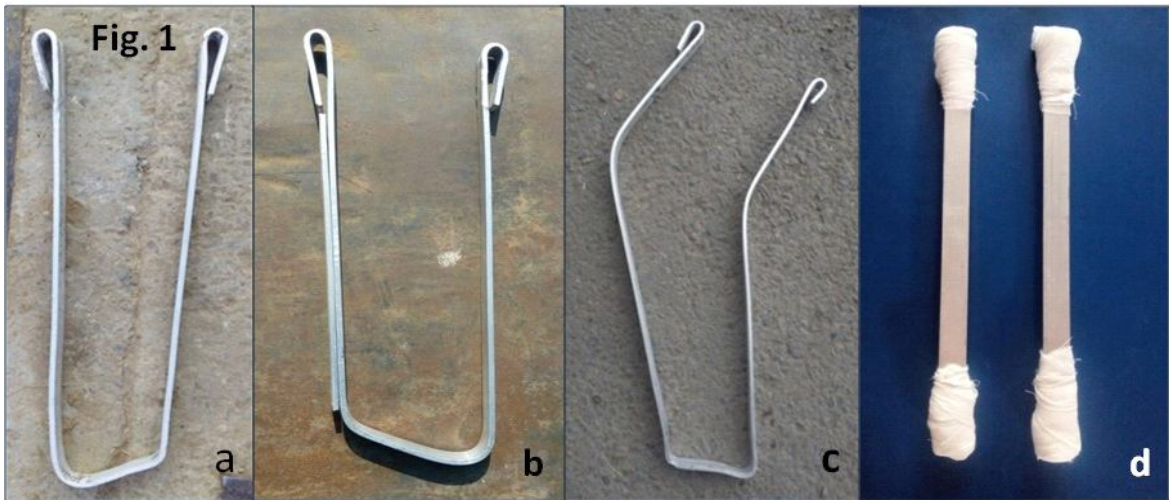

Fig 1: Photographs showing aluminium U' splint for metacarpal (a), with double arm (b), U' splint for metatarsal (c) and straight side splints with ends padded (d).

Fig 2: Photographs showing the procedure for U' splint application in simple metacarpal fracture. At presentation (a), application of zinc oxide and traction with thick cotton string (b), placement of cotton rolls under dew claw and all over the region (c), application of cotton bandage over the cotton rolls (d), application of wet bandage in inter-digital space and U' splint with double arms placed in saggital plane (e), tying of thick cotton string (f and g), application of fiberglass bandage (h), Standing buffalo with support of the affected limb after application of cast (i).

limb especially under the dewclaws, and bony protuberances like accessory carpal.

3. For MC fractures, the external coaptation included fixation of both carpal and the fetlock joints. Similarly, for MT fractures it included both tarsal and the fetlock joint of the affected limb.

4. The cotton rolls (approx. 6 inch wide x 1 inch thick) were applied all around the limb from the coffin joint to the proximal/mid radius ulna/ tibia region. Cotton was especially thick under the dew claws and at carpal joint to avoid splint induced pressure sores and to make the whole limb thickness uniform.

5. Wet cotton bandages were applied over the cotton.

6. A full wet cotton bandage or wet cotton was placed in the inter-digital space before placing the 'U' shaped splint so as to avoid injury due to U' part of the splint.

7. The U' Splint was applied over the bandaged limb in saggital plane and was tied hard with the thick cotton string in double interlocking manner so as to make it sufficiently tight to prevent slipping downwards and to fix the fetlock, pastern and carpal joint in near straight position. This was done to shift the weight on the limb from claws to the side bars of the splint. Care was taken that the cotton padding was more than the length of splint. For straight splints, they were applied on dorsal and plantar/palmar aspect and lateral and medial sides as per the requirement of the case. A layer of cotton bandage was applied over the tied splint.

8. Usually 2 fiberglass cast rolls for MC and 3 for MT in adult animals were used for cast application. For bovine weighing less than 100 Kg, one fiberglass cast roll for MC and 2 for MT were applied. The rolls were applied, with the following layer covering 75% of the previous layer. With the application of 2 rolls in adult metacarpal bone lead to almost 4 layers of fibreglass. The hoof was partially included in bovine with 'U' splint as the cast breaks while weight bearing and also it presses the splint on the third phalanx, thus causing pain. However, in bovine with straight splints, the hoof was fully included.

9. For the open MC or MT fractures (Fig 3), the application of external coaptation was slightly different as a window/ fenestration was required for daily antiseptic dressing of the wound. The wound margins were clipped or shaved of hairs and was generously cleaned with normal saline solution. If the wound was large, skin sutures (using silk no. 3) were also applied before cast application except for highly contaminated or old wounds which were usually left unsutured after flushing.

10. Analgesic (inj. Meloxicam @ 0.2mg/kg, intramuscular) was advised for 3 days in all the cases. In open fractures, antibiotics (inj. Ampicillin and Cloxacillin @ 10 mg/kg intramuscular and inj. Gentamicin sulphate @ 5 mg/kg

Fig 3: Photographs showing procedure of application of aluminum U' splint in compound metatarsal fracture in cattle. Aseptic preparation of wound (a), Suturing of wound (b), wetting of bandages (c), Application of zinc oxide (d), cotton rolling (e), window making at wound (f), wet cotton in inter-digital space and applying of U' splint (g), Tying of cotton string by leaving wound site (h), application of fiberglass cast and making window in it (I and j), placing of U' splint in hoof (k), bandaging of wound with antiseptic solution (l).

intramuscular) were prescribed for 5 days. The owner was advised to keep the bovine on the clean and padded floor, and to avoid slipping. Sutures were advised to be removed at 12-14 days, even if the wound was bad. In case of recumbent animals, the owner was advised to make the animal stand with support at least twice a day, may be with the help of chain pulley system and change the side of the bovine every 4-6 hours (to prevent the development of pressure sores on the body prominences) till the animal was able to stand of its own. The cast was advised to be kept for one month in young and 2 months in adult bovine.

