The Haryana Veterinarian (December, 2023) ISSN 0033-4359 (P)
62(2), 35-40

Research Article

COMPARATIVE EVALUATION OF SURGICAL MANAGEMENT OF LONG BONE FRACTURE WITH INTERLOCKING NAILING ALONE AND ALONG WITH β-TRICALCIUM PHOSPHATE IN DOGS

MANIKANT, SANDEEP SAHARAN*[1], AMIT KUMAR, ANJU POONIA, DEEPAK KUMAR TIWARI and MANEESH SHARMA[1]
Department of Veterinary Surgery and Radiology, [1]Department of Veterinary Clinical Complex,
Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar-125 004 Haryana, India

Received: 09.03.2023; Accepted: 28.05.2023

ABSTRACT

The goal of the current study was to assess the effectiveness of β- tricalcium phosphate (β-TCP) in healing of bone in dogs with long bone fractures repaired using interlocking nail technique. Twelve dogs regardless of age, breed, or sex were chosen and divided into two groups at random. Six canines were enrolled in group I, and interlocking nailing was done on them while six dogs were included in group II where β-TCP was placed over fractured site after the fracture was stabilized with interlocking nailing. Postoperatively, clinical and radiographic examinations were done on days 15th, 30th and 60th. At different times during the study, group II performed better than group I in terms of mean weight bearing and mean bone union scores. The results of the current study indicate that β-TCP efficiently speeds up bone healing in dogs who have long bone fracture.

Keywords: β-Tricalcium Phosphate, Fracture, Interlocking nailing

How to cite: Manikant, Saharan, S., Kumar, A., Poonia, A., Tiwari, D.K. and Sharma, M. (2023). Comparative evaluation of surgical management of long bone fracture with interlocking nailing alone and along with β-tricalcium phosphate in dogs. *The Haryana Veterinarian* **62(2)**: 35-40.

A fracture will always result in pain and suffering, in addition to the injured limb losing its function (Vardhan *et al.*, 2017). Weight-bearing long bone fracture typically results from severe trauma, such as a vehicle accident (Huang *et al.*, 2012). The goal of fracture treatment is to facilitate the patient's earliest ambulation and the fastest healing feasible (Shahar, 2000). Long bone fracture in dogs is repaired using both conservative and operative techniques (Brinker *et al.*, 1994). Compared to repair methods used outside of the bone, the interlocking nail's placement within the medullary canal offers a biomechanical benefit because it is aligned with the construct's neutral axis (Dueland *et al.*, 1996).

Alloplasts, often known as "bone substitute materials," are inert synthetic graft materials that comprise tricalcium phosphate (TCP) and synthetic hydroxyapatite ceramics. These substances only have osteoconduction as their mode of action. They serve as a scaffold for improved bone tissue growth and healing (Liu and Kerns, 2014). Ceramics made of calcium phosphate, which are common in native human bone, have started to be recognised as appropriate biomaterials (Kanazawa *et al.*, 1975). It has been noted that calcium phosphates have osteoconductive and osteoinductive properties, and they support mesenchymal stem cells' osteogenic development (Shih *et al.*, 2014). This ceramic's ability to increase adenosine signalling in phosphate metabolism and provide osteoinductive growth factors has been proposed as a way to enhance osteogenesis (Hoppe *et al.*, 2011; Shih *et al.*, 2014). The function of osteoclasts is inhibited by agonists of the Adenosine A2A receptor, which is strongly related to bone metabolism. Adenosine A2A receptor agonists can also activate osteoblasts and attract mesenchymal stem cells to the bone marrow (Lopez *et al.*, 2019). Additionally, it is believed that β-TCP has a favourable impact on the expression of the gene for bone morphogenetic protein (BMP-2) (Tang *et al.*, 2017). So, the present study was undertaken to evaluate the effects of Beta-tricalcium phosphate on bone healing along with interlocking nail in canines.

MATERIALS AND METHODS

The 12 dogs used in this study were brought to the department for treatment of long bone fractures. They were separated into two groups at random, regardless of their age, breed, sex, or body weight, as shown in Table 1.

