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Research Article

A Randomized Clinical Study to Evaluate Effect of Working Length and Rod Size for Plate Rod Fixation of Unstable Diaphyseal Femoral Fracture in Dogs

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Abstract

Study was conducted to evaluate clinical effect of working length and rod size for plate rod fixation of unstable diaphyseal femoral fracture repair in dogs. Twenty-four cases were randomly divided into four groups A, B, C and D having six animals in each. Three bicortical screws in proximal and three in distal fragments with minimum two empty holes at the centre were fixed for short plate working length (SPWL) in groups A and B with intramedullary rod (IMR) occupying 30% and 40% of medullary canal, respectively. Two bicortical screws in proximal and two in distal fragments were fixed with minimum four empty holes at the centre for long plate working length (LPWL) in groups C and D with IMR occupying 30% and 40% of medullary canal, respectively. Fracture healing progress in all the groups was assessed using clinical, photographic and radiographic observations. All the groups showed either excellent or very good functional, radiographic and long-term outcome at the end of week 14 post-surgery. The time taken to show complete mobility and weight bearing was non-significantly ($P > 0.05$) less in groups A and B. The functional, radiographic and long-term outcomes of repair were excellent in groups A and B without any major complications. Short plate working length with IMR occupying 40% of medullary canal of plate rod fixation provided comparatively better stability with fewer complications for femoral fracture repair in dogs.

Keywords: Plate Working Length; IMR Diameter; Plate-Rod; Femur; Dog

Introduction

Locking compression plate (LCP) has revolutionized internal plate fixation technique for long bone fracture management in animals [1]. The combination of intramedullary (IM) pin/rod and bone plate significantly increases the construct stiffness and estimated number of fatigue failure when compared to plate alone and been found to be an ideal implant system for management of comminuted fractures in dogs and cats [2].

The distance between the proximal and distal screws in closest proximity to the fractures defined as the "working length" of the plate [3]. Recognition of weakness of exposed span with empty screw holes at the center of the construct termed as plate working length led to the concept of combining a plate and intra-medullar pin. Addition of IM pin to a bone plate decreases strain on the plate two-fold and subsequently increases the fatigue life of the plate-rod construct 10-fold compared with that of plate alone [4]. A pin of at least 30% of intramedullary diameter is required to increase the bending stiffness and additional significant stiffness is gained by the use of a 40% IM pin [5].

To reduce plate stress, working length should be minimized by locating screws close to the fracture ends on either side of fracture gap [6]. A recent biomechanical study opines that screw configurations which shorten the plate working length provide maximum axial and bending stiffness [5]. As per the authors knowledge clinical studies on the effect of plate working length and size of IM rod using LCP as plate rod construct for the repair of unstable femoral fracture in dogs are not reported yet. We hypothesize that the combination of long plate working length of LCP with IM pins of 40%

diameter would be a better choice for treatment of unstable femoral diaphyseal fractures in terms of less stiff fixation that would stimulate secondary bone healing. It also reduces stress in the plate as it will be spread over a wide plate span. Therefore, present study was planned to evaluate the clinical effect of plate working length and IM pin/rod size as plate rod fixation for the management of unstable diaphyseal femoral fracture in dogs.

Materials and Methods

The study conducted on clinical cases of dogs presented unstable diaphyseal femoral fracture in dogs at. Informed consent was obtained from the owner of each dog before surgery.

A total of 24 clinical cases of dogs presented with unstable fractures of femur were selected and randomly divided into 4 groups A, B, C and D having six animals in each. Locking compression plates were used for plate-rod constructs. Combinations of short plate working length (3 bicortical screws in proximal and distal fragments with minimum2-hole gap) for plate rod constructs using IMR of 30% and 40% size of medullary canal were used in groups A and B, respectively. For long plate working length (2 bicortical screws in proximal and distal fragments with minimum4-hole gap) plate-rod constructs using IMR of 30% and 40% size of medullary canal were used in groups C and D, respectively (Figure 1). Dogs with concurrent injuries, nutritional and metabolic disorders of bone were excluded from the study.