Follow up and Clinical outcome

Based on the poor prognosis due to prolonged recumbency or poor wound condition (in open fractures), 10 bovine (with 11 fractures) were recommended for euthanasia before treatment and were not included in evaluating the outcome of external coaptation. The remaining bovine, were followed for fracture healing and the clinical outcome. But among these, 23 bovine died within a few days (due to recumbency, dystocia or sudden fall) though, the external coaptation was stable and intact. So, these (23 bovines) were also excluded from the study. The 7 bovine lost to follow up. So in total 60 survived bovine with 61 fractures were evaluated for the survival outcome of fractures; 35 cattle with 36 fractures (10 metacarpal and 26 metatarsal) and 25 buffaloes (19 metacarpal and 6 metatarsal). The fracture healing was assessed based on the affected limb usage based on the short videos and/or photographs sent by the owner through social media, owner satisfaction and radiographic findings when the bovine was presented to the hospital. The Mean ± Sd time of follow up was 61.56 ± 36.12 days (range 30 days to 270 days). One cow calf was followed for an exceptionally longer period i.e. for 480 days due to gastrocnemius laxity in contralateral limb.

The outcome of the surviving bovine was assessed as healed or non-union. Full weight bearing on the affected limb was considered healed. The following prognostic factors (signalment based and radiographic type of fracture based) were evaluated and correlated with the overall and survival outcome:

I. Signalment based:

1. The bovine presentation as recumbent or standing.
2. The fracture was closed or open.
3. The cause of trauma leading to fracture.
4. The age of the fracture, i.e., the duration of fracture at the time of presentation to the hospital. Based on the age of fracture the data was divided into 0-1 day old, 2-5 days, 6-10 days and 11-30 days old.
5. The first aid provided in the field before presentation to the hospital. Thick cotton padding with bandaging, or bamboo splint with bandaging or Plaster of Paris cast application including both proximal and distal joint was considered as adequate first aid.
6. The age of the bovine. It was classified into 3 groups. i.e., 0-1year, > 1 to 3 year and > 3 year.

7. The weight of the bovine. It was also classified into 3 groups. i.e., up to 100 Kg, 101-350 Kg and >350 Kg.

II. Radiographic type of fracture based: open and closed

The type of fracture based on radiographic classification such as Proximal Simple (PS), Proximal Comminuted (PC), Proximal Comminuted involving joint (PCA), Mid shaft Simple (MS), Mid shaft Comminuted (MC), Distal Simple (DS), Distal Comminuted (DC), Salter Harris (SH) I to V, Shattered whole bone (SWB) and Shattered whole bone with joint involvement (SWBA). Salter and Harris (1963) classification is recommended for young animals having epiphyseal plate so in the present study bovine of up to 18 months of age were included in it (Steiner *et al.* 1993a).

Statistical analysis

The quantitative data generated was subjected to statistical analysis using Microsoft Excel 2010. The mean and the standard deviation of all the numerical parameters were calculated in all the bovines. The student t-test was applied to test the significance of differences in different groups wherever required. The subjective data was analyzed using percentage basis; relative or absolute

RESULTS AND DISCUSSION

The details of 100 bovine (89 females and 11 males) with 103 fractures of MC and MT presented during the one year study period is depicted in Table 1. A markedly high per cent mortality/euthanasia (more than double) associated with MC and MT fractures in cattle was recorded {41.27%; 26 out of 63 (10 euthanized and 16 died)} as compared to buffaloes (18.92%; 7 out of 37; all 7 died). All except four bovine (2 cattle and 2 buffaloes) that died from day 2 to day 30 of treatment, the reason for death was recumbency. Majority of the non-survivors cattle (14/16, 87.5%) were recumbent and had open fractures; whereas in buffaloes, the reason for death was recumbency even in closed fractures (5/7; 71.43%). The overall per cent survival outcome for MC or MT fractures was almost similar in cattle and buffaloes (Table 2). Of the total survivors bovines fractures (n=61), U splint was applied in 29 and side splint in 32. In the cited literature, MC fractures have been reported to occur in double frequency than the MT fractures in cattle (Tulleners, 1986a; Steiner *et al.* 1993b; Tulleners, 1996; Arican *et al.* 2014) which were contradictive to the findings of this study. A high percentage of MC fractures in neonatal calves due to traction during assisted delivery might be a reason for this (Gangl *et al.* 2006; Arican *et al.* 2014; Belge *et al.* 2016; Akin, 2017), but in this study, only 2 cases of trauma due to traction were recorded (one MC and one MT). In this study the outcome of MC and MT fractures in cattle and buffaloes in relation to various prognostic parameters is as follows:

I. Prognostic Outcome based on the signalment (Table 2)
Prognostic outcome based on closed or open fracture

Of the total 103 fractures presented, 44 were closed (44/103=42.72%) and 59 (59/103=57.28%) were open. More per cent buffaloes had (67.57%; 25/37) closed fractures as compared to cattle (28.79%; 19/66). The 62.5% (30/48) of MC fractures and 25.45% (14/55) of MT fractures presented in bovine were closed suggesting that MT fractures are prone to become open. Among survivor bovine, 100% success was recorded in closed fractures (Fig 4 and Fig 5) and 65.51% (19/29) in open fractures (Fig 6 and 7). A high mortality was recorded in bovine with open (50.84%; 30/59) as compared to closed fractures (27.27%; 12/44). There were 54.36% fractures on the right side (56/103) of the MC and MT bones and 45.63% on the left side. The mortality of bovine was marginally high with left side fractures (22/47=46.80%) compared to the right side (20/56=35.71%).

Of the total 59 open fractures, in majority of bovines (71.18%, 42/59) the wound was present on the medial aspect followed by the lateral aspect (16.95%, 10/59), posterior aspect (8.47%, 5/59) and all around (3.39%, 2/59). In the entire buffaloes the wound was present on the medial aspect (11/12) except one on the posterior aspect. In cattle too, majority of the wounds were located on the medial aspect (31/47=65.96%). Two cattle had wound all around the bone and they died/euthanized in due course of time.

Long term and pain free survival had been reported to be excellent in closed fractures and fair to good in open fractures of MC and MT repaired using external coaptation in cattle (Tulleners, 1986b; Arican *et al.* 2014; Köstlin *et al.* 1990). External coaptation had also been reported to be economically and technically feasible with MC and MT fractures in cattle (Tulleners, 1996). In bovine, the survival outcome of closed fractures of MC and MT, irrespective of

Table 1: The details of 100 bovine suffering from metacarpal or metatarsal fracture (OS%=survival outcome as healed, C=closed, O=open).