β- tricalcium phosphate (β-TCP): β-tricalcium phosphate (β-TCP) granules having a particle size range of 355 to 500μ were employed as an osteoconductive material to fill the bone defect at the fracture site. Prior to surgery, all the animals were administered intramuscular injections of prophylactic antibiotic Ceftriaxone @ 25 mg/kg body weight, @ 0.04 mg/kg of Atropine Sulphate, and @ 0.2 mg/kg of Meloxicam as pre-emptive analgesia. After waiting for five minutes, an intramuscular injection

*Corresponding author: saharan007@gmail.com

of a combination of xylazine hydrochloride (1 mg/kg body weight) and ketamine hydrochloride (5 mg/kg body weight) was given. After the swallowing reflex was lost, the patient underwent endotracheal intubation, and isoflurane anaesthesia was maintained for the remainder of the surgery at a flow rate of 1.0-3.0%.

Surgical technique: The femur, tibia, and humerus were approached for interlocking nailing in the current study. Fracture fragments were lifted with a bone hook and held with bone holding forceps once the fracture site had been made visible. A tampon was used to remove the haematoma at the fracture site and detach the muscles' adhesion to the fracture fragments. For the femur, humerus, and tibia in both groups, interlocking nails of suitable diameter were placed normogradely through the medullary cavity. An L-shaped structure with a threaded knob is called an external aiming device (Jig), and it can be used to align screws with holes in nails. Additionally, intraoperative C-Arm use was used to ensure anatomical reduction and the correct pin position.

In group II, 1 cc of sterile beta-tri calcium phosphate bone graft was deposited in a sterile petridish mixed with NSS and administered using a spatula at the fracture gap after anatomical reduction and internal fixation in a similar manner. As per conventional procedure, the skin was closed with silk no. 1 and the muscles with Vicryl no. 1.

Post-operatively meloxicam was advised @ 0.3 mg/kg body weight I/M and Ceftriaxone @ 25 mg/kg body weight I/M for 5 days. After the operation, a modified Robert Jones bandage was put on to support the operated limb, and it was suggested that you walk on a leash for two weeks. After 15 days following surgery, the skin sutures were taken out.

Post-operative evaluation: Clinical and radiographic evaluations were performed at day 0, 15th, 30th and 60th following surgery to assess postoperative bone healing. Weight bearing while standing and walking was evaluated according to the method recommended by Sahu *et al.* (2017) and has been presented in Table 2. In accordance with Lane and Sandhu (1987), radiographic assessments were performed to assess bone formation scores and bone union scores (Table 3), and the stage of bone union (Table 4) was assessed in accordance with Hammer *et al.* (1985). A classification system adopted by Fox (1995) was used to evaluate clinical outcomes based on functional limb usage (Table 5).

Statistical analysis: The statistical analysis of data was done by one-way-ANOVA with linear repeated measure by SPSS software. All the data values were expressed as Mean ± Standard error of mean (Mean±S.E.). P-value less than 0.05 considered as statistically significant.

RESULTS AND DISCUSSION

In dogs with long bone fractures fixed using interlocking nails, this study was done to determine the

Table 1. Design of the study

Group	Treatment plan
Group I (n=6)	Internal fixation using interlocking nailing
Group II (n=6)	Internal fixation using interlocking nailing along with β-TCP at fracture site

Table 2. Weight bearing scoring system while standing and walking (Sahu *et al.*, 2017)

Score	Description
	Weight bearing while standing
0	Carrying the limb off the ground
1	Touching the toe on the ground
2	Touching the paw on the ground
3	Full weight bearing
	Weight bearing while walking
0	Carrying the limb off the ground
1	Occasional touching of toe/paw on each step
2	Frequent touching of toe/paw on each step
3	Touching the toe on every step
4	Touching the paw on every step

Table 3. Radiographic scoring system (Lane and Sandhu, 1987)

