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Naz Namreen
M.V.Sc. Scholar, Department of Veterinary Surgery and Radiology, College of Veterinary Science, Rajendranagar, Hyderabad, Telangana, India

Jagan Mohan Reddy K
Assistant Professor, Department of Veterinary Surgery and Radiology, College of Veterinary Science, Rajendranagar, Hyderabad, Telangana, India

Chandra Sekhar EL
Professor & University Head, Department of Surgery and Radiology, College of Veterinary Science, Rajendranagar, Hyderabad, Telangana, India

Rajendranath N
Professor & Head, Department of Anatomy, College of Veterinary Science, Rajendranagar, Hyderabad, Telangana, India

Corresponding Author:
Naz Namreen
M.V.Sc. Scholar, Department of Veterinary Surgery and Radiology, College of Veterinary Science, Rajendranagar, Hyderabad, Telangana, India

A clinical study on the use of locking t-plate in radius-ulna fractures in dogs

Naz Namreen, Jagan Mohan Reddy K, Chandra Sekhar EL and Rajendranath N

Abstract
The present clinical study on repair of distal radius-ulna fractures using Locking T-plates was conducted on six dogs which are presented for treatment at Department of Surgery and Radiology, College of Veterinary Science, Rajendranagar, Hyderabad. The distal radius-ulna fractures were diagnosed and confirmed using routine clinical, orthopaedic examination and radiography. The clinical signs like lameness, pain, non-weight bearing, swelling, dangling of the limb and abnormal angulation. Physical examination revealed crepitation at the fracture site in all of the dogs. Fractures were confirmed by two orthogonal views of the proximal and distal joints on the medio-lateral and cranio-caudal radiographs of the affected limbs. Three of them had oblique fractures and three of them had transverse fractures. Measurements from the pre-operative radiographs were important in determining the length of the Locking T-plates and the length of the screws to be used accurately in the fracture fixation of long bone fractures. Locking T-plate of 2.7 mm and 3.5 mm were used for stabilization of radius ulna fractures resulted in good fracture fixation and immobilization.
Immediate post-operative radiographic evaluation confirmed proper placement of the Locking T-plate and screws, proper apposition and alignment of distal radius fracture fragments in all the six cases. Immobilization was considered satisfactory in all six cases. Length of the Locking T-plate and screws, their size and position were appropriate in all cases. Sequential post-operative radiographs showed progressive bone healing. Post operatively plate bending was observed in two cases. In one dog plate bending was observed at fracture site by post-operative 15th day and in one dog by 30th post-operative day due to subsequent jump from height. All six dogs displayed partial weight bearing from very 1st post-operative day. Two dogs achieved complete weight bearing by the 15th post-operative day, one dog by 30th post-operative day, two dogs by 60th post-operative day and one dog by 90th post-operative day.
Based on present study it was concluded that use of Locking T-plates for repair of distal fractures of radius and ulna in dogs offer mechanical and biological advantage over traditional bone plates. It is helpful in potentiating healing in areas of lower healing areas such as distal radius and ulna. It is implant of choice for dogs with limited bone stock available for fracture fixation i.e., distal fractures of radius and ulna. Locking T-plate will mitigate complications by optimizing the fracture biology and properties of the construct. Hence it is the plate of choice/ gold standard for internal fracture fixation of distal fractures of radius and ulna in dogs.

Keywords: Locking t plate, internal fixation, radius ulna fractures, canines, dogs

Introduction
Long bone fractures are the most frequent orthopaedic problems are seen in canine species. This might happen as a result of the dogs wandering and anxious behavior. The causes of more long bone fractures were car accidents and falls from height (Marvania *et al*., 2020) [23]. The femur (37%) had the highest incidence of fractures, followed by the radius-ulna (28.7%), Tibia-fibula (20.4%) and humerus (7.9%) (Kallianpur *et al*., 2018) [16].
According to (Mosneang and Igna, 2012) [27] the femur (34.69%), tibia and fibula (33.62%), radius-ulna (17.88%) and humerus (13.79%) are the most often fractured long bones. The incidence is highest in the pectoral limb is seen in radius and ulna (65.25%), then humerus (16.01%) (Simon *et al.*, 2011) [35].
Stable fixation and anatomical restoration are important to recover the functional ability of the affected limb at the quickly. The distal third fractures of the radius present a variety of difficulties for the orthopedic surgeon due to their close proximity to the joint and the presence of a small fracture fragment that does not allow for appropriate fixation and increases the risk of growth plate injury.