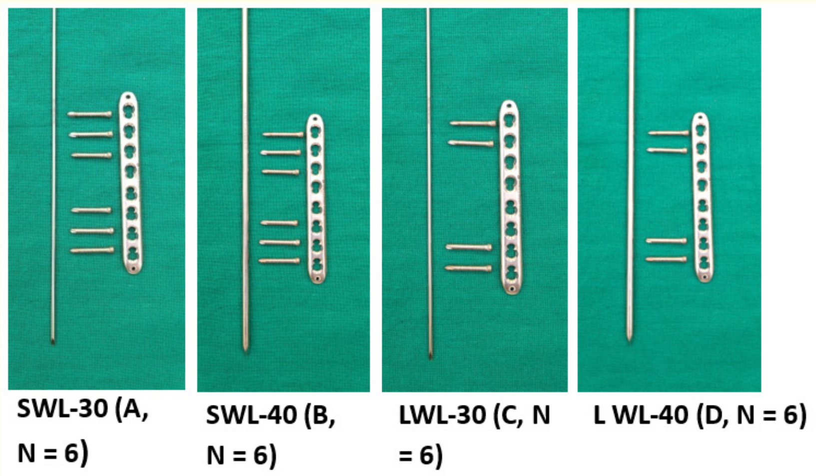

Figure 1: Representative images of the constructs of rod and plate configurations. (SWL: Short Working Length; LWL: Long Working Length).

Pre operatively, food was withheld for 12 hours and water for 6hours in all the dogs. Dogs were pre-medicated with atropine sulphate at the rate of 0.04 mg/kg body weight subcutaneous injection. After 15 minutes diazepam was given @ of 0.5 mg/kg body weight followed by butorphanol @ 0.05 mg/kg body weight intravenously. General anesthesia was induced with thiopentone sodium, @ 12.5 mg/kg body weight intravenously. Endotracheal intubation was done and the anesthesia was maintained with isoflurane.

The diameter of the IMR and the dimensions of the locking plates to be used were predetermined based on medio-lateral radiographs of the fractured and contra lateral femurs. An open fracture reduction through a standard cranio-lateral approach to femur was considered. IMR was inserted in a normograde fashion to re-establish the spatial alignment of fractures fragments. Locking plates were applied using self-tapping fixed angle locking screws of corresponding sizes. The holes were drilled under the guidance of a drill sleeve and were fixed as per the description in all groups given in table 1 using standard AO-ASIF recommendations [7]. The excessive IMR protruding out at the proximal end was cut as short as possible.

Data regarding age, body weight, sex breed, etiology, time elapsed and external were recorded. The fractures were classified according to the Unger's classification [8] and number of fractured fragments was noted. The duration of surgery, extent of manipu-

Sl no	Dog no	Age (months)	Breed	Sex	Body weight (Kg)	Etiology of fracture	Type of fracture (Unger's class)	Fracture Orientation/ Complexity	Plate size	Type of complication	Complications	Compliance with post operative care	Functional outcome
1	AI	8	Labrador Retriever	M	25	RTA	32A2	Short oblique	10 holes,3.5mm × 11mm	-	-	Compliant	Excellent
2	AII	9	Labrador Retriever	F	27	RTA	32A2	Short Oblique	9 holes, 3.5mm × 11mm	-	-	Compliant	Excellent
3	AIII	9	Non-Descript	M	13	RTA	32B2	Several reducible wedges	8 holes, 3.5mm × 11mm	-	-	Compliant	Excellent
4	AIV	11	German Shepherd	F	17	Fall	32A2	Short oblique	9 holes, 3.5mm × 11mm	-	-	Non-compliant with movement restriction	Excellent
5	AV	8	Labrador Retriever	F	11	RTA	32A3	Transverse	8 holes, 3.5mm × 11mm	-	-	Compliant	Excellent
6	AVI	32	Non-Descript	F	16	RTA	32B2	Several reducible wedges	8 holes, 3.5mm × 11mm	Minor	Seroma formation and periosteal reaction (2nd week)	Compliant	Excellent
	Mean ± SE	12.83 ± 3.85			18.16 ± 2.63								

Table 1: Case details of dogs with femur fracture repaired in group A.

lation, soft tissue damage, the technique adopted, dimensions and configurations of implants used and degree of ease or technical difficulty in application of implants were also recorded. Duration of surgical procedure (in minutes) was calculated as the total time required for the procedure from skin incision up to the application of the last skin suture. Time till repair (in days) was calculated as the interval between the fractures occurred till the fracture is fixed surgically.

Lameness grading was done as numerical rating scale with six levels of severity by lameness evaluation at stance, walk and trot of the dog on day of presentation and on 4th, 6th, 10th and 14th post operative weeks. Scoring was done based on grading system suggested by [9] for hind limb lameness as 5: No detectable lameness at walk or trot and no detectable lateral weight shift at a stance, 4: No detectable lameness at walk or trot and minor lateral weight shift at a stance, 3: Lameness at walk or trot without hip hike, 2: Lameness at walk or trot with hip hike, 1: Non-weight bearing at trot, 0: Non-weight bearing at a stance.

