FULL ARTICLE

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Treatment of fractures and other orthopedic problems in cats and dogs using versatile external fixator

Tratamento de fraturas de extremidades de cães e gatos usando fixador externo versátil

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ABSTRACT

Many complicated bone fractures can be healed by different techniques including linear external fixation. New generation linear external fixators enhanced the scope of application for bone fractures by mechanical progress. Difficulties include implementing enough pins through fixation clamps to the comminuted fragments or clamp addition and fixing it properly to the rod with the correct pin insertion angle. Effective configurations may not always result. This study sought to reveal the clinical efficiency of modified clamps of a versatile external fixator (VEF) to fix different types of fractures and orthopedic problems according to the radiographic and clinical results. We used this fixator on 17 cats and 17 dogs of different ages and sizes, having different types of antebrachium, humerus, tibia, ulna fractures, and bone-muscle deformities. Clamps had different features to connect fixator pins. Many fixator configurations were created according to the fracture type and body weight of the animals. The most used ones were unilateral and bilateral configurations. The callus formation and visual gait analysis were observed after the operations, until the removal of the fixator. After fixator removal, the visual gait status of the limbs was excellent in 67% of the cases, good in 15%, fair in 12%, and poor in 6%. We found that rods and fixator pins were connected easily by semi-locked clamps. Also, the double pin holding clamps saved space on the fixation rod by the application of two pins through one clamp. We think that clamps of versatile external fixators can easily be constructed to limb fractures and save time during surgery.

Keywords: Clamps. Bone fractures. Linear fixators. Osteosynthesis. Fixator pins.

RESUMO

Diversas fraturas ósseas complicadas podem ser tratadas por diferentes técnicas, incluindo fixadores externos lineares. Os fixadores externos lineares de nova geração aumentaram o escopo de aplicação para fraturas ósseas devido ao progresso mecânico. A dificuldade é implementar um número suficiente de pinos através de clamps de fixação aos fragmentos osseos ou adição de clamps com fixação adequadamente à haste com o ângulo correto de inserção do pino. As configurações eficazes nem sempre podem ser realizadas. Este estudo pretendia revelar a eficácia clínica das clamps modificadas de um fixador externo versátil para corrigir diferentes tipos de fraturas e problemas ortopédicos de acordo com os resultados radiográficos e clínicos. O fixador foi utilizado em 17 gatos e 17 cães de diferentes idades e tamanhos, com diferentes tipos de antebraço, úmero, tíbia, fratura de ulna e deformidades ósseo-musculares. Os clamps tinham recursos diferentes para conectar os pinos do fixador. Muitas configurações de fixadores foram criadas de acordo com o tipo de fratura e peso corporal dos animais. As mais utilizadas foram as configurações unilateral e bilateral. A formação do calo e a análise visual da marcha foram observadas após as cirurgias, até a retirada do fixador. Após a retirada do fixador, a utilização dos membros foi excelente em 67% dos casos, bom em 15% dos casos, regular em 12% dos casos, ruim em 6% dos casos. Concluímos que as hastes e os pinos do fixador foram facilmente conectados por clamps semi-travados. Além disso, os clamps de fixação de pino duplo economizaram espaço na haste de fixação com a aplicação de dois pinos em clamp. Acreditamos que os clamps de fixadores externos versáteis podem ser facilmente construídas para fraturas de membros, economizando tempo na cirurgia.

Palavras-chave: Clamp. Fraturas ósseas. Fixadores lineares. Osteossíntese. Pinos fixadores.

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Introduction

Bone plates and interlocking nails can be used with limb fractures. However, external fixators have also been used widely for stabilization (Shahar, 2000; Wander, 2019). They have mainly been applied to open, infected, comminuted fractures, arthrodesis, and corrective osteotomies in human and veterinary orthopedics (Petfield et al., 2017; White et al., 2003).

Some critical biomechanical factors are positive profile pins (Fragomen & Rozbruch, 2007), and the number and thickness of the pins (Canapp, 2004). These factors affect the fixator's stabilization (Giotakis & Narayan, 2007; Roe, 2014). Although circular external fixators are the most rigid fixators and thin Steinmann pins are applicable, linear fixators are less expensive (Piermattei et al., 2016).

IMEX-SK and Securos external fixation systems include new generation linear external fixators (Kraus et al., 2003). The mechanics of these clamps and their stiffness make them more advantageous than Kirschner-Ehmer splints. These fixators have ease of use during fixator construction at the operations (Lewis et al., 2001). However, problems can still occur, and transarticular frames are significantly more likely to develop mechanical complications (Beever et al., 2018).

