



## Comparative functional outcome of supracondylar femoral fracture stabilized with cross and end threaded intramedullary pinning in dogs

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Received: 28 July 2017; Accepted: 17 August 2017

### ABSTRACT

The study was conducted on 24 clinical cases of dogs (with 26 fractures) suffering from supracondylar fractures of femur which were stabilized using cancellous negative intramedullary (IM) end-threaded pin with 5 screws (Group I, n=8), cross-pinning (Group II, n=8, 9 fractures) and cancellous negative end threaded IM pin having 10–18 threads (Group III, n=8, 9 fractures). Data collected included signalment, fracture characteristics (etiology, duration, Salter-Harris classification, pre-operative and post-operative displacement), surgical information (implant size, surgical duration) and outcome assessment (functional outcome and complications). Cross pinning technique used to stabilize supracondylar fracture of femur adversely affects flexion angles of stifle joint leading to joint stiffness compared to either of the end threaded pinning techniques; however, extension angles remain unaffected. Early weight bearing in group II suggested that crossing pinning is a rigid fixation technique compared to either end threaded pinning techniques. Minor implant related complications were recorded in group II (3) followed by group 3 (2) and group 1(1) which were managed successfully. Though fixation of supracondylar fractures using double armed end threaded pin with 5 cancellous negative threads was associated with shorter duration of surgery, and fewer postoperative complications; however, based on formation of minimal and smooth callus and better functional outcome, conventional end threaded pin with 10–18 cancellous negative threads was assessed to be a better fixation technique and was recommended for the repair of supracondylar fractures of femur in dogs.

**Key words:** Dog, Functional outcome, Goniometry, Orthopaedic surgery, Stifle joint stiffness, Supracondylar femur fracture

Supracondylar fractures of femur involving distal femoral physis (Salter-Harris type I or II) represent 37% of the physeal fractures and occur most commonly in dogs aged less than one year (Aithal *et al* 1999, Harasen 2001). Supracondylar femoral fractures are considered to include simple, low metaphyseal fractures and Salter-Harris type I and II physeal injuries (Salter and Harris 1963). It is important to preserve distal femoral physis as it accounts for 70% of femoral growth and 40% of overall limb length (Harasen 2001). The short length of distal segment, the large medullary canal and the caudal bow of the distal femur are major concerns for stabilization of supracondylar fractures (Simpson and Lewis 2003).

Close reduction is difficult to maintain and is likely to result in some stiffness of stifle joint. Intra and extra articular adhesions are likely to form during the period of immobilization of joint (Brinker *et al.* 1983). Open surgical

repair is essential to facilitate normal function of the stifle joint, to maximize the possibility of further growth at this physis, and to minimize the possibility of fracture disease, specifically contracture of the quadriceps femoris muscle (Ferguson 1998). Simple intramedullary pinning (Aithal *et al.* 1998, Stigen 1999), crossed K wires (Aithal *et al.* 1998, Singh 2000, Mahajan *et al.* 2007), Rush pins (Mahajan *et al.* 2007), dynamic intramedullary cross pinning (Whitney and Schrader 1987) and rigid fixation techniques (Aithal and Singh 1998) have been described for the repair of supracondylar fractures. Each technique was reported to be associated with implant related complications such as the pin migration, osteomyelitis, instability (Stigen 1999), lameness, non-union, malunion (Newton 1985) and quadriceps contracture (Ferguson 1998).

Threaded pins provide a comparably higher holding strength than non-threaded tipped intramedullary pin (Ogurtan 2006) and associated with fewer implant related complication for the repair of diaphyseal fractures (Kaur *et al* 2015). End threaded IM pins were also recommended for the management of distal third and supracondylar fractures of long bones in dogs (Kaur *et al.* 2016). There is lack of literature on comparison of end threaded pinning

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and cross pinning techniques for the repair of canine supracondylar femoral fractures. Therefore, this study was planned with the objective to compare the functional outcome of supracondylar femoral fractures repaired with cross and end threaded pinning in dogs.

## MATERIALS AND METHODS

**Animals:** This clinical study was duly approved by the Institutional Animal Ethical Committee. It was partially prospective and retrospective. Twenty four clinical cases of dogs (with 26 fractures) suffering from supracondylar fractures of femur were studied. The dogs were randomly divided into three groups with eight animals in each group; group 1 (cancellous negative IM end-threaded pin with 5 screws), group 2 (cross-pinning) and group 3 (cancellous negative end threaded pin having 10–18 threads).

**Signalment, history and clinical examination:** On presentation of the cases, signalment (age, sex, breed, weight) and history (involved limb, cause and duration of trauma) were recorded. Clinical examination such as recording of respiration and heart rates, rectal temperature, colour of mucus membrane and capillary refill time was performed. General condition of the affected animal was assessed from its normal alertness, ability to walk or stand on the healthy limbs and stable cardio-pulmonary parameters. Palpation of the affected bone was done to assess crepitation and soft tissue swelling at the fractured site (none, mild, moderate and severe). Other associated orthopaedic or spinal injuries were assessed.