Conservative and surgical methods might be used as treatment options for these fractures. External compitation is routinely considered and when applied properly can be beneficial in case of non displaced fractures. The inter fragmentary stress and inadequate intra and extra-osseous blood flow at the fracture site are more common in small breeds of dogs with distal third radius and ulna fractures. External coaptation is unable to provide enough tight fixing in these circumstances to consistently yield favorable outcomes. External coaptation can lead to complications such as mal union, nonunion and delayed union, soft tissue injury and fracture diseases such as joint stiffness, muscle atrophy and disuse osteopenia (Harasen, 2012) [12].

Conventional plates and Locking plates operate according to entirely distinct mechanical theories and as a result they offer various biological conditions for healing. For periarticular fractures that necessitate complete anatomical reduction and for some nonunion that need additional stability for union conventional plates may remain the fixing method of choice. Locking plates are recommended for bridging severely comminuted fractures, plating fractures where anatomical restrictions prevent plating on the tension side of the bone and treating diaphyseal/metaphyseal fractures in osteoporotic bone. (Soileau *et al*., 2007 [37] and Egol *et al*., 2004) [8].

Bone plating is a common method for stabilizing radial fractures however it has limitations when it comes to fixing distal third fractures since the smaller distal segment does not allow enough space for reduction. This issue is resolved by the extended section of the T-plate which allows for a stable fixation by accommodating an adequate number of screws in the long bone extremities. T-plating has fewer side effects such as osteomyelitis, requires less postoperative care and promotes quick bone repair (Balfour *et al*., 2000) [4].

A relatively novel technique for fixing canine distal diaphyseal/metaphyseal fractures is the locking T-plate. The locking compression plate combines a traditional screw hole which uses non-locking screws with a locking screw hole which utilizes locking head screws. This enables the plate to be used in more diverse ways (Miller and Goswami, 2007) [25]. The locking head screws are intended to lock tightly in the plate giving axial and angular stability of the screw relative to the plate (Wagner, 2003) [41].

The use of Locking T-plate provided early weight bearing, stable fixation, excellent limb usage and good fracture healing with minor complications (Taranjot Kaur Sran *et al*., 2021) [39].

Materials and Methods

Anamnesis

The age of these six dogs from 3 months to 6 months with a mean of 4.83±0.43 out of these six dogs 4 males and 2females. Among the six dogs two dogs were Labrador retrievers, three were mongrels and one was Pomeranian. The body weight ranged from 8 kg-25kg with a mean of 13.5±2.63Kg. The primary causes of fractures in these six dogs were found to be due to automobile accidents in four dogs (66.6%) and fall from height in two (33.3%) dogs. The dogs were brought for treatment between 3 to 11 days after occurrence of fracture with a mean of 6±1.1 days. No pets were reported to have concurrent diseases. (Table.1).

Table 1: History and Signalment of the dogs selected for the study in this group

Case no.	Breed	Age (months)	Sex	Body Weight (kg)	Cause	Days since fractures
1.	Mongrel	3	Female	14 kg	Fall from height	5
2.	Mongrel	5	Male	12 kg	Automobile accident	3
3.	Mongrel	6	Male	8 kg	Fall from height	11
4.	Labrador	5	Male	25 kg	Automobile accident	8
5.	Labrador	4	Male	17kg	Automobile accident	4
6.	Pomeranian	6	Female	5 kg	Automobile accident	5
	Mean ± S.E	4.83±0.43		13.5±2.63		6±1.10

Pre-operative observations

The dogs brought for treatment of radius-ulna fractures showed signs like lameness, pain, non-weight bearing, swelling, dangling of the limb and abnormal angulation (Fig.1). Physical examination revealed crepitation at the fracture site in all of the dogs. There were no neurological issues and all six dogs had closed fractures.