Although external fixation is a successful method, it may not always be easy to apply them on comminuted and short distal fractures (Witte et al., 2014). All the Steinmann fixator pins have to be inserted using a proper technique, considering the tissue damage and the safe corridors for fixator pin application (Seibert et al., 2011; Palmer, 2012). It may not always be possible to use safe corridors to insert the pins without damaging vessels and muscle tissue according to the fracture type, fracture localization, and soft tissue injuries (Piermattei et al., 2016). A concession of the ideal ways is made in many cases (Kraus et al., 2003). There may not be enough room to insert a pin through the short oblique fragments (Guerin et al., 1998). The rods are not pliable, and passing the pins through the bone cortex is not easy in comminuted and distal fractures (Beck & Simpson, 1999). This can lead to fixation application difficulties and complications (Clarke & Carmichael, 2006). A higher complication rate has been found in the femur, tarsus, and radius/ulna than the other long bone fractures. This affects the healing time and fixation strength (Beever et al., 2017). New clamps may contribute to better fixator constructs (Wander, 2019).

In this study, we aimed to determine the ease of application of VEF, possible lesser clamp usage, evaluate clinical and radiological results. We made clamp modifications and produced a versatile (linear) external fixator (VEF) that allows the usage of 1.2 mm Kirschner pins in small dogs and cats. Also, semi-locked and standard clamps were questioned to investigate if easier fixator construction can be made during fracture fixation. Although similar clamps have been used in human medicine, it is not likely to be used in veterinary medicine.

Material and Methods

VEF fixator

VEF (Serbay®) has 4 mm and 6 mm diameter titanium alloy connection rods. These are 8, 10, 11, 12, 20 cm long. Fixator has three different types of clamps. The first type is the standard clamp, which is attached from the end of the rods. This clamp is different from the IMEX-SK and Securos clamps. It is made of two parts. These are connected by teeth, which are actually like a gearwheel. Each part has a hole. Both parts are equal to each other, and a blue pin holder is inserted into one of them. The rod passes from the other part. Both the two parts and the teeth between them are compressed when tightened with a screwdriver. The second type of clamp can be attached directly over the rod. It is called a semi-locked clamp. It is made of two different parts with teeth between them. One part holds the fixator pin, and the other is locked to the rod. The third type of clamp is a double pin holding clamp which can hold two Steinmann pins. These clamps can hold 1.2 mm and bigger diameter Steinmann pins. This clamp also has two different parts. One part holds two Steinman pins while the other holds the rod. It also has teeth between two parts for stabilizing each other.

The blue pin holder is inserted into the hole of the clamp. A fixator pin can be applied through this pin holder after it is placed into the clamp (except double-pin holding clamp).

We used 3 mm and 4 mm titanium alloy positive profile pins and 1.2 mm and 1.5 mm smooth Steinmann pins. VEF components are shown in Figure 1.

Surgical procedures:

The patients were brought to İstanbul University-Cerrahpaşa, Faculty of Veterinary Medicine, Department of Surgery, with the humerus, radius/ulna, femur, tibia, talus fractures, malunion, and bone deformities. The Local Ethics Committee of Animal Experiments approved the study at İstanbul University-Cerrahpaşa with report number 72 and supported by İstanbul University-Cerrahpaşa Scientific Research Projects (BAP) Unit. It is composed of a Ph.D. thesis. Informed consents from the owners of the patients were also obtained. Radiologic evaluations were made with OREX PcCR 1417 x-ray machine. 1 mg/kg Xylazine hydrochloride intravenously (IV) as preanesthetic and 5 mg/kg Ketamine hydrochloride (IV) for general anesthetic were used. Animals were intubated just after ketamine hydrochloride administration. Anesthesia was sustained by isoflurane or sevoflurane by inhalation gas anesthesia machine with no signs of pain. Ceftriaxone sodium 22 mg/kg IV was administered as a preoperative antibiotic. The choice of fixator configuration was decided by the authors (surgeons). Body weight, age, gender, breed, and information about the orthopedic problem were recorded. We (surgeons) evaluated gait analysis at controls according to the classification in Table 1 as Fox et al. (1995) previously described. Some clients could not bring their pets. We evaluated those dogs and cats by asking about the gait status of clients' pets. It is classified as excellent, good, fair, and poor according to visual gait analysis. Bone union was interpreted according to the radiological findings regarding complete callus formation or not. Clients were asked to come for postoperative radiographic controls every 15 days. Some of them communicated by phone. Union time and complications were recorded.

Statistical analysis

Collected data were statistically analyzed with Microsoft excel. The student's t-test was used to evaluate the null hypothesis between the type of fracture and healing time. The fracture type is considered both open or closed and simple or complex. The presence of minor or major complications and healing time together with clamp type (standard or double pin holding or semi-locked clamp) and healing time were also evaluated.

