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Application of anatomically contoured intramedullary interlocking nailing for fixation of femoral diaphyseal fractures in dogs

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ABSTRACT

The study was conducted on 10 client-owned dogs of either sex presented for fixation of femoral diaphyseal fractures. After thorough clinical, orthopaedic and radiographic examinations, the patients were subjected to application of specially-designed anatomically contoured intramedullary interlocking nailing (ACIILN) for fixation of fractures. All the fractures were closed and involved mid (n=9) to slightly distal (n=1) diaphysis. The diameter of used ACIILN ranged from 5–7 mm and the length from 11–15 cm. All the ACIILN were applied in static fashion with at least 2 screws each in both proximal and distal fracture fragments. The duration of surgery for application of ACIILN ranged from 35–75 min. The technique was found to be moderately difficult with extent of tissue manipulation in the category of low to moderate. Pain and inflammation decreased gradually in all the cases in an anticipated manner.With gradual improvement in weight-bearing capability, the limb function was restored in all cases quiet fast in the postoperative period. More amount of the callus formed over medial and caudal surfaces indicating less amount of stability at these surfaces. Anatomically contoured intramedullary interlocking nailing technique provided clinically viable fracture fixation technique resulting into early limb function.

Keywords: Diaphyseal, Dog, Femur, Fracture, Interlock nailing, Intramedullary

Femur is the most commonly fractured long bones in dogs (Harasen 2003). Femoral fractures cannot be managed by simpler methods of closed reduction and external coaptation such as casts or splints and therefore, internal fixation is necessary to fix them (Dejardin and Cabassu 2005). Several internal fixation techniques have been used for the repair of femoral fractures in dogs. Intramedullary interlocking nailing (IILN) is one such technique that is used for fixation of femoral diaphyseal fractures (Harish 2016). IILN offers the advantage of countering all disruptive biomechanical forces (bending, axial and rotational) acting on a fractured bone quite efficiently.

The conventional interlocking nails are straight, whereas, the shaft of dog's femur is slightly curved with a convex surface facing cranially. Moreover, in mature dogs, the femoral shaft tapers to mid-shaft isthmus and then flares to distal metaphysis (Nunamaker and Newton 1985). Therefore, if the isthmus region in mid-diaphysis is intact in a femoral fracture, a problem is often faced in seating the appropriately sized ILN in the medullary cavity of bone as it impinges on the isthmus. Therefore, either a smaller-diameter ILN is to be utilized or more intramedullary reaming is to be performed to make sufficient space for the nail. Unlike intramedullary pins, there is a limit to construct small diameter ILNs as they need to accommodate the cannulations for interlocking screws. As any intramedullary reaming process invariably entails removing some of the endosteal bone and the adjoining medullary component, it damages the blood supply to the fracture site while also thinning the bone and thus is likely to impact the bone-healing adversely. If the femoral fracture involves the diaphysis at or around isthmus, though it is possible to seat the straight intramedullary implants in both fracture fragments, yet it often leads to malalignment and subsequent re-curvatum deformity of the affected bone (Harish 2016).

Therefore, an anatomically contoured intramedullary interlocking nail (ACIILN) was designed for dogs' femur to overcome above-mentioned constraints. Such nails were gently curved cranio-caudally at their centre. Proptotypes of such nails were tested in fresh cadaver bones and necessary design modifications were done. A corresponding anatomically contoured aiming device, the 'jig' was also designed to seat such ILNs. The jig was designed in such a way that the same instrument could be used to seat ACIILN in either left or right femur of dog. For it, instead of having fixed arms, the jig was developed with detachable arms whose sides could be flipped after removing the attached bolts and a right-sided jig could be turned in to left-side one and vice-versa.