	MC Buffaloes	MC Cattle	MT Buffaloes	MT Cattle
Bovine presented (n=100)	27	18 (+3 bilateral)	10	45
Bovine euthanized	0	3 (2C, 2O) (1 bilateral)	0	7 (1 C, 6 O)
Bovine treated	27	15 (16 fractures)	10	38
Bovine died	5 (3 C, 2 O)	5(1 C, 5 O)(1 bilateral)	2 (O)	11 (2 C, 9 O)
Lost to follow up	3	1	2	1
Bovine followed for outcome	19	9 (10 fracture)	6	26
Healed	17	8 fracture	5	21
OS %	17/19=89.47	8/10=80.00	5/6=83.33	21/26=80.77

Table 2: Outcome of metacarpal and metatarsal fractures based on various signalment based prognostic factors.

	Prognostic factors		MC Buffaloes (27)					MC Cattle (18+3)					MT Buffaloes (10)					MT Cattle (45)				
			P	SFU	H	NU	SO%	P	SFU	H	NU	SO%	P	SFU	H	NU	SO%	P	SFU	H	NU	SO%
1	**Presented closed or open**																					
	Closed		20	15	15	0	100	10	7	7	0	100	5	4	4	0	100	9	6	6	0	100
	Open		7	4	2	2	50	11	3	1	2	66.67	5	2	1	1	50	36	20	15	5	75
	Total		27	19	17	2	89.47	21	10	8	2	80	10	6	5	1	83.33	45	26	21	5	80.77
2	**Presented recumbent or standing**																					
	Recumbent	C	0	-	-	-	-	4	2	2	0	100	1	0	0	0	0	5	2	2	0	100
		O	0	-	-	-	-	4	0	0	0	0	4	2	1	1	50	10	2	2	0	100
	Standing	C	20	15	15	0	100	6	5	5	0	100	5	4	4	0	100	4	4	4	0	100
		O	7	4	2	2	25	7	3	1	2	33.33	0	0	-	-	-	26	18	13	5	72.22
	Total		27	19	17	2	89.47	21	10	8	2	80	10	6	5	1	83.33	45	26	21	5	80.77
3	**Cause of fracture**																					
	Slipped	C	14	9	9	0	100	4	3	3	0	100	3	3	3	0	100	4	2	2	0	100
		O	2	1	0	1	0	3	0	0	0	0	4	3	1	1	50	20	12	9	3	75
	Fight	C	2	2	2	0	100	0	0	-	-	-	0	0	-	-	-	1	0	0	0	0
		O	2	1	1	0	100	0	0	-	-	-	0	0	-	-	-	2	2	2	0	100
	Trapped in rope	C	4	4	4	0	100	1	1	1	0	100	0	0	-	-	-	1	1	1	0	100
		O	1	1	1	0	100	3	3	1	2	33.33	1	0	0	0	0	3	0	0	0	0
	Accident	C	0	0	0	-	-	4	2	2	0	100	2	1	1	0	100	2	2	2	0	100
		O	0	0	0	-	-	5	0	0	0	0	0	0	-	-	-	11	6	4	2	83.33
	Field trauma	C	0	0	0	-	-	1	1	1	0	100	0	0	-	-	-	1	1	1	0	100
		O	2	1	0	1	100	0	0	-	-	-	0	0	-	-	-	-	-	-	-	0
	Total		27	19	17	2	94.74	21	10	8	2	80	10	6	5	1	83.33	45	26	21	5	80.77
4	**Age of fracture**																					
	0-1 day		7	3	2	1	100	6	1	1	-	100	1	1	1	0	100	7	5	3	2	60
	2-5 days		8	6	6	0	100	10	5	4	0	80	4	2	1	1	50	18	9	7	2	77.78
	6-10days		6	4	4	0	100	1	0	-	-	0	2	1	1	0	100	10	5	4	1	80
	11-30 days		6	6	5	1	83.33	4	3	2	1	66.67	3	2	2	0	100	10	7	7	0	100
	Total		27	19	17	2	89.47	21	10	8	2	80	10	6	5	1	83.33	45	26	21	5	80.77
5	**Age of Bovine**																					
	0-1yr	C	2	2	2	0	100	4	3	3	0	100	2	2	2	0	100	4	4	4	0	100
		O	0	0	-	-	-	3	1	1	0	100	0	0	-	-	-	7	6	5	1	80
	>1-3yrs	C	1	1	1	0	100	3	2	2	0	100	0	0	-	-	-	0	0	-	-	-
		O	2	2	0	2	0	2	0	0	0	0	5	2	1	1	50	13	9	7	2	77.78
	>3yrs	C	17	12	12	0	100	3	2	2	0	100	3	2	2	0	100	5	2	2	0	100
		O	5	2	2	0	100	6	2	0	2	0	0	0	-	-	-	16	5	3	2	60
	Total		27	19	17	2	89.47	21	10	8	2	80	10	6	5	1	83.33	45	26	21	5	80.77
6	**Body weight of Bovine**																					
	Upto 100kgs	C	2	2	2	0	100	3	2	2	0	100	1	1	1	0	100	2	2	2	0	100
		O	0	0	-	-	-	2	0	0	0	0	0	0	-	-	-	4	3	2	1	66.67
	101-350kgs	C	1	1	1	0	100	3	2	2	0	100	1	1	1	0	100	3	3	3	0	100
		O	2	2	0	2	0	3	2	1	1	50	4	1	1	0	100	15	11	11	0	100
	351-600kgs	C	17	12	12	0	100	4	3	3	0	100	3	1	2	0	100	4	1	1	0	100
		O	5	2	2	0	100	6	1	0	1	0	1	1	0	1	0	17	6	2	4	33.33
	Total		27	19	17	2	89.47	21	10	8	2	80	10	6	5	1	83.33	45	26	21	5	80.77

MC=Metacarpal, MT=Metatarsal, P=Presented, SFU=Survival follow up, H=Healed, NU=Non-union, SO%=Survivor outcome as healed=H/SFU, C=Closed fracture, O=Open fracture.

fracture configuration, was 100% with the application of external coaptation applied in this study, so it was emphasized that radiographic evaluation may be skipped and early application of external coaptation is recommended to avoid fracture becoming open.

Prognostic outcome based on ambulation status of bovine as recumbent or standing (Table 2)

Of the total 100 bovine (with 103 fractures), 29% (29/100) were recumbent and the remaining 71 were standing. Markedly high per cent mortality was recorded in bovine presented as recumbent (72.41%) as compared to standing bovine (29.58%). However, among survivor recumbent (which later stood after treatment) the outcome of healing was 100% for cattle and 50% for the buffaloes.