The chi-square test (IBM SPSS Statistics 27) was also used to assess the null hypothesis between the type of fracture (open or closed fracture and simple or complex fracture) and walking grade. Clamp type (standard or double pin holding or semi-locked clamp) and bone union, clamp type, and walking grade were evaluated. The level of significance was set at $P< .05$ for all the tests.

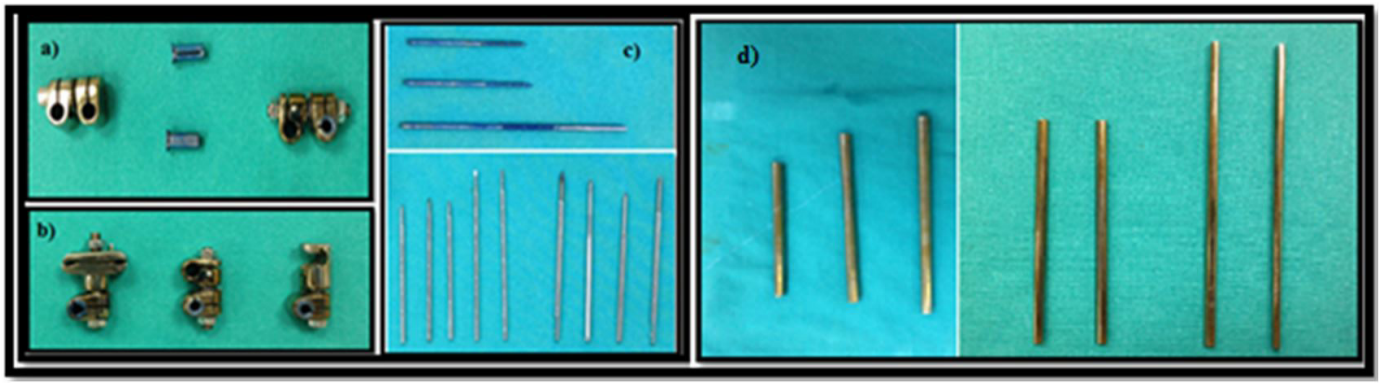

Figure 1 – Clamps and fixator pins of the VEF. (a) shows standard clamps and blue pin holders; (b) shows on the left two Steinmann pin holding clamps, in the middle standard clamp, on the right semi-locked clamp. Figure 1c shows 3 mm and 4 mm diameter positive profile pins used in dog and cat cases; (d) shows titanium connection rods.

Table 1 – Clinical evaluation of the visual gait status of dog and cat cases

Grade	Visual gait status	Definition
I	Excellent	Complete usage of the limb when standing, walking, running and able to give the full body weight to the leg
II	Good	Slight lameness after running
III	Fair	Continuous lameness but being able to give body weight to the leg
IV	Poor	Severe lameness and not able to give body weight to the leg

Results

Thirty-five orthopedic problems of 17 dogs and 17 cats were operated on and evaluated. Six cats were female and 11 were male, while five dogs were female and 12 were male. Eight dog breeds and three cat breeds were operated in the study. The mean age was 3.78 years in dogs (median, two years; range between 0.5 years to 13). Mean age was 1.98 years in cats (median, one year; range between 0.5 years to 6). Mean body weight was 20.47 kg for dogs (median, 23; range, 7 to 32 kg) and 3.25 kg for cats (median, 3.2 kg; range, 2.5 to 5.2 kg). Eleven (32.3%) of the patients were brought in due to unknown trauma, 7 (20.6%) traffic accident, 6 (17.7%) fall from height, 3 (8.8%) squeezed to car engine, 2 (5.9%) human-caused trauma, 2 (5.9%) gunshot and 3 (8.8%) developmental problems.

Thirty (85%) fractures (1 dog had bilateral antebrachium fracture), 1 (3%) short femur (osteotomy was performed), 1 (3%) elbow dysplasia (fixator pins were applied to humerus and radius, and then fixed with the VEF), 1 (3%) angular deformity (osteotomy was performed), 1 (3%) malunion (osteotomy was performed), 1 (3%) contracture (fixator pins were applied to femur and tibia, and then fixed with the VEF) in 34 patients (17 cats and 17 dogs) were operated. Five (14%) of the operations were performed on the femur, 18 (51%) on the tibia, 8 (23%) on antebrachium, 2 (6%) on the humerus, 1 (3%) on talus, and 1 (3%) on humerus and antebrahium for elbow dysplasia. Ten (33%) of the fractures were open and 20 (67%) were closed.