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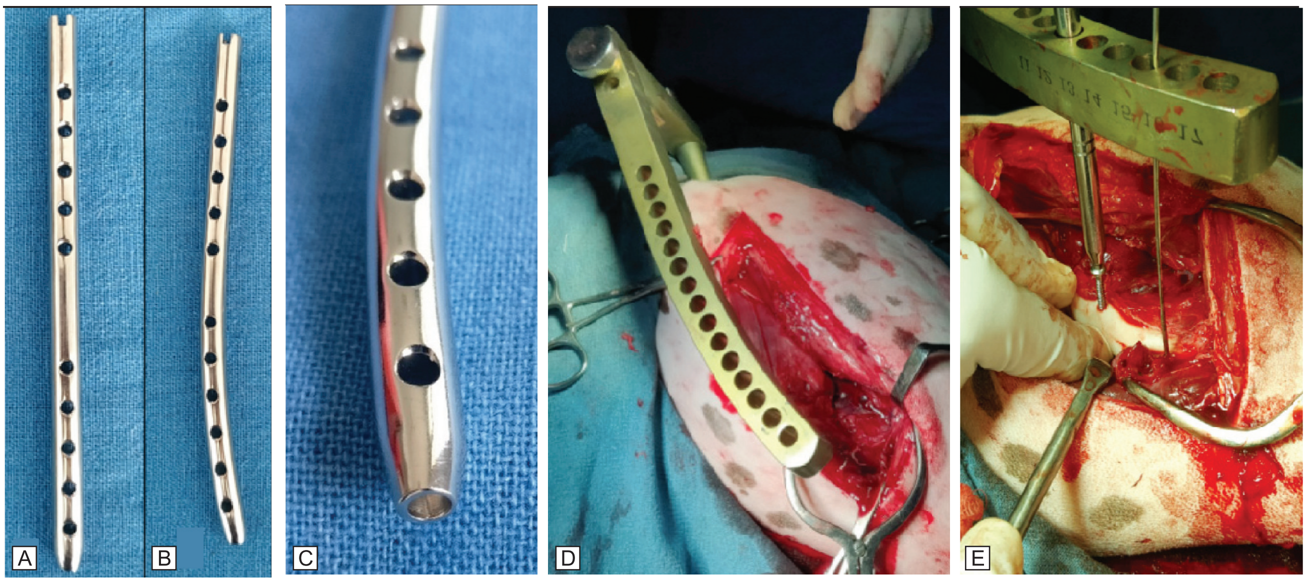

Fig. 1. Anatomically contoured intramedullary interlocking nailing and its intra-operative application. (**A**) Conventional straight ILN; (**B**) ACIILN; (**C**) Shallow recess at the distal end of ACIILN; (**D**) Introduction of ACIILN with the help of contoured aiming device; (**E**) Placement of transverse screws to fix ACIILN in place.

Eventually, the ACILNs were made in 3 diameters, i.e. 5, 6 and 7 mm to be used with 2 mm cortical screws in first one and 2.7 mm screws in remaining two types. The screw cannulations were 1 cm apart and the length of ILNs ranged from 11–17 cm with 1 cm difference. The nails were gently bent slightly distal to centre at an angle of 11°. Additionally, the distal tip of such nails was provided with a recess to engage a guide pin to facilitate insertion of ILN in a normograde manner (Fig 1C). The base of ACIILN was developed in such a manner that a single conical bolt can fit in to all of them so that additional bolts are not required during surgical fixations using different sized nails.Thereafter, a study was undertaken to access the clinical utility of these ACIILNs to fix the femoral diaphyseal fractures in dogs.

MATERIALS AND METHODS

Ten dogs of either sex weighing 10–30 kg having closed diaphyseal fractures of femur were subjected to placement of ACIILN aseptically under general anaesthesia. The femoral diaphyses were approached by standard cranio-lateral site as per Newton and Nunamaker (1985). Surgical technique was almost similar to conventional intramedullary nailing technique as described by Kumar (2016). ACIILNs were applied in static fashion in all the cases without any auxillary fixation. These were seated within the medullary cavity of fractured bones after sufficient intramedullary reaming was accomplished using straight rigid reamers. The reaming was started usually with a 4 mm reamer and progressed with a larger diameter reamer with 1 mm increment each time until sufficient reaming was achieved to seat the ACIILN easily. A K-wire/Steinmann pin (1.5–3 mm) was inserted in the medullary canal from the fracture site in a retrograde manner and pushed proximally to come out of the bone through sub-trochanteric fossa and the overlying skin. The skin wound was enlarged enough to accommodate the diameter of ACIILN to be inserted thereafter. An appropriately sized ACIILN was mounted on aiming device fastened with conical bolts and it was pushed in to the medullary cavity of proximal fragment by engaging the tip of K-wire/Steinmann pin acting as a guide-pin in to its distal recess.While the guide-pin was withdrawn, the ACIILN was simultaneously advanced in to the medullary cavity. The guide-pin was removed once ACIILN entered in to the medullary cavity. Thereafter, the fracture was reduced and the ACIILN was pushed in to distal fragment as much as possible so as to accommodate at least 2 screws in either fragment subsequently. Using drill sleeves in the aligned cannulation of aiming device with that of nails, the holes were drilled in the proximal and distal fragment of bone and the nails were interlocked within the medullary cavity using a number of self-tapping 2 or 2.7 mm cortical screws depending upon the diameter of nails.

