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Clinico- physiological and haemato-biochemical observations while using external skeletal fixation for the treatment of fracture of long bones in goats#

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Abstract

The study was conducted in six clinical cases of fracture of metatarsal and metacarpal bones in goats free from neurologic, metabolic or infectious diseases, irrespective of age, breed, sex, and bodyweight. All the goats found fit for surgical procedure were treated with uniplanar bilateral external skeletal fixation using epoxy putty connecting bars under general anaesthesia. Clinical, physiological, haematological and biochemical evaluations were conducted preoperatively and during second, fourth, sixth and eighth postoperative weeks. Normal weight bearing with excellent functional outcome was noticed by eighth postoperative week. In the present study, physiological and haematological parameters varied within the normal range throughout the period of observation. The serum calcium and phosphorus levels showed a decline initially followed by increase in eighth postoperative week, but the values were within the normal physiological range. The preoperative serum alkaline phosphatase level was found elevated during the day of presentation which decreased at second postoperative week and increased during the later weeks. From the present study, it could be concluded that surgical management of long bone fractures using a uniplanar bilateral external skeletal fixation using epoxy putty connecting bars did not significantly affect the physiological and haemato-biochemical parameters in goats.

Keywords: *Fracture, External skeletal fixation, haematology, biochemistry, goats*

Fractures of long bones are one of the most frequently reported orthopaedic problems in goats and require effective stabilisation for restoration of limb function. Traditional methods such as external coaptations are generally inadequate for providing rigid immobilisation, often result in malunion, delayed union, or non-union of fractures, limb stiffness and skin slough off (Wright, 2022; Lakshmi, 2024). Internal fixation techniques like intramedullary pinning, bone plating, and interlocking nailing have been successfully employed to provide rigid fixation, but these methods are associated with disadvantages including extensive surgical exposure, increased operative time and disruption of soft

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tissue and vascular structures surrounding the fracture site (Jahangirbasha, 2019). These limitations necessitated the exploration of alternative fixation systems that can ensure adequate stability while preserving the biological environment essential for bone healing.

External skeletal fixation (ESF) has been increasingly recognised as a valuable technique in small animals for the management of long bone fractures. The method provides rigid stabilisation with minimal surgical exposure and allows preservation of the periosteal blood supply, thereby promoting biological osteosynthesis (Julie, 2005; Vogel and Anderson, 2014). ESF also offers several practical advantages such as versatility in frame configuration, adjustability during the healing period, reduced risk of implant failure and relatively lower cost compared to internal fixation systems (Julie et al., 2007 and Bini and Syam, 2014b). Moreover, the technique facilitates early functional weight bearing, which is beneficial for preventing complications like muscle atrophy and joint stiffness.

Fracture healing is a dynamic biological process that progresses through inflammatory, reparative and remodelling stages, accompanied by distinct biochemical alterations indicative of bone regeneration. Biochemical markers such as serum calcium, phosphorus, and alkaline phosphatase (ALP) are closely associated with bone mineralisation and osteoblastic function. Assessment of these parameters offers important insights into the metabolic events occurring during bone repair (Kumar and Poddar, 2025).

Taking into account these attributes, the present investigation was undertaken to evaluate the clinical, physiological, and haemato-biochemical responses associated with the use of external skeletal fixation in the management of long bone fractures in goats. The findings of this study are expected to contribute to the understanding of systemic and local responses during fracture healing when treated with ESF, thereby strengthening its application as a reliable technique in small ruminant orthopaedics.

Material and methods

Six goats of varying breed, sex, age and bodyweight presenting with long bone fractures, were selected for the study. Pre-surgical evaluation of the patient was conducted and all the goats were subjected to treatment of fracture by uniplanar bilateral ESF using epoxy putty connecting bars under general anaesthesia with informed consent of the owner (Suresh et al., 2017). Clinical, physiological, haematological and biochemical evaluations were conducted preoperatively and on second, fourth, sixth and eighth postoperative weeks. The goats were administered with antibiotics Ceftriaxone at 15 mg per kg body weight for five days and analgesics Meloxicam 0.5 mg per kg body weight for three days postoperatively and the operated limb was protected with a bandage to prevent entanglement. Statistical analysis of data was carried out using Repeated measures of ANOVA and Friedman test by SPSS version 24.0.