Fig 1: Non-weight bearing of fractured limb (grade V)

Pre-operative radiographic observations

Orthogonal views of plain Medio-lateral and cranio-caudal radiographs of the affected bone including the proximal and distal joints were found to be satisfactory to confirm the tentative diagnosis. Pre-operative radiographs revealed radial fractures and also showed the type of fracture as three of them had oblique fractures and three of them had transverse fractures. Pre-operative radiographs of the dogs with radial fractures are presented in Fig. 2. The details regarding the fractures encountered in all the dogs are presented in Table 2.

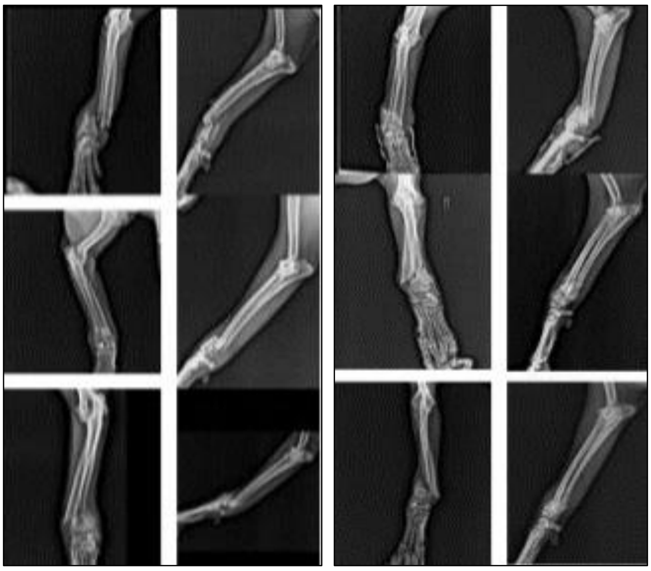

Fig 2: Pre-operative radiographs of dogs with Radius and Ulna fractures (cranio-caudal view) and (medio-lateral view)

Table 2: Fracture classification

S. No	Side	Location of fracture	Type of fracture
1.	Right radius and ulna	Distal-diaphyseal	Closed complete transverse fracture
2.	Right radius and ulna	Distal-diaphyseal	Closed complete transverse fracture
3.	Left radius and ulna	Distal-diaphyseal	Closed complete transverse fracture
4.	Right radius and ulna	Distal-diaphyseal	Closed complete oblique fracture
5.	Left radius and ulna	Distal-diaphyseal	Closed complete oblique fracture
6.	Left radius and ulna	Distal-diaphyseal	Closed complete oblique fracture

Planning of surgery

Measurements obtained from the pre-operative radiographs of the affected limb like length of the bone and trans-cortical diameter at different regions and diameter of medullary cavity at the isthmus region of bone proved vital in selecting the appropriate length and diameter of interlocking nail to be used and the length of the screws.

Patient preparation

The operative site was shaved and scrubbed using povidone-iodine surgical scrub. Painting the surgical site with 5% povidone iodine solution followed by application of surgical spirit and the draping was considered satisfactory since post-operatively no signs of infection were encountered in any of the dogs that underwent surgery.

Anaesthesia

Atropine sulphate [2] was administered subcutaneously to all the dogs at the rate of 0.04 mg/kg body weight as a premedication and 15 minutes later xylazine hydrochloride [3] and ketamine hydrochloride [4] was administered intramuscularly at the rate of 1 mg/kg body weight and 10 mg/kg body weight respectively. General anesthesia was established ten minutes later by injecting intravenous injection of Propofol [5] at the rate of 4 mg/kg body weight. The dogs were intubated with endotracheal tubes of suitable size after induction. Anaesthesia was maintained with isoflurane [6] at the rate of 2.5 in 100% oxygen during the surgical procedure.

Positioning of the Animal

The dogs with distal radius fractures were laid down in lateral recumbency with the contra-lateral limb secured out of the way and the fractured limb down. To separate the non-sterile parts the distal end of the limb was bandaged with sterile gauze. The radius-ulna cranio-medial aspect was exposed. After applying surgical spirit, the prepared site was coated with a 5% povidone-iodine solution. The entire limb was wrapped in sterile drape.

Materials used

Orthopaedic instruments

The general surgical and standard orthopaedic instruments were used.