Standard peri-operative management included administration of antibiotics, non-steroidal anti-inflammatory drugs, calcium-supplements, anti-septic dressing and bandaging as and when required in all the cases. Owners were advised to allow only limited activity of the animal for 15 days and leash-walking thereafter until fracture healing.

Different perioperative observations like status of pain, inflammation, muscle atrophy and lameness were recorded at different intervals during the study. The status of pain, inflammation and muscle atrophy were scored from 0–3 in line with increasing severity. Status of weight-bearing was recorded on the scale of 5 as: 0, test limb not touching the ground; 1, toe of test limb touching the ground occasionally; 2, toe of test limb touching the ground frequently; 3, the paw of test limb touching the ground occasionally; 4, the paw of test limb touching the ground frequently; and 5, the

Table 1. Cases of dogs with femoral fractures fixed with ACIILN

Case no	Breed, sex, age, weight	Type of fracture	Implant dimension (diameter and length of nail)	Number of screws used	Final reappraisal day (FRD)
1	Non-descript, female, 8 months, 12.5 kg	Closed complete mid-diaphyseal short oblique fracture of left femur	7 mm × 15 cm	3 proximal and 2 distal	36
2	Pomeranian, male, 12 months, 16 kg	Closed complete mid-diaphyseal long oblique fracture of right femur	5 mm × 14 cm	2 proximal and 3 distal	15
3	Doberman pinscher, male, 11 months, 25 kg	Closed complete mid-diaphyseal transverse fracture of right femur	7 mm × 16 cm	3 proximal and 3 distal	30
4	Pit-bull, female, 5 months, 17 kg	Closed complete distal-diaphyseal transverse fracture of left femur	6 mm × 15 cm	2 proximal and 2 distal	16
5	Mixed, female, 5 months, 20 kg	Closed complete mid-diaphyseal transverse fracture of left femur	6 mm × 11 cm	3 proximal and 3 distal	134
6	Pit-bull, male, 5 months, 20 kg	Closed complete mid-diaphyseal long oblique fracture of left femur	6 mm × 15 cm	3 proximal and 2 distal	69
7	Dalmatian, male, 15 months, 30 kg	Closed complete mid-diaphyseal short oblique fracture of right femur	6 mm × 14 cm	2 proximal and 3 distal	103
8	Non-descript, female, 5 months, 15 kg	Closed complete mid-diaphyseal wedge fracture of left femur	6 mm × 13 cm	3 proximal and 2 distal	–
9	Non-descript, male, 4 months, 14 kg	Closed complete mid-diaphyseal short oblique fracture of left femur	6 mm × 13 cm	2 proximal and 2distal	25
10	Non-descript, male, 3 months, 10 kg	Closed complete distal-diaphyseal transverse fracture of right femur	7 mm × 12 cm	2 proximal and 3 distal	25

paw of test limb touching the ground regularly. Net weight-bearing score (max.10) was calculated by adding individual score of standing and walking phases (max.5 in each) for a particular patient.

Besides, both lateral and cranio-caudal radiographic views of the affected bones were taken at different time intervals such as before surgery, immediately after surgery and on final reappraisal day to analyse the fracture-healing. For discussion sake, only two days of observations are included in the text, i.e. implant fixation day (IFD) and final reappraisal day (FRD). Details of the fractures and surgical fixation are given in the Table 1.