**Hematology and serum biochemistry:** Whole blood sample (2 ml) was collected in EDTA for the estimation of hemoglobin, packed cell volume, total and differential leukocyte count and total platelet cell count. Blood samples (3 ml) were collected in syringe and kept undisturbed to form a clot so as to separate serum for the estimation of alkaline phosphatase (ALP), calcium (Ca) and phosphorus (P). These hemato-biochemical parameters were used to assess bone and overall health status and to correlate with postoperative complications, if any.

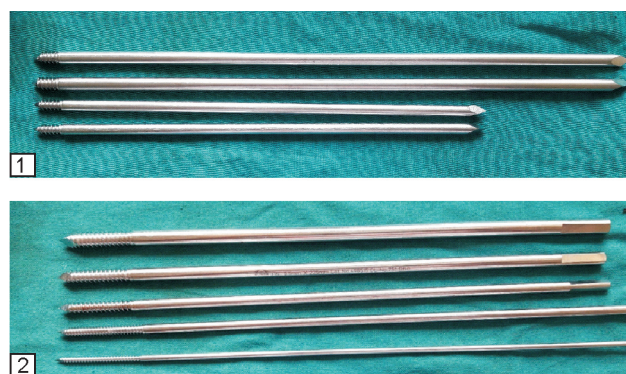
**Radiographic examination:** Preoperative radiographs were taken in two orthogonal i.e. craniocaudal and mediolateral views to assess the location and type of fracture. Preoperative radiographs were evaluated for Salter-Harris classification and displacement. Preoperative fracture displacement was graded as previously described by Arkader *et al.* (2007) (grade 1 = <1/3 of bone width; grade 2 = 1/3–2/3 of bone width; grade 3 = >2/3 of bone width and grade 4 = comminuted fracture). Diameter of medullary cavity at isthmus and length of distal bone fragment were measured electronically, on computerized radiography system.

**Preoperative care:** The affected limb was externally immobilized by modified Robert-Jones bandaging until the day of surgery. If otherwise health status was found normal, the operation was scheduled as early as possible irrespective of the type and duration of fracture. Animal were kept off feed and off water for 12 h before the surgery.

**Premedication, anaesthesia and surgical preparation:** A 20–22 G intravenous canula was placed in the cephalic or the saphenous vein to maintain intravenous line. Injection of normal saline solution was administered throughout the surgical procedure and till the recovery from anaesthesia. The preanaesthesia included an intramuscular combination of butorphenol @ 0.2 mg/kg, acepromazine @ 0.05 mg/kg, and glycopyrolate @ 0.01 mg/kg. Anesthetic induction was done using injection propofol given strict intravenously @ 4 mg/kg. A cuffed endotracheal intubation was done and anaesthesia was maintained with 1–2% isoflurane in oxygen connected to a partial rebreathing /circle system of the Boyle's apparatus. Injection cefotaxime was given @ 20 mg/kg, intravenously, intraoperatively. Limb to be operated was shaved from lumbosacral region to mid tibia. The dog was placed in lateral recumbency with the affected limb up and adequate amount of traction was applied on the fractured limb. The surgical site was cleaned and scrubbed using chlorhexidine and was painted with betadine prior to surgery.

**Implants:** In this study various types of implants made of stainless steel (LC 316) were used. A new double armed end threaded Steinmann pins were designed with one end as trocar end and other having 5 negative threads (group 1) (Fig. 1). Kirschner (K) wires with diameter 1 to 1.5 mm were used in group 2. Conventional stainless steel IM pins with cancellous negative with 10–18 threads (group 3) were used (Fig. 2). Approximate size of implant was selected occupying 60–70% of the narrowest diameter of the medullary canal of the femur, which was measured using computerized radiography system, preoperatively.

**Surgical technique:** In this study, standard surgical approach for open reduction and stabilization of supracondylar fractures of femur was followed as described by Johnson (2014). In groups 1 and 3 supracondylar / metaphyseal femoral fractures were repaired by end threaded pinning in a retrograde fashion. After exposing the fracture site, the medullary canal of the proximal bone fragment was reamed using the simple Steinmann pin. Then end threaded pin of suitable size was inserted into the medullary canal of the proximal fragment and was pushed



Figs 1–2. 1. Double armed end threaded IM pins with 5 cancellous negative threads. 2. Photograph showing conventional end threaded pins with 10–18 cancellous negative threads.

by giving rotatory movements till it passes out through the trochanteric fossa. The pin was withdrawn from the proximal segment by making anticlockwise rotations till the distal end of pin was slightly protruding the fracture site. Fracture was reduced using toggling and maintained with bone holding forceps. The pin was seated into the distal fragment by making clockwise rotations and keeping the stifle joint in over extended fashion so as to seat the threaded portion of the pin into distal metaphysis or epiphysis up to maximum depth. Care was taken to avoid piercing of articular surface of distal fragment. Pin interference in the distal joint was checked by flexing and extending the joint. The pin protruding through the trochanteric fossa was cut as short as possible.