Implants

In the present study indigenously made Locking T-plates [7] were used for stabilization of fractures in all six dogs. Locking T-plates with 2.7 mm diameter with corresponding locking screws were used for fracture fixation in two dogs and in other four dogs Locking T-plates with 3.5mm diameter holes were used (Fig.3). The type of plate to be used was determined on the basis of the weight of the dog and the size of the bone as measured on radiographs. The 2.7 mm Locking T-plate was used in dogs weighing up to 12 kg and 3.5 mm Locking T-plate was used in dogs weighing greater than 12 kg.

Fig 3: Locking T-plates

Surgical procedure

Surgical approach to the radius ulna

The surgical method described by Piermattei and Greeley (1979) [28] was used for open reduction of the radius and ulna. On cranio-medial part of the limb a skin incision was taken by protecting the cephalic vein extended from around the middle of the radius to the styloid process of the radius. On the same line the superficial antebrachial fascia and subcutaneous fat were incised. Radius was revealed through the deep antebrachial fascia following the retraction of the skin borders. Between the extensor carpi radialis and common digital extensor muscle, the deep antebrachial fascia was incised. Retraction of the common digital extensor was done caudally and the extensor carpi radialis muscle was done cranially. Now long digit abductor muscle and the body of the radius were visualized. The abductor pollicis longus muscle was sectioned and shifted cranially if more exposure was required. This made it possible to see the entire distal part of the radius.

Fracture reduction and fixation by locking t-plate

Using a standard surgical procedure, open reduction was performed on all fractures, regardless of the type of implant used. The area was cleaned of fibrous tissue residues and blood clots after the bone had been exposed. The fracture was reduced to their almost normal anatomical location with the ends of both the proximal and distal pieces exposed and freshened. Two types of Locking T-plates with 2.7 mm and 3.5 mm diameter holes were used. The Locking T-plate was sized appropriately and shaped to fit the cranial surface of the radius after fracture reduction. (Fig. 4). In all the six cases, the distal screws were placed first in order to anchor the plate to the distal fragment and then the proximal screws were placed afterwards (Lakshmi *et al*., 2007) [21].

Care was taken to make sure that the plate's width didn't go beyond the radius it covered (Sardinas and Montavon, 1997) [32]. A low speed high torque power drill was used to drill a 2.5 mm hole for a 2.7 mm T-plate and a 2.7 mm hole for a 3.5 mm T-plate across the radial diaphysis through the holes of the Locking T-plate. The radial diaphysis was continued to be drilled across until the drill bit had gone through the near and far cortices. The medio-later thickness of the radius at various distances from the fracture site was measured directly from the radiographs in order to determine the length of the screws needed for application of the Locking T-plate in each patient. This measurement was confirmed during the surgical procedure by using a depth gauge. The plate was then fastened to the bone by inserting a screw of the proper length into the drilled hole and tightening it with a hexagonal orthopedic screwdriver until the screw tip protruded from the distant cortex. By leaving the fracture line and inserting the necessary number of screws in both the proximal and the distal fracture fragments, bone plating was achieved.

Fig 4: Surgical approach and fracture reduction and application of Locking T Plate in dog

Closure of the surgical wound

Subcuticular sutures were applied in simple continuous pattern using No. 2-0 polyglactin 910 and the skin incision was closed in a row of cruciate mattress sutures using 2-0 polyamide.

Post-operative care and management

A thin layer of sterile gauze bandage dipped in 5% povidone iodine solution was placed over the suture line. A large cotton pad was put over this. After that a gauze bandage was placed over it and finally a layer of surgical paper tape was used. The dressing was changed every other day up to the 12th post-operative day, when the sutures were removed. Injection ceftriaxone sodium [10] was administered intramuscularly twice day for seven days following surgery at the dose rate of 25 mg/kg body weight. Injection meloxicam [11] was given intramuscularly once per day for three days at the rate of 0.2 mg/kg body weight. Owners were advised to limit the animal's movement for the first two weeks following operation.

Results and Discussion

The results of the present study showed that the age of the dogs presented with Radius ulna fractures ranged from 3-6 months with a mean of 4.83±0.43 months. The incidence of fractures was higher under 6 months of age. This finding was in agreement with Rani *et al*., (2004), Simon *et al*., (2010) [34], Kallianpur *et al*., (2018) [16]. Four out of six dogs were male indicating that fractures were more common in males than in females. This finding was in agreement with Gahlod *et al*., (2004) [9], Simon *et al*., (2010) [34], Kumar *et al*., (2019) [18], Jagan Mohan Reddy *et al*., (2020) [13], Basiri Dinesh *et al*., (2021) [5], Jagan Mohan Reddy *et al*., (2021a) [15] and Bhoomaiah *et al*., (2022) [6].