Specific intra-operative observations included duration of surgery, extent of tissue manipulation, degree of technical difficulty, the extent of intramedullary reaming requirement, the size of ACIILN, the number of interlocking screws used in either fragment, status of fracture reduction and fixation, complications and any other remarkable observations. Extent of tissue manipulation, degree of technical difficulty, status of fracture reduction and fixation were evaluated on a scale of 1–3.

RESULTS AND DISCUSSION

The technique of ACIILN was used for fixation of femoral fractures in 10 dogs aged 5–15 months weighing 10–30 kg. All the fractures were closed and involved femoral diaphysis with primarily a transverse or short oblique fracture line. Adequate exposure of femoral shaft could be achieved following standard cranio-lateral incision. The ACIILNs could be easily seated in the proximal fracture fragment with intramedullary reaming tunnel just 1 mm larger than the diameter of nails but additional reaming to the extent of 2–3 mm was often required in the distal segment to accommodate the nail to its fullest extent possible. Despite of being anatomically contoured nail, distally the nail end reached just above the level of curved distal metaphysis in most of the cases; in one case (no. 4), the nail crossed the distal cranial cortex adjacent to trochlea while being pushed a little hard.

Three different ACIILNs having diameter 5/6/7 mm were used and their length ranged from 11–15 cm in different patients. The number of interlocking screws ranged from 4–6 in different cases; a minimum of 2 screws were placed in both proximal and distal fracture fragments. The overall fracture reduction and fixation were graded ‘good to excellent’ with a mean numeric value of 3.8±0.13 and 3.3±0.21 respectively. The duration of surgery for application of ACIILN ranged from 35–75 min (63±3.51). Extent of tissue manipulation as well as the technical difficulty ranged from low to high (1–3) with a mean of 1.9±0.18 and 1.7±0.20 respectively somewhat corresponding to moderate levels. In none of the cases, recurvatum deformity developed in the bone even after placement of fullest extent of nail.

Drilling of screw-holes over the sloping surface of femur in distal fragment was the main difficulty during surgery. Despite using appropriate drill sleeves and prior use of trocar to indent the surface, the drill bits, particularly the smaller ones, often slipped a little over theses slopes resulting in to causing an eccentric hole and hence screws sometimes missed the ACIILN cannulation. Many times, such misalignment could be appreciated at the time of surgery itself particularly when no other screw was engaging the distal fragment, but many a times such faults came to notice only when postoperative radiographs were examined. However, subsequent radiographs revealed that at least one screw was in proper place in the distal segment of fractures in all cases. Overall, in as many as 6 cases (Case no. 1, 2, 6, 8, 9 and 10), one or two locking screw failed to engage the cannulation of ACIILN during placement. In all but one case (no. 6), the mal-alignment occurred at most distal hole; in case 6, the penultimate screw was found mal-aligned. Similar findings of misdirection of distal screws in interlocking nailing technique for long bone fracture fixation in dogs were observed by Durall (1996), Arican (2017), Kumar (2016) and Kaur (2017).

Another difficulty was to accomplish proper intramedullary reaming in distal fragment of fracture. As the reamers were straight, but the distal ends of the femur and ACIILN were curved, wider reaming of distal metaphyseal area had to be done by angling the reamer many times in cranial to caudal directions during this process. But it proved difficult in many cases where the distal segment was longer and angling the reamer beyond a limit was not possible. In such instances (case nos 7 and 9), the ACIILN could not be placed as distally as originally contemplated. In another instance (case 10), an undesirable straighter course of intramedullary reaming in distal segment of fracture lead to inadvertent piercing of distal cranial cortex just above trochlea and consequently wrong placement of nail-end there.

The postoperative appraisal of all dogs could not be done at uniform intervals due to the non-compliance of dog-owners to bring their pets to hospital at stipulated intervals. However, few of the parameters could be recorded regularly based on telephonic follow ups. Overall out of 10 cases of dogs whose fractures were fixed with ACIILN technique, 9 were presented for postoperative follow-ups (no. 8 was not). The case nos. 7 and 9 had multiple fractures; case no. 7 had concomitant open avulsion fracture (tibio-tarsal) of contra-lateral limb and pelvic fracture and case no. 9 had additional fractures of pelvis and tibia in the same limb. The case no. 9 was additionally diagnosed with sciatic neuropathy. Therefore, these cases (7, 8 and 9) are omitted for discussion except radiological observations.

