

A novel custom-made external fixator for treating femur fractures in goats

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Abstract

External fixation is commonly used to treat long bone fractures in goats. It provides good enough stabilization on fractures to improve healing, minimizes soft tissue injury and only causes mild obstruction of the blood supply around the wounds. However, the large size and heavy weight of traditional external fixators (TEFs) cause them leave something to be desired. In this study, the feasibility of a novel custom-made external fixator (CMEF) for treating femoral fractures in goats was evaluated. Three one-year-old Anglo-Nubian female goats were subjected to experimental femoral fractures to their left femur with a CMEF installed for fixation. To evaluate the recovery status, radiological images and gait pattern were analyzed. In gait analysis, the subjects could bear weight in leash walking in the tenth week post-surgery. Radiological examination revealed that all goats could recover well before 12 weeks after surgery. In conclusion, CMEF is considered to be a practicable choice for repairing femur fractures in goats.

Keywords: Custom-made external fixator, femur fracture, goats, osteosynthesis

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Received September 10, 2020.

Accepted February 17, 2021.

doi: <https://doi.org/10.14456/tjvm.2021.45>

Introduction

Long bone fractures in goats are extremely common orthopedic issues caused by accidents during capture by humans, climbing or jumping to access feed sources (Smith and Sherman, 2009). A survey in India has indicated that the incidence of lone bone fractures (include femur, tibia and radius-ulna) in goats can reach 58.89% (Aithal and Singh, 1999). External fixators have been used to treat fractures in goats for years. These devices are suitable for open fractures and for those places difficult to fix by bandage such as proximal to the femur but they are expensive and heavy (Bini and Syam, 2014). Traditional external fixators (TEF) for human medicine use more parts, such as bar and half-pings, rings and hybrid designs, to make them suitable for bones and joints at different

sites. However, the more complicated design necessarily increases its weight and may cause inconvenience to patients (Ma, et al., 2017). When TEF is used in animals (Fig. 1), their voluntary movements with the heavy TEF may increase the chance of being shocked or injured (Ma, et al., 2013). Under these circumstances, a novel custom-made external fixator (CMEF), originating from an application of the external locked plating technique for human tibia fractures (Ma, et al., 2017), was adopted. Similar custom-made unilateral external fixators have been applied in horse mandibular fractures (Turek, et al., 2019). However, the external fixator applied in long bones still needs to be tested by strength tests and animal tests (Turek, et al., 2015). The purpose of this study was to evaluate the adaptability of the CMEF for treating femoral fractures in goats.

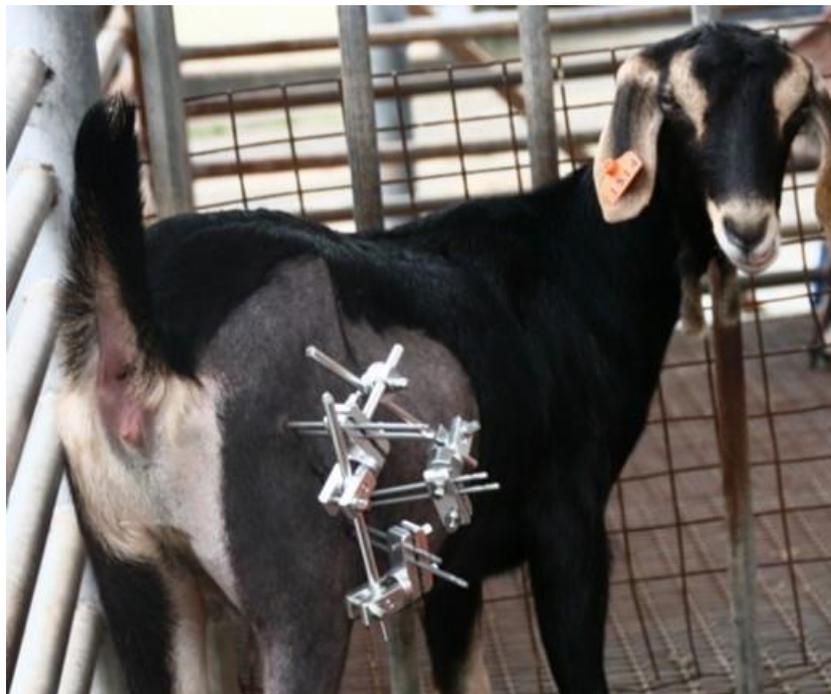


Figure 1 Traditional external fixator (TEF) installed on goat.