Radiographs taken were evaluated to assess the status of fixation; status position and configuration of implant used; any post operative complication; and status of fracture healing during the 4th, 6th, 10th and 14th post operative weeks. Fracture healing was evaluated by score followed by [10] with numerical scaling of 1-5 as follows. A score of 1 reflected no evidence of callus (distinct fracture line), 2: minimal callus formation (distinct fracture line), 3: moderate callus formation (discernible fracture line), 4: advanced callus formation (barely discernible fracture line) and 5: complete callus formation (obliterated fracture line).

The functional outcome of the repair was scored during the 14th post operative weeks and graded as 1: Poor (Those with a permanent moderate to severe gait abnormality), 2: Fair (those with a frequent mild to moderate weight bearing lameness) 3: Good (Those animals with very mild intermittent lameness after prolonged vigorous exercise) and 4: Excellent (animals that returned to complete normal function without any detectable gait abnormality) [11] .

Time required attaining normal mobility and complete weight bearing of affected limb (in days) was calculated from the date of surgery to the day when affected limb shows mobility and weight bearing. Time taken to attain complete radiographic healing (in weeks): was calculated from the date of surgery to the day when complete radiographic healing was noticed on the orthogonal projections.

Complications were graded as major (severe malalignment, severe arthrosis in the surrounding joints, nonunion, osteomyelitis, muscle contractures and implant failure were graded as major were complications) or minor (slight malalignment, hypertrophic callus, mild arthrosis in the surrounding joints and delayed union) as described in literature [12].

Summary statistics such as mean ± SE and, median and interquartile ranges (IQR, 25% to 75% quartile) were calculated for all the variables. Single measurements of continuous variables between groups were compared using one way analysis of variance (ANOVA) and Turkey's HSD *post-hoc*test. An independent sample't' test was used to compare the parametric data between two groups (screw density and IMR diameter). Non-parametric variables such as scores at different intervals between groups were compared using Kruskal-Wallis H test. Wilcoxin signed rank test was used to evaluate non parametric data at different time intervals within a group.

Results and Discussion

The locking compression plates are preferred over conventional plates owing to its biological and mechanical advantages. It provides nearly uniform bending stiffness along the entire length of the plate [13], does not compromise periosteal blood supply and convert axial load to a compressive force rather than to shear stress [14].

The breeds, age, sex, body weight, etiology, type of fracture, Unger's class, fracture orientation, plate size, complications, and compliance with post operative care and functional outcome of each case of the study have been shown in table 2-4. There was no significant difference ($P > 0.05$) observed between any of the groups with respect to the age, body weight, time elapsed, etiology and preoperative soft tissue inflammation scores. All the dogs were in good general body conditions and met the criteria for inclusion in the study particularly with respect to bone quality. Body weight of the dogs is a mechanical factor that determines the amount of stress and strain acting on a bridging construct [4]. The dimensions of LCPs used in the present study were in agreement with the previous studies [15].

The soft issue inflammation subsided following stabilization of fractures in all the groups on 2nd post operative week. The seroma formation, cellulitis and mild instability of construct due to pin mi-

Sl no	Dog no	Age (months)	Breed	Sex	Body weight (Kg)	Etiology of fracture	Type of fracture (Unger's class)	Fracture Orientation/ complexity	Plate size	Type of complica-tion	Complications	Compliance with post operative care	Functional outcome
1	BI	9	German Shepherd	F	24	RTA	32C3	Non reducible wedges	9-hole, 3.5 mm × 8mm	-	-	Compliant	Excellent
2	BII	9	Non-Descript	F	15	RTA	32B2	Several reduc-ible wedges	8 holes, 3.5mm × 11mm	-	-	Compliant	Excellent
3	BIII	5	Labrador Retriever	F	10	Fall	32B1	One reducible wedge	8 holes, 2.7mm × 8mm	-	-	Compliant	Excellent
4	BIV	8	Non-Descript	F	12	RTA	32A2	Long oblique	8 holes, 3.5mm × 11mm	-	-	Compliant	Excellent
5	BV	9	Rottweiler	F	27	Fall	32A3	Short Oblique	8 holes, 3.5mm × 11mm	-	-	Non-com-pliant with movement restriction	Excellent
6	BVI	36	Non-Descript	F	17	Fall	32B2	Several reduc-ible wedges	8 holes, 3.5mm × 11mm	Minor	Slight mal-alignment and seroma formation (2nd week)	Compliant	Excellent
Mean ± SE 12.66 ± 4.70 17.50 ± 2.74													

Table 2: Case details of dogs with femur fracture repaired in group B.

