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Surbhi Aggarwal
M.V.Sc student, Department of Veterinary Surgery and Radiology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India

Tarunbir Singh
Scientist, Department of Veterinary Surgery and Radiology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India

Pallavi Verma
Associate Professor, Department of Veterinary Surgery and Radiology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India

Rahul Udehiya
Associate Professor, Department of Veterinary Surgery and Radiology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India

Jitender Mohindroo
Associate Professor, Department of Veterinary Surgery and Radiology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India

Nameirakpam Umeshwori Devi
Associate Professor, Department of Veterinary Surgery and Radiology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India

Ashwani Kumar
Professor cum Head, Department of Veterinary Surgery and Radiology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India

Corresponding Author:
Tarunbir Singh
Scientist, Department of Veterinary Surgery and Radiology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India

Comparative evaluation of minimally invasive and mini incision bone plating techniques for the repair of radius fractures in dogs

Surbhi Aggarwal, Tarunbir Singh, Pallavi Verma, Rahul Udehiya, Jitender Mohindroo, Nameirakpam Umeshwori Devi and Ashwani Kumar

Abstract
Minimally invasive plate osteosynthesis (MIPO) has been considered as an alternative to open method of fracture stabilization. It has the advantage of less soft tissue injury compared with open reduction and internal fixation. Minimally invasive approaches ranged from a closed approach under C-arm guidance to an open approach that is limited to incision to ensure proper placement of implant. Through this study, two techniques of minimally invasive bone plating for repair of radius fractures in dogs were evaluated. Animals were divided in two groups and treated with bone plating using C-arm guidance (4) and mini-incision techniques of minimally invasive bone plating (8). It was found that animals with fractures repair using C-arm technique, were able to bear weight on affected limb earlier than animals with fractures repaired using mini-incision MIPO technique. However, proper patient selection is important, as C-arm technique is not feasible for all the patients and fracture types. For cases demanding exact fracture apposition, mini-incision method of bone plating was preferred over close C-arm method. Thus, both the techniques have their benefits in fracture healing.

Keywords: Dog, radius fractures, C-arm MIPO, mini-incision MIPO

Introduction
Radius-ulna fractures are the third most common among long bone fractures in companion animals. Fracture fixation techniques used by various workers for repair of these fractures included external skeleton fixation, intramedullary pinning or cross pinning, rigid plates with screws, reconstruction plates and biodegradable plates associated with autogenous cancellous bone grafts [1, 2, 3, 4]. Complications with external coaptation include malunion, delayed union, or non-union, soft tissue injury and fracture diseases like joint stiffness, muscle atrophy, and disuse osteopaenia associated with prolonged casting of the limb [5]. However, these techniques are having limitations like interference in the already poor blood supply to the distal radius and ulna, due to removal of soft tissue and periosteum for application of implants, and blood vessel damage caused with high speed drills for placing screws [6].
Recently, a trend towards the use of fracture fixation techniques which preserve the local fracture environment, known as biological osteosynthesis, has been evolved. This trend has resulted in development of a less traumatic method of bone plating referred to as minimally invasive plate osteosynthesis (MIPO). This method involves application of bone plate, typically in bridging fashion, without making an extensive surgical approach to expose the fracture site [7]. Biologic fracture fixation techniques that limit iatrogenic surgical trauma while yielding appropriate construct stability appear to be advantageous for facilitating healing of these fractures. MIPO technique is a safe and effective method with the advantages of less soft-tissue trauma, haemorrhages and post-operative pain [8]. Technique involves making small skin incisions proximal and distal to fracture site. A plate is then inserted through an epi-periosteal tunnel [9].
Many a time complete close technique is not feasible as it also compromises proper bone alignment. Requirement of proper fracture apposition may require opening the surgical site. Therefore, mini-incision minimally invasive bone plating can be performed. This method helps in reducing the size of incision line, causes less soft tissue trauma and reduces chances of infection. The study was therefore conducted with an aim to investigate these two techniques of radius fracture repair under different conditions.