In group 2, supracondylar / metaphyseal femoral fractures were repaired using cross-pinning technique. After surgical exposure, the stifle joint was flexed to allow better exposure to the femoral condyles. The fracture was slightly over corrected. The K-wires were inserted from the lateral and medial sides of the trochlear groove. Care was taken that the wires cross above the fracture line. Number of wires used varied from 2 to 5 which were decided based on achieving adequate stability at the fracture site. The wires were cut as short as possible.

Fracture site and stifle joint were flushed with sterile normal saline solution to remove debris. The joint capsule and tensor fascia lata were sutured together with vicryl No. 2-0 or 3-0 using simple interrupted sutures and the tensor fascia lata above the patella was sutured using simple continuous pattern. Subcuticular and skin suturing done as routine in all the groups.

*Intraoperative observations:* The type and dimensions of the implant, the method used to immobilize the fracture, duration of surgical procedure, ease of reduction of fracture, nibbling of bone fragments and extent of soft tissue damage were recorded during surgery.

*Postoperative care:* The surgical wound was dressed using Povidine Iodine solution and Neosporin powder on every 4<sup>th</sup> or 5<sup>th</sup> day till suture removal. Robert Jones bandaging (RJB) was applied on the operated limb for 2 to 3 weeks. Postoperatively all dogs were administered with cefotaxime @ 20 mg/kg body weight intramuscularly twice a day for 5 days. Meloxicam was given intramuscularly @ 0.2 mg/kg body weight once a day for 3 days. Skin sutures were removed after 10–15 days. Syrup Osteopet (Virbac Animal Health Pvt Ltd, India) was supplemented @ 1–2 tsp, orally for one month. The owners were advised to restrict the movement by cage rest and leash walking for first 15 days. Owners were advised to provide passive range of motion to the affected limb after the removal of RJB to facilitate movement of joint.

*Postoperative radiographic evaluation:* Immediate postoperative radiographs of the operated limb were taken in cranio-caudal and medial-lateral views. These radiographs were evaluated and graded (0 to 3 scale) for quality of reduction and articular alignment as described by Cook *et al.* (1999) as follows: Grade 0–anatomical

reduction, Grade 1–minimal (< 1 mm) malreduction, Grade 2–moderate (1–3 mm) malreduction and Grade 3–severe (> 3 mm) malreduction.

Follow up radiographs were also taken at 2 weeks and at 4–6 weeks or whenever the case was presented for clinical and radiographic assessment. The radiographs taken at various intervals were assessed for the status of fracture reduction, stability of implant, progress of fracture healing and for any complication. Radiographic fracture healing was assessed and scored for fracture healing (0 to 3 scale) based on callus formation and/or elimination of the fracture line or gap as described by Cook *et al.* (1999).

*Functional assessment:* The dogs were assessed for weight bearing and functional usage of the affected limb while standing and walking/running at various intervals during the postoperative period. While standing, weight bearing was scored as: 0 – carrying the limb, 1 – touching the toe, 2 – touching the paw. While walking and running, weight bearing was scored as: 0–carrying the limb, 1 - occasional touching of toe/paw, 2 - frequent touching of toe/paw, 3 – touching the toe on every step with partial weight bearing, 4 - touching the paw on every step with complete weight bearing. Total score was thus calculated by adding the scores obtained for weight bearing at standing and walking/running (range 0–6) on days 0, 15, 30, 45 and 60, postoperatively.

Functional status of the stifle joint was assessed by measuring range of motion (including maximum extension and flexion) of the affected joint and contralateral joint by goniometer. The center of the goniometer was placed at the joint and the arms of the goniometer along the long axis of the adjacent diaphysis.

Long term follow-up (maximum up to 6 months after surgery) was obtained by examination of the dog at our clinics (18) or by telephonically (3). Functional outcome was classified as full, acceptable, or unacceptable as defined as previously by Cook *et al.* (2010). Clinical lameness score (0–5) as previously described by Cook *et al.* (1999) was given at the final follow up examination. Surgical wound or implant (minor and major) related complications were recorded.

*Implant removal:* Implants were removed upon observation of satisfactory functional and radiographic bone union or complete recovery. End threaded pins (group 1 and 3) were removed from the proximal end of the femur under sedation and local anesthesia. The pin was removed by rotating in anti-clockwise fashion whereas in group 2, only protruding or migrated pins were removed.

*Statistical analysis:* The data were grouped, processed for mean and standard error (SE) and analysed for statistical differences between various groups by t-test using Microsoft Excel 2013.

## RESULTS AND DISCUSSION

This study was carried out on 24 dogs suffering from 26 supracondylar femoral fractures. Associated diaphyseal fractures of tibia, femur and humerus were also recorded

in one dog each.