Sl no	Dog no	Age (months)	Breed	Sex	Body weight (Kg)	Etiology of fracture	Type of fracture (Unger's class)	Fracture Orientation/ complexity	Plate size	Type of complica-tion	Complications	Compliance with post operative care	Functional outcome
1	CI	6	Non-descript	M	11	Fall	32B2	Several reduc-ible wedges	8 holes, 2.7 mm × 8 mm	Minor	Slight mal alignment	Compliant	Excellent
2	CII	8	Pitbull	M	14	RTA	32B1	One reducible wedge	8 holes, 3.5 mm × 11 mm	Major	Partial IMR migration, screw loosening (2nd week), implant failure and mal union	Non-compliant with movement restriction	Fair
3	CIII	9	German Shepherd	F	24	Fall	32C3	Non-reducible wedges	10 holes, 3.5 mm × 11 mm	Minor	Plastic deforma-tion of plate and inward angling of screws and limb shortening	Non-compliant with movement restriction	Good
4	CIV	12	Non-descript	M	13	RTA	32A2	Short Oblique	8 holes, 2.7 mm × 8 mm	-	-	Compliant	Excellent
5	CV	18	Pitbull	F	21	Fall	32A3	Transverse	8 holes, 3.5 mm × 11 mm	-	-	Compliant	Excellent
6	CVI	14	Non-descript	F	14	RTA	32B1	One reducible wedge	8 holes, 3.5 mm × 11 mm	-	-	Compliant	Excellent
Mean ± SE 11.16 ± 1.90 16.16 ± 2.08													

Table 3: Case details of dogs with femur fracture repaired in group C.

Sl no	Dog no	Age (months)	Breed	Sex	Body weight (Kg)	Etiology of fracture	Type of fracture (Unger's class)	Fracture Orientation/ complexity	Plate size	Type of complication	Complications	Compliance with post operative care	Functional outcome
1	DI	8	German Shepherd	F	19	Fall	32B1	Several reducible wedges	8 holes, 3.5 mm× 11 mm	Minor	Hypertrophic callus (8th week)	Compliant	Excellent
2	DII	10	Spitz	F	10	Fall	32A2	Short oblique	8 holes, 3.5 mm × 11 mm	-	-	Compliant	Excellent
3	DIII	17	Non-descript	M	13	RTA	32A3	Transverse	8 holes, 3.5 mm × 11 mm	Minor	Periosteal reaction	Compliant	Excellent
4	DIV	12	Non-descript	M	17	Fall	32A3	Transverse	8 holes, 3.5 mm × 11 mm	Minor	Seroma formation	Compliant	Excellent
5	DV	8	Doberman	M	25	RTA	32C3	Non-reducible wedges	9 holes, 3.5 mm × 11 mm	Minor	Osteolytic changes at pin insertion point, muscle atropy	Non-compliant with movement restriction	Good
6	DVI	11	Labrador	M	29	Fall	32C3	Non-reducible wedges	8 holes, 3.5 mm × 11 mm	-	-	Compliant	Excellent
Mean ± SE 11.00 ± 1.36 18.83 ± 2.92													

Table 4: Case details of dogs with femur fracture repaired in group D.

gration and cerclage wire irritation added to the soft tissue inflammation in assorted cases.

The mean ± SE values of duration of surgery, number of fracture fragments, time till repair, intramedullary cavity diameter, no. of screws in proximal fragment, no. of screws in distal fragment, no. of empty holes in the centre (working length), screw density, IMR occupying medullary cavity diameter, radiographic healing time in weeks and time taken to attain mobility and complete weight bearing in weeks in all groups has been depicted in table 5. The stress and overall deformation on the screws and strain on the plate were comparatively less in group B than groups A and C. Hindrance in placement of bicortical screws along the diaphysis was encountered in few cases of groups B and D might be due to the inability of locking screws to comply with more than five degrees of angulations in order to achieve angle stable lock with the plate holes. Similar observation of hindrance in placement of screws for plate rod construct for femoral fracture repair has been reported [15]. The mean screw densities used were 0.75 ± 0.00, 0.75 ± 0.00, 0.48 ± 0.01 and 0.48 ± 0.01 in groups A, B, C and D, respectively. It is adequate to keep the plate screw density value below 0.5 to 0.4 empirically while bridging a comminuted fracture i.e., only less than half of the plate holes should be occupied by the screws [13].

