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Repair of femoral shaft fractures by elastic plate osteosynthesis using veterinary cuttable plates in young dogs

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ABSTRACT

Immature young dogs (12), 2–5 month-old, weighing 4–9 kg, with unstable femoral diaphyseal fractures were selected and stabilized with indigenously designed veterinary cuttable plate (VCP) along with compatible size of cortical screws by elastic plate osteosynthesis (EPO) technique. Clinical lameness evaluation and radiographic evaluation for implant stability, fragment alignment and callus formation were studied. Postoperatively, all cases showed grade I lameness and complete removal of implant was done on an average 5–7 weeks after radiographic appearance of cortical union. Complications like delayed cortical union in 1 case was noticed due to wound dehiscence with distal screw pullout in which revision of surgery was performed. Outcome of fracture healing in all cases was evaluated by lameness grading, radiographic and biochemical analysis. Based on present study, elastic plate osteosynthesis (EPO) technique using VCP (narrow, thin and cut to desired length) was better suited for the treatment of femoral diaphyseal fractures than other conventional methods in young dogs with thin cortical bones and active growth plates.

Key words: Elastic plate osteosynthesis, Femoral shaft fractures, Veterinary cuttable plate, Young dogs

External coaptation methods, such as casts or splints are ineffective and contraindicated for repair of femur in young growing dogs due to anatomical orientation of hind limb. Internal fixation of long bone diaphyseal fractures in puppies has to take into account the particularities of growing bones. Especially in these cases, the surgical technique has to ensure alignment and apposition of bone fragments and also prevention of iatrogenic damage to growth plates and to preserve the periosteum. During the initial growth phase, both structural and material properties of immature bone are considerably different from those of adult bone and are characterized by lower strength, stiffness as well as lower yield stress and elastic modulus. In addition, the diaphyseal cortices are considerably thinner in young dogs compared to adults (Black and Withrow 1979). Owing to the shortcomings of intramedullary nailing and external fixation techniques, plate osteosynthesis remains the treatment of choice for femoral diaphyseal fractures in dogs. However, strict adherence to the classic AO principles of rigid internal fixation during the early growth phase routinely results in catastrophic implant failure via screw pullout and the stress shield effect at the fracture site (Dejardin and Cabassu 2008). The critical evaluation of these failures has led to the development of a new biological, elastic plate osteosynthesis technique (EPO) better suited to the treatment of femoral diaphyseal fractures in juvenile dogs. The technique relies on the increased overall compliance of the femur/plate construct to reduce the risk of focal failure of the screw/bone interface (Cabassu 2001). This led to development of veterinary cuttable plates (VCP) especially designed for internal fixation of long bone fractures in young puppies and cats with thin cortices. The purpose of this study was to standardize elastic plate osteosynthesis (EPO) internal fixation technique and size of veterinary cuttable plates (VCP) for stabilization of above fractures.

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MATERIALS AND METHODS

Immature young dogs (12), 2–5 month-old and weighing 4–9 kg, with unstable femoral diaphyseal fractures were selected and fracture stabilization was done by elastic plate osteosynthesis (EPO) technique, using indigenously designed 2.7/2.0 mm VCP and screw system according to size of the bone, fracture configuration and weight of the dog. 2.7 mm VCP for 5–9 kg body weight and 2.0 mm VCP for up to 5 kg body weight were used. The VCP in 2 sizes having common measurements of width of 7.0 mm and 50-hole length measuring 300 mm with the hole to hole distance of 6.0 mm were used. Only thickness and hole measurements changed according to size of screw (Theoret and Moens 2007) (Fig. 1).

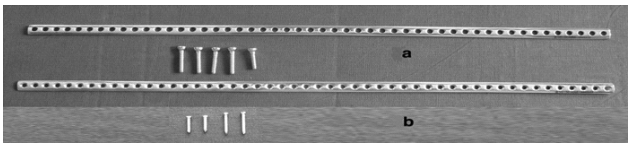

Fig. 1. Implants. a. VCP – 300 mm length, 2.7 mm plate with compatible 2.7 mm cortical screws. b. VCP – 300 mm length, 2.0 mm plate with compatible 2.0 mm cortical screws.