Materials and Methods

Animals: Three 12-month-old Anglo-Nubian female goats (No. 121, 122, and 123) with an average body weight (BW) of 35.8 ± 2.5 kg were used in this experiment and all goats were healthy and free of any orthopedical problems. The use of animals was approved by IACUC of the National Pingtung University of Science and Technology, protocol number NPUST-103-063. The three goats were adult and were born in the same month.

CMEF: The novel CMEF was set on the left femur of all three goats and the left femur was cut by bone saw to create an artificial fracture. The CMEF was developed by Dr. Yuan-Kun Tu and Dr. Ching-Hou Ma (E-Da Hospital, Kaohsiung City, Taiwan) based on the integration of the locked plating technique and the external fixation theory. The original prototype (Fig. 2) was designed and manufactured by Dr. Ting-Sheng Lin (Biomechanics Innovation and Application Lab., Department of Biomedical Engineering, I-Shou

University, Taiwan). The composition of CMEF included one bar, self-tapping screws and movable custom-made clamps. The material of all devices was made of stainless steel. The dimensional spaces and the total weight of the CMEF were 654 cm^3 (Height:7 cm; Length:24.6 cm; Width:3.8 cm) to 748 cm^3 (Height:8 cm; Length:24.6 cm; Width:3.8 cm) and 0.25 kg. The artificial tibia (# 3402 Sawbones, Washington, USA) had been tested with CMEF six repeats as a test model before this surgery, showing the average axial load was 1026.79 ± 116.48 N, the average axial stiffness was 210 ± 13 N/mm and the average displacement of artificial tibia was 4.87 ± 0.44 mm, which followed Ang's method in 2017 (Ang, et al., 2017).

Operation Procedure: Before the goats were subjected to surgery, they were anesthetized by intramuscular administration of xylazine (0.1 mg/kg BW) followed by intravenous administration of zoletil (1 mg/kg BW). The area for surgery was shaved to remove all hair and then scrubbed until clean. The shape of the fixator was

marked on the skin. A screw was attached to each end of the femoral bone and then the middle screws from between the head and the end of the plate were fixed. After fitting the fixator, a skin incision was made and a bone saw was used to cut the femur at the central line. Finally, the cut was sutured and the surgery area was cleaned. Thereafter, tolfenamic acid was administered (2 mg/kg BW) IM twice daily for pain management in the animals(Murison, et al., 2010).

Radiological examination: Radiological examination of the cut femur in a lateral and dorsal recumbency was

conducted every two weeks. Briefly, the goats were fasted for 12 h and anesthetized by the process as for the surgery above.

Gait analysis and recording of wound recovery: Each goat was walked with a guide leash for 10 m in an open area and the gait pattern was recorded on camera. Five-point gait scoring system in goats was applied to evaluate the status of the wound recovery of the leg (Table 1)(Deeming, et al., 2018).