Materials and Methods

Animals with radius-ulna fractures were distributed in to two groups. Selection of animal was made on the basis of fracture, ease of reduction and utility of animal. In group 1, fractures in 4 animals were repaired using minimally invasive bone plating technique under C-arm guidance. In group 2, radius-ulna fractures in 8 animals were treated using mini-incision minimally invasive bone plating technique by opening the fracture site. Signalment, aetiology, duration of fracture and type of fracture were recorded at the time of presentation in all the dogs irrespective of groups to correlate health status of the animal and to select type of implant used. Plate selection was based on animal size and pre-operative radiographs. A thorough physical examination was performed to determine the soft tissue swelling, associated injuries and general condition of the animal. Pre-operative radiographs were taken in cranio-caudal and medio-lateral views to determine the location and type of fracture and type of technique to be used. Pre-operative haematological and biochemical parameters were recorded to access general condition of the animal.

In Group 1, completely close C-arm guided minimally invasive technique of bone plating (MIBP) was performed using a cranio-lateral approach. Affected limb was extended laterally for indirect reduction and fracture stabilization. Traction and counter traction were applied for ease in reduction of fracture fragments. Closed reduction of fracture fragments was done using indirect technique by applying traction. Fracture fragments were not exposed. After the fracture segments were aligned, about 1 cm distal insertion point was created using a MIPO approach (Fig. 1, 2). With blunt dissection using straight metzenbaum scissors with its jaws closed, a distal to proximal tunnel was created. Bone plate was introduced by creating an epiperiosteal soft tissue tunnel using blunt dissection. After insertion of plate from distal incision, a proximal incision was created. After achieving proper reduction, screws were placed in plate holes by making small nich incisions with scalpel blade number 11. A parallel plate of same length and diameter was used for insertion of proximal and distal screws through small skin niches. Placement of screws and plate was done under C-arm guidance to access the contoure and position of plate on the bone (Fig. 3 to 8).

In Group 2 animals, mini incision bone plating technique was used by giving about 1.5-2.0cm skin incision on the fracture site to expose fracture fragments. Manual reduction of fracture fragments was achieved with traction and bone hook. After reduction of fracture fragments, bone plate was inserted from the fracture site towards distal side by creating epi-periosteal tunnel (Fig. 12, 13). Proximal and distal screws were placed using stab skin incisions adjacent to the plate holes by using parallel plate technique.

Operated limb was given external support with a modified Robert Jones bandaging (RJB) for 12 days after antiseptic dressing using Povidone-iodine. Bandaging was changed after every two days. After suture removal bandaging was changed after every 5 days for approximately 30 days. Dogs were administered broad spectrum antibiotics Inj. Cefotaxime @ 20-25 mg/kg b.wt. IM twice daily for 7 days and Inj. Amikacin.[1] @ 10 mg/kg b.wt. IM once a day for 5 days. Analgesia was provided by Inj. Meloxicam[2] @ 0.2 mg/kg b.wt. IM once a day for 3 days. Syp. Osteopet [3] was given orally twice daily for 30 days. Balanced diet plan was prescribed for the patient for promoting bone healing.

Restricted movement was advised for first few days of surgery followed by leash walking. Skin sutures were removed after 10-15 days of surgery. Physiotherapy of carpal joint was advised after every two days post operatively during the change of bandage in cases of distal third fractures to facilitate movement of joint. Postoperative wound healing, weight bearing and angulation was recorded. Follow up observations were recorded at various post-operative intervals till complete fracture healing depending upon the presentation of a particular case. These observations were recorded at the time of arrival for post-operative care or the clients were contacted on telephone and asked about the recovery of the pet with reference to post-operative weight bearing, wound condition, gait, joint movement and any other complications.

During surgery, observations like extent of soft tissue damage (mild, moderate and marked), extent of overriding of main segments (mild, moderate and marked), ease of fracture reduction (Easy, moderate and difficult), fixation technique, technical difficulties, time of surgery, screw placement in plate and intra-operative stability (stable and unstable) were recorded. Soft tissue damage was graded as mild (no or mild swelling), moderate (moderate swelling of the fractured area with injury to the surrounding area of the fractured ends) and marked (swelling of whole limb, extensive injury to the surrounding with sharp fracture fragments and multiple bone chips). Incision length was recorded in different treatment groups. In group 1, incision length included the sum of incision at proximal and distal portion of fracture and niche incisions given for screw placement. In group 2, incision length included the sum of fracture site incision and incisions for placement of proximal and distal screws.