Fracture healing in all the dogs of groups A and group C was satisfactory with gap healing or early callus formation. This can be attributed to biological osteosynthesis with more compliant bridging constructs using smaller diameter IMR filling 30% of medullary cavity. It is in agreement with biomechanical findings that smaller diameter IMR should be desired for greater compliance and beneficial micromotion between fracture fragments [16]. The major complication encountered in group C animals may be attributed to the insufficient relative stability provided by the construct. Hence further studies are required in larger number of dogs to evaluate the demarcation between beneficial effect of micromotion desired by lesser diameter IMR which should not compromise with construct stability and bending strength leading to implant failure. There were no major complications observed in groups B and D which can be correlated with the biomechanical findings suggested that the overall stiffness increases 6%, 40% and 78% when rods filled 30%, 40% and 50% of the medullary canal, respectively [17].

Lameness scores improved significantly from 2nd to 6th week post-surgery and reached excellent level on 10th and 14th week post-surgery in all groups (Figure 2-5, Table 6). The scores on the 4th, 6th, 10th and 14th week did not show any significant difference ($P > 0.05$) between the groups, while a non-significant decline in the median scores was observed in group C at 6th and 10th post

Group	Duration of Surgery (minutes)	No. of fracture fragments	Time till repair (days)	Intra-medullary cavity diameter (mm)	Approx % of medullary cavity occupied by IMR	No. of screws in proximal fragment	No. of screws in distal fragment	No. of empty screw holes at the centre (working length)	Screw density	Radiographic healing time (weeks)	Time taken to attain mobility and complete weight bearing (weeks)
A	54.33 ± 1.80	2.82 ± 0.54	3.50 ± 0.34	10.25 ± 0.29	31.77 ± 1.07*	3.16 ± 0.47	3.16 ± 0.30	2.16 ± 1.66	0.75 ± 0.04*	16.37 ± 0.55	10.50 ± 1.36
B	55.33 ± 2.17	4.83 ± 1.37	3.00 ± 0.36	8.98 ± 0.38	39.12 ± 1.36	3.33 ± 0.49	2.50 ± 0.22	2.00 ± 0.00	0.73 ± 0.01*	17.16 ± 0.83	7.16 ± 0.47
C	48.83 ± 1.42	4.30 ± 1.28	4.33 ± 0.91	9.90 ± 0.85	29.76 ± 1.42*	2.00 ± 0.00	2.00 ± 0.00	4.33 ± 0.33	0.48 ± 0.01	16.77 ± 0.52	8.16 ± 1.27
D	51.83 ± 2.28	4.50 ± 1.58	5.83 ± 3.07	9.15 ± 0.55	38.23 ± 0.71	2.00 ± 0.00	2.00 ± 0.00	4.16 ± 0.16	0.48 ± 0.01	15.56 ± 0.64	10.83 ± 2.62

Table 5: Mean ± SE, values of duration of surgery, no. of fracture fragments, time till repair, details of implants used, radiographic healing time in weeks and taken to attain mobility and complete weight bearing in weeks.

* Differ significantly between groups.

Group	Lameness scores based on stance, walk and trot (Weeks post-surgery)				
	0 day	4th week	6th week	10th week	14th week
A	0.00 (0.00) a	3.00 (2.75-400) b	4.00 (4.00-5.00) c	4.75 (5.00) cd	5.00 (5.00) d
B	0.00 (0.00) a	3.00 (2.75-3.25) b	4.5 (4.00-5.00) c	5.00 (4.75-5.00) c	5.00 (4.75-5.00) c
C	0.00 (0.00) a	3.00 (1.75-3.25) b	3.75 (4.00-4.25) c	4.00 (4.00-5.00) cd	5.00 (4.75-5.00) d
D	0.00 (0.00) a	3.00 (2.00-3.00) b	4.00 (4.00-4.25) c	5.00 (4.75-5.00) c	5.00 (4.75-5.00) c

Table 6: Comparison of lameness scores among the experimental groups (Median and IQR).

abc Differ significantly between intervals within respective group.

Different lowercase superscripts within a row indicates the effect of time post-surgery within a group. Values in each cell indicates median and the value within a parenthesis indicates inter-quartile range.

operative weeks, owning to complications. Lameness subsided at 14th week post-surgery in all the groups and scores did not differ significantly (P > 0.05) between the groups during the 12th post operative week. Early limb function with PRCs can be attributed to the fact that plate-rod technique enables adequate fracture reduction and load sharing between the implant and bone [18]. Intramedullary pin acts as replacement of transcortical defect in the bony column and acts in concert with eccentrically placed plate to resist bending [19].

Radiographic union scores improved significantly from 4th to 14th week predominantly by secondary healing in most of cases (Figure 2-5, Table 7). Normal fracture healing was achieved in all cases except complications like slight malalignment of the limb (case CI, Figure 6, A and B) and IMR migration (dog CII, Figure-6, C and D) during early load sharing phase were observed in group C. The inevitable removal of migrated IMR led to the development of subsequent complications like plate instability, slight to severe mal alignment of fracture fragments, plastic deformation of locking plates, screw loosening, delayed union and even failure of the implants. However, in groups A, B and D no instances of implant related complications were recorded.