Results and discussion

In the present study, clinical evaluation revealed non–weight-bearing lameness, oedema, and pain on palpation of the fracture site in all the cases at the time of presentation to the hospital. Oedema subsided by the third day following the application of magnesium sulphate–glycerine paste and a Modified Robert-Jones bandage, while pain on palpation resolved by the second postoperative week. The physical status of all the cases indicated normal growth and development during the postoperative period. Lameness grade showed gradual improvement, progressing to normal weight-bearing by the eighth postoperative week, with a good functional outcome. The conjunctival mucous membrane remained

Table 1. Observations on physiological parameters

Physiological parameters	DOP	DOS	Week 2	Week 4	Week 6	Week 8	p value
Rumen motility* (per 2 min)**	1(1)	1 (0.25)	1 (0)	1 (1)	1 (1)	1.5 (1)	0.453^{ns}
Capillary refill time	Less than two seconds in all animals						-

(*** Rumen motility was analysed using the Friedman test (values expressed as Median (IQR)); ns = non-significant)

Table 2. Observations on physiological parameters

Physiological parameters	Day of presentation	Day of surgery	Week 2	Week 4	Week 6	Week 8	p value	F value
Respiration rate (per min)	30.00±0	28.83±0.48	33.00±1.32	30.67±1.28	32.50±1.98	30.50±1.28	0.212^{ns}	1.544
Pulse rate (per min)	100.67±5.16	99.67±2.49	100.8±3.03	104.8±4.06	100.83±1.99	103.17±2.4	0.725^{ns}	0.567
Rectal temperature (°C)	$39.0±0.10^{a}$	$39.6±0.11^{b}$	$39.2±0.14^{ab}$	$38.9±0.14^{c}$	$39.2±0.09^{abc}$	$39.4±0.10^{d}$	0.002**	5.280

(Parameters were analysed using Repeated Measures ANOVA. Means bearing different superscripts within a row differ significantly.)
(** Significant at $p < 0.01$; * Significant at $p < 0.05$; ns = non-significant)

pink and capillary refill time was consistently less than two seconds in all cases throughout the study period (Table 1). Similar findings were reported by Ashok et al. (2018).

The pulse rate and rate of respiration varied between weeks but did not differ significantly, whereas rectal temperature (°C) differed significantly between the weeks during the observation period (Table 2). This could be due to the stress induced by long distance transportation of the animal.

Total erythrocyte count, packed cell volume, and haemoglobin concentration values remained within the normal physiological limits. An increase in these values was observed by the eighth postoperative week compared to the day of presentation, but the difference was not statistically significant. These findings were in accordance with Kokila et al. (2023), who reported that a well-balanced diet and proper care of affected animals helped to maintain haematological stability. A transient decrease in packed cell volume after surgery, followed by a gradual increase in the subsequent weeks, might be attributed to splenic sequestration of erythrocytes, as suggested by Uwagie-Ero et al. (2016). The low RBC values after surgery might have been due to blood loss, surgical stress, and the fracture itself, which is consistent with the observations of Athira (2018) (Table 3).

The total leucocyte count showed a gradual but non-significant decrease during the study period. In contrast, a significant decrease in the total granulocyte count was observed from the day of presentation up to the eighth postoperative week, which is in agreement with the findings of Rani (2025). Neutrophil counts increased initially, reflecting their role as the body's first line of defence, mediated by inflammatory chemical factors such as bradykinin, cytokines, serotonin (5-HT), prostaglandins, and wound-healing mediators. A significant rise in lymphocyte count was also recorded during the same period, which may be attributed to tissue injury and inflammation stimulating macrophages and monocytes to release immunoregulatory cytokines. Monocyte counts exhibited non-significant variations at different postoperative intervals, as observed by Kumar et al. (2016) in goats. The platelet count remained within the normal physiological range, and the variations were not significant, which was in accordance with the findings of Kokila et al. (2023) (Table 3).

Serum calcium and phosphorus levels in the present study exhibited fluctuating patterns during the postoperative period but remained within the physiological range. Calcium showed a slight decline at the inflammatory phase, followed by a gradual rise, reaching peak values by the eighth week remodelling phase (Table 4) (Fig. 1). This trend, though statistically non-significant, might reflect the role of calcium in callus formation and mineralisation of osteoid matrix, in line with the observations of Rani and Ganesh (2003), Mohiuddin (2018) and Sravanti et al. (2022), while Athira (2018) and Sharat et al. (2022) reported that calcium levels increased during the initial postoperative weeks and returned to normal by the eighth postoperative week when using Type II ESF and bone plating. Phosphorus levels increased at the second week, declined to the lowest point by the sixth week, and rose