Score	Description
	Bone Formation Scores
0	No evidence of bone formation
1	Bone formation in 25% of the gap
2	Bone formation in 50% of the gap
3	Bone formation in 75% of the gap
4	Bone formation in 100% of the gap
	Bone Union Scores
0	With complete fracture trace
2	With incomplete fracture trace
4	Absence of fracture trace

Table 4. Stage of bone union radiographic scoring system (Hammer *et al.*, 1985)

Grade	Callus Formation	Fracture Line	Stage of Union
1	Homogenous bone structure	Obliterated	Achieved
2	Massive- Bone trabeculae crossing the fracture line	Achieved	Barely discernible
3	Apparent-Bridging of fracture line	Discernible	Uncertain
4	Trace- No bridging of fracture line	Distinct	Not Achieved
5	No callus formation	Distinct	Not Achieved

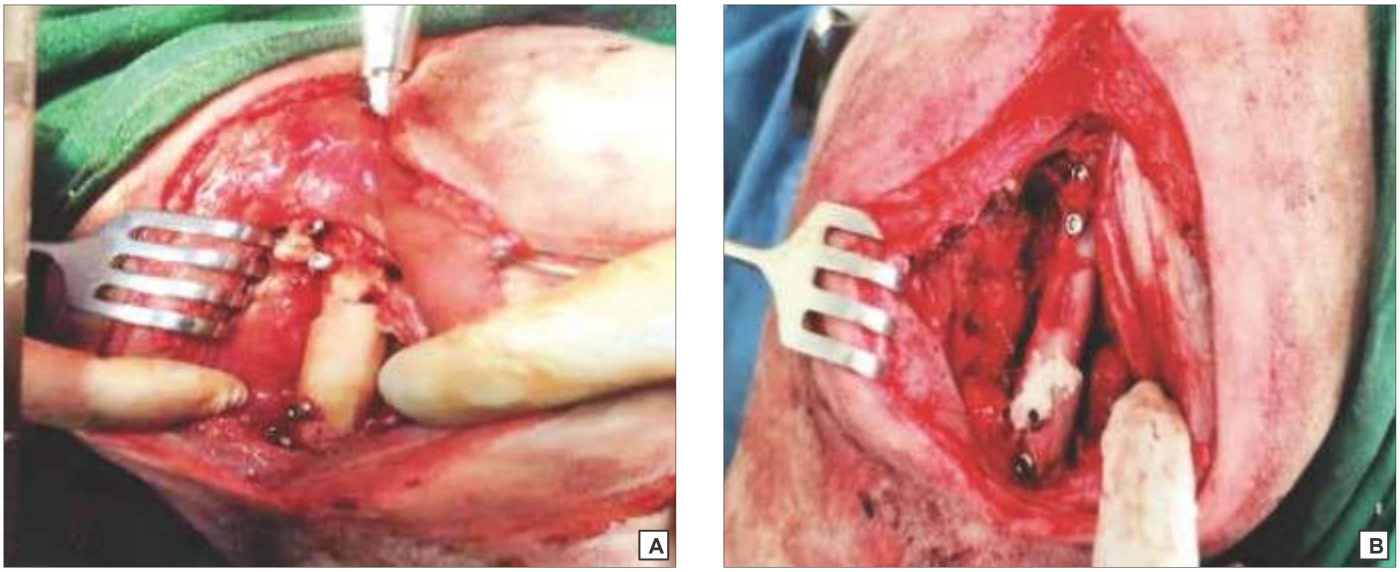

Fig. 1. Internal fixation of fracture using, A) Interlocking nailing, B) Application of β-TCP