Among them two dogs belonged to Labrador, onedog belonged to Pomeranian, and rest of the dogs were Mongrels. Majority of dogs were mongrels. This finding was in agreement with Jagan Mohan Reddy *et al*., (2020) [13], Basiri Dinesh *et al*., (2021) [5] and Bhoomaiah *et al*., (2022) [6]. These results differed with observation of McCartney *et al*., (2010) [24] and Minar *et al*., (2013) [26]. The body weight of the dogs ranged from 8 to 25kg with a mean body weight of 13.5 ± 2.63kg.

Out of the six dogs, the main cause of fracture was found to be automobile accident in four (66.6%) dogs, this is in accordance with Kumar *et al*., (2020), Baderiya *et al*., (2021) [3], Chanakya *et al*., (2021) [7], Jagan Mohan Reddy *et al*., (2021a) [15], Jagan Mohan Reddy *et al*., (2021b) [15] and Bhoomaiah *et al*., (2022) [6] followed by fall from height in two (33%) dogs which is in accordance with Singh *et al*., (2015). It was found in the present study that the dogs with fractures were presented for treatment between 3 to 11 days with a mean of 6 ±1.10 days after occurrence of fracture.

In the present study, the clinical signs of fracture noticed were abnormal angulation, lameness and pain on manipulation. Other symptoms included swelling, limb swinging, lack of weight bearing, unusual angulation of the limb and on physical manipulation crepitation at the fracture site. These similar observations were recorded by Jagan Mohan Reddy *et al*., (2021a) [15], Chanakya *et al*., (2021) [7] and Bhoomaiah *et al*., (2022) [6].

In the present study, the medio-lateral and cranio-caudal radiographs facilitated well in diagnosing the type of fracture encountered. This is in accordance with Ayyapan *et al*., (2009), Piermattei *et al*., (2016) [30], Chanakya *et al*., (2021) [7] and Bhoomaiah *et al*., (2022) [6] also stated that two orthogonal views of the affected bone should be taken for proper fracture treatment planning. Radiographs of the six dogs showed that three of them had oblique fractures and three of them had transverse fractures.

Post-operative clinical observations

Clinical evaluation was carried out every alternate day to check for the presence of swelling, exudation and weight bearing in all the dogs**.** None of the dogs developed post-operative swelling and suture dehiscence and the surgical wounds healed well in all the dogs without any complications.

Implants

In present study 2.7mm and 3.5 mm Locking T-plates and locking head screws were used for treating oblique and transverse fractures. Locking T-plate used for stabilization of radius ulna fractures resulted in good fracture fixation and immobilization. Piermattei and Flo (1997) stated that it is necessary to apply the T-plate cranially and it was recommended for the repair of distal radial fractures and other others like Levin *et al*., (2008) [22], Schmelzer-Schmied *et al*., (2009) [33] and Kwan *et al*., (2011) [20] opined similar recommendations for repair of distal fractures of radius ulna.

Post-operative lameness grading

Post-operatively, lameness grade showed gradual improvement to normal weight bearing over the period of study. The lameness grade was carried out in accordance with protocol developed by Vasseur *et al*., (1995) [40] shown in table 3.

All the six dogs operated in the present study displayed partial weight bearing from very 1st post-operative day. Two dogs achieved complete weight bearing by the 15thpost-operative day, one dog by 30thpost-operative day, two dogs by 60th post-operative day and one dog by 90th post-operative day. All animals showed lameness grade V preoperatively based on weight bearing recorded before surgical intervention of the fracture. Post-operatively, grade I lameness was achieved in 2 dogs by 15th post-operative day, one dog by 30th post-operative day, two dogs by 60th post-operative day, one dog showed grade I lameness by the end of 90th post-operative day. (Fig. 5)

