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Evaluation of polyaxial locking plate system and locking compression plate for tibial fracture repair in goats

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ABSTRACT

The present study was conducted to evaluate polyaxial locking plate system (PAX) and locking compression plate (LCP) in twelve tibial fracture of goats. The cases were divided into two groups, viz. group I and group II having six goats in each. Group I and II treated with Polyaxial locking plate system (PAX) and Locking compression plate (LCP), respectively. The two techniques were evaluated on the basis of clinical and radiological changes observed on pre-operative day and at post-operative days 0, 15, 30 and 60. All the animals showed slight to moderate weight bearing from 7th to 15th post-operative day and moderate to good weight bearing by 30th post operative day. Good to excellent weight bearing was achieved by 60th post-operative day. Functional weight bearing was observed in all the groups by day 60. Radiological evaluation revealed that fracture healing in all the groups was through primary callus formation. Initiation of periosteal callus was noticed on day 15 in all the groups. Apparent bridging of the fracture site was noticed in all the groups on day 30. Cortico-medullary union was established on day 60. The complete union and initiation of remodelling of fracture was observed to be earlier in group II, compared to group I. Both Polyaxial Locking plate system and locking compression plates had sufficient strength to provide stability at fracture site but slightly better weight bearing without any complication was observed in animals treated with LCP.

Keywords: Fracture, Goat, LCP, PAX, Tibia

The most common orthopaedic problem in goats has been described as fractures. Non-invasive external immobilisation techniques such as bandages, splints, plaster of paris and/or fibreglass casts have a large number of drawbacks, including malunion, delayed union, and non-union (Singh *et al.*1984). There is large callus formation, tendon weakening, muscle atrophy, delay in weight bearing, interference with radiographic evaluation, slippage of plasters, softening of plaster cast, and wetting of cast due to poor management, which ultimately leads to an increase in expenses due to reapplication (Mbuiki and Byagagaire 1984). According to Sirin *et al.* (2013) biological osteosynthesis with bone plates is one of the most stable fracture fixation techniques available to veterinary orthopaedic surgeons. The PAX polyaxial locking system is a 316 L stainless steel variable-angle locking system. It allows locking screw angulation of up to 15° degrees off the central axis. The PAX is a three-dimensional contouring reconstruction plate. It can be used as a locking plating system with locking head screws, as a conventional bone plating system with cortical standard screws, or as a hybrid system. However, due to the design of the plate holes, it cannot be used as a compression plate.

The locking compression plate (LCP) has a specially designed combination hole that accepts both standard bone screws and locking screws, allowing the plate to be used as a compression plate, a locking plate (internal fixator principle), or a combination of both principles. The LCP is a fixed angle structure that relies on friction at the plate-bone and screw-bone interfaces. Instead, friction is used at the threaded screw-plate interface.

Locked plating is a more recent fracture fixation technique. Understanding the principles and limitations of locked plating technology has been critical to maximising its effectiveness since its introduction into fracture repair just over two decades ago. Research studies comparing different materials might improve the technique and aid in the selection of the most appropriate treatment, maximising benefits while minimising complications. A search of literature revealed, dearth of literature regarding the evaluation of newer locking plates as internal fixator in goats; especially polyaxial locking plate and locking compression plate.

MATERIALS AND METHODS

The present study was conducted on 12 clinical cases of goats presented with the history of tibial bone fracture in the Department of Veterinary Surgery and Radiology. Diagnosis of tibial fracture was made based on clinical and radiographic examination. In group I, fractures were

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Table 1. Fracture details and treatment adapted in goats

Group	Case no.	Type of fracture		Implant size	Screw length	Screw placement sequence	Unpurchased holes at fracture site
I (PAX)	Case 1	Mid-diaphyseal	Transverse	10 hole	14-24 mm	4-00-4	2
	Case 2	Mid-diaphyseal	Transverse	10 hole	14-24 mm	4-00-4	2
	Case 3	Proximal-diaphyseal	Transverse	10 hole	14-24 mm	5-0-4	1
	Case 4	Distal-diaphyseal	Oblique	10 hole	14-24 mm	4-00-4	2
	Case 5	Mid-diaphyseal	Comminuted	10 hole	14-24 mm	5-0-4	1
	Case 6	Mid-diaphyseal	Oblique	10 hole	14-24 mm	4-00-4	2
II (LCP)	Case 1	Mid-diaphyseal	Transverse	8 hole	14-24 mm	3-0-4	1
	Case 2	Mid-diaphyseal	Comminuted	12 hole	18-28 mm	4-00-4	2
	Case 3	Proximal-diaphyseal	Comminuted	12 hole	18-34 mm	7-0-4	1
	Case 4	Mid-diaphyseal	Transverse	8 hole	14-24 mm	4-0-3	1
	Case 5	Proximal-diaphyseal	Oblique	10 hole	14-24 mm	4-00-4	2
	Case 6	Distal-diaphyseal	Transverse	8 hole	14-24 mm	4-0-3	1

treated using polyaxial locking plate system (PAX). In group II, fractures were treated using locking compression plate (LCP). The details of fractures and treatments are given in Table 1.