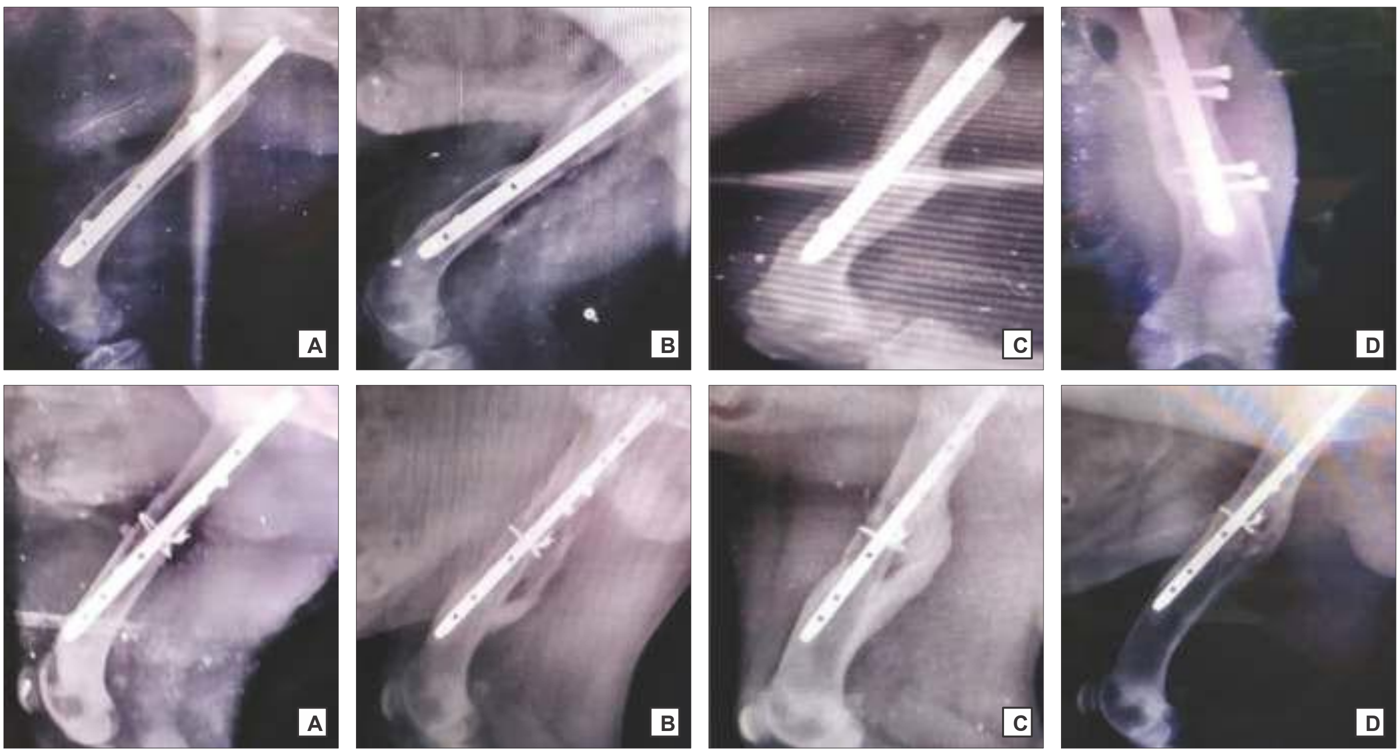

Fig. 2. Radiographs showing fracture healing in group I (upper row) and group II (lower row) Immediately after surgery, B. On 15th day, C. On 30th day, D. On 60th day)

Fig. 3. Weight bearing while standing in group I (upper row) and group II (lower row) (A. On 15th day, B. On 30th day, C. On 60th day)

effectiveness of β-tricalcium phosphate (β-TCP) in promoting bone healing. At various time intervals, the bone formation scores (BFS) in group II were not significantly higher than those in group I (Table 6). Similar to this, group II's bone union scores (BUS) were not significantly higher than group I's (Table 7). Group II has reached the stage of union earlier than Group I (Table 8 and Fig. 2). The administration of the osteoconductive substance, β-TCP, at the fracture site has resulted in an

Table 5. Functional limb usage assessment (Fox *et al.*, 1995)

Grade	Description
	Functional limb usage
Excellent	Weight bearing without lameness
Good	Slight Lameness
Fair	Slight to moderate lameness principally after exercise
Poor	Intermittent or consistent non-weight bearing lameness

Table 6. Bone formation scores at different time intervals in both the groups (Mean± S.E.)