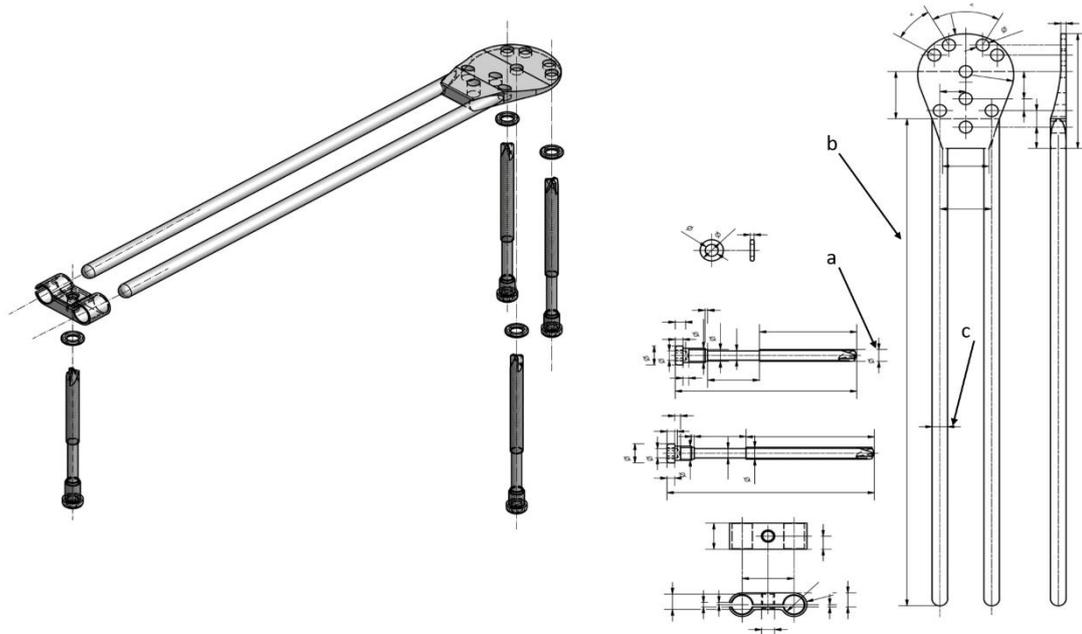


Figure 2 The detailed structure of a custom-made external fixator (CMEF). The diameter of the self-tapping screw(a) was 0.5cm. The length of bar(b) was 20.6cm and the diameter(c) was 0.6cm.

Table 1 The 5-point gait scoring system

Scores	Limp	Moving forward	Weight bearing	Head nod	Identify affected leg(s)	Other descriptors
1	No	Yes	Yes	No	—	Smooth, walks on all 4 legs.
2	No	Yes	Yes	No	No	Shorter gait, joints slightly stiff, inward or outward swinging of a hoof at each stride.
3	Yes	Yes	Yes	No	Possibly	One or more legs may be affected. Mild limp.
4	Yes	Reluctant	Reluctant	Possibly	Yes	One or more legs may be affected. Moderate limp or slight goose-stepping.
5	Yes	Unwilling or unable	unable	Yes	Yes	One or more legs may be affected. Severe limp or pronounced high goose-stepping.

Results and Discussion

The concept of CMEF, originating from an application of the external locked plating technique for human tibia fractures(Ma, et al., 2017), was modified for use in goats because the external locked plating could be constrained by the location of the inserted screws. The advantages of the new CMEF were not only confined to the strength of the locked plating but

also to its provision of flexible options for the screw insertion sites. The slim size of CMEF reduced the risk of goats getting the fixator stuck in the bars of the recovery cage. The maximum axial stiffness was measured by axial load test(Ang, et al., 2017), was 210 ± 13 N/mm, which is much higher than that of TEF (22.8 ± 2.1 N/mm)(Ma, et al., 2017). In Figure. 3a, b is the overview of CMEF on one of the goats at the first week after surgery and 12 weeks post-surgery.

The X ray taken on the day of surgery displayed the cut line at the center of the femur bone (Fig. 4a, b). After two weeks, the gap between the fractured bones decreased and there was a slight periosteal response (Fig. 4c, d). Four weeks post-surgery, the bone cut line became blurry, indicating the commencement of periosteal and endosteal callus formation (Fig. 4e). The ossification of the external callus was demonstrated by the radiopaque areas at the surgery site, indicating

bone remodeling. Fig. 4f shows a lateral view of the periosteal response. On the day of the fixator removal (12 weeks after surgery), good compact bone formation and radiolucent spots from the screw tracts were observed and the subjects were well healed (Fig. 5g, h). Because the newly formed cortical bone was still thin, a faint fracture line was observed. The images of other weeks (6-10 weeks) are shown in Fig 5a-f.



Figure 3 The overview of CMEF on the patient at the first week after surgery (a) and 12 weeks post-surgery (b).