Fig. 2. Representative pre- and post-operative weight bearing status of dogs in cases of normal fracture healing.

Postoperatively, inflammation decreased gradually in all the cases in an anticipated manner. The weight-bearing also improved gradually in the postoperative period in all the cases and its score varied from 4–10 with a mean of 7.57±1.21 on FRD (Fig. 2). Pain also decreased postoperatively in all cases but it persisted until FRD in two cases (nos. 2 and 6). In case no. 2, the persistence of pain was attributed to an early FRD of case (day 15) whereas, in case no. 6, the pain was attributed to sensitization of sciatic nerve due to long end of nail protruding out of bone from its insertion site. Additionally, the dog kept its limb in abnormally extended position with stifle in a slight external rotation throughout the post-operative period. However, there was complete weight-bearing on this limb in this case at FRD and there was no inflammation at site but mild muscle atrophy of thigh region was visible. The postoperative radiographs revealed altered femoral neck-shaft angle in this case with neck assuming a slightly straighter course and the distal femur slightly turned outwards. Nunamaker and Newton (1985) also opined that such abnormality could be associated with rotation of fractured fragments which is radiographically characterized by change in femoral neck-shaft angle and orientation of head of femur with that of patella. Such outward rotation of distal femur occurred during postoperative period perhaps due to suboptimal fixation in that segment as only one screw could be interlocked properly and the penultimate screw missed the ACIILN cannulation during surgery. Moreover, this particular dog suffered a long spiral fracture whose fracture line extended from mid to distal diaphysis. Further, this dog was having bulky muscular body and its fracture line was longest among the group and so was inherently more amenable to fracture distraction in the face of suboptimal fixation. Biomechanically, at least two screws in either fracture fragment is considered essential to effectively resist rotational disruptive forces working upon the fracture site (Nunamaker 1985). However, despite only one screw engaging the ACIILN in distal fragment in as many as 4 dogs in this study (nos. 1, 6, 8 and 9), only case no. 6 showed abnormal external rotation of distal fragment in the postoperative period. However, the other cases also showed greater amount of callus at fracture site indicative of presence of slight motion there during healing period which however incidentally did not interfere with healing and alignment of bone axis. The abnormal gait in the case no. 6 can also be attributed to sensitization of sciatic nerve due to adjacent tissue reaction in response to longer end of the ACIILN protruding out of pin-insertion site. This explanation seemed plausible as the patient continued to evince pain up to FRD at 69th day when ACIILN was finally removed. However, in many other cases where similarly long ACIILN were used did not exhibit any such problems. Overall, the pain score