Time interval	0th day	15th day	30th day	60th day
Group I	$0.00^{a}\pm0.00$	$0.67^{b}\pm0.21$	$1.67^{c}\pm0.21$	$3.00^{d}\pm0.26$
Group II	$0.00^{a}\pm0.00$	$0.83^{b}\pm0.31$	$2.00^{c}\pm0.26$	$3.33^{d}\pm0.33$

(Means with different superscripts (a, b)/ (A, B) varies significantly ($p<0.05$) within group/ between the group)

Table 7. Bone union scores at different intervals in both the groups (Mean± S.E.)

Time interval	0th day	15th day	30th day	60th day
Group I	$0.00^{a}\pm0.00$	$0.67^{ab}\pm0.42$	$2.00^{cd}\pm0.00$	$0.67^{d}\pm0.42$
Group II	$0.00^{a}\pm0.00$	$0.67^{b}\pm0.42$	$2.00^{abc}\pm0.00$	$3.00^{c}\pm0.45$

(Means with different superscripts (a, b) varies significantly ($p<0.05$) within group)

Table 8. Stages of bone union at different time intervals in group I and group II

Group I	0th day	15th day	30th day	60th day
IA	Not Achieved	Not Achieved	Uncertain	Achieved
IB	Not Achieved	Not Achieved	Uncertain	Uncertain
IC	Not Achieved	Not Achieved	Not Achieved	Uncertain
ID	Not Achieved	Uncertain	Uncertain	Achieved
IE	Not Achieved	Not Achieved	Uncertain	Achieved
IF	Not Achieved	Not Achieved	Uncertain	Uncertain
Group II				
IIA	Not Achieved	Uncertain	Achieved	Achieved
IIB	Not Achieved	Not Achieved	Uncertain	Uncertain
IIC	Not Achieved	Uncertain	Uncertain	Achieved
IID	Not Achieved	Not Achieved	Not Achieved	Uncertain
IIE	Not Achieved	Uncertain	Achieved	Achieved
IIF	Not Achieved	Uncertain	Achieved	Achieved

increase in the rate of bone formation, which has led to an increase in the mean bone union scores in group II. The osteoconductive properties of β-TCP were also described by Goel *et al.* (2013) and Preethi *et al.* (2021), demonstrating that it was a secure and efficient therapeutic choice for fracture repair in significant osteo-periosteal abnormalities.

The mean weight bearing score when standing (Table 9) gradually increased over time in both groups, moving from 0.00 ± 0.00 on day 0 to 2.67 ± 0.21 on day 60th in group I and 0.00 ± 0.00 to 2.83 ± 0.17 on day 60th in group

Table 9. Weight bearing scores while standing at different time intervals in both the groups (Mean ± S.E.)

Group	0^{th} day	15^{th} day	30^{th} day	60^{th} day
Group I	$0.00^{a}\pm0.00$	$0.67^{b}\pm0.21$	$1.50^{c}\pm0.22$	$2.67^{d}\pm0.21$
Group II	$0.00^{a}\pm0.00$	$0.83^{b}\pm0.17$	$1.67^{c}\pm0.21$	$2.83^{d}\pm0.17$

(Means with different superscripts (a, b)/ (A, B) varies significantly ($p<0.05$) within group/between group, respectively)

Table 10. Weight bearing scores while walking at different time intervals in both the groups (Mean ± S.E.)