Type Ia (7 cases, 20%), type Ib (10 cases, 28%), type Ib with tie-in (1 case, 3%), type II (7 cases, 20%), unilateral tie-in (8 cases, 23%), bilateral tie-in (1 case, 3%) and type III (1 case, 3%) fixator configurations were composed for fixation. A total of 35 operations were performed. Out of the 35 operations, standard clamps were used in 23 (65%) of them, in 3 (9%) double pin holding, and in 9 (26%) semi-locked clamps were used. Destabilization was performed in 15 (42%) patients when callus formation was started. One cat died on the postoperative fifth day. All the patients had minor pin tract infections. Two (5.9%) cases of 34 operations (33 alive patients) had a severe infection. Pin breakage occurred in 7 (20.6%) cases, and fixator failure was observed in 2 (5.9%) cases. Fixator failures were due to pin loosening at the bone, and they were reoperated. There was no loosening between pin-clamp or bar-clamp connections of the VEF. All the semi-locked clamps were implemented to bars in seconds. Other clamps were attached from the end of the bars.

According to postoperative rechecks, out of 33 patients, four patients had mineralized callus formation on day 30 (12.1%), seven on day 45 (21.2%), seven on day 60 (21.2%), five on day 75 (15.2%), five on day 90 (15.2%), one on day 120 day (3%). Two (6%) patients had no callus formation. Callus formation time was not properly known in two (6%) patients due to the poor connection for rechecks. The average number of these rechecks was 2.6 (range 1 to 6). The mean mineralized callus formation for 31 animals (2 unknown) was 58 days.

The walking grades of the patients according to the visual gait analysis were excellent in 22 (66.7%) cases, good in 5 (15.2%), fair in 4 (12.1%), and poor in 2 (6%). Orthopedic evaluations and the healing status of the animals were shown in Table 2.

No significant differences between open or closed fractures (P=0.54), simple or complex fractures (P=0.64), standard or double pin holding, or semi-locked clamps (P=0.28) were determined.

Preoperative and postoperative radiographs of VEF implementations of three cases were shown in Figures 2, 3, and 4.

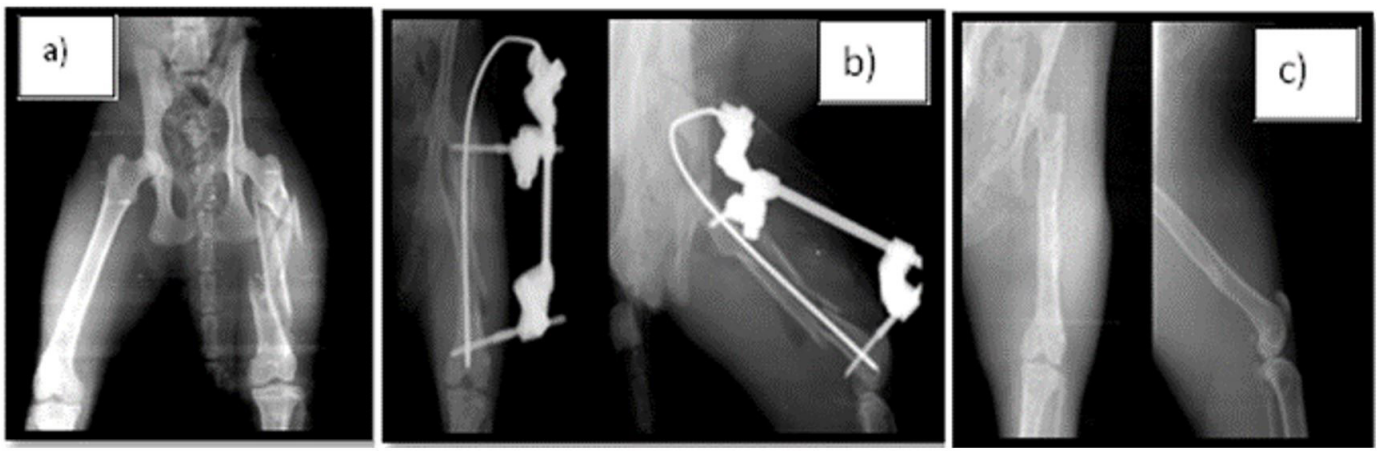

Figure 2 – Figure 3a shows a preoperative radiograph of comminuted fracture of the cat's femur, 3b postoperative radiograph, and 3c after fixator removal (case 4).