The dogs included in this study had a mean $\pm$ SE age of 6.06 $\pm$ 0.93 months (range 1.5–24 months). The highest occurrence of supracondylar fractures of femur was seen in dogs of 3–6 month (45.84%) followed by 6–9 month (33.33%) age group. All dogs except one, were under one year of age. Similar findings had been reported by Mahajan *et al.* (2010) who observed common occurrence of supracondylar fracture of the femur in immature animals less than one year of age. Similarly, Balagopalan *et al.* (1995) found that dogs of age group of 3–6 months were most commonly affected (30.8%) followed by age group of day old to 3 months (27.9%). Sandhu (2000) reported the higher incidence of supracondylar fracture in age group of 2–6 months (66.67%). Higher incidence of fracture in young animals might be due to their active nature and open epiphysis (Aithal *et al.* 1999).

The male dogs were affected more (n=15, 62.50%) than female (n=9, 37.50%). The higher incidence of male animals may be due to their aggressive nature which make them more prone to falls and accidents. Similar findings were also reported by various authors (Aithal *et al.* 1999, Sandhu 2000, Mahajan *et al.* 2010, Kaur *et al.* 2015, Singh *et al.* 2015).

In this study, highest incidence of fractures was observed in non-descript dogs (20.83%, n=5). It was followed by American Bully with 16.66% (4), Pitbull and Pomeranian with 12.5% each (3), German Shepherd with 8.33% (2) and one each of Beagle, Bull Terrier, Caucasian Shepherd, Grey Hound, Labrador Retriever, Rottweiler and Cocker Spaniel. Higher incidence of fractures in non-descript dogs may be due to higher population and their free roaming nature which make them more vulnerable to road accidents. Similarly Jani *et al.* (2014) and Singh *et al.* (2015) reported higher incidence of fractures in non-descript dogs. Sandhu (2000) and Mahajan *et al.* (2010) reported higher occurrence of supracondylar fractures in Spitz breed.

The mean body weight of the dogs with supracondylar femoral fractures was 12.90 $\pm$ 1.64 kg (range 2.2–35 kg). Lower mean body weight, in this study, might be due to the fact that supracondylar fractures occur in young growing dogs. Maximum number of animals (n=11, 45.83%) were in weight group of less than 10 kg followed by in 10–20 kg with 37.50% (9) and more than 20 kg weight group with 16.67% (4). Boekhout *et al.* (2017) reported that the mean body weight of dogs and cats suffering from physal fractures was 10.4 kg (range 1.7–39.6 kg).

Fall from the height was recorded as a major cause of supracondylar fractures in 45.83% (n=11) cases, followed by automobile accident (37.5%, n=9), abusive (hit by someone) (12.5%, n=3) and fight with other dogs (4.17%, n=1). Aithal *et al.* (1999) reported that majority of supracondylar fractures occur due to fall from height (55.17%). Similarly, Kushwaha *et al.* (2011) reported a higher incidence of fracture due to fall from height (43.24%) followed by road traffic accident (27.03%). The fractures due to fall may be associated with agility in young dogs.

In this study, left limb was found most commonly (65.38%) affected as compared to right limb (34.62%). Similar findings had been reported earlier (Aithal *et al.* 1999, Singh 2000). Whereas Sandhu (2000) reported that right femur fracture were common compared to left one.

The mean hemoglobin values were within normal range in all the three groups. The preoperative samples showed increased TLC and relative neutrophilia accompanied by lymphocytopenia which may be due to stress associated with the fracture and inflammation at the fracture site. Benjamin (1985) also found that neutrophilia and lymphocytopenia might be seen as a response of the body to stress and inflammation. Mean serum levels of Ca (10.19 $\pm$ 0.24 mg/dl), ALP (158.37 $\pm$ 8.29 IU/l) and P (6.02 $\pm$ 0.28 mg/dl) and Ca: P ratio were within normal physiological range thereby ruling out any pathological fracture.

Out of 26 fractures, Salter-Harris type II fracture were highest in number (57.69%, n=15) followed by Salter-Harris type I (23.08%, n=6) and metaphyseal fracture (19.23%, n=5). Marretta and Schrader (1983) reported that majority of distal femoral physal injuries were of Salter-Harris type II. Similar findings had also been reported by Sandhu (2000) and Mahajan *et al.* (2010). On the basis of degree of displacement, 16 (61.53%) out of 26 fractures were of grade 3, 7 (26.92%) were of grade 2, 2 (7.69%) were of grade 4 and 1 (3.84%) was of grade 1.

As most of the fractures in this study were markedly displaced it suggested the importance of open reduction and internal fixation for the management of supracondylar femoral fractures. Boekhout-Ta *et al.* (2017) found that grading of preoperative fracture displacement play an important role in selection of fixation technique for physal injuries in dogs and cats. Simpson and Lewis (2003) stated that contraction of the gastrocnemius muscle contributes to caudal angulation or displacement. Cranial displacement or angulation rarely occurs. Swelling was non-appreciable in majority of the cases which could be related to low energy trauma (fall from height) and transverse to short oblique configuration of the fractures. Arnoczky *et al.* (1985) stated that the swelling at the site of fracture may vary depending upon the etiology, type of fracture, adjoining soft tissue damage and it was a normal response of tissue to injury and it begins immediately after fracture and persists until initiation of cartilage or bone formation