Cranio-caudal and medio-lateral radiographs of the affected bones were taken immediate post operatively and at various post-operative intervals until there was evidence of complete fracture healing. Implant characteristics assessment (Table 5) was done by determining two parameters, namely the plate bridging ratio (ratio between the plate length and the bone length) and the plate working length (distance between proximal and distal screw closest to the fracture, reported to the length of the plate) as per classification given by Proteasa and coworkers [10]. Plate type and length (mm) as well as the number of plate holes filled with screws used were recorded. The plate span ratio was calculated by taking the quotient of the plate length over the overall fracture length. Plate screw density was calculated as the quotient formed by the number of screws inserted over the total number of screw holes in the plate [11].

Post-operative weight bearing and angulation were recorded. Fracture healing was accessed using healing score system given by Hammer and coworkers [12] by grading callus formation (homogenous bone structure, massive bone trabeculae crossing the fracture line, apparent bridging of the fracture line, no bridging of the fracture line or no callus formation), fracture line visibility (obliterated, barely discernible, discernible or distinct) and stage of union (achieved, uncertain or not achieved). Complete bone union was considered when there was complete bridging of fracture lines in both the radiographic views. Post-operative

[1] Inj. Alfakim, Ranbaxy Laboratories Ltd.

[2] Inj. Melonex, Intas Pharmaceuticals Ltd., Ahmedabad

[3] Syp. Osteopet, Virbac Animal Health India Pvt. Ltd., Mumbai

complications were also recorded. Implant removal was taken up after complete healing of bone.

Functional limb usage was categorized using classification devised by Fox in 1997 [13] as excellent (weight bearing without lameness), good (weight bearing with slight lameness), fair (slight to moderate lameness mainly after exercise) and poor (Intermittent or consistent non-weight bearing lameness) Observations were recorded and data was analysed.

Results and Discussion

Mean duration of fracture at the time of presentation in Group I (MIBP), was 1.75±0.75 days ranging between 1-4 days. Swelling of affected limb was seen in 2 animals. Preoperative haematological and biochemical parameters were within normal range. Mild degree of soft tissue injury was observed in four animals with mild swelling of the affected limb (n=2) and no swelling (n=2). Mild degree of overriding was observed in all the four cases (Table 1). Reduction was easy in all the four cases. Easy reduction was due to minimum displacement of fracture fragments. Mean length of skin incisions was 6.38±0.22 cm (6.0-7.0cm). All the plates used were straight locking compression plates. Implants were stable in all cases intra-operatively. Mean duration of surgery (Table 3) was 90.00±12.25 minutes (60-120 minutes). Weight bearing on operated limb (Table 4a) was varied between 2-4 days (3.00±0.41 days). Out of 4 animals, 3 were presented for complete radiographic follow up. Skin wound healing was complete by 12 days as small incisions (Fig. 9). Callus formation was homogenous in all presented animals. Stage of complete fracture union was achieved in 3 animals presented for complete follow up. Mean radiographic healing time was 45.67±2.33 days (45-50 days). Implant removal was done in one animal by using mini-incision technique with parallel plate technique (Fig. 10, 11). All animals in group I, showed 100% limb usage percentage (Table 7).