Radiograph taken at 2nd week revealed retention of stable fixation with slightly increased radiolucency of fracture line in most of the cases. A faint periosteal bridging callus was seen on 2nd week which turned into dense periostel bridging callus on 8th week post-surgery. Disappearance of fracture line and cortical continuity was noticed in the 10th to 12th post operative week radiographs. The scores on the

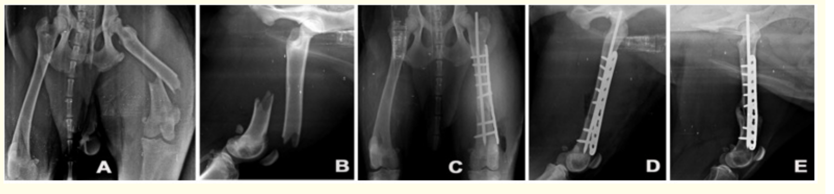

Figure 2: Representative radiographs of cranio-caudal (A) and mediao-lateral (B) views of the fractured femur in a dog of group A. Note an increased opacity and dense periosteal bridging callus (E) at week 6 post-surgery as compared with the immediate post operative cranio-caudal(C) and mediao-lateral (D) views of the fracture site.

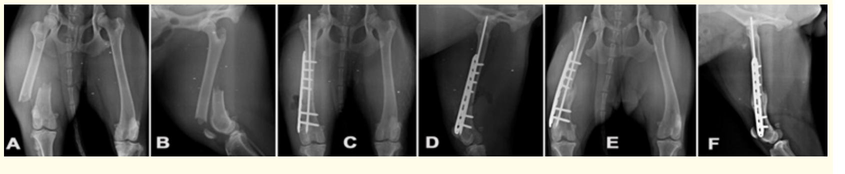

Figure 3: Representative cranio-caudal radiographs taken (group B) preoperatively ventrodorsal (A) medio lateral (B), immediate post operative status of implants (C and D) cortical continuity and apparent disappearance of the fracture line at 14 week post-surgery (E and F).

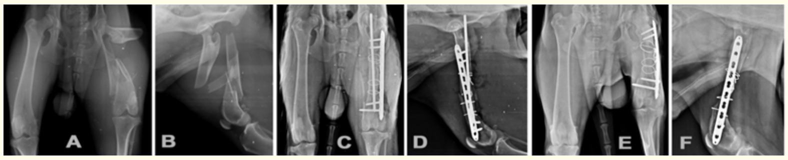

Figure 4: Representative cranio caudal views radiographs of a dog (group C) with preoperative ventrodorsal and mediolateral (A and B), post operative status of the implants (C and D) and disappearance of the fracture line with cortical continuity at week 14 post-surgery with slight plastic deformation of the plate (E and F).

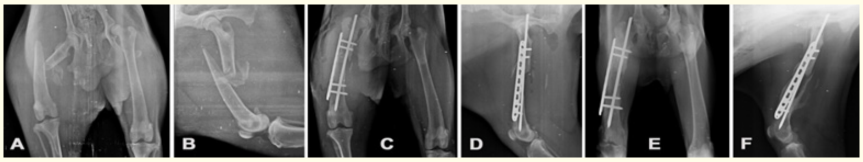

Figure 5: Representative radiographs (group D) showing the fracture (A; dorsoventral and ventrodorsal views), immediate post-operative status of the implants (C and D; ventrodorsal and mediolateral views, respectively) and formation of bridging callus at week 4 post-surgery (E and F).

Group	Week post-surgery				
	0	Week 4	Week 6	Week 6	Week 6
A	1.00 (1.00) [a]	2.00 (2.50-3.00) [b]	2.00 (3.00) [b]	3.00 (4.00) [c]	3.75 (5.00) [d]
B	1.00 (1.00) [a]	2.00 (3.00) [b]	2.75 (4.00) [c]	3.75 (4.50-5.00) [d]	4.50 (5.00) [d]
C	1.00 (1.00) [a]	2.00 (3.00) [b]	2.75 (4.00) [c]	3.00 (4.00-5.00) [d]	3.75 (5.00) [e]
D	1.00 (1.00) [a]	2.00 (2.50-3.00) [b]	2.00 (3.50-4.00) [c]	3.00 (5.00) [d]	3.75 (5.00) [d]

Table 7: Comparison of the radiographic union scores among the experimental groups (Median and IQR).
Different lowercase superscripts within a row indicates the effect of time post-surgery within a group.
Values in each cell indicates median and the value within a parenthesis indicates inter-quartile range.