The mean $\pm$ SE distal fragment length was 3.01 $\pm$ 0.31 cm, 2.47 $\pm$ 0.19 cm and 2.98 $\pm$ 0.35 cm in groups 1, 2 and 3, respectively, with an overall mean 2.82 $\pm$ 0.17 cm (range 1.40–4.20 cm). Lidbetter and Glyde (2002) stated that due to the composition of distal femur, minimal bone stock was available for implant placement. So, they suggested to use alternate devices other than simple IM pin such as bone plates which provide better stability. However, use of bone plates is contraindicated for the treatment of supracondylar fractures in young growing dogs. Sufficient implant purchase in the distal segment can be difficult in dogs due to small distal fragment and large medullary canal and

complicate the stabilization of these fractures with both pins and bone plates (Lewis *et al.* 1993). Recent study recommended use of end threaded IM pins for the stabilization of diaphyseal and supracondylar fractures of long bones in dogs (Kaur *et al.* 2015, Kaur *et al.* 2016).

Reduction of fracture fragments, intraoperatively, was easily achieved in 16 cases but it was difficult in 10 cases. Intraoperative findings suggested that the reduction was difficult in cases which were delayed for more than 1 week. Berzon (1980) stated that anatomical reduction of Salter-Harris type I and II fractures can be difficult particularly if more than 48 h has lapsed since the inciting trauma.

Surgical time (Mean $\pm$ SE) was minimum in group 1 (55.00 $\pm$ 5.44 min) followed by group 2 (60.00 $\pm$ 4.83) and group 3 (61.87 $\pm$ 6.06). Mean surgical time was less in group 1 in which newly designed double armed end threaded pin was used (One end pointed and other end threaded). Time was saved as same pin could be used to ream the proximal fragment.

Assessment of immediate postoperative radiographs revealed no malreduction (Excellent reduction) in 8 fractures, malreduction of less than 1 mm in 3, malreduction of 1–3 mm in 5 and malreduction of more than 3 mm in 10 fractures (Table 1). The mean ratio of implant and medullary cavity was similar in group 1 (0.58 $\pm$ 0.02) and group 2 (0.58 $\pm$ 0.04).

Table 1. Grades of fracture reduction on radiographs

Fracture reduction	Group 1		Group 2		Group 3		Total	
	No.	%	No.	%	No.	%	No.	%
Grade 0	3	37.50	2	22.22	3	33.34	8	30.77
Grade 1	1	12.50	2	22.22	0	0	3	11.54
Grade 2	1	12.50	2	22.22	2	22.22	5	19.23
Grade 3	3	37.50	3	33.34	4	44.44	10	38.46
Total	8	100	9	100	9	100	26	100

The surgical wounds healed by primary intention in all the cases and skin sutures were removed after 10–15 days. Seroma at the proximal pin exit site was observed in three animals of group 1 and in two animals of group 3.

Postoperative radiography was done at various intervals in order to assess the implant stability and progression of fracture healing (Figs 3–5).

**Implant stability:** In this study, a total of 5 cases had implant related complications. Out of which major implant related complications leading to dislodgement were recorded in 3 animals (1 in group 2 and 2 in group 3). In the remaining 2 animals, with minor implant related complications (pin migration), it did not affect the fracture healing and functional outcome.

No implant related complications were recorded in the animals of group 1. In group 2, slight proximal migration of two pins was seen in one case and complete proximal migration of pin was seen in one case resulting in soft tissue irritation. This was of no poor consequence as the fixation was maintained and bridging periosteal callus was present

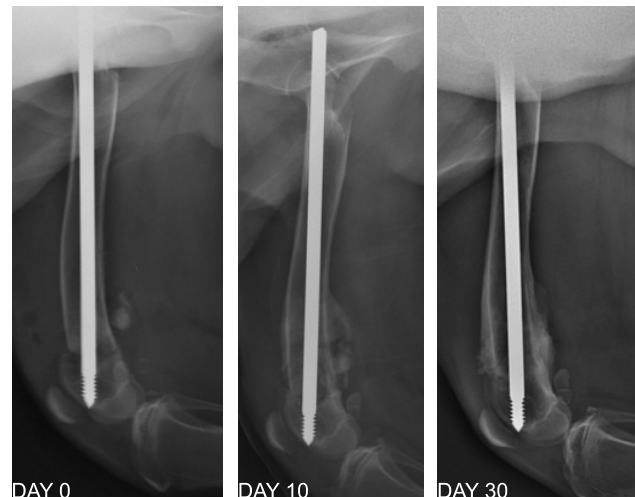


Fig. 3. Preoperative and postoperative medio-lateral radiographs of 8 month old German shepherd dog presented with grade 3 Salter-Harris type II fracture repaired with end threaded intramedullary pins having 5 threads.



Fig. 4. Preoperative and postoperative mediolateral radiographs of 5 month old Cocker-Spaniel dog presented with grade 2 Salter-Harris type I fracture repaired with Cross-pinning technique.