Group 2 included 8 radius-ulna fractures treated using mini incision minimally invasive plate osteosynthesis technique. Fracture site was exposed using mini-incision technique (Fig. 7). Mean duration of fracture till presentation was 2.13±0.74 days ranging between 1-7 days. Swelling of the fractured limb was seen in 5 animals. Delayed presentation, high swelling and were the factors responsible for opting mini incision surgery in group 2. Preoperative haematological and biochemical parameters were within normal range. Cranio-caudal and medio-lateral radiographs were taken and it was found that in 3 dogs, proximal third of bone was fractured. In 5 animals distal third was affected which was suggested that mini-incision MIPO technique can be used for distal fracture repair also. Fracture site was exposed by giving multiple mini skin incisions on the fracture site. Degree of soft tissue damage was mild in six and moderate in two cases. Overriding was mild in one, moderate in five and marked in two cases. Reduction was easy in four, moderately easy in two and difficult in two cases (Table 2). Mean length of skin incisions was 7.10± 0.23 cm (6.1-8.1cm). Out of 8 plates, 3 were T-plates (Fig. 11) and 5 were straight plates. Implants were stable in all cases intra-operatively. Mean duration of surgery was 116.25±11.49 minutes (Table 3). Initial weight bearing (Table 4b) on operated limb varied between 4-8 days (5.63±1.30 days). In four cases, serous fluid discharge from the surgical wound site was observed for 3-5 days after surgery. Complete fracture union was achieved in 6 animals presented for complete radiographic follow up (Table 7). Mean radiographic healing time was 89.67±15.86 days (55-140 days). Out of 8 animals, 6 were presented for complete radiographic follow up. Callus formation was homogenous in 4 animals and massive bone trabeculae crossing the fracture line were seen in 2 animals. In group 1, fracture was obliterated in 1 and discernible in other animal, while in group 2, fracture line was obliterated in 5 animals and discernible in 1 animal. Complications encountered were exposure of implant from distal skin incision in one animal, 15 days after surgery and stiffness of radio-carpal joint in one animal of group 2. In group 1, no such complication was observed. Implants were removed in six cases (Fig 14.). Seventy five percent of animals in group 2 showed excellent limb usage. In 12.50%, limb usage was good and in 12.50% limb usage was fair (Table 8). Short skin incisions, lesser intra-operative tissue damage and preservation of haematoma lead to early healing and weight bearing.

Frigg and Ulrich in 2003 [14] opined that for bone reconstruction and fracture healing, soft tissue condition and local blood circulation were the most important factors. Therefore, extra damage to soft tissue should be avoided during surgery. Requirement of minimum trauma to soft tissue coined the use of minimally invasive technique for fracture repair. In present study, complete fracture healing was achieved in both the groups. Implant stability was 100% in both the groups (Table 7). Skin incisions in group 1 were smaller as compared to group 2. Cranio-lateral approach was used by keeping the animal in lateral recumbency. In contrast to that, Pozzi and coworkers in 2009 [9] used cranio-medial approach by keeping the animal in dorsal recumbency. It was found that cranio-lateral approach was also feasible for bone plate insertion in minimal invasive way. C-arm guided MIPO technique was easier to use in proximal third and mid-shaft fractures whereas mini-incision MIPO can be used for repair of distal third radius fractures also. Slight non-significant difference in duration of surgery between two groups was recorded. In group 1, duration of surgery was lesser than group 2. There was subjective difference of initial weight bearing between groups 1 and 2. Group 1 animals showed first weight bearing in lesser time than group 2. Smaller skin incisions, preservation of fracture haematoma and less soft tissue trauma could be the reasons for early weight bearing in group 1 animals. Sarangabani and coworkers in 2017 [15] Obtained early pain free and functional usage of limb, less postoperative complications and rapid fracture healing using MIPO plate-rod technique in comparison to open plate-rod technique. According to view of Horstman and coworkers in 2004 [16], the dogs operated by biological fixation were bearing weight the day after surgery whereas dogs treated with open anatomical reconstruction used limb late in the post-operative period. In present study, working length (%) of the plates used in group 1 (38.05± 9.14) was significantly ($p<0.05$) more than group 2 (19.55±1.64) indicating lesser screw loading in group 1 as compared to group 2. Gautier and Sommer in 2003 [17] found high working length of the plate led to reduced screw loading, thus fewer screws need to be inserted and the plate screw density can be kept low. Knowledge of the working length of the screw was helpful for the proper choice of monocortical or bicortical screws. There was no significant difference of plate span ratio, plate bridging ratio and screw density between the groups. Although screw density of group 1 dogs (0.81± 0.04) was subjectively lesser than group 2 indicating less screws were used in C-arm guided MIPO technique for bone plating than mini-incision MIPO technique. Group 1 animals showed very less post-operative complications than group 2 animals.

Conclusions
Both the techniques have benefits in repairing radius fractures in minimal invasive way. C-arm guided MIPO technique can gave better results in selected cases, however, mini-incision bone plating is a more versatile technique in which a variety of complicated fractures can be operated.