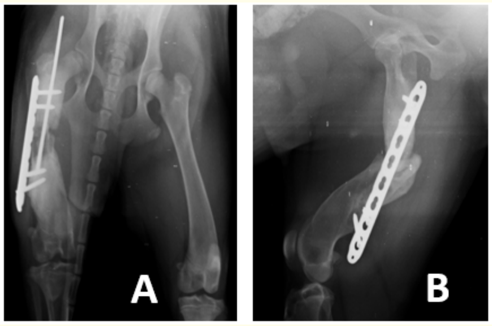

Figure 6: Mediolateral and ventrodorsal views (CII of group C) showing intramedullary rod migration, screw loosening and plate displacement on 2nd week (A): and malunion and loss of bone alignment at week 10 (B).

4^{th}, 6^{th}, 10^{th} and 14^{th} week did not show any significant difference ($P > 0.05$) between the groups. Radiological healing scores indicated bridging plate osteosynthesis enabled faster indirect bone healing by promoting callus formation. The difference in healing times between the groups may be attributed to the cases that faced complications and fracture configurations. It was attempted that cases were uniformly distributed with same degree to comminution among each group to evaluate bridging plate osteosynthesis. The minimum time taken for mobility, complete weight bearing, and time taken for complete radiographic healing were comparable in all the groups. Similar timings for radiographic healing in 10 to 28 weeks post-surgery using plate-rod technique for the repair of comminuted fractures in dogs are documented [15]. The delay in radiographic healing in few cases can be mainly attributed to the age, degree of comminution, complications anticipated and encountered during post operative period. Comparatively early radiographic healing was obtained in younger animals of present study irrespective of technique used.

The healing of simple transverse fractures was by primary gap healing (1 case). Comminuted fractures healed by endosteal callus formation (22 cases) and bone bridging and hence healing under the callus formation envisaged the relative stability of all the four combinations of PRCs. Excellent outcome was observed in groups A and B and no implant related major post operative complications were observed. Groups C and D, with less rigid and more elastic fixation had satisfactory outcome apart from one incidence of implant failure in group C. The time taken for mobility, weight bearing, and time taken to attain complete radiographic healing was non significantly less in groups B than other groups (Table 5). The functional outcome of repair was excellent in all dogs of group A, five dogs each of groups B and D and four dogs of group C (Tables 1-4). Excellent and very good functional and radiographic healing grades and scores at 14^{th} week post operatively in of animals in groups A and B can be attributed to the perfect alignment and apposition, early resolution of pain and early callus formation are in agreement with earlier findings [20]. It might also be due to additional stability provided by more number of screws used in these groups. Similar outcomes, ranging from poor to excellent, with PRCs were reported previously by many researchers [21].

The study was not without any limitations: First, the plate length was selected on patient size, and then either 2-3 screws were applied to the plate, which has resulted into different working lengths for different patients (number of empty screws was almost 2 in short working length but varied from 4-5 in long working length due to different body sizes and femur lengths) which makes comparison between groups difficult. Second, it was difficult to prospectively randomize orthopedic fracture cases as fracture configuration dictates the plate length and screw configuration. Third, errors in measurement of medullary cavity in digital imaging due to magnification of the femur in ventrodorsally positioned animal and selection approximate of intramedullary rod of either near to 30% or 40% of this measurement leads to a range which also adds to the limitations of this study. Fourth, force plate gait analysis is required to evaluate fracture healing as subjective lameness scoring scales most accurately reflect force plate analysis when lameness is severe. It was reported that subjective lameness scoring scales may not accurately reflect lameness and do not replace force plate gait analysis and the peak vertical forces acting on the implant post-surgery would not be similar in all the dogs [22].

Conclusion

It is concluded that clinical application of LCP as short plate working length with IMR occupying 40% of medullary canal provided better fracture stability with fewer complications in radiographic healing of unstable diaphyseal femoral fracture in dogs although the healing time with long plate working length were similar. The apparent advantage of long plate working length noted in the present study was ease of application, which shortened the duration of surgery. The findings the present study contradicted the hypothesis that use of long plate working length with IMR filling 40% of medullary cavity provides adequate stability and enable fracture healing better than short plate working length. The beneficial effect of long plate working length providing acceptable relative stability and enhancing early callus formation and mobility may not be clinically evident and stability with only two bicortical screws in each fragment with a 30-40% IMR may not be adequate especially in non-compliant dogs for movement restriction. Further studies involving force gait plate analysis is required with less randomized and more standardized clinical trial.