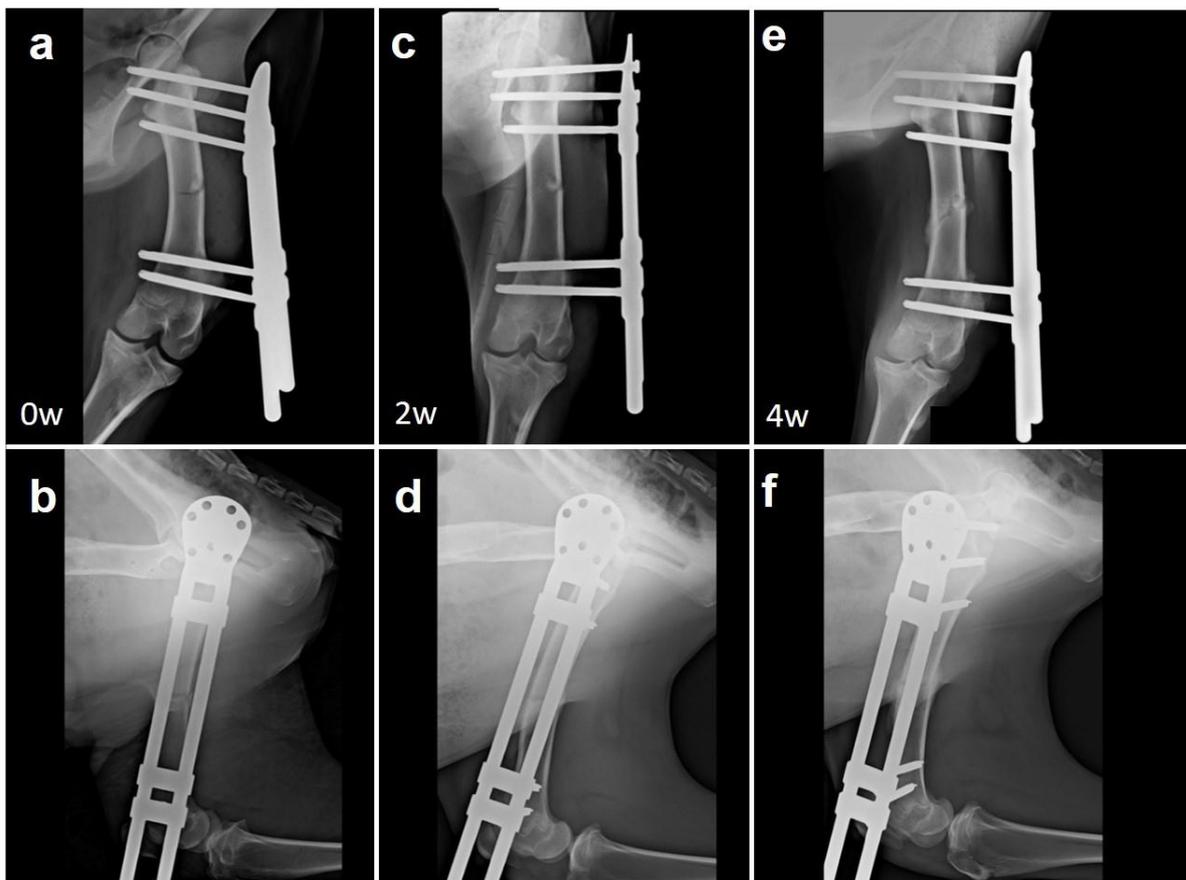


Figure 4 X ray photograph taken on the day of CMEF surgery in dorsal recumbence (a) and right lateral recumbence (b). X ray photograph taken two weeks post-surgery in dorsal recumbence (c) and right lateral recumbence (d). X ray photograph taken on four weeks post-surgery in dorsal recumbence (e) and right lateral recumbence (f).