Table 2 – Fracture types, fixation methods, clamp types, and healing status of the cases

Case No	Age, species	Weight, gender	Fracture type or the orthopedic problem	External Fixation Method	Clamp Type	Union Time	Visual Gait Analysis (According to Table 1)
1	6 months cat	2.5 kg male	Femur contracture	Type Ia	Standard clamp	45. day	III
2	7 months cat	2.7 kg female	Sagital diaphyseal humerus fracture	Type Ia	Standard clamp	45. day	I
3	5 years cat	3.7 kg male	Comminuted tibia fracture	Type Ib	Standard clamp	60. day	I
4	2 years cat	3.2 kg female	Comminuted femur fracture	Unilateral with tie-in	Standard clamp	75. day	I
5	7 months cat	2.5 kg male	Antebrachium fracture	Type II	Standard clamp	60. day	II
6	6 years cat	5.2 kg female	Tibia fracture	Type II with a tie-in	Standard clamp	60. day	I
7	1,5 year cat	3.2 kg male	Tibia fracture	Type II	Standard clamp	90. day	I
8	1 year cat	3.0 kg male	Open tibia fracture	Type II	Standard clamp	60. day	I
9	6 months cat	2.8 kg male	Open tibia fracture	Unilateral with tie-in	Standard clamp	45. day	I
10	5 years cat	3.9 kg male	Open oblique distal tibia fracture	Type Ib	Standard clamp	90. day	I
11	10 months cat	3.4 kg female	Open tibia fracture	Unilateral with tie-in	Standard clamp	75. day	I
12	1 year cat	3.2 kg male	Diaphyseal sagittal antebrachium fracture	Type Ia	Standard clamp	45. day	I
13	1 year cat	3.3 kg male	Comminuted antebrachium fracture	Type II	Standard clamp	45. day	I
14	6 months cat	2.6 kg male	Open tibia fracture	Type Ia	Standard clamp	-	Died on postoperative 5. day
15	3 years cat	3.7 kg male	Tibia fracture	Type Ia	Standard clamp	75. day	I
16	9 months cat	2.8 kg female	Comminuted femur fracture	Unilateral with tie-in	Standard clamp	Unknown	I
17	4 years cat	3.6 kg female	Diaphyseal sagittal tibia fracture	Type Ia	Standard clamp	45. day	I
18	5 years dog	28 kg female	Diaphyseal sagittal antebrachium fracture (bilateral)	Type Ib both legs	Semi-locked clamp	60. day	II
19	2 years dog	32 kg male	Oblique tibia fracture	Type Ib	Standard clamp	60. day	I
20	9 years dog	7 kg male	Tibia fracture	Type Ib	Standard clamp	90. day	I
21	7 years dog	21 kg male	Open comminuted proximal antebrachium fracture	Type III	Double pin holding clamp	No callus formation	III
22	5 months dog	18 kg female	Open proximal tibia fracture	Type II	Standard clamp	30. day	I
23	7 months dog	8 kg female	Short femur	Type Ia after osteotomy	Semi-locked clamp	30. day	IV
24	2 years dog	25 kg male	Femur fracture	Unilateral with tie-in	Standard clamp	75. day	II
25	10 months dog	23 kg male	Elbow dysplasia	Unilateral with tie-in	Semi-locked clamp	No callus formation	IV
26	3 years dog	28 kg male	Antebrachium fracture	Type Ib	Semi-locked clamp	75. day	I
27	3,5 months dog	9 kg male	Oblique tibia fracture	Type II	Standard clamp	30. day	I
28	13 years dog	24 kg male	Sagital diaphyseal tibia fracture	Type Ib	Semi-locked clamp	45. day	I

Table 2 – Continued...

Case No	Age, species	Weight, gender	Fracture type or the orthopedic problem	External Fixation Method	Clamp Type	Union Time	Visual Gait Analysis (According to Table 1)
29	11 years dog	28 kg male	Open talus fracture	Type Ib	Standard clamp	Unknown	III
30	6 years dog	26 kg male	Open tibia fracture	Type Ib	Semi-locked clamp	90. day	I
31	6 months dog	23 kg female	Angular deformity on antebrachium	Type Ib	Semi-locked clamp	60. day	III
32	5 months dog	15 kg female	Malunion of tibia	Type II after corrective osteotomy	Double pin holding clamp	30. day	I
33	2 years dog	19 kg male	Open tibia fracture	Unilateral with tie-in	Double pin holding clamp	90. day	II
34	1 year dog	14 kg male	Comminuted humerus fracture	Unilateral with tie-in	Semi-locked clamp	120. day	II