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Table 1: Intra-operative observations in animals of Group 1

Dog No.	Soft tissue damage	Over-riding	Ease of reduction	Size of proximal fragment (cm)	Size of distal fragment (cm)	Type of Implant	No. of screws
1	Mild	Mild	Easy	9.48	8.05	10H, LCP	8 (P4,D4)
2	Mild	Mild	Easy	18.78	11.74	10H, LCP	7 (P4,D3)
3	Mild	Mild	Easy	9.15	10.16	7H, LCP	6 (P2,D4)
4	Mild	Mild	Easy	11.15	8.42	7H, LCP	6 (P4,D2)

P= Proximal; D= Distal

Table 2: Intra-operative observations in animals of Group 2

Dog No.	Soft tissue damage	Overriding	Ease of reduction	Size of proximal fragment (cm)	Size of distal fragment (cm)	Type of Implant	No. of screws
1	Mild	Moderate	Easy	17.51	6.93	10H, LCP	9 (P6,D3)
2	Mild	Moderate	Easy	17.28	2.89	7H, LC-T	8 (P4,D4)
3	Moderate	Marked	Difficult	19.31	2.79	10H, LC-T	12(P6,D6)
4	Mild	Moderate	Moderate	9.4	8.22	10H, DCP	9 (P4,D5)
5	Mild	Moderate	Easy	5.05	11.36	7H, LCP	6 (P3,D3)
6	Moderate	Moderate	Moderate	18.2	4.88	6H, LC-T	8 (P2,D6)
7	Mild	Mild	Easy	14.73	4.49	10H, LCP	8 (P5,D3)
8	Mild	Marked	Difficult	7.32	13.94	9H, LCP	8 (P4,D4)

P= Proximal; D= Distal

Table 3: Mean±S.E values of surgical time in different groups

Parameter	Group 1	Group 2
Surgical time (minutes)	90±12.25	116.25±11.49
Range (minutes)	60-120	80-150

Table 4a: First weight bearing, limb usage score and radiographic healing time in Group 1

Dog no.	First wt. Bearing (days)	Limb usage score	Radiographic evidence of union (days) (n=2)
1	3	Excellent	45
2	2	Excellent	42
3	3	Excellent	NRF
4	4	Excellent	50
Mean ±S.E.	3.00±0.41		45.67±2.33
Range	2-4		

NRF - Not Reported for Follow up radiographs

Table 4b: First weight bearing, limb usage score and radiographic healing time in Group 2

Dog no.	First wt. Bearing (days)	Limb usage score	Radiographic evidence of union (days) (n=6)
1	5	Excellent	88
2	5	Excellent	60
3	7	Good	55
4	4	Excellent	135
5	5	Excellent	NRF
6	5	Excellent	NRF
7	6	Excellent	60
8	8	Fair	140
Mean±S.E.	5.63±1.30		89.67±15.86
Range	4-8		55-140

NRF-Not Reported for Follow up radiographs

Table 5: Mean±S.E. values of Implant Associated Parameters for dogs in different groups

Parameters	Group 1	Group 2
Fracture gap (mm)	3.61±0.66	4.14±0.22
Plate length (mm)	119.2±7.86	124.02±3.17
Plate span ratio %	35.52± 4.62	30.38±1.52
Plate bridging ratio	0.57± 0.07	0.61± 0.03
Screw density	0.81± 0.04	0.87±0.02
Working length %	38.05± 9.14	19.55± 1.64

Table 6: Radiographic assessment of fracture healing at different post-surgical intervals in animals belonging to different groups

Groups	Total animals presented for evaluation	15-30 days		31-60 days		61-120 days		>120 days		Healing in dogs presented	
		N	%	N	%	N	%	N	%	N	%
1	2	0	0.00	2	100.00	0	0.00	0	0.00	2	100.00
2	6	0	0.00	3	50.00	1	16.67	2	50.00	6	100.00

Table 7: Implant stability in animals of different treatment groups

Parameter		Group 1 (N)	%	Group 2 (N)	%
Implant stability	Stable	4	100	8	100
	Unstable	0	0	0	0