In this study, none of buffalo with MC fracture was recumbent whereas 60% buffaloes with MT fractures were presented as recumbent. However, in cattle, recumbency

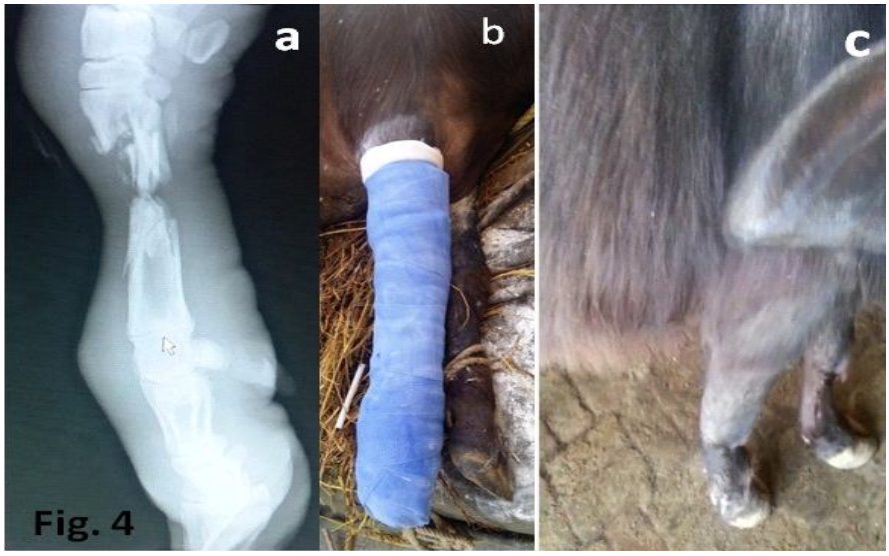

Fig 4: Buffalo, 1.5 yrs, 250 kgs, simple metacarpal, Lateral radiograph with comminuted proximal fracture and gaping (a), after side splints and fiberglass cast application with hoof involved (b), full weight bearing at 3 months (c).

Fig 5: Buffalo 5 years old, 400 kgs, one day old, trauma while running, simple metacarpal at presentation (a), Salter Harris II (b), weight bearing immediate after cast and U. splint (c), limb at 2 months after cast removal (d), radiograph at 2 months showing slight malunion but bridging callus (e), full weight bearing after cast removal at 2 months with slight bowing which got corrected in next follow up at one month (f).

Fig 6: Buffalo, 8yrs, trapped in rope, compound metacarpal fracture 25 day old (a), bone chip removed at cast application (b),Shattered whole bone (c), weight bearing immediate after cast application (d), full weight bearing at 3 month follow up (e).

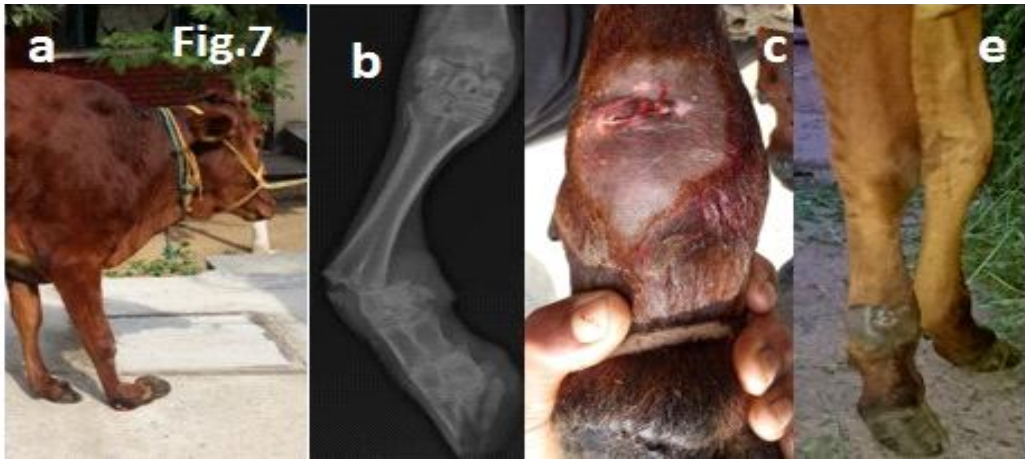

Fig 7: The 8 month old Sahiwal calf with one day old compound metacarpal fracture (a and c), Salter Harris I (b), full weight bearing with wound healed at 2.5 month follow up (e).

Fig 8: Bilateral simple metacarpal fracture in cow calf of 1.5yrs age, 3 day old occurred while running in field (a), Multiple fractures in left and midshaft comminuted in right (b), after cast and side splints application (c), follow up at 2 month with full weight bearing (d), compensatory hypertrophy of caudal femoral muscles (e), radiographic fracture healing at 2 months (f), immediately after fiberglass cast removal (g), at 3 month follow up with full proper weight bearing on both forelegs (h).

could not be correlated with the bone involved i.e. 27.77% with MC and 33.33% with MT fractures. Among recumbent MC fractures in cattle (n=5), 3 had bilateral fractures, so were supposed to be recumbent. Among these, one was euthanized, one died during follow up and one recovered completely (Fig 8).

Among recumbent, 10 (34.48%) had closed and 19 (65.52%) had open fractures suggesting that open fractures may lead to recumbency. The 16.67% (8/48) of MC fractures and 38.18% (21/55) of MT fractures in both the species (open or closed) were recumbent suggesting that MT fractures may lead to recumbency. Among standing survivor bovine, the outcome was 91.30% (21/23) in buffaloes and 76.67% (23/30) in cattle.

Euthanasia had been recommended in cases of MC and MT fractures of cattle due to economic reasons, osteomyelitis or concurrent lameness (Steiner *et al.* 1993b). Recumbent or standing cattle were not discussed as prognostic criteria for fracture healing in the published literature. But, in the present study, recumbency was found to be associated with open and MT fractures and mortality was more than double in recumbent bovine with MC or MT fractures compared to those presented standing. The bovine which died on follow up treatment, were not included in the evaluation of success of fracture healing in this study as the mortality was not related to external coaptation failure. In contrast to buffaloes, open fractures with recumbency were the major reason of non-survivability in cattle. Frequent occurrences of open fractures of MT and MC in cattle have been reported to be associated with large force necessary to cause the fracture and the limited soft tissue supporting structures covering the bone (Ferguson, 1982). Thick skin of buffaloes as compared to cattle might be the reason for less percent of open fractures in buffaloes compared to cattle. No correlation between the closed and open fractures in relation to age or body weight was found (Steiner *et al.* 1993a); instead the fracture configuration with sharp fragments was the predisposing factor for the fracture to become open. Another study by Adams and Fessler, (1996) found that delay in fracture treatment result in soft tissue damage and also increases the risk of infection.