1. Smaller VCP (2.0): Plate thickness of 1.0 mm, plate hole length of 3.3 mm and plate hole width of 2.3 mm with 2.0 mm screws.
2. Larger VCP (2.7): Plate thickness of 1.5 mm, plate hole length of 3.8 mm and plate hole width of 2.8 mm with 2.7 mm screws.

Food and water was withheld for 12 h before treatment in all animals. The dogs were premedicated with atropine sulphate @ 0.04 mg/kg body weight subcutaneously, followed by sedation with xylazine hydrochloride after 5 min @ 1 mg/kg body weight intramuscularly before surgery. General anaesthesia was induced, after 10 min using ketamine hydrochloride at the dose rate of 10 mg/kg body weight intramuscularly and diazepam at the dose rate of 0.2 mg/kg body weight intravenously. Anaesthesia was maintained with intravenous injection of ketamine hydrochloride and diazepam at the dose rate of 1/4th of initial normal dose, for internal fixation.

The surgical site was prepared in standard manner for strict aseptic surgery. An incision was made along the cranio-lateral border of the thigh. After incising skin and subcutis along the cranial border of the biceps femoris muscle, fascialata was incised. After retracting biceps femoris caudally, vastus lateralis was reflected from the surface of femur to expose the femoral diaphysis (Piermattei and Greeley 1993). The fracture fragments were reduced with traction and counter traction. During reduction, thin cortical bone and periosteal damage was prevented using Backhaus towel clips for the manipulation of bone fragments of femur in puppies, rather than bone reduction forceps to achieve normal anatomical alignment. The fracture hematoma was not removed in some cases because of its favourable effects on healing (Dejardin and Cabassu 2008). After reduction of fracture fragments, stabilization was done using appropriate size of the VCP. According to the anticipated position of the screws in relation to the growth plates, for diaphyseal region, a strip of plate with the desired number of holes was cut between holes to the desirable length (length of the plate maintained between 8 to 13 holes/plate) from the 300 mm VCP using standard pin cutter. The plate was applied according to the principles of bridge plating which was called EPO technique in young animals (use of a longer plate and fewer screws). Screw holes were drilled with appropriate size of drill bit (1.5 or 2.0 mm) using drill guide. To increase resistance to screw pullout, the 2 adjacent screw holes drilled in diverging planes. After measuring the length of the screw with depth gauze, cortical screws were inserted without tapping. The cortical screws were placed on the most 2 or 3 proximal and distal holes of the plate leaving central plate span without screws as long as possible and included not less than three consecutive empty screw holes at the fracture site. The proximal screws were inserted near the origin of the vastus lateralis muscle and the distal screws were inserted away from metaphysis and distal growth plate. The placing and direction of the screws were done only on diaphysis without including growth plates and configuration of the fracture.

Owners were advised to restrict the activity of the dogs by keeping in confined area and not in cage rest as young puppies were difficult to be put under more restriction. So early post-operative weight bearing and mild physical activities such as leash walking, trotting to avoid fracture disease was suggested. Antibiotic therapy with ceftriaxone @ 20 mg/kg body weight intravenously was administered twice daily for 7 days. Multimodal analgesic therapy was done using meloxicam @ 0.3 mg/kg body weight and tramadol @ 2 mg/kg body weight were administered intravenously for 5 days. Plastic muzzle basket was advised to prevent self mutilation of the wound. The skin sutures were removed on the 10th post-operative day.