Table 8: Limb usage score (%) in animals of different treatment groups

Group	Excellent		Good		Fair		Poor	
	Number	%	Number	%	Number	%	Number	%
1	4	100	0	0	0	0	0	0
2	6	75	1	12.5	1	12.5	0	0

Fig1: Skin incisions proximal and distal to the fracture site

Fig 2: Skin incisions after placement of bone plate and screws

Fig 3: Pre-operative cranio-caudal and mediolateral radiographs of right radius-ulna

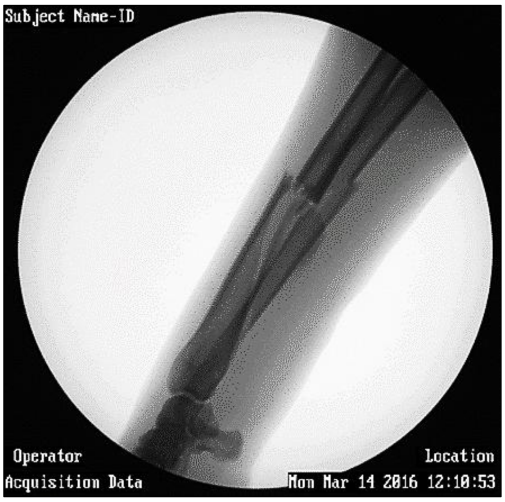

Fig 4: Pre-operative C-arm radiograph showing midsahft fracture of right radius-ulna follwing application of traction and counter traction

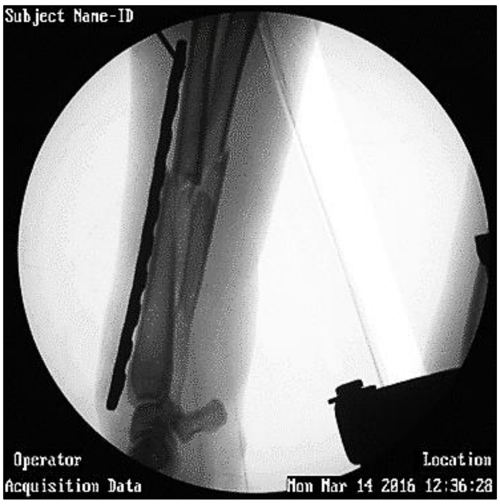

Fig 5: C-arm radiograph showing insertion of plate on the fracture site

Fig 6: C-arm radiograph showing placement of distal most screw in the plate

Fig 7: C-arm radiograph showing placement of proximal screws in the plate

Fig 8: C-arm radiograph showing fracture alignment with 3 distal and 4 proximal screws

Fig 9: Photograph showing healing of skin incisions

Fig 10: 4 Months post-operative radiographs showing complete bone union

Fig 11: Photograph showing weight bearing after 4 months of surgery

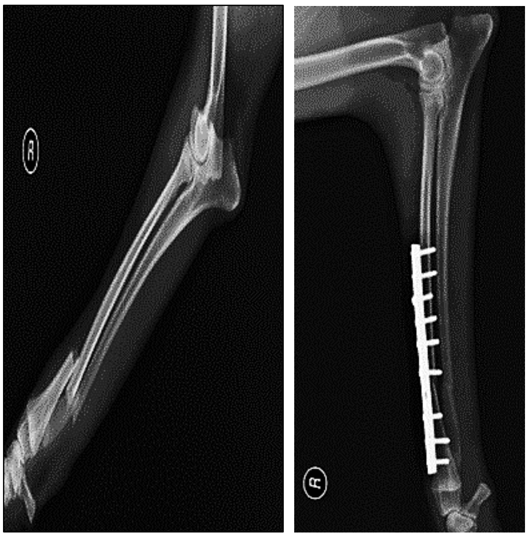

Fig 12: Pre-operative in immediate post-operative medio-lateral radiographs shownig repair of distal 3rd overriding fracture of right radius-ulna

Fig 13: Intraoperative photograph showing skin incisions on fracture site, proximal and distal to fracture site

Fig 14: 3 months post-operative medio-lateral radiograph showing homogenous callus formation and complete union (a). Radiograph after implant removal (b).

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