Prognostic outcome based on the cause of trauma (Table 2)

Slipping on the hard floor (stall fed system followed in the region of study) was the major reason for MC and MT fracture in bovine (53% with 54 fractures) with buffaloes slightly more affected (62.61%: 23/37) than cattle (47.61%: 30/63). The fractures occurring due to slipping were mostly open (23 out of 31=74.19%) in cattle compared to buffaloes (6 out of 23=26.08%). The second most common cause for fracture in cattle was accident (30.16%: 19/63) due to vehicle followed by trauma due to entangling in a rope {n=14 (13.59%); 6 buffaloes (16.21%) and 8 cattle (12.12%)} and fight with another bovine {n=7: 6.79%; 4 buffaloes (10.81%) and 3 cattle (4.55%)}. In buffaloes, the fight resulted in closed MC fracture while in cattle mostly open MT fractures. Dystocia traction was the reason for fracture in 2 cow calves (one MC and one MT). Both the calves recovered. The calf with MT fracture also had the gastrocnemius laxity in the contra-lateral limb, which healed slowly with time (Fig 9).

Overall, trauma due to fight or field trauma or traction during dystocia has 100% survival outcome as healed fracture and lowest mortality (25% to 28.57%). Highest

Fig 9: Photographs showing proximal metatarsal fracture (a) in a new born calf due to traction during delivery. The other limb also showed gastrocnemius laxity (b), One month follow up radiograph with bridging callus (c), full weight bearing on fractured limb at one month but laxity in other limb (d), complete recovery in both limbs at 16 months (e).

mortality was seen in accident cases (54.17%) followed by fractures due to slipping (38.88%).

Prognostic outcome based on the age of fracture (Table 2)

The highest numbers of fractures of MC and MT were presented in the 2-5 days of trauma (n=40, 38.83%; 12 in buffaloes (32.43%) and 28 (42.42%) in cattle). More per cent of open fractures (25: 62.5%) were presented early as compared to closed (15: 37.5%) and more than 50% (n=22) of the bovine presented in this group were euthanized or died in due course of time. Among the survivors the outcome was 100% for the closed fractures (n=11) and 75% (6/8) for open fractures, irrespective of the species.

The second highest number of bovines was presented from 11-30 days of trauma (n=23: (22.33%) with 9 (24.32%) in buffaloes and 14 (13.59%) in cattle). Only 5 bovines (21.74%) of this group were euthanized or died in the course of the disease, which in comparison to 2-5 days group was quite low. In this group, the outcome of the survivors for MT fractures was 100% for both cattle and buffaloes.

Overall, highest mortality was recorded in the bovines presented early on 0-1 day (52.38% =11/21) followed by 6-10 days (47.37% =9/19), 2-5 days (45% =18/40) and the least in 11-30 days group (21.74% =5/23). However, the overall per cent survival outcome as healed was maximum in 6-10 days and 11-30 days as 90% (9/100) and 88.88% (16/18) respectively, and the lowest at 0-1 day as 77.77% (7/9). From the above observations, it was concluded that the mortality decreased with the increase in the age (duration) of fracture while the survival outcome as healed increased which may be because, with the passing days, most of the poor prognostic bovine might have been died and were not presented for treatment at referral hospital. The age of fracture at presentation had been reported to be between 1-144 hrs (Steiner *et al.* 1993a) and 0-42 days (Gangl *et al.* 2006) which might vary depending upon the availability of treatment facilities. Steiner *et al.* (1993a) reported no correlation between the duration of fracture at treatment with the outcome.

Prognostic outcome based on First aid provided before presentation

Out of 103 fractures presented, none of the bovine was provided with adequate first aid as per the criteria in materials and methods. The 23 bovines had some level of first aid (22.33%) and the remaining 80 bovines (77.67%) were presented without any first aid. Mild first aid or bandaging was usually done in bovines with compound fractures so that bleeding can be stopped. Comparatively high per cent of bovine that were presented with no first aid, were euthanized or died (43.75%; 35 out of 80) as compared to those having some level of first aid done (30.43%; 7 out of 23).

Correct first aid is strongly recommended for MC and MT fractures, as these are prone to becoming open as soon as the bovine takes weight on the affected limb while trying to get up after trauma (Tulleners, 1996). In first aid, at least proximal and distal joint are to be incorporated in splint or PVC pipes (Tulleners, 1996; Fessler and Adams, 1996, Anderson and Jean, 2008); however, some even recommend splinting up to the point of shoulder (Mulon, 2013), to avoid bending of the limb. But in the region of this study, farmers have the notion that if carpal or tarsal joint was included in the splint, the bovine would not be able to sit, so they tightly tie the fractured bone in between the joints using bamboo splints and jute rope, thus leading to wound formation, and hence, a guarded prognosis in even closed fractures. In this study, the survival healing was better in bovine not provided first aid, but the mortality was also higher in this group, thus, it was found that though the first aid may not affect the healing of fracture but it may reduce the mortality in fractured bovine as it reduces the pain due to movement of fracture fragments. The PVC pipes, cotton and cast are also recommended as treatment option for small ruminants like goat, sheep and young bovine (Diphode, 1994; Prabhakar *et al.* 2012; Velavan *et al.* 2014; Jahangirbasha and Desai, 2017).

Prognostic outcome based on the age of the bovine (Table 2)

A total of 55 bovine (53.4%) with 25 buffaloes (25/37=67.57%) and 30 cattle (30/66=45.45%) were > 3years of age. In this age group; buffaloes had 20 closed fractures (80%) and 5 open fracture, while in cattle; 8 closed (26.67%) and 22 open fractures. Out of 55 bovine, 50.90% bovine were euthanized /died or lost to follow up (28/55) of which 9 were buffaloes (32.14%) and 19 were cattle (67.56%), and 10 closed and 18 open fractures. The survivor outcome as healing of this group was 85.18%.

The next age group with maximum fractures was 1-3 years (26/103=25.24%) with 8 buffaloes (8/37=21.62%) and 18 (18/66=27.27%) cattle. The mortality was 34.61% (9/26) and the survival outcome as healed was 68.75% in this group. Twenty two fractures (21.36%) were recorded in bovine upto 1 year of age with 4 buffaloes (4/37=10.81%) and 18 cattle (18/66=27.27%). None of the buffaloes died in this group while the mortality was 18.18% (4/22) in cattle. The overall outcome as healed among survivor bovine was 93.75%.