Prior to surgery, the animals were fasted for 12 h and deprived of water for 6 h. Before surgery, all the animals were administered with broad-spectrum antibiotic (Inj. amoxicillin + cloxacillin @10 mg/kg body weight) intravenously and Inj. Melonex @0.3 mg/kg body weight intramuscularly.

The affected limb was shaved and aseptically the operative site was scrubbed using povidone iodine surgical scrub, followed by application of surgical spirit. The animals were placed in lateral recumbency, with the affected limb below. The surgery was performed under general anaesthesia, using inj. xylazine hydrochloride @ 0.22mg/kg b.wt. i/v as pre-anaesthetic (sedative) after 5 min followed by inj. ketamine hydrochloride @11 mg/kg b.wt. i/v for induction. Maintenance of anaesthesia was done using inj. ketamine hydrochloride @11 mg/kg b.wt. and inj. propofol @4 mg/kg b.wt. bolus.

Tibia fractures were repaired using a medial approach. An incision was made on the cranio-medial aspect of the leg region, proximally towards the stifle and distally towards the hock, from the fracture site. The muscles were exposed after skin and fascia incisions. To expose the fracture site, the bellies of the tibialis anterior and flexor digitorum plofundis muscles were retracted cranially and caudally, respectively. The fracture segments were identified and brought into alignment. Following satisfactory fracture reduction and limb alignment, the locking bone plates from the grouping were applied along the medial surface of the tibia in accordance with AO/ASIF plate fixation principles.

Self-tapping locking cortical screws (3.5 mm) were inserted and locked at the bone plates' locking holes with a 3.5 mm hexagonal screw driver. Until the last and first hole of the plate, a similar procedure was followed in the hole closest to the fractured site in the proximal/distal fragment. One to three screw holes at the fracture site were left unpurchased in order to pre-dynamize the fracture site. A minimum of three screws were inserted in the proximal fragment and three screws in the distal fragment. Finally, all of the screws on the proximal and distal fragments were tightened alternately to provide a rigid fixation of the bone plate to the fractured bone. A similar procedure was employed for all tibial fractures.

The muscles were sutured with simple interrupted pattern using trugut no.1-0 suture material followed by closure of skin incisional wound in simple interrupted using nylon. Immediate post-operative radiographs in cranio-caudal and medio-lateral views were taken to assess fracture apposition, limb alignment, and implant status. Inject amoxicillin + cloxacillin @10 mg/kg b.wt i/v bid administered for seven days after surgery. Until the incisional wound healed, it was surgically dressed daily or on alternate day. After wound healing, the skin sutures were removed between 10 to 15 days post-operatively. The animal owners were advised to restrict animal's moment up to 2 weeks post- surgery, and then mild walking up to 2-4 weeks.

The cases were evaluated on days 0, 15, 30, and 60 for lameness grading as 1- Normal weight bearing on all limbs at rest and while walking; 2- Normal weight bearing at rest, favours affected limb while walking; 3- Partial weight bearing at rest and while walking; 4- Partial weight bearing at rest, does not bear weight on affected limb while walking; 5- Does not bear weight on limb at rest or while walking as recommended by Vasseur *et al.* (1995). Also, cases were evaluated for weight bearing based on limb usage as Excellent- functionally normal; Good- slight lameness only after extensive exercise; Fair- Slight to moderate lameness but consistent weight bearing; Poor- non-weight bearing lameness as recommended by Fox *et al.* (1995).

Post-operatively radiographs were obtained immediately after plate fixation (day 0) and on day 15, 30, and 60 to monitor bone healing. Statistical analysis of data obtained was carried out by employing Student't' test as per the standard procedure outlined by Snedecor and

Cochran (1994).

Intra-operative and post-operative complications related to wound, bone/implant and complications during fracture healing (malunion/delayed/union/non-union/osteomyelitis) and death, if any were observed and recorded in all the groups**.**

RESULTS AND DISCUSSION

The clinical signs of non-weight bearing and reluctance to move the limb, lifting the limb above ground level, or simply touching the toe to the ground were used to diagnose fractures in the current study. A broken bone was indicated by the limb dangling. Palpation of the fractured tibia fragments revealed crepitation of the fractured site, as well as pain and swelling at the fracture site. Singh *et al*. (2008) evaluated long bone fractures in goats using clinical signs such as swelling, pain, abnormal mobility, crepitation, and limb dysfunction.