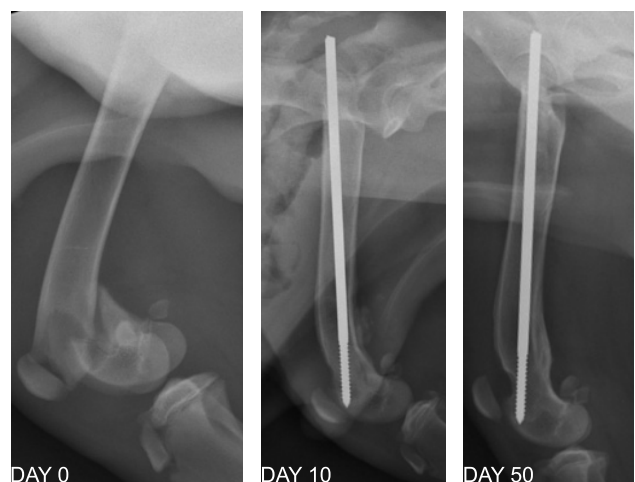


Fig. 5. Preoperative and postoperative medio-lateral radiographs of 5 month old American Bully dog presented with grade 3 Salter-Harris type II fracture repaired with end threaded intramedullary pins having 15 threads.

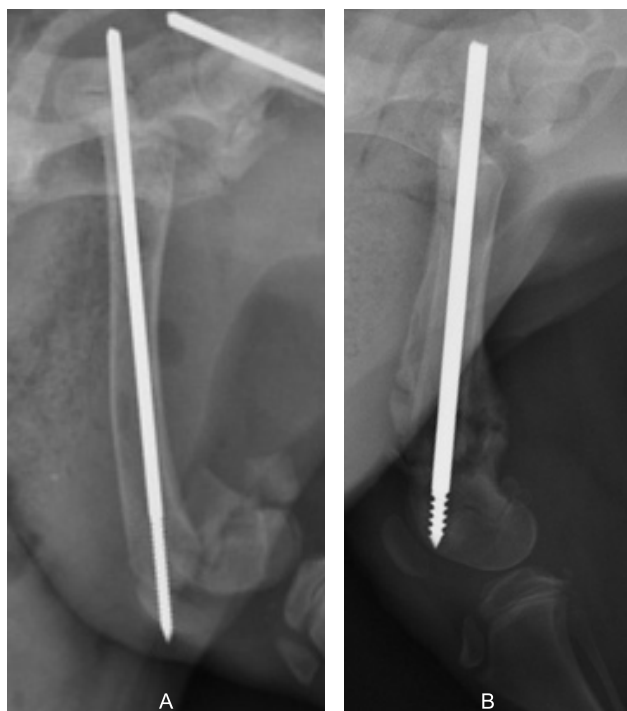


Fig. 6. Complications encountered. A. Implant dislodgement. B. Osteomyelitis.

when the pins migrated. Sandhu (2000) reported occurrence of pin migration in 5 out of 6 cases. In 4 cases, there was distal migration of pin towards lateral condyle and proximal migration in one case. Similar findings had been reported by Singh (2000) and Mahajan *et al.* (2007).

In group 3, implant was dislodged in two cases (Fig. 6A). In both the cases, improper seating of implant into the distal fragment was the reason for dislodgement. In the first case, dislodgement of implant occurred on day 4 of surgery. As the size of distal fragment in supracondylar fractures was very small so, proper seating of pin in the distal fragments is required for adequate implant stability. Similar findings had been reported previously (Kaur *et al.* 2016). In the second case, implant failure occurred on day 10 post-operatively despite of high implant to medullary cavity ratio (0.84). Both the cases were re-operated using suitable implants (end threaded pins of suitable size) and it lead to complete fracture healing.

**Radiographic assessment of fracture healing:** Group 1- On day 30, bridging periosteal callus was evident in 4 animals and complete obliteration of fracture line, radiographically, was seen in 2 animals. On day 45, bridging periosteal callus was evident in 2 animals and complete obliteration of fracture line, radiographically, was seen in 2 animals. Majority of the animals had excessive, irregular callus (5) and smooth callus in 2 animals suggesting end threaded with 5 cancellous negative threads provides less rigid fixation at the site of fracture. McKibbin (1978) stated that the amount of callus is directly related to the degree of instability at the fracture site i.e. as the stability increases, external callus diminishes. Other studies by Aithal *et al.* (1998) and Stigen (1999) observed that simple IM pin

technique in the repair of supracondylar femoral fractures, though, less traumatic to epiphysis but is associated with prolonged lameness, periosteal callus formation, less stability and more chances of complications with healing in comparison with cross pinning.

Group 2 - On day 30, bridging periosteal callus was present in 3 animals and complete obliteration of fracture line was seen in 1 animal. On day 45, bridging periosteal callus was present in 1 animal. In all animals, fracture healing was well under progress, however not completely healed at final follow-up. All the animals which were presented for radiographic evaluation showed minimum and smooth callus formation suggesting cross-pinning as rigid fracture fixation technique. Similarly, Aithal *et al.* (1998) reported that cross pinning technique provides greater stability as compared to single pin technique.