The overall mortality increased with the age of the bovine in MC and MT fracture, however, the survival outcome as healed was similar in very young or adult bovine. Moreover, no correlation between the age of the bovine and open fracture was recorded in the current study.

The MC and MT fractures in cattle are more reported in young age (upto 3 years) (Tulleners, 1996), but, in this study bovine up to the age of 9 year were reported. Steiner *et al.* (1993a) reported no correlation between the age of the bovine or with the duration of fracture at treatment with the outcome which corroborated to the findings of this study. However, Jean and Anderson (2014) observed that success of fracture treatment was more in young compared to adult cattle due to light body weight and higher healing rate and greater stability of fixation devices.

Prognostic outcome based on the body weight of the bovine (Table 2)

Maximum number of bovine (n=57, 57/103=55.34%) were presented in the weight group of 351-600Kg which included 26 buffaloes (26/37=70.27%) and 31 cattle (31/66=46.97%). The mortality was 50.88% (29/57) of which 9 were buffaloes (9/26=34.62%) and 20 cattle (20/31=64.51%). The overall survival success rate of fracture healing was 78.57% in this group.

The second highest numbers of fractures were reported in the weight group of 101-350 kgs (32/103; 31.07%) with 8 buffaloes (8/37=21.62%) and 24 (24/66=36.36%) cattle. The mortality was 28.13% (9/32) with 88.88% (8/9) in open fractures. The overall survivor bovine success rate was 86.96%.

The least number of bovines were presented in the weight group of up to 100 kgs with 14 bovine (14/103=13.59%: 3 buffaloes (3/37=8.11%) and 11 (11/66=16.67%) cattle). All the 3 buffaloes and 50% cattle had closed fractures. No buffalo died in this group while 3 cattle (4 fractures) were euthanized or died (3/14=21.43%). The survival outcome as healed fracture was 90% for this group.

Thus, the overall mortality increased with the increase in the body weight while the survival outcome as healed was maximum in young calves of body weight upto 100 Kg (90%). Steiner *et al.* (1993a) reported no correlation between the weight of the bovine with the outcome. However, Jean and Anderson (2014) observed that success of fracture treatment was more in young compared to adult cattle due to light body weight and higher healing rate and greater stability of fixation devices which corroborated to the findings of this study.

II. Prognostic outcome based on the radiographic type of fractures

The radiographic classification of fractures (Fig 10 and 11) was done separately for closed and open fractures (Table 3). Of the total 59 open fractures (59/103=57.28%) of MC and MT presented; 12 were in buffaloes (12/59=20.34%) and 47 in cattle (47/59=79.66%). There were 13 proximal (13/59=22.03%), 22 midshaft (22/59=37.29%), 15 distal (15/59=18.25.43%), 5 Salter Harris (5/59=8.47%) and 4 shattered whole bone fractures (4/59=6.78%) recorded. The maximum number of open fractures recorded was midshaft simple (oblique or transverse) in cattle MT. In comparison to cattle, the buffaloes had no midshaft simple, proximal comminuted, distal comminuted or Salter Harris II type of open fracture. The cattle had more percentage of open fractures (79.66%), with 87.23% (41/47) fracture of midshaft or distal region and that too oblique with sharp edges or transverse which might be the reason for high occurrence of open fractures in cattle.

A total of 44 closed fractures of MC and MT were presented in bovine with 25 in buffaloes (25/44=56.81%) and 19 in cattle (19/44=43.18%). Proximal fractures were 14 (14/44=31.81%), midshaft 12 (12/44=27.27%), distal 4 (4/44=9.09%), Salter Harris 6 (6/44=13.64%) and shattered

Fig 10: Radiographs showing different type of fractures in buffalo; Proximal third Comminuted (a), Midshaft Transverse (b), Midshaft Oblique (c) Midshaft Comminuted (d), Distal third Oblique (e), Distal third Comminuted (f), Salter Harris I (g), Salter Harris IV (h), Salter Harris V (i), Shattered Whole Bone (j).

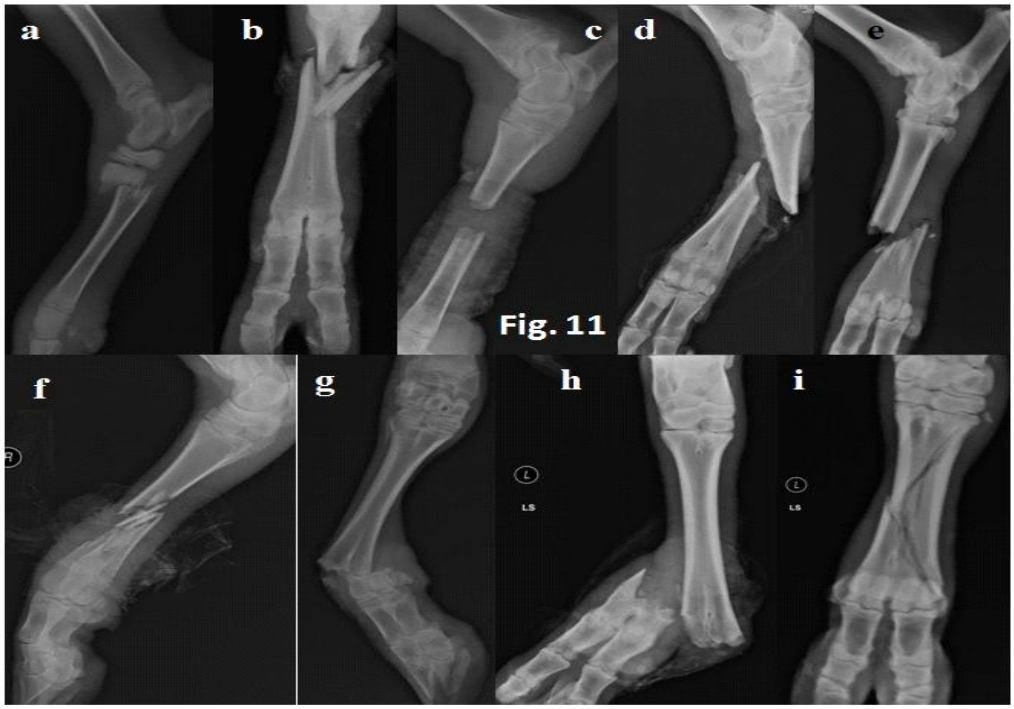

Fig 11: Radiographs showing different types of fractures in cattle; Proximal Transverse (a), Proximal Comminuted (b), Midshaft Transverse (c), Midshaft Oblique (d), Distal Oblique (e), Midshaft Comminuted (f), Salter Harris I (g), Salter Harris II (h), Shattered Whole Bone (i).

whole bone 8 (8/44=18.18%). In buffaloes, most of the Salter Harris and shattered whole bone fractures were closed, while in cattle more than 50% of Salter Harris fractures were open. The overall survival outcome as healed of Salter Harris fractures in bovine was 90.90% (10/11) with 100% in closed fractures.