Group	0^{th} day	15^{th} day	30^{th} day	60^{th} day
Group I	$0.00^{a}\pm0.00$	$0.83^{a}\pm0.40$	$2.00^{b}\pm0.52$	$3.17^{c}\pm0.48$
Group II	$0.00^{a}\pm0.00$	$1.50^{b}\pm0.43$	$2.50^{b}\pm0.43$	$3.50^{c}\pm0.34$

(Means with different superscripts (a, b) varies significantly ($p<0.05$) within group)

II, respectively (Fig. 3). For the entire post-operative period, group II's mean weight bearing scores were higher. Also, on the day of the presentation, all animals in both groups displayed non-weight bearing lameness. Because a fracture results in pain in the affected area from inflammation and injury to the surrounding muscles, animals often lift the injured limb off the ground (Gupta, 2015). On the fifteenth day, group II's weight bearing scores non-significantly increased in comparison to group I. In addition, all of the animals in group II were observed contacting the toe or paw of the ground, but most of the animals in group I were carrying the limb off the ground. On the 30^{th} day, the majority of the animals were discovered touching a toe or paw on the ground, showing that group I's weight bearing score had improved, whereas in group II, majority of the animals only began fully bearing weight on the injured limb on the 30^{th} day. On the 60^{th} postoperative day, animals from both groups displayed full weight bearing.

Similarly, the weight bearing scores while walking (Table 10) was non-significantly higher in group II as compared to group I at different intervals. Singh *et al.* (2020) noted related results as well. The early and better fracture healing in dogs of group II, which was supported by radiographic scores and was probably connected to local administration of β-TCP at the fracture site, was the cause of the improvement in the weight bearing scores (when standing and walking). The group that received osseomold (DMB and Calcium sulphate hemihydrate) and autogenous cancellous bone graft at the fracture site had the lowest mean lameness scores, which was a sign of early fracture healing, according to Kumar (2020).

In group I, there was one case where the functional use of the limb was excellent, three cases where it was good, one case where it was fair, and one case where it was bad. In group II, three examples were excellent, two were good, and one was fair. The timing of the recovery of limb functions with complete range of motion in group II animals who had early callus development and weight bearing is consistent with this finding. Singh *et al.* (2020) also reported similar results.

Due to its osteoconductive properties and improved *in vivo* degradation, β-tricalcium phosphate (β-TCP) has emerged as a viable material for applications involving bone regeneration. Through controlling osteogenic processes like the differentiation of mesenchymal stem cells into osteoblasts, the development of new blood vessels, the release of angiogenic growth factors, and blood clot formation, β-TCP promote bone regeneration (Lu *et al.*, 2021). In the group of animals receiving β-TCP treatment, the weight bearing scores, bone union scores, and functional limb usage were all improved. Thus, β-TCP helps dogs heal faster. As a result, it is determined that interlocking nailing in β-TCP is superior to interlocking nailing alone for the treatment of long bone fractures in dogs.

REFERENCES

Brinker, W.O., Piermattei, D.L. and Flo, G.L. (1994). Le manuel d'orthopédie et de traitement des fractures des petits animaux. (2nd Edn.), Point Vétérinaire, Maisons Alfort. pp. 9-137.

Dueland, R.T., Berglund, L., Vanderby, R. and Chao, E.Y.S. (1996). Structural properties of interlocking nails, canine femora and femur-interlocking nail constructs. *Vet. Surg.* **25**: 386-396.

Fox, S.M., Bray, J.C., Guerin, S.R. and Burbridge, H. (1995). Antebrachial deformities in the dog and treatment with external fixation. *J. Small Anim. Pract.* **36**: 316-320.

Goel, S.C., Singh, D., Rastogi, A., Kumaraswamy, V., Gupta, A. and Sharma, N. (2013). Role of tricalcium phosphate implant in bridging the large osteoperiosteal gaps in rabbits. *Indian J. Exp. Biol.* **51**: 375-380.

Gupta, S. (2015). Fracture healing using biphasic calcium phosphate with dynamic compression plating in goats. M.V.Sc. thesis submitted to Nanaji Deshmukh Veterinary Science University, Jabalpur.

Huang, S., Wen, B., Bian, W. and Yan, H. (2012). Reconstruction of comminuted long bone fracture using CF/CPC scaffolds manufactured by rapid prototyping. *Med. Sci. Monit.* **18(11)**: 435-440.

Hammer, R.R., Hammerby, S. and Lindholm, B. (1985). Accuracy of radiographical assessment of tibial shaft fracture union in humans. *Clin. Orthop.* **199**: 233-238.