The fractured fragments were adequately reduced and aligned before the bone plates were applied to all of the animals in both groups. Sommer *et al.* (2003) believes that before using LCP, the fractured bone must be properly aligned.

In all of the cases locking bone plates were used as an internal fixator (bridging plate) without pre-stressing or contouring. According to Cronier *et al.* (2010), locking plates do not need to be perfectly contoured to the bone surface to maintain fracture reduction. According to Wagner (2003) and Cronier *et al.* (2010), in locking systems, the screw head is securely fixed to the plate, eliminating the need for the plate to be compressed to the bone. Kowaleski (2009), encountered when a fracture is bridged with a locking plate, the bridge plates must be longer and fewer screws are required. They recommended that, the length of the plate be greater than twice the length of the fracture zone.

Bottlang *et al*. (2016) came to the conclusion that overly rigid locked plating constructs inhibit callus formation and healing. They hypothesised that active locking plates, by providing axial dynamization, would result in faster callus formation, consistent and circumferential bridging, and stronger healing when compared to standard non-locking plates. According to Schutz and Sudkamp (2003), each main fragment should have at least three monocortical locking head screws (LHSs) securely anchored. Under clinical study, weight bearing and lameness grading was done and is depicted in Table 2.

Over the course of the study, the lameness grade improved gradually to normal weight bearing. At the end of the study, all of the goats had recovered completely functionally. In the current study, the principles of biological osteosynthesis, combined with the rigid stability provided by the plates, resulted in a good to excellent functional outcome.

Normal weight bearing on all limbs at rest and while walking was graded 1 (as seen between 15-60 days), which attributed to adequate fracture reduction with

locking bone plates, load sharing between implant and bone, and minimal soft tissue disruption. The statistical analysis of the overall lameness score on pre-operative and post-operative days in the groups at different time intervals revealed a significant ($P \leq 0.01$) difference between the time intervals and a non-significant difference between the three groups studied.

Prior to surgery, none of the animals could bear weight on the fractured limb. All of the animals had semi-flexed joints above the fracture site, with the toe touching the ground while standing. All of the cases had non-weight bearing lameness. In all cases of fracture, there was dangling of the distal part of the hind limb below the fracture line, swelling at the fracture site, and crepitation.

Reilly *et al*. (2012) claimed the hallmark of long bone fractures in small ruminants is acute non-weight bearing lameness. According to Venugopalan (2009), the major

Table 2. Evaluation of lameness score as per method recommended by Vasseur *et. al.* (1995)

Group	Case	Pre-op	Post-operative			
			Day 0	Day 15	Day 30	Day 60
Group-I (PAX)	1	5	4	3	1	1
	2	4	4	4	3	2
	3	5	4	3	2	1
	4	5	4	3	2	1
	5	4	4	3	2	1
	6	5	4	3	2	1
Group-II (LCP)	1	4	3	3	1	1
	2	5	4	2	1	1
	3	5	4	3	2	1
	4	5	4	2	1	1
	5	5	4	3	2	1
	6	4	3	3	2	1
Group-I		4.66±0.19	4.00±0.00	3.16±0.15*	2.00±0.23**	1.66±0.15**
Group-II		4.66±0.19	3.66±0.19	2.66±0.19*	1.50±0.20**	1.00±0.00**

Means bearing superscript * differ significantly ($p \leq 0.05$) within groups at different intervals when compared to '0' day. Means bearing superscript ** differ significantly ($p \leq 0.01$) from day '0'.