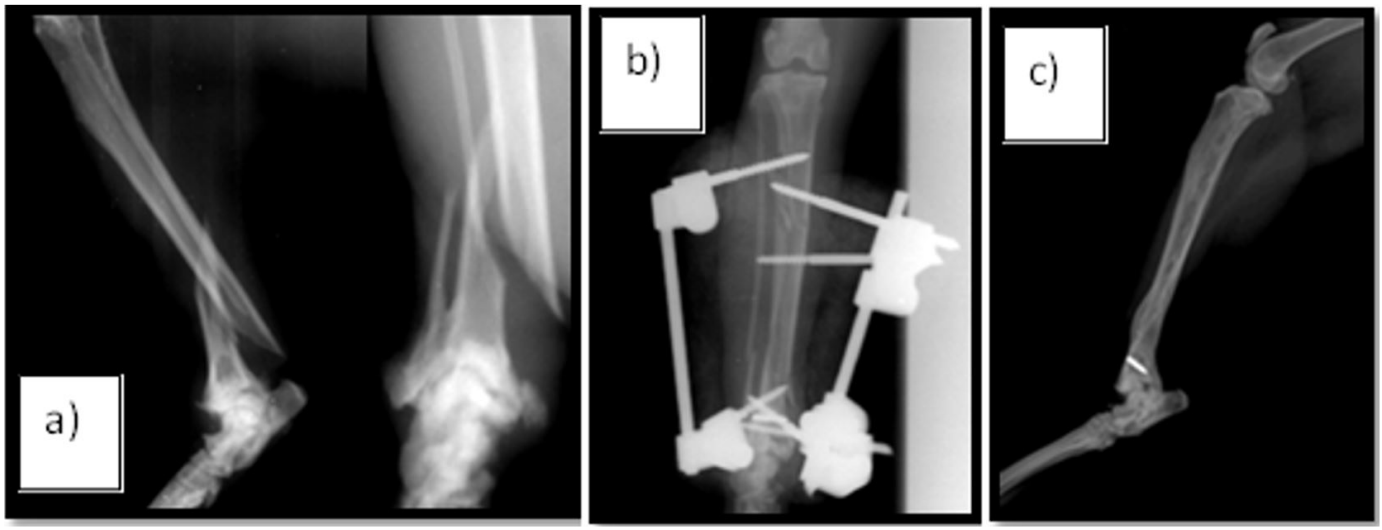

Figure 3 – Figure 2a shows distal oblique fracture of the tibia in a cat before operation and Figure 2b just after pin implementation (case 10). Figure 2c is the radiograph after fixator removal. One fixator pin was broken and stayed inside the bone.

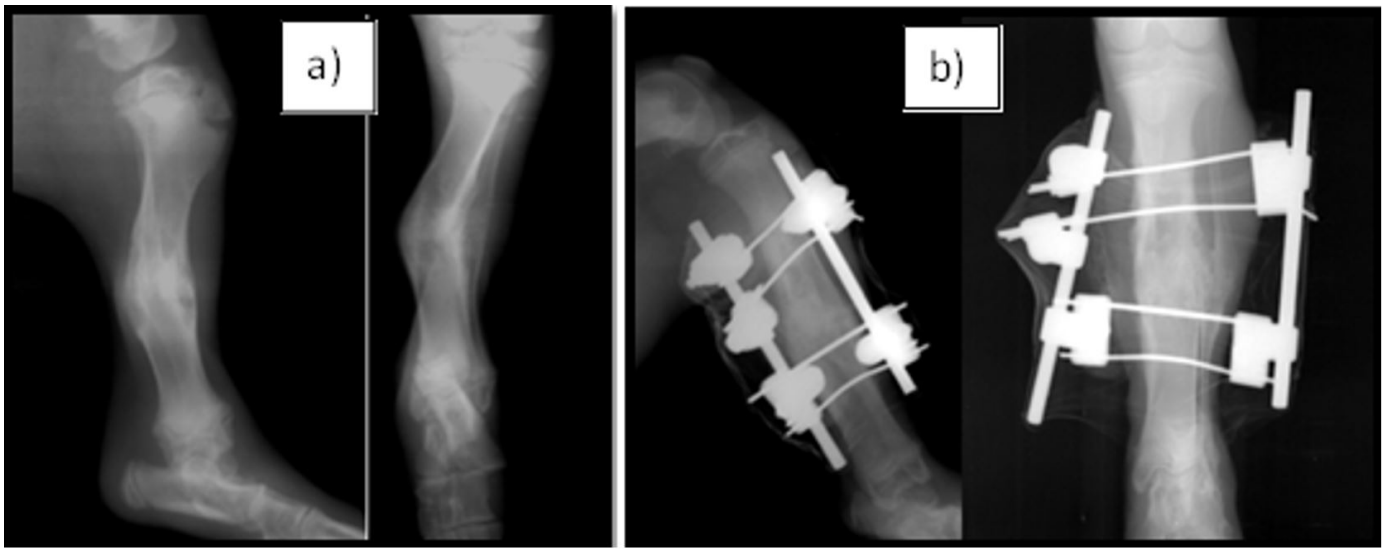

Figure 4 – 5 months old dog with malunion of the tibia (case 32). Figure 4a is the preoperative radiograph and Figure 4b is the postoperative radiograph on day 30.