Tulleners (1996), reported a high percentage of distal epiphyseal and distal metaphyseal fractures (32% each) followed by 26% diaphyseal and only 10% proximal metaphyseal, but the results of this study showed the highest fractures to be diaphyseal (33.33%) followed by proximal metaphyseal (27.27%) region in cattle. In buffaloes, the shattered whole bone and Salter Harris fractures of MC and MT were less open, and the distal oblique and midshaft simple fractures were not recorded in buffaloes, while they were seen in cattle and were predominantly open. In cattle of this study, the number of SH I fractures were more, although literature reveal SH II to be most common (Tulleners, 1986a). Steiner *et al.* (1993a) reported that long term outcome of closed physeal fractures healed with external coaptation to be disappointing due to developmental limb deformity in young calves, but the outcome was recorded satisfactory in this study. The difference is radiographic configuration of fractures in cattle and buffaloes may be due to the length or circumference of bone in the two species.

Wilson and Vanderby (1995) reported that fiberglass with a single splint (made of 4 layers of 2" wide casting materials) applied to compression and tension sides had more tensile strength than fiberglass with a single splint applied to tension side or cast without splints. The complication of breakage of cast on the compression site (Mulon and Desrochers, 2014) was not recorded in the present study, which may be due to use of aluminium splints that are strong and easy to mould. Also that with the use of aluminium splints a maximum of 4 layers of fiberglass cast in MC and 6 in MT were applied for the adult bovine, thus markedly reducing the cost of treatment. In contrast, Mulon (2013) recommended 6-8 layers of fiberglass cast in calves and upto 15 layers in adult. The compression sites like caudal aspect of carpal and proximal aspect of tarsal should be strongly reinforced to avoid bending and cracks in the casts (Diphode, 1994). In adult buffaloes having MC fracture, the arms of the U splint were doubled to avoid bending of splint at the caudal aspect of the carpal. Use of side splints with involvement of hoof in cattle reduces the superficial flexor tendon laxity after removal of cast, which otherwise is common if hoof is not involved (Tulleners, 1986a; Mulon, 2013; Mulon and Desrochers, 2014). The cast in adult bovine was usually removed at 2 months, while in calves at one month. No reapplication of cast was done in closed fractures of this study. Although, literature recommends reapplication of cast after 2-4 weeks in young bovines (Adams and Fessler, 1996; Mulon, 2013) and 6-8 weeks in adult cattle (Mulon, 2013) and to be kept for 4 weeks in young physeal fractures and 6 weeks in non-physeal and 8-10 weeks or may be 12-16 weeks in adults for the clinical union (Anderson and Jean, 2008). Delayed removal (more than 2 months) of

Table 3: Outcome of metacarpal and metatarsal fractures based on radiographic type of fracture as a prognostic factor.

Prognostic factors		MC Buffaloes (27)					MC Cattle (18+3)					MT Buffaloes (10)					MT Cattle (45)				
		P	SFU	H	NU	SO%	P	SFU	H	NU	SO%	P	SFU	H	NU	SO%	P	SFU	H	NU	SO%
1 Radiographic type of open fractures																					
Proximal	S	1	1	0	1	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0
	Co	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	CA	0	0	0	0	0	2	0	0	0	0	1	1	1	0	100	6	4	3	1	75
Midshaft	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	5	3	2	60
	Co	2	1	1	0	100	3	1	0	1	0	2	1	1	0	100	2	1	0	1	0
Distal	S	1	0	0	0	0	4	1	0	1	0	0	0	0	0	0	9	6	5	1	83.33
	Co	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
SH I		1	1	0	1	0	1	1	1	0	100	0	0	0	0	0	3	3	3	0	100
SWB		1	1	1	0	100	0	0	0	0	0	1	0	0	0	0	1	1	1	0	100
SWBA		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		7	4	2	2	50	11	3	1	2	33.33	5	2	2	0	100	36	20	15	5	75
2 Radiographic type of closed fractures																					
Proximal	S	0	0	0	0	0	1	1	1	0	100	0	0	0	0	0	2	1	1	0	100
	Co	4	3	3	0	100	2	1	1	0	100	0	0	0	0	0	0	0	0	0	0
	CA	1	1	1	0	100	1	0	0	0	0	1	1	1	0	100	2	2	2	0	100
Midshaft	S	2	1	1	0	100	1	1	1	0	100	2	1	1	0	100	0	0	0	0	0
	Co	4	2	2	0	100	1	1	1	0	100	0	0	0	0	0	2	1	1	0	100
Distal	S	2	2	2	0	100	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Co	1	1	1	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SH I		1	1	1	0	100	1	1	1	0	100	0	0	0	0	0	0	0	0	0	0
SH II		0	0	0	0	0	1	1	1	0	100	0	0	0	0	0	2	2	2	0	100
SH V		1	1	1	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SWB		4	3	3	0	100	1	1	1	0	100	2	2	2	0	100	1	0	0	0	0
Total		20	15	15	0	100	10	7	7	0	100	5	4	4	0	100	9	6	6	0	100

MC=Metacarpal, MT=Metatarsal, P=Presented, SFU=Survival follow up, H=Healed, NU=Non-union, SO%=Survivor outcome as healed=H/SFU, S=Simple, Co=Communited, CA=Communited articular, SH=Salter Harris, SWB=shattered whole bone with minimal displacement, SWBA=shattered whole bone articular.

the cast in the bovine of the present study was found to cause pressure sores due to splint. In the present study, in open fractures, a window was left in the cast for wound dressing, although this technique of window in the cast of open fractures is variably accepted (Mulon, 2013), as it is believed that it weakens the cast, but this complication was not recorded in this study which would be due to the use of aluminium splints.