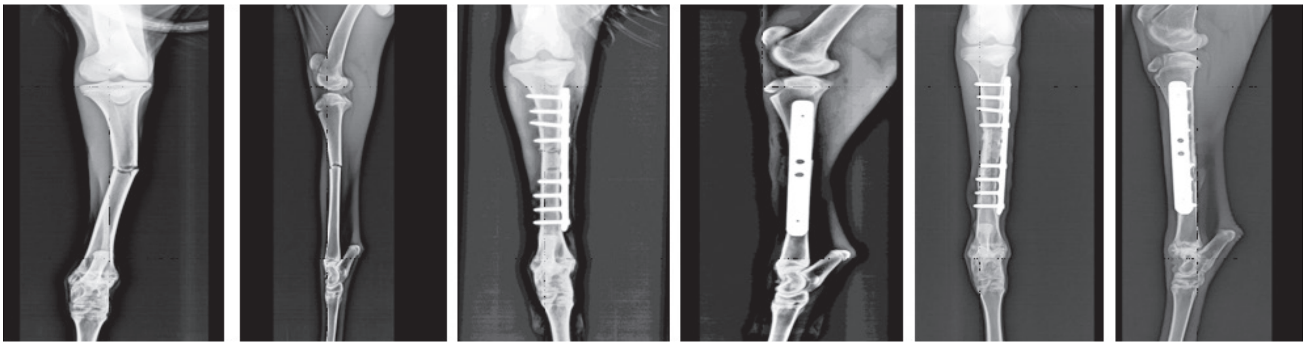

Fig. 1. Cranio-caudal and Medio-lateral radiographs of Group I (PAX) of before operation, immediately after operation and post-operative 60th day showing bridging callus formation at fracture site.

clinical signs displayed by animals with fractures are loss of function of the affected limb, abnormal mobility at the fracture site, and deformity due to displacement of fractured fragments.

On day 0, nine of the twelve goats were able to stand up without assistance. Two of the goats were able to stand up with ease after some assistance, while the remaining goat could only stand up with assistance and move slowly on its three legs. A moderate inflammatory response may cause difficulty bearing weight and pain. The rigidity of the locking plate construct, which provides better immobilisation of fracture fragments, may be attributed to intermittent weight bearing with moderate pain in the immediate post- operative period.The weight bearing was good in both the groups and this could be attributed to improved bone-to-plate contact, resulting in a more rigid fixation.

The lameness grades improved by the 15th day interval, and mild to intermittent lameness with partial weight bearing at rest and while walking was observed. Mild bridging between fractured segments, as evident by a hazy fracture line, traces of callus at the fracture site, the initiation of periosteal callus, and a decrease in inflammation at the fracture site, may be a factor for improved weight bearing.

On the 30th day, consistent weight bearing with mild lameness was observed, which could be attributed to increased periosteal callus and visible bridging of fracture fragments, as evidenced radiographically, which contributed to consistent weight bearing.

On day 60th, the lameness scores in all cases improved across the board, and the animals demonstrated normal weight bearing at rest and while walking. As seen on radiographs, the bridging callus formation between the fractured fragments had obliterated the fracture site. It was possible to achieve radiographic union. This could have resulted in complete weight bearing without lameness, explaining why the animal favoured the limb while walking.

Walking and running did not cause the goats any discomfort. This could be attributed to the formation of the cortico-medullary union, a reduction in the size of the periosteal callus, and remodelling of the fractured bone. According to Butterworth (1993), as healing progresses, the animal begins to use the limb more.

Jackson and Cockroft (2002) found a healthy alert goat will rise when approached, bear weight equally on all four limbs, and pass dry faecal pellets. Lameness in goats resulted in muscle wasting in the affected limb. The authors also observed goats' reluctance to move when forced as an possible indication of pain.

Sequential radiographs showing fracture healing of Group I (PAX) and Group-II (LCP) is depicted in Fig.1 and Fig. 2 respectively.

Whelan *et al*. (2002) proposed antero-posterior and lateral radiography of the tibia at each follow-up visit, with measurement of the number of cortices (0 to 4) bridged by callus, as the most reliable method for assessing fracture healing progression. Post-operative radiographic evaluation was done on days 0, 15, 30, and 60 to assess fracture

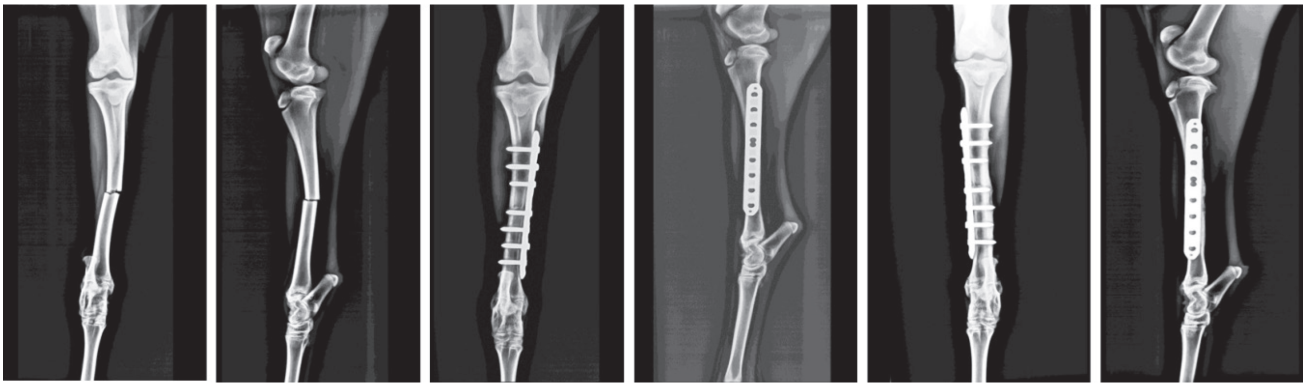

Fig. 2. Cranio-caudal and Medio-lateral radiographs of Group II (LCP) of before operation, immediately after operation and post-operative 60th day showing callus formation.