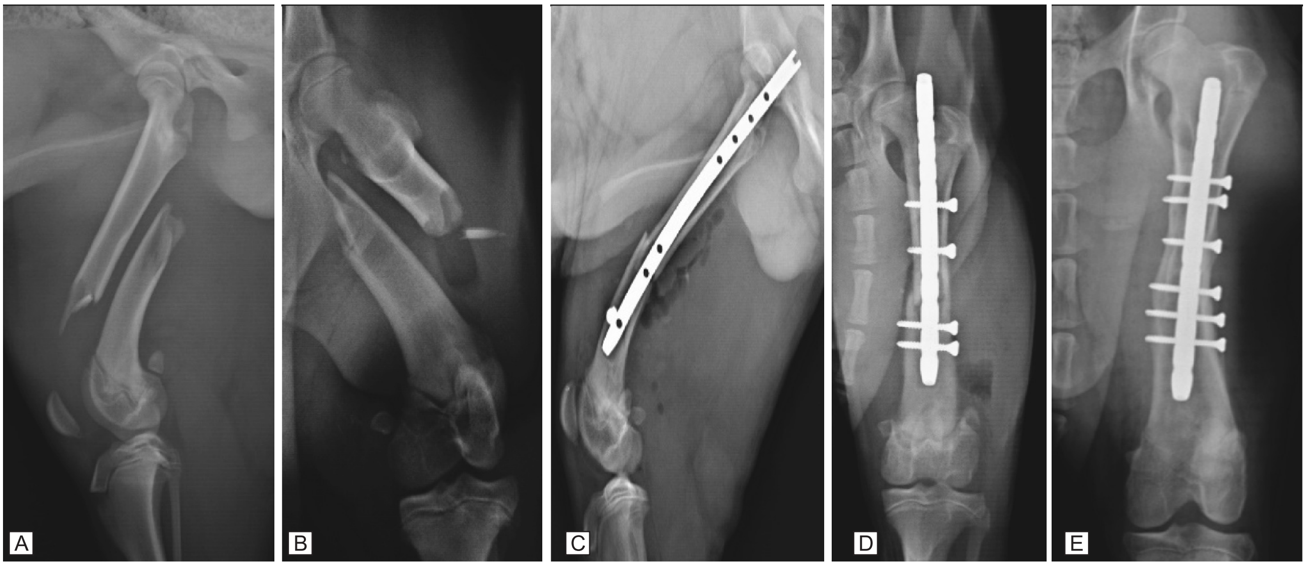

Fig. 3. Pre- and post-operative radiographs of femur fracture showing uneventful healing following ACIILN. (**A-B**) M-L and Cr-Cd view of femoral fracture of a dog (case no. 5) at '0' day; (**C**) M-L and Cr-Cd view of femur immediately after fixation with ACIILN; (**D-E**) Cr-Cd view of femur at FRD on 134th day showing advanced remodelling of callus.

ranged from 2 to 3 (mean 2.1±0.15) on IFD and 0 to 1 (mean 0.28±0.18) at FRD. Kumar (2016) reported that weight-bearing improved gradually in dogs when fractured femurs were treated with straight IILN and Kaur (2017) also reported improved weight-bearing while using straight IILN for the treatment of long bone fractures in dogs.

In all but one fractures fixed with ACIILN, uneventful 'bridging osteosynthesis' was observed. It was characterized by classical radiographic features of 'secondary fracture-healing' (Fig. 3). The size of callus during such healing process however, varied from case to case. Minimal amount of callus was noticed in 2 cases, moderate in 2 and large in 5 cases. In most of the cases, more amount of the callus formed over medial and caudal surfaces (Fig. 4) indicating less amount of stability at these surfaces.

Delayed union of bone was observed in one case (case no.7). These types of findings were also observed/reported by Duhautois (2003), Raghunath and Singh (2002), Wheeler *et al.* (2004) and Ikem (2007).

Slight shortening of limb was recorded in one dog (case no. 4) on FRD. In this case, the ACIILN was found to have crossed the distal physeal plate of femur inadvertently during surgery. Though the post-operative fracture healing and angulation of limb remained good and thus the ACIILN was removed quite early in this patient (on day 14th).

In another case despite being anatomically contoured, the nail penetrated the cranial cortex (case no. 10) but the animal did not show any sign of lameness in the post-operative period. Kumar (2016) and Kaur (2017) also reported inadvertent penetration of distal cortex of different