Cattle were applied more of straight side splints while, adult buffaloes were always applied 'U' splint, as inter digital cleft was sufficiently wide so as to get the 'U' splint properly fitted into the hoof, providing saggittal stability and the buffalo can immediately support weight on it, which is one of objective in bovine (Mulon and Desrochers, 2014). The 'U' splints and side splints were observed to be suitable for buffaloes and cattle, respectively, in both closed and open fractures.

The problem of over-swelled wound was found in few open fracture (Mulon, 2013) which in the present study was supposed to be due to pressure of cotton strings or fiber glass cast on the both sides of the wound. This granulation was removed surgically in most of the cases of the present study.

Akin (2017) reported left sided MC fracture to be more (19/32=59.37%) compared to right side (13/32=40.62%), but in this study, comparatively, right side was more affected than the left side. One calf out of 3 reported with bilateral MC fractures, in the present study, survived and healed using external coaptation using aluminium splints and fiberglass cast, which was rare and required great care by the owner. Earlier also, successful treatment of ipsilateral fractures in 2 buffalo calves using external coaptation had been reported (Prabhakar *et al.* 2012).

CONCLUSION

• Cattle are prone to compound fractures of metacarpal or metatarsal bone and are associated with high mortality as compared to buffaloes.

• All metatarsal and open metacarpal fractures associated with recumbency are indicators of poor prognosis in bovine.

• The survival outcome as healed, of closed metacarpal and metatarsal fracture is excellent, irrespective of species and radiographic configuration.

• The aluminium U splints with fiberglass cast is recommended for the management of metacarpal / metatarsal fractures in adult heavy cattle and buffaloes whereas side splints with fiberglass cast involving hoof is recommended in young bovine.

ACKNOWLEDGEMENT

Authors are thankful to Indian Council of Agricultural Research (ICAR), India for the financial support provided under the project, 'All Indian Network Program on Diagnostic Imaging and Management of Surgical Affections in animals'. Authors also acknowledge Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India for providing necessary facilities to conduct this study.

REFERENCES

Adams, S.B., Fessler, J.F. (1983). Treatment of radial-ulnar and tibial fractures in cattle using a modified Thomas splint-cast combination. Journal of American Veterinary Medical Association. 183(4): 430-433.

Adams, S.B., Fessler, J.F. (1996). Treatment of fractures of the tibia and radius-ulna by external coaptation. Veterinary Clinics of North America: Food Animal Practice. 12(1): 181-98.

Akin, I. (2017). Calf metacarpal fractures in association with bovine dystocia: Case series among calves. Ataturk University Journal of Veterinary Science. 12(3): 235-241.

Anderson, D.E., Jean, G.S. (2008). Management of fractures in field settings. Veterinary Clinics of North America: Food Animal Practice. 24: 567-582.

Arican, M., Erol, H., Esin, E., Parlak, K. (2014). Retrospective study of fractures in neonatal calves: 181 Cases (2002-2012). Pakistan Veterinary Journal. 34(2): 247-250.

Belge, A., Akin, I., Gülaydin, A., Yazici, M.F. (2016). The treatment of distal metacarpus fracture with locking compression plate in calves. Turkish Journal of Veterinary and Animal Sciences. 40: 234-242.

Diphode, J.M. (1994). Comparative study of different types of splintage in the treatment of long bone fractures of sheep and goats. Indian Veterinary Journal. 71:70-72.

Ferguson, J.G. (1982). Management and repair of bovine fractures. Compendium of Continuing Education Practice Veterinary. 4: 128-136.

Fessler, J.F., Adams, S.B. (1996). Decision making in ruminant orthopaedics. Veterinary Clinics of North America: Food Animal Practice. 12(1): 181-198.

Gangl, M., Grulke, S., Serteyn, D., Touati, K. (2006). Retrospective study of 99 cases of bone fractures in cattle treated by external coaptation or confinement. Veterinary Record. 158(8): 264-268.

Jahangirbasha, D., Desai, T. (2017). Surgical management of long bone fractures with POP and moulded PVC pipes – A clinical study in Khillari bullocks. Intas Polivet. 18(2): 459-461.

Jean, G.S., Anderson, D.E. (2014). Decision analysis for fracture management in cattle. Veterinary Clinics of North America: Food Animal Practice. 30(1): 1-10.

Köstlin, R.G., Nuss, K., Elma, E. (1990). Metacarpal and metatarsal fractures in cattle: Treatment and results. Tierärztliche Praxis. 18(2): 131-144.

Mulon, P.Y. (2013). Management of long bone fractures in cattle. In Practice. 35: 265-271.

Mulon, P.Y., Desrochers, A. (2014). Indications and limitations of splints and casts. Veterinary Clinics of North America: Food Animal Practice. 30(1): 55-76.

Prabhakar, V., Raghunath, M., Singh, S.S., Mohindroo, J., Singh, T., Verma, P. (2012). Clinical management of metacarpal and metatarsal fractures in two buffalo calves. Intas Polivet. 13(2): 395-398.

Salter, R.B., Harris, W.R. (1963). Injuries involving the epiphyseal plate. Journal of Bone and Joint Surgery. 45: 587-622.

Steiner, A., Iselin, U., Auer, J.A., Lischer, C.J. (1993a). Physeal fractures of the metacarpus and metatarsus in cattle.

Veterinary Comparative Orthopaedic and Traumatology. 6: 131-137.

Steiner, A., Iselin, U., Auer, J.A., Lischer, C.J. (1993b). Shaft fractures of the metacarpus and metatarsus in cattle. Veterinary Comparative Orthopaedic and Traumatology. 6: 138-145.

Tulleners, E.P. (1986a). Management of bovine orthopedic problems, Part I: Fractures. Compendium of Continuing Education Practice Veterinary. 8: 69-79.

Tulleners, E.P. (1986b). Metacarpal and metatarsal fractures in dairy cattle: 33 cases (1979-1985). Journal of American Veterinary Medical Association. 189: 463-468.

Tulleners, E.P. (1996). Metacarpal and metatarsal fractures in cattle. Veterinary Clinics of North America: Food Animal Practice. 12(1): 199-209.

Velavan, A., Sivaraman, S., Krishnakumar, K. (2014). Successful management of a compound fracture in a Buffalo using a fabricated Polyvinylchloride splint in a field setting. Buffalo Bulletin. 33(3): 246-250.

Wilson, D.G., Vanderby, R. (1995). An evaluation of fiberglass cast application techniques. Veterinary Surgery. 24(2): 118-121.