healing. All fragments with soft tissue attachments were retained in all cases with comminution and non-reducible wedge, promoting biological osteosynthesis. Furthermore, intact periosteal vascularity promoted osteogenesis and bone healing in all cases, was consistent with Egol *et al.* (2004).

In all 12 cases, the fracture line after alignment was clearly defined at 0 day, with sharp and well-defined loss of radiographic density. The implants were stable and long enough. In all cases, the fracture fragment was extremely stable.

On day 15, radiographic healing through bone resorption and the initiation of periosteal callus, as well as the presence of callus traces at the fracture site, were observed. In all of the cases, the fracture line was distinct. Mild to exuberant periosteal callus was observed all along the length of the bone at trans cortex, particularly at the screw attachment points. According to Singh *et al*. (2006), the first evidence of increased osteoblastic proliferation was detected about 8 h after the fracture and reached a peak by 24 h. Initially, the increased periosteal activity was generalised, extending throughout the bone, however it was later localised to the fracture site. Morgan (1972) defined periosteal callus as a faint hazy area developing adjacent to and directly overlapping the site of fracture. He believed that callus formation was proportional to fracture fixation rigidity.

The fracture line was less visible on the 30th post-operative day, becoming hazy and fading in all cases. There was apparent bridging of the fracture line. The extent, density, and homogeneity of periosteal callus appeared to be greater. Traces of callus infiltration were found on the bone plate. These cranio-caudal findings are consistent with the findings of Singh *et al*. (2008), who reported complete union of the fracture site with obliteration of the fracture line, ossification, and bridging of the cortex from the fourth to the eighth week following casting.

On the 21st day of fracture healing, Chaudhary (1982) observed radiographically visible periosteal reaction in sheep and goats. He noticed a translucent shadow in the callus as well as the still visible fracture gap in the radiographs. According to Reems *et al.* (2003), the bridging callus should form in 3 to 5 weeks in immature patients and 4 to 6 weeks in mature patients.

The fracture line had been completely obliterated by the 60th post-operative day, with massive radio-dense callus completely filling the fracture site. The radiolucent fracture line was not visible, indicating that radiographic union had been achieved. The periosteal callus had shrunk and become more homogeneous. The callus was becoming smoother and more uniform in density. Early cortico-medullary remodelling was observed, indicating that clinical union had occurred.

Vinit (2017) used Veterinary cuttable plate and PMMA plates for fracture repair in goats and reported that radiographs on the 15th day showed the initiation of periosteal reactions, radiographs on the 30th day showed the development of a minimal radio-dense callus with a visible fracture line, and radiographs on the 60th day showed complete union of fractured fragments.

Yadav *et al.* (2016) used LCP to treat long bone fractures and found radiographic evidence of complete fracture healing after 60 days. According to Chandini (2018), the locking compression plate and locking reconstruction plate provided adequate stability to the fractured fragments in dogs, allowing for proper healing of the fracture at scheduled intervals, as evidenced by radiographic findings during the study.

Barnhart *et al.* (2012) noticed the time it took to achieve functional union ranged from 2 to 30 weeks (mean, 7.10 weeks) in animals treated with polyaxial locking plate system. Functional unions occurred between 2 and 12 weeks in animals that did not have complications (mean, 6.40 weeks). There were no complications following the functional union.

Bassanino *et al.* (2021) radiographically confirmed outcomes after fracture reapir with Polyaxial locking plate system for dogs and cats, and found that, the median radiographic union time was 67.80 days (range, 32-180) for dogs and for cats, it was 77 days (range, 30-180). There were no intra-operative complications, Due to the owners' inconsistent follow-up in the early post-operative period; post-operative complications were limited to wound infection.

Based on clinical and radiological findings it was concluded that, both polyaxial locking plate system and locking compression plates had sufficient strength to provide stability at fracture site. However, animals treated with LCP showed slightly better weight bearing, complete fracture union and early initiation of fracture remodelling.

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