Group 3 - On day 30, bridging periosteal callus was seen in 4 animals and complete obliteration of fracture line was seen in 1 animal. On day 45, bridging periosteal callus was seen in 2 animals and complete obliteration of fracture line was seen in 3 animals. In one case, resorption of bone edges was seen on day 60 which is a common finding of fracture healing particularly in metaphyseal fractures (Brand 1979). Majority of the animals showed smooth and minimal callus formation (4) and 2 animals had excessive callus formation suggesting end threaded IM pins with 10–18 cancellous negative threads provides better rigid fixation. This finding corroborates to Kaur *et al.* (2016) who stated that end threaded IM pins lead to minimal or no callus formation in distal diaphyseal and supracondylar fractures.

Out of 20 fractures, 11 fractures showed complete radiographic healing at final follow up and 9 fractures showed appropriate progression towards healing but not completely healed radiographically (Table 2). However, 100% healing percentage was recorded for all the three groups.

Aithal *et al.* (1998) reported early fracture healing in cross intramedullary pin as compared to single pin fixation. Boekhout *et al.* (2017) reported that the physeal fractures treated with fluoroscopic assisted percutaneous pinning healed in less than 12 weeks.

**Functional outcome:** Long term follow up was obtained by examination of dog at our clinics in 18 cases (20 fractures) and by telephonic conversation in 3 cases. Out of 23 fractures, full functional outcome was observed in 15 fractures (65.22%), acceptable function was observed in 7

Table 2. Fracture healing score, radiographically, in various groups on final follow-up

Fracture healing	Group 1	Group 2	Group 3	Total	%
0	4	3	4	11	55.00
1	3	3	3	9	45.00
2	0	0	0	0	0
3	0	0	0	0	0
Total	7	6	7	20	100

Table 3. Assessment of functional outcome in cases of supracondylar fractures

Group	Full	Acceptable	Unacceptable
Group 1	5	2	1
Group 2	4	3	0
Group 3	6	2	0
Total	15	7	1
Per cent	65.22	30.44	4.34

fractures (30.44%) and unacceptable function was observed in one fracture (4.34%) (Table 3).

**Weight bearing score:** In group 1, five animals started bearing weight on the 5<sup>th</sup> postoperative day on the operated limb whereas remaining three animals started bearing weight between 15 to 30 days.

In group 2, all except two animals started bearing weight on operated limb from the very first postoperative day suggesting that cross pinning provides rigid fixation of fracture as observed previously also (Aithal *et al.* 1999, Mahajan *et al.* 2010). However, at the final follow-up, weight bearing score was less as compared to other two groups. This may be attributed to the stiffness of joint caused by the interference of pins in the stifle joint.

In group 3, on the 5<sup>th</sup> postoperative day, five animals started bearing weight on the operated limb whereas three animals started bearing weight between 15 to 20 days. On day 15, weight bearing scores remained less than normal in all the three groups. Lameness was more intense in group 1 and weight bearing scores remained less for a prolonged period (day 45) (Table 4). Weight bearing improved gradually to attain near normal level at the end of follow up in most of the animals. Sandhu (2000) reported that normal weight bearing and locomotion was restored earlier in cases repaired with retrograde intramedullary pinning as compared to cases repaired with cross-pinning.

Table 4. Weight bearing scores at various intervals

Group	Day 0	Day 15	Day 30	Day 45	Day 60
Group 1	0.5±0.26	1.87±0.61	2.87±0.76	3.87±0.58	5.12±0.35
Group 2	0.42±0.29	2.42±0.65	3.42±0.84	4.28±0.74	4.85±0.63
Group 3	0.5±0.18	2.12±0.69	3.12±0.87	4.37±0.42	5.25±0.31

**Goniometry:** Extension and flexion angles in dogs upon complete healing of supracondylar fractures in all the groups is depicted in Table 5. Goniometry was performed with goniometer in 18 animals with 20 fractures to assess the range of motion of stifle joint.

In group 1, one dog had increased range of motion by 5° in extension. Decreased range of motion was noted in 3 out of 7 cases. Four animals had normal range of motion. In group 2, decreased range of motion was noted in 4 out of 6

Table 5. Extension and flexion angles of stifle joint in dogs with supracondylar femur fractures.

Parameter	Group	Day 15	Day 30	Contralateral limb
Extension angle (degree)	Group 1	136.85±2.04	138.85±2.15	138.14±2.21
	Group 2	132±4.01	135±2.24	135±2.24
	Group 3	135±2.44	137.14±1.84	137.14±1.84
Flexion angle (degree)	Group 1	53.57±10.00	41.28±8.46	37.57±1.58
	Group 2	70±4.29	60.83±6.27	36.66±1.05
	Group 3	53.42±4.94	46.28±4.39	34.57±0.20

cases. Two dogs had normal range of motion. In group 3, decreased range of motion was noted in 3 out of 7 cases. Four animals had normal range of motion.