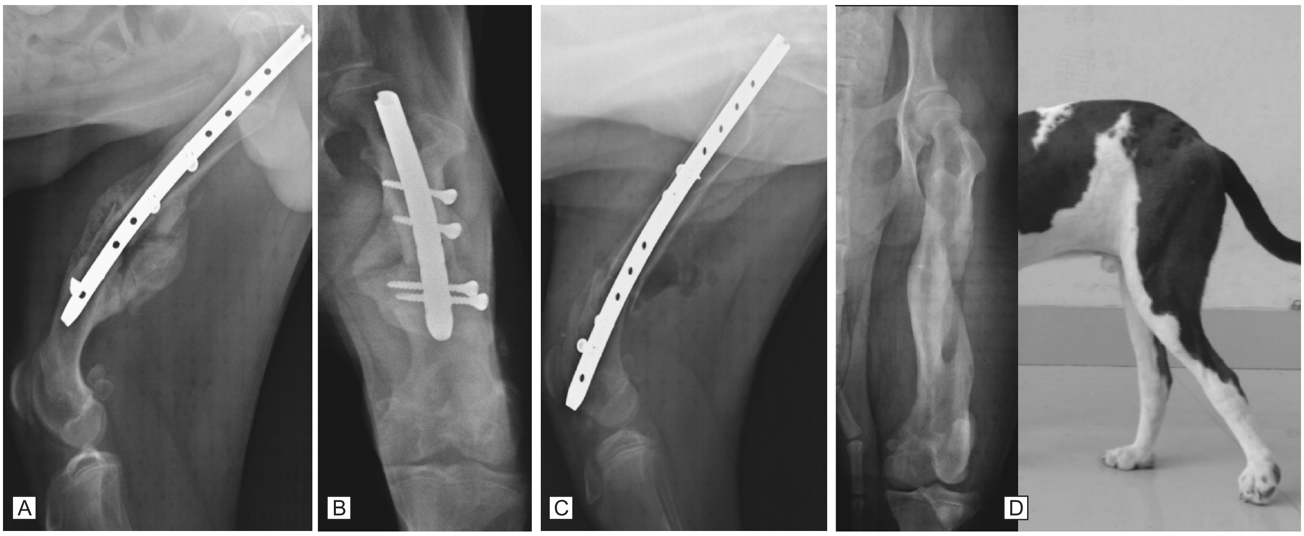

Fig. 4. Post-operative radiographic observations and complications. (**A-B**) 25 days PO-Large amount of external periosteal callus at caudal and medial cortex of bone (case 9); (**C**) Crossing of physeal plate and misdirection of the one of distal screw (case 4); (**D**) Altered angle of femoral neck and shaft (shown here after removal of ACIILN) resulting in awkward placement of limb in exaggerated extension (case no. 6).

degrees while utilizing straight IILN with or without clinical significance.

So, in conclusion, it can be inferred that anatomically contoured intramedullary interlock nailing technique can be used successfully to fix femoral fracture in dogs to bring about bridging osteo-sysnthesis. This technique requires little or no intramedullary reaming at isthmus of bone thereby preserving the medullary blood supply in an effective manner. On the other hand, placement of this nail in the most distal segment of femur is little tricky if the fracture line is way above the supracondylar region.

REFERENCES

Arican M, Alkan F, Altan S, Parlak K and Yavru N. 2017. Clinical experience of interlocking nail stabilization of long bone fractures in dogs—A retrospective study of 26 cases. *Israel Journal of Veterinary Medicine* **72**: 45–50.

Durall I and Diaz M C. 1996. Early experience with the use of an interlocking nail for the repair of canine femoral shaft fractures. *Veterinary Surgery* **25**: 397–406.

Duhautois B. 2003. Use of veterinary interlocking nail for diaphyseal fractures in dogs and cats. 121 cases. *Veterinary Surgery* **32**: 8–20.

Déjardin L M and Cabassu J P. 2005. Femoral fractures in young dogs. *AO Dialogue* **3**: 39–43.

Harasen G. 2003. Common long bone fractures in small animal practice–Part 1. *Canadian Veterinary Journal* **44***:* 333–34.

Ikem I C, Ogunlusi J D and Ine H R. 2007. Achieving interlocking nails without using an image intensifier. *International Orthopaedics* **31**: 487–90.

Newton and Nunamaker D M. 1985. Methods of internal fixation. *Textbook of Small Animal Orthopaedics*. (Eds) Newton C D and Nunamaker D M. International Veterinary Information Service, Ithaca, New York, USA.

Kumar H. 2016. 'Comparative evaluation of different fixation techniques for fixation of femoral fractures in dogs'. M.V.Sc. Thesis, Department of Veterinary Surgery and Radiology, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India.

Kaur J. 2017. 'Evaluation of interlocking nailing technique for fixation of long bone fractures in small animals'. M.V.Sc. Thesis, Department of Veterinary Surgery and Radiology, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India.

Raghunath M and Singh S S. 2002. Intramedullary interlocking nailing (ILN) for long bone fracture fixation in dogs using indigenously designed equipments. *Indian Journal of Veterinary Surgery* **23**: 89.

Wheeler J L, Lewis D D, Cross A R, Stubbs W P and Parker R B. 2004. Intramedullary interlocking nail fixation in dogs and cats: Clinical applications. *Compendium*: *Continuing Education* for *Veterinarians (Small animals)* **26**: 531–44.