Discussion

External fixators have basic implementation techniques. The parts of the external fixator should be arranged according to the patient's size, age, the character of the animal, and fracture type (Marcellin-Little, 2003). In our study, we used different configurations according to the fracture type, age, and body weight of the animal.

Various fixator apparatus can be designed using Kirschner-Ehmer, IMEX-SK, and Securos fixator models. Clamps of these fixators have different features for fixator stabilization (Piermattei et al., 2016). The clamps of the Securos and IMEX-SK fixators are attached from the rods' edge (Kraus et al., 2003; Sylvestre, 2019). Standard and double-pin holding clamps of VEF are also attached from the rods' edge, but semi-locked clamps can be attached anywhere on the rod. Kirschner-Ehmer clamp, Securos clamp, IMEX-SK clamp (Corr, 2005), and VEF's semi-locked clamps are shown in Figure 5. Complex fixator structures can be made quickly and easily with semi-locked clamps due to their ease of pluggability. Quick connection with these clamps has saved time in applying type III and type Ib fixations especially. All the clamps of VEF could rotate 360°. This provides ease of usability as other fixators do. Semi-locked clamps were the best to gain time when compared to the standard and double pin holding clamps.

Fixation of the rods together using another rod improves the construct's strength in type Ib and type III applications (Johnson, 2018). The callus hardness increases during the bone union. This allows conveying the body weight through the fracture side. Increasing the load on the fractured bone by disassembling the fixator allows limited axial movement between fragments and accelerates the final stages of bone healing (Foxworthy & Pringle, 1995). For this reason, adjustability of the robustness of the fixator is very important for bone union (Mora & Forriol, 2000; Auger et al., 2002; Canapp, 2004; Rovesti, 2016). Fifteen cases healed by increasing the load on the fractured side. Quick destabilization of the semi-locked clamps enabled the use of low-dose anesthesia. It was achieved by disassembling the semi-locked clamps of VEF that connected the fixation rods or removing the intramedullary pin used in tie-in fixations. VEF's semi-locked clamps provided a significant convenience to reapply a new fixation pin when a correction was needed after postoperative radiography.

At least two fixator pins have to be implemented to each fragment, but three or more are frequently needed (Aronsohn & Burk, 2009). For not to crack the bone, the pin's diameter should be a maximum of 20-25% of the bone diameter (Johnson, 2018). A diameter of a minimum of 1.6 mm pin in the Securos fixator and 0.9 mm pin in the IMEX-SK fixator can be used for fixation, as Corr (2005) reported. It is advantageous to be able to use suitable diameter fixator pins in young or small animals. It is possible to use both 1.2 mm (or larger) diameter smooth Steinmann and