RESULTS AND DISCUSSION

In this study, femoral diaphyseal fractures in young dogs of age group 2–5 months were selected and the highest incidence was reported in non-descript followed by Spitz, Pomeranian, Doberman, German Shepherd, Dachshund, Pug and Labrador Retriever. This was probably due to local population of ND dogs was more and further these dogs were owner less, let loose in streets and hence were more susceptible to road accidents. Young male dogs were more prone for femoral fractures than females. The main cause of trauma was road accidents followed by fall from a height and due to jumping. Selection of appropriate size of plate and screws according to the size of the bone, weight of the dog and type of fracture configuration in each animal provided good fracture stability. Backhaus towel clips were more useful in reduction to prevent periosteal damage and thin cortex of juvenile fractured fragments. No technical difficulties were encountered while application of VCP by EPO technique in all the cases and was appeared to be easy for diaphyseal region of thin cortical bones with advantages like long thin plate (length of the plate was maintained between 8 to 13 holes/plate), more plate hole density, limited number of cortical screws at each fracture fragment (2 or 3) away from fracture site without involving growth plates. Screw positioning and their application without tapping gave good results in all selected cases.

Lameness grading: Clinical evaluation with functional outcome and lameness grading based on weight bearing was done on first, seventh, 14th, 28th, 45th and 60th day post-operative. Post-operatively, all cases showed early functional limb usage with full weight bearing with grade I lameness (Fig. 2) except case No 7, in which primary wound dehiscence with distal screw slight loosening was observed by fifth day in which revision of surgery was performed,

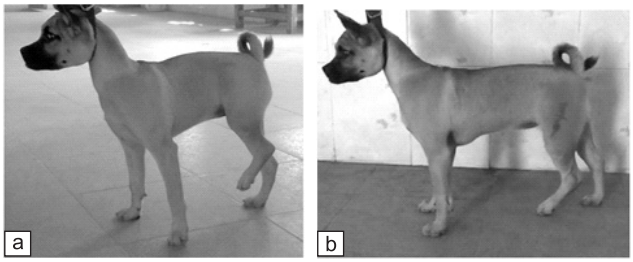

Fig 2 a,b. **(a)** Pre-operative nonweight bearing. **(b)** Weight bearing on 7th post-operative day.

and then showed Grade III lameness after 2 weeks, further the dog showed normal weight bearing of Grade I lameness after 5 weeks. Functional limb outcome was excellent in 4 cases, good in 8 cases.

Radiographical evaluation: The stability of the implant, position, fragment alignment and callus formation was assessed based on radiographic confirmation and the radiographic results evaluated in immediate post-operative stage, after third, fifth, seventh and ninth weeks in all the cases were studied (Fig. 3). The fractures showed radiographically excellent postoperative healing of cortical union, absence of fracture line with bridging and periosteal callus in an average 3–5 weeks and further remodeling changes with complete cortical union were observed in all cases by 7 weeks with some complications like slight bending of plate at fracture site observed in case No. 10 by third week but not much affected the fracture fragment alignment except case No. 7, in which slight mal-alignment observed by third week but not affected the outcome. Plate removal was done on an average of 5–7 weeks after appearance of radiographical cortical union.

Serum biochemical evaluation: Statistical analysis, the mean ± SE values revealed a highly significant difference ($P<0.01$) in serum alkaline phosphatase, calcium values in different stages of post-operative intervals and the values significantly increased from 1st day to 14thday and thereafter gradually decreased in levels noticed to normal values by 28th post-operative day. The serum phosphorus level showed no significant difference during post-operative healing period. C-reactive protein values in different stages of post-operative intervals significantly increased from 1st day to 14th day and thereafter gradually decreased in levels (Table 1).

Complications: No major intraoperative complications

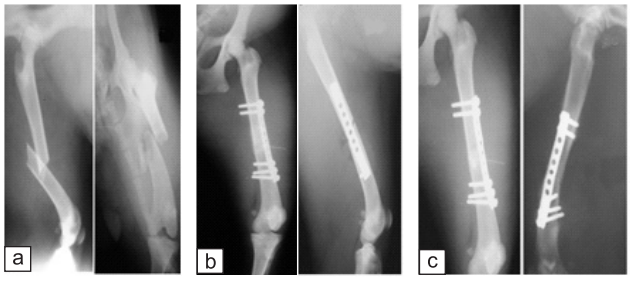

Fig. 3 (a-c). Radiographic evaluation. **a**. Pre-opeative. **b**. Immediate post-operative. **c**. Five weeks post-operative.