The flexion angles of the affected stifle joints was more on day 15 as compared to that of normal joints. Increased in flexion angle on day 15 could be attributed to inflammation and pain observed in the early postoperative period. The range of motion improved gradually to attain near normal level. Among extension and flexion angles, flexion was more affected than extension. The flexion angle was more affected in group 2 as compared to group 1 and 3 (Table 5). Stifle joint stiffness had been reported as common postoperative complication of supracondylar fractures of femur (Aithal *et al.* 1998, Aithal *et al.* 1999, Singh 2000, Mahajan *et al.* 2007).

**Lameness score:** Lameness score observed at the final follow up examination ranged from 0 to 2. Fifteen dogs had a score of 0, six dogs had a score of 1 and two dogs had a score of 2 (Table 6). No observable lameness was found in majority of the animals at the final follow-up examination.

Table 6. Lameness score in various groups

Score	Group 1	Group 2	Group 3	Total
0	5	4	6	15
1	2	2	2	6
2	1	1	0	2
3	0	0	0	0
4	0	0	0	0

**Complications:** Radiographically, 7 cases had complications but all these cases lead to full functional outcome. These included delayed union (2), slight malalignment (5) and implant failure (2) (Table 7). Another 5 cases with acceptable functional outcome also had radiographically apparent abnormalities such as slight malalignment (4), implant failure (3) and osteomyelitis (1) (Fig. 6B) (Table 8).

Clinically apparent complications were recorded in three cases. Two cases showed signs of sciatic nerve paralysis and one case showed quadriceps contracture. Lidbetter and Glyde (2000) stated that supracondylar femoral fractures predispose the animal to soft tissue complications like quadriceps contracture and tie-downs which results into

Table 7. Radiographically apparent complications and/or combinations of these complications of supracondylar femoral fractures in 7 cases with full functional outcome

Group	Breed (n=7)	Age (months)	Minor complications		Major complications	
			Delayed union	Slight malalignment	Implant failure	Osteomyelitis
Group 1	Beagle	6	Yes	Yes	-	-
	Rottweiler	24	-	Yes	-	-
Group 2	American Bully	3.5	Yes	Yes	-	-
	Cocker Spaniel	5	-	-	Yes	-
Group 3	Spitz	6	-	Yes	-	-
	Non-descript	3	-	Yes	-	-
	Spitz	7	-	-	Yes	-

Table 8. Radiographically apparent complications and/or combinations of these complications of supracondylar femoral fractures in 5 cases with acceptable functional outcome

Group	Breed (n=5)	Age (months)	Minor complications		Major complications	
			Delayed union	Slight malalignment	Implant failure	Osteomyelitis
Group 1	American Bully	3.5	-	Yes	-	-
	Bull Terrier	4	-	Yes	-	Yes
Group 2	Grey Hound	6	-	Yes	Yes	-
	Non-descript	12	-	-	Yes	-
Group 3	Non-descript	3	-	Yes	Yes	-

rigid hyperextension of the affected leg with reduced flexion of both the stifle and hock joint. Palmer *et al.* (1988) reported that the normograde pinning of the femur may be less likely to induce sciatic nerve injury, particularly in midshaft and distal fractures as compared to retrograde pinning. During retrograde application, holding the hip joint in slight extension and adducting the leg minimizes soft tissue penetration and prevents the exposed pin from damaging the sciatic nerve (Deyoung and Probst 1993).

Implant removal was done either upon complete radiographic clinical union (11) or implant was removed 25 days postoperatively due to osteomyelitis (1). In one case, implant was not removed as it was seated deep enough due to growth of bone and the remaining 3 animals (with 4 fractures) were not presented for implant removal but had satisfactory functional outcome as conveyed on telephonic follow up. Macias and Mckee (2003) suggested that the implants crossing a physis should be removed in skeletally immature animals once the fracture is healed, so that any potential bone growth is not restricted. In Group II, implant removal was done in two cases due to proximal migration of pins. The fracture was healed at the time of migration and the Kirschner wire was removed resulting in resolution of the associated clinical signs. Whitney and Schrader (1987) stated that pin removal should only be attempted if pin migration or irritation results in lameness.

From the present study, the following conclusions were drawn

- Though fixation of supracondylar fractures using double armed end threaded pin with 5 cancellous negative threads was associated with shorter duration of surgery, and fewer postoperative complications;

however, based on formation of minimal and smooth callus and better functional outcome, conventional end threaded pin with 10–18 cancellous negative threads was assessed to be a better fixation technique and is recommend for the repair of supracondylar fractures of femur in dogs.

- Cross pinning technique used to stabilize supracondylar fracture of femur leads to rigid fracture fixation but it adversely affects flexion angles of stifle joint leading to joint stiffness compared to either of the end threaded pinning techniques; however, extension angles remain unaffected.

#### ACKNOWLEDGEMENTS

Authors are thankful to Indian Council of Agricultural Research, New Delhi for financial support under 'All India Network Program on Diagnostic Imaging and Management of Surgical Conditions in Animals'.

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