Bibliography

1. Basha KMA., *et al.* “Elastic plate osteosynthesis by long plate working length using locking compression plate as plate-rod constructs for the treatment of unstable diaphyseal femoral fractures in dogs”. *Indian Journal of Veterinary Surgery* 41.2 (2020): 107-112.

2. Beale B. “Orthopaedic Clinical Techniques Femur fracture repair”. *Clinical Techniques in Small Animal Practice* 19 (2004): 134-150.

3. Chao P., *et al.* "Effect of plate working length on plate stiffness and cyclic fatigue life in a cadaveric femoral fracture gap model stabilized with a 12-hole 2.4 mm locking compression plate". *BMC Veterinary Research* 9 (2013): 125-131.

4. Dvorak M., *et al.* "Complications of long bone fracture healing in dogs: Functional and radiological criteria for their assessment". *Acta Veterinaria Brno* 69 (2000): 107-114.

5. Field R and Ruthenbeck GR. "Qualitative and quantitative radiological measures of fracture healing". *Veterinary and Comparative Orthopaedics and Traumatology* 31 (2018): 1-9.

6. Gautier E and Sommer C. "Guidelines for the clinical application of the LCP". *Injury* 34 (2003): 63-76.

7. Gilbert S., *et al.* "Locking compression plate stabilization of 20 distal radial and ulnar fractures in toy and miniature breed dogs". *Veterinary and Comparative Orthopaedics and Traumatology* 28 (2015): 441-447.

8. Hulse D., *et al.* "Reduction in plate strain by addition of an intramedullary pin". *Veterinary Surgery* 26 (1997): 451-459.

9. Hulse D., *et al.* "Effect of intramedullary pin size on reducing bone plate strain". *Veterinary and Comparative Orthopaedics and Traumatolog*y 13 (2000): 185-190.

10. Koch D. "Implants: description and application". In: Johnson AL, Houlton J. and Vannini R. AO principles of fracture management in dog and cat. Davos Platz Switzerland: AO Publishing; 2015: 26-52.

11. Niemeyer P and Sudkamp NP. "Principles and clinical application of the locking compression plate (LCP)". *Acta Chirurgiae Orthopaedicae et Traumatologiae Cechoslovaca* 73 (2006): 221-228.

12. Pearson T., *et al.* "The effect of intramedullary pin size and monocortical screw configuration on locking compression plate-rod constructs in an *in vitro* fracture gap model". *Veterinary and Comparative Orthopaedics and Traumatology* 28 (2015): 95-103.

13. Ramirez J., *et al.* "Complications and outcome of a new modified Maquet technique for treatment of cranial cruciate ligament rupture in 82 dogs". *Veterinary and Comparative Orthopaedics and Traumatology* 28 (2015): 339-346.

14. Reems MR., *et al*. "Use of a plate-rod construct and principles of biological osteosynthesis for repair of diaphyseal fractures in dogs and cats: 47 cases (1994-2001)". *Journal of the American Veterinary Medical Association* 223 (2003): 330-335.

15. Roe SC. "The interaction of working length and plate strain". *Veterinary and Comparative Orthopaedics and Traumatology* 29 (2016): 7-8.

16. Rutherford S., *et al.* "Effect of intramedullary rod Diameter on a string of Pearls Plate-rod construct in mediolateral bending: An *In Vitro* mechanical study". *Veterinary Surgery* 44 (2015): 737-743.

17. Sarangom SB., *et al. "*Plate-rod technique for the repair of comminuted Diaphyseal femoral fractures in young dogs". *International Journal of Advanced Biological Research* 8 (2018): 451-453.

18. Shiju SM., *et al.* "Plate-rod technique for the management of diaphyseal femoral fractures in dogs". *Indian Journal of Veterinary Surgery* 31.1 (2010): 41-42.

19. Simon MS., *et al.* "Plate-rod technique for the management of diaphyseal fracture in a dog - A case report". *Indian Veterinary Journal* 92.7 (2015): 85-86.

20. Unger M., *et al.* "Classification of fractures of long bones in the dog and cat: Introduction and clinical application". Veterinary and Comparative Orthopaedics and Traumatology 3 (1990): 41-50.

21. Urbanova L., *et al*. "Comparison of the resistance to bending forces of the 4.5 LCP plate-rod construct and 4.5 LCP alone applied to segmental femoral defects in miniature pigs". *Acta Veterinaria Brno* 79 (2010): 613-620.

22. Vallefuoco R., *et al.* "Complications of appendicular fracture repair in cats and small dogs using locking compression plates". *Veterinary and Comparative Orthopaedics and Traumatology* 29 (2016): 46-52.