Table 1. Mean ± SE serum biochemical values in pre- and post-operative days

Days	Alkaline phosphatase (IU)	Calcium (mg/dl)	Phosphorus (mg/dl)	C-reactive protein (µg/ml)
0th	75.41 ± 1.26^{b}	9.38 ± 0.48^{a}	5.05 ± 0.19^{a}	13.60 ± 0.25^{b}
7th	128.58 ± 1.95^{e}	12.58 ± 0.39^{b}	5.73 ± 0.66^{b}	39.13 ± 1.12^{d}
14th	119.31 ± 1.17^{c}	14.03 ± 0.51^{a}	5.32 ± 0.36^{a}	25.01 ± 0.64^{c}
28th	99.36 ± 0.54^{d}	12.34 ± 0.37^{b}	5.16 ± 0.19^{a}	15.23 ± 0.52^{b}
45th	68.26 ± 1.14^{a}	10.22 ± 0.36^{a}	5.12 ± 0.82^{a}	9.99 ± 0.65^{a}

Fig. 4. Post-operative 7 weeks (healed fracture).

were observed. Post-operatively, delayed cortical union was observed comparatively in case No.7 where wound dehiscence with distal screw pullout was observed by fifth day in which surgery was revised but overall outcome was not affected. Slight bending of plate at fracture site in case No.10 was noticed which further did not show any mal-alignment of fractured fragments.

Implant removal: Implant removal was done on an average 5–7 weeks after radiographic appearance of cortical union (Fig. 4). Implants were removed in all the cases and all the dogs showed grade I lameness after removal.

The experimental study conducted for design and biomechanical properties of VCP by Fruchter and Holmberg (1991), Crigel and Balligand (2002), Hammel *et al.* (2006), Zahn *et al.* (2008), Rose *et al.* (2009) and Bichot *et al.* (2011) was helpful in this study. The limited number of cortical screws usage at each fracture fragment (2 or 3) away from fracture site without involving growth plates did not show any post-operative complications like premature closure of growth plate or other deformities (Cabassu 2001, Sarrau *et al*. 2007, Dejardin and Cabassu 2008). The beneficiary effect of EPO technique by maintaining plate working length, plate screw density and screw positioning in *in vitro* study conducted by Gautier (2009) was helpful to overcome the post-operative complication of implant failure.

Lameness grading based on weight bearing of all the animals under study was carried out using Vasseur *et al.* (1995). The early healing with callus formation might be due to reducing the stress shield effect on bone and allowing micromotion at the fracture site further hastens biological healing (Sarrau *et al*. 2007). Implant removal was done on an average 5–7 weeks after radiographic appearance of cortical union in accordance with Piras (2000) and Sarrau *et al*. (2007). The data regarding serum biochemical parameter values were subjected to standard statistical analysis using one way ANOVA as described by Snedecor and Cochran (1994) using SPSS^{R} 15 software package.

Based on present study, it was concluded that elastic plate osteosynthesis technique (EPO) better suited to the treatment of femoral diaphyseal fractures in young dogs. The unique design of VCP (cut to the desired length with large number of screw holes per unit length) used in this technique allowed for desired placement of screws over bones with thin cortices to reduce the risk of focal failure of the screw/bone interface. Application of elastic plate osteosynthesis technique on femoral diaphyseal fractures was more advantageous than rigid plate osteosynthesis by reducing the stress shield effect on bone and hastened the bone healing by allowing micromotion at the fracture site to more closely mimic biological healing and is more reliable than any other internal fixation techniques as it did not interfere with functional growth plates in young dogs. Implant used in this technique was not much expensive, making it amicable to use in veterinary practice.

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