Table 3. Observations of haematological parameters

Haematological parameters	Day 0	Week 2	Week 4	Week 6	Week 8	p value	F value
Total erythrocyte count (10^6/µL)	13.11±1.42	12.93±0.99	12.64±0.97	13.27±0.68	13.19±0. 90	0.902^{ns}	0.257
Haemoglobin concentration (g/dL)	9.18±0.36	9.25±0.39	8.90±0.19	9.22±0.17	9.21±0.18	0.725^{ns}	0.516
Volume of packed red cells (%)	17.9±2.80	15.11±1.10	15.85±1.19	17.71±1.14	18.11±1.03	0.369^{ns}	1.134
Total leukocyte count (10^3/µL)	11.18±1.79	9.78±1.86	8.31±0.85	8.76±0.76	8.55±0.62	0.221^{ns}	1.69
Total Granulocyte Count (per cent)	$32.43±4.75^{ab}$	$30.18±3.60^{a}$	$22.01±3.77^{ab}$	$23.13±2.90^{b}$	$21.61±3.19^{b}$	0.120	2.091
Lymphocyte Count (per cent)	$60.90±4.15^{ab}$	$62.93±3.90^{a}$	$70.21±3.11^{ab}$	$71.91±2.55^{b}$	$76.86±4.28^{b}$	0.021*	3.699
Monocyte Count (per cent)	6.70±1.32	6.23±0.71	7.53±0.89	6.46±0.39	6.18±0.73	0.734^{ns}	0.503
Platelet count (10^3/µL)	235.0±54.1	258.67±49.86	275±38.14	292.83±43.78	264.67±28.42	0.838^{ns}	0.354

(Parameters were analysed using Repeated Measures ANOVA. Means bearing different superscripts within a row differ significantly.)
(** Significant at $p < 0.01$; * Significant at $p < 0.05$; ns = non-significant)

Table 4. Observations of biochemical parameters

BIOCHEMICAL PARAMETERS	DAY 0	WEEK 2	WEEK 4	WEEK 6	WEEK 8	p value	F value
Serum calcium (g/dL)	9.014±0.69	8.19±0.60	8.37±0.46	9.22±0.44	10.97±1.22	0.05^{ns}	2.874
Serum phosphorus (g/dL)	5.37±0.77	6.47±1.05	5.28±0.94	4.89±0.29	6.44±0.711	0.447^{ns}	0.968
Serum alkaline phosphatse (IU/L)	202.33±32.44	83.53±9.34	123.90±20.39	171.15±62.09	164.65±52.59	0.157^{ns}	1.863

(Parameters were analysed using Repeated Measures ANOVA. Means bearing different superscripts within a row differ significantly.)
(** Significant at $p < 0.01$; * Significant at $p < 0.05$; ns = non-significant

again by the eighth week, with the early rise possibly linked to the osteoclastic activity and bone resorption (Table 4). Similar findings were reported by Bhimanand (2024), whereas Bini and Syam (2014a) and Kokila (2023) observed a significant decline in the second to fourth weeks, followed by a gradual rise during the later stage of healing.

Serum alkaline phosphatase (ALP) levels in the present study exhibited a fluctuating pattern, characterised by an initial decline during the second postoperative week, followed by a gradual increase at the fourth and sixth weeks, and a slight reduction by the eighth week. Although these variations were statistically non-significant ($p = 0.157$), the observed trend may reflect dynamic metabolic changes occurring during fracture healing (Table 4). The early decline in ALP could be attributed to the transition from the inflammatory phase to the reparative phase, while the subsequent increase during the fourth and sixth weeks may indicate enhanced chondroblastic and osteoblastic activity associated with callus formation and bone matrix synthesis, as alkaline phosphatase plays a pivotal role in bone mineralisation. The slight decrease observed at the later stage may suggest progression toward consolidation and reduced osteoblastic turnover. Similar trends of an initial decline followed by a gradual increase in ALP levels during fracture healing have been reported by Kumar et al. (2024) and Salisu et al. (2024). In contrast, Ashok et al. (2018) and Sravanti et al. (2022) observed an early postoperative increase in ALP followed by a decline during later stages, highlighting variations in biochemical response depending on species, fracture configuration, and healing dynamics.

Conclusion

The results of the study revealed that there were no significant alterations in the clinico-physiological and haemato-biochemical parameters during the period of the treatment of fractures in goats using external skeletal fixation with connecting bars. Although, some of the parameters showed significant changes, the values remained within the normal physiological range. The observed fluctuations in biochemical parameters could be attributed to the ongoing process of fracture healing.

Limitation of the study

The relatively small sample size may have reduced the ability to detect statistically significant differences and may limit extrapolation of the results to a larger population.

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