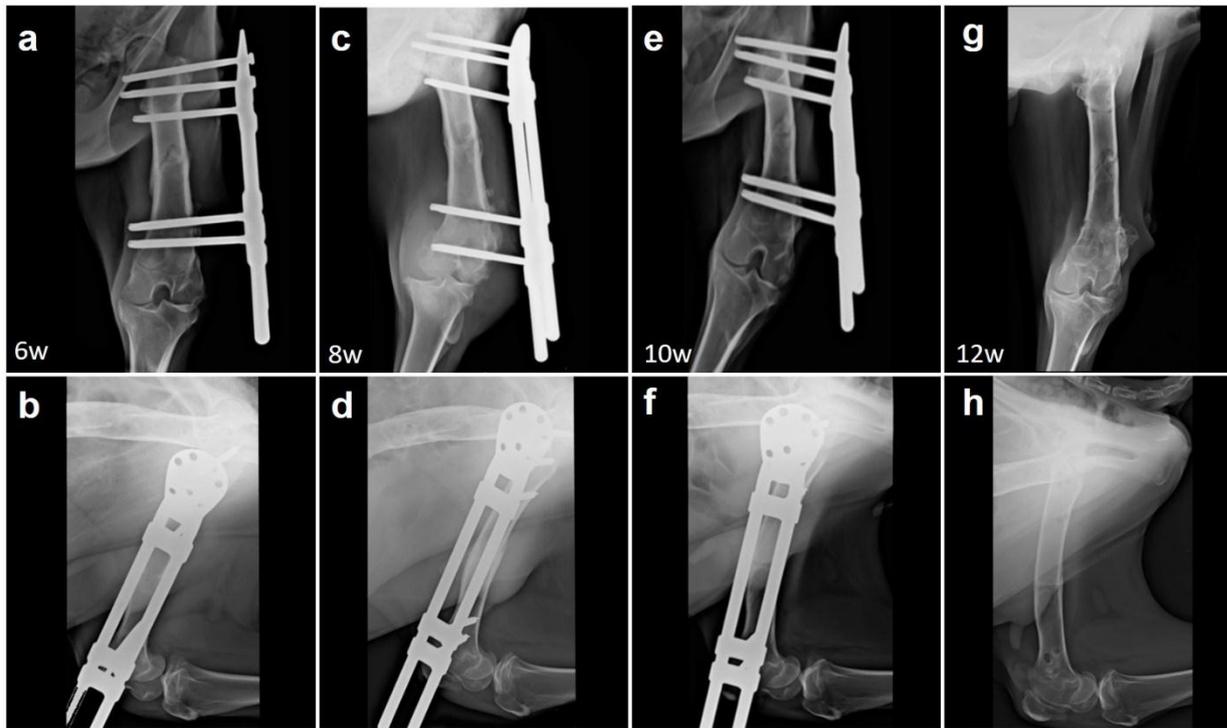


Figure 5 X ray photograph taken at six weeks post-surgery in dorsal recumbence (a) and right lateral recumbence (b). X ray photograph taken at eight weeks post-surgery in dorsal recumbence (c) and right lateral recumbence (d). X ray photograph taken at ten weeks post-surgery in dorsal recumbence (e) and right lateral recumbence (f). X ray photograph taken on the day of external fixator removal (12 weeks post-surgery) in dorsal recumbence (g) and right lateral recumbence (h).

The changes in the gait patterns of the three goats in this study tended to be consistent (Table 2) and we could divide the gait patterns into five stages by the weight bearing ability of the left hind leg (surgery leg): (1) Prior to surgery: the left hind leg was healthy and had good weight-bearing ability(1/5 point). (2) Non-weight-bearing: in the first week after surgery, the left hind leg was unable to touch the ground or to bear weight (5/5 point). (3) Partial weight bearing: four weeks after the surgery, the leg could touch the ground for a short time and could support a light weight (4/5

point). (4) Weight-bearing run: after the removal of the external fixator (approximately 12 weeks post-surgery) the goats could walk and run with good weight bearing on the left hind leg with shorter gait (2/5 point). The wounds made by screws were treated by antibiotic and NSAIDs based on bacteria culture and antibiotic resistance results. Most of the bacteria found in wound were normal flora on the skin; after antibiotic and NSAID treatment, patients were well in the following recovery process.

Table 2 The changes of gait scores in 3 goats

Goat	Gait scores				
	Prior to surgery	First week after surgery	Fourth week after surgery	Tenth week after surgery	Twelfth week after surgery
121	1	5	4	3	2
122	1	5	4	3	2
123	1	5	4	3	2

We could observe the fracture recovery process under X ray examination. We could see a clear and sharp cutting line of the femoral bone, and the alignment of bone and the satisfactory of external fixator at surgery day (Fig. 4a, b). Continual remodeling of fractured bone made the edge of bone become smooth. The gait scores also from 5 points improved to 2 points. On the day of removing the external fixator (12 weeks after surgery), good compact bone formation and radiolucent spots from screw tracts were noticed and the healing status of the patient was good. Because the new formed cortical bone was

still thin, we could see an unclear fracture line in radiography (Fig. 5g, h). At the same time, the goats could walk and run with good weight bearing on the left hind leg.

In conclusion, CMEF had the advantage of a small size and light weight and it also decreased the risk of animals getting stuck in cages compared to TEF. The recovery of 3 goats in this study tended to be consistent and it showed the stable treatment effect of CMEF. CMEF is suitable for bone re-construction surgery in goats without compromising the recovery rate. CMEF

can be considered as a practicable choice for repairing the femur or other long bone fractures in goats.

Acknowledgements

We thank our cooperators, the original designer Dr. Ting-Sheng Lin from I-Shou University, Dr. Yuan-Kun Tu and Dr. Ching-Hou Ma, from E-Da Hospital, who provided insight and expertise that greatly assisted the research. We also thank the doctors and students in NPUST Veterinary Medical Teaching Hospital who took very good cares of our patients in this research.

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