Hoppe, A., Guldal, N.S. and Boccaccini, A.R. (2011). A review of the biological response to ionic dissolution products from bioactive glasses and glass-ceramics. *Biomater.* **32(11)**: 2757-2774.

Kanazawa, T., Umegaki, T. and Monma, H. (1975). Apatites, new inorganic materials. *J. Ceram. Soc. Jpn.* **10(7)**: 461-468.

Kumar, R. (2020). Evaluation of positive profile end threaded titanium intramedullary pins with and without application of biomaterials for management of long bone fractures in dogs. Ph.D. thesis submitted to Sri Venkateswara Veterinary University Tirupati, India.

Lane, J.M. and Sandhu, H.S. (1987). Current approaches to experiment bone grafting. *Orthop. Clin. North Am.* **18**: 213-225.

Liu, J. and Kerns, D.G. (2014). Mechanisms of guided bone regeneration: A review. *Open Dent. J.* **8**: 56-65.

Lopez, C.D., Bekisz, J.M., Corciulo, C., Mediero, A., Coelho, P.G., Witek, L., Flores, R.L. and Cronstein, B.N. (2019). Local delivery of adenosine receptor agonists to promote bone regeneration and defect healing. *Adv. Drug Deliv. Rev.* **146**: 240-247.

Lu, H., Zhou, Y., Ma, Y., Xiao, L., Ji, W., Zhang, Y. and Wang, X. (2021). Current application of beta-tricalcium phosphate in bone repair and its mechanism to regulate osteogenesis. *Front. Mater. Sci.* **8**: 698-915.

Preethi, K., Kumar, V.G., Raghavender, K.B.P., Kumar, D.P. and Lakshman, M. (2021). Use of beta-tricalcium phosphate bone graft with collagen membrane as guided bone regeneration in long bone fractures with bone loss in dogs: a clinical study. *Indian J. Anim. Res.* **55(2)**: 222-225.

Sahu, S., Pathak, R., Shah, M.A., Reetu, Jayalekshmi, S., Dharshan, G.T., Sharma, D., Aithal, H.P., Amarpal, Kinjavdekar, P. and Pawde, A.M. (2017). Evaluation of locking compression plate in wedge and complex fracture of long bones in dogs. *Indian J. Vet. Surg.* **38(2)**: 81-85.

Shahar, R. (2000). Relative stiffness and stress of type I and type II external fixators: Acrylic versus stainless steel connecting bars-a theoretical approach. *Vet. Surg.* **29**: 59-69.

Shih, Y.R.V., Hwang, Y., Phadke, A., Kang, H., Hwang, N.S., Caro, E.J., Nguyen, S., Siu, M., Theodorakis, E.A., Gianneschi, N.C., Vecchio, K.S., Chien, S., Lee, O.K., and Varghese, S. (2014). Calcium phosphate-bearing matrices induce osteogenic differentiation of stem cells through adenosine signalling. *Proc. Natl. Acad. Sci.* **111(3)**: 990-995.

Singh, R., Chandrapuria, V.P., Shahi, A., Swamy, M., Bhargava, M.K. and Shukla, P.C. (2020). Guided tissue regeneration with β-tricalcium phosphate and platelet-rich plasma for fracture repair in dogs using internal fixation. *J. Anim. Res.* **10(1)**: 25-31.

Tang, Z., Tan, Y., Ni, Y., Wang, J., Zhu, X., Fan, Y., Chen, X., Yang, X. and Zhang, X. (2017). Comparison of ectopic bone formation process induced by four calcium phosphate ceramics in mice. *Mater. Sci. Eng. C.* **70**: 1000-1010.

Vardhan, K.H., Prasad, V.D., Sreenu, M. and Syaamsundar, N. (2017). Histopathological evaluation of polymethyl methacrylate and hydroxyappatite implants for fracture healing in rabbits. *J. Vet. Sci. Technol.* **6(3)**: 3-6.