Table 3: Post-operative details of lameness grading

Case no	Locking T-plate	Pre-operative	Post-operative lameness grades					
			Day 1	Day 7	Day 15	Day 30	Day 60	Day 90
1	3.5mm	V	III	II	I	I	I	I
2	3.5mm	V	III	II	I	I	I	I
3	2.7mm	V	III	III	II	II	I	I
4	3.5mm	V	IV	III	II	I	I	I
5	3.5mm	V	III	II	II	II	I	I
6	2.7mm	V	IV	III	III	II	II	I
Mean ± SE		5.0±0.0	3.33±0.19	2.50±0.20	1.83±0.28	1.50±0.20	1.16±0.15	1.0±0.0

Grade I: Normal weight bearing on all limbs at rest and while walking.
Grade II: Normal weight bearing at rest, factors affected limb while walking.
Grade III: Partial weight bearing at rest and while walking.
Grade IV: Partial weight bearing at rest; does not bear weight on affected limb while walking.
Grade V: Does not bear weight on limb at rest or while walking.

Fig 5: Progressive weight bearing on different post-operative days [15, 30, 60, 90] in dogs with locking T plate for radius and ulna fracture

Post-operative radiographic observations

Immediate post-operative radiographic evaluation confirmed proper placement of the Locking T-plate and screws, proper apposition and alignment of distal radius fracture fragments in all the six cases. Follow-up radiographs obtained on 15th post-operative day showed proper position and alignment of the fracture fragments in six cases. In one dog plate bending was observed at fracture site by post-operative 15th day due to subsequent jump from height. Follow-up radiographs obtained on 30th post-operative day revealed bridging callus. The callus was smoother and opaque and radiolucent fracture line was faintly visible in all six dogs. In one dog plate bending was observed at fracture site by 30th post-operative day due to subsequent jump from height. Follow-up radiographs obtained on 60th post-operative day, the fracture line was disappeared and continuation of cortico-medullary was observed on radiographs. These findings were similar to Aikawa *et al*., (2018) and Jagan Mohan Reddy *et al*., (2020) [13], Bhoomaiah *et al*., (2022) [6].

Follow-up radiographs obtained on 90th post-operative day, revealed complete bone healing with evident cortico-medullary continuity caused by the re-modelling of excess callus. These findings were similar to Piermattei *et al*., (2016) and Aikawa *et al*., (2018), Bhoomaiah *et al*., (2022) [6]. Radiographic healing shown in Fig. 6.

Fig 6: Case. No. 5. Progressive radiographic changes in dog with radius and ulna fracture in medio-lateral view on different intervals i.e., immediately after surgery, 15th, 30th, 60th and 90th Post-operative days

Stability of implant

In the present study with 2.7 mm and 3.5 mm Locking T-plates with locking head screws produced rigid fixation and excellent improvement with normal limb function. In all six dogs throughout the observation period good implant stability was observed with minor complications. In the present study, locking T-plate helpful in potentiating healing in the areas of lower healing capability such as the distal radius and ulna in small or toy breeds of dogs or in cases of sustained severe comminution fractures. This is in congruence with (Guiot and Guillou, 2019) [11].

The locking T-plate is often the primary determinant of implant choice for patients with limited bone stock for fixation in fracture fragments. This is in congruence with the findings of Guiot *et al*., (2012) [10].

Complications

Locking T-plate in dogs in the present study with minor complications i.e. in one dog plate bending was observed at fracture site by post-operative 15th day and in one dog by 30th post-operative day due to subsequent jump from height (Fig. 7). This was in accordance with Kaur (2011) whereas others reported as tendon irritation and plate screw pull out Soong *et al*., (2011) [38].

Fig 7: Case No-2 plate bending in one dog by 15th-operative day and Case No-4 plate bending in one dog by 30th post-operative day (Medio-lateral view)

Conclusion

Use of Locking T-plates for repair of distal fractures of radius and ulna in dogs offer mechanical and biological advantage over traditional bone plates. It is helpful in potentiating healing in areas of lower healing areas such as distal radius and ulna. It is implant of choice for dogs with limited bone stock available for fracture fixation i.e., distal fractures of radius and ulna.

Locking T-plate will mitigate complications by optimizing the fracture biology and properties of the construct. Hence it is the plate of choice/gold standard for internal fracture fixation of distal fractures of radius and ulna in dogs.

Conflict of interest: No conflict of interest.

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