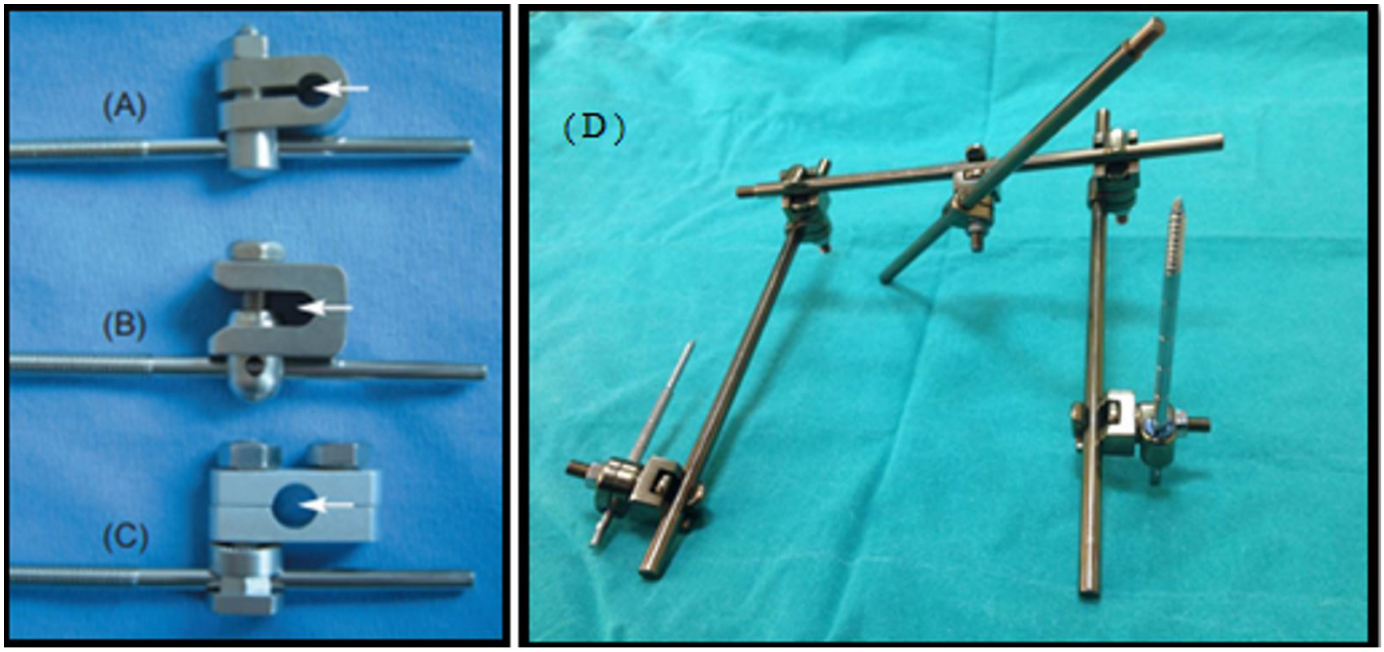

Figure 5 – Clamps of VEF. Figure 5a shows Kirschner-Ehmer, Figure 5b Securos, and Figure 5c IMEX-SK clamps. White arrows show the holes that rods pass. In Figure 5d semi-locked clamps are displayed holding bars and fixator pins in different angles. They can be attached to any rod. The clamp can rotate 360°. It fixes the fixation pin and rod when tightened with a screwdriver.

positive profile fixator pins via VEF's double pin holding clamps. Steinmann pins that were thought not to break the bone can be applied through oblique and comminuted fracture fragments with these clamps. Acrylic external fixator systems have the same advantage (Shahar, 2000). However, it is not possible to change the configuration of the fixator when it is rigid. The distance between the holes of the double pin holding clamp is 15 mm. This makes it easy to manage short fragments to implement two pins with one clamp. Normally when two clamps are used in a short fragment, they may overlap on the rod because of the inadequate space at the short fragment side. The double pin holding clamps occupied a smaller space than the counter side, where two clamps were used, as shown in Figure 4. Gaining space may be advantageous in many configurations. Using one double pin holding clamp instead of two standard clamps makes the fixator slightly lighter, which may be of great importance especially in small animals.

Movement can occur between the clamp and fixator pin, which can loosen the pin from the clamp. Mostly inappropriate safe corridors, pin tract infection, type II fixators, heat while pinning may cause this problem by pin-bone loosening and increasing the load on the clamps (Gemmill et al., 2004; Gilley et al., 2009). The blue pin holders inserted into the clamps' holes increase the frictional force between the inner and outer contact surfaces. Positive profile fixator pins pass through the hole of pin holders. The outer surface of the pin holder is in contact with the inner surface of the clamp hole. The advantage of frictional force is used in standard and semi-locked clamps by creating increased contact areas. There was no movement observed between clamps, pins, and bars of VEF considering 33 patients. The material strength of the clamps and bars was out of the scope of this study. VEF is made of titanium alloy, which is used to produce fixator materials by Serbay®.

Earlier callus formation and a diminished healing time for comminuted fractures were not observed compared to other external fixators types (Gemmill et al., 2004; Könning et al., 2013; Kraus et al., 2003; Langley-Hobbs et al., 1997). According to simple fractures, young patients healed early, and complicated fractures took more time to heal. This shows that VEF has no superiority over IMEX-SK and Securos fixators when healing time and callus formation are taken into account. However, operation success depends on fracture type, infection, the time elapsed after accident, fixation technique, surgeon's experience, patient's temperament, environment, and postoperative care (Beever et al., 2018).

The costs of VEF materials are the same as the IMEX-SK and Securos fixators. VEF has no cost advantage over other external fixators.

Conclusion

Most of the fracture types can be fixed with new generation linear external fixators. Problematic and thin diameter bone fractures need an extra advantage to successfully heal. Pin holders, the double pin holding clamps, and semi-locked clamps do not exist in these external fixators.

We think that VEF does not have specific stability superiority over the Securos and IMEX-SK linear external fixators. However, with its different clamps, VEF has implementation simplicity compared to new generation fixators while constructing them. Saving time and using fewer clamps, when needed, will be beneficial for surgeons.

Conflict of interest

There is no conflict of interest between the authors.

Ethics Statement

The Local Ethics Committee of Animal Experiments approved the study at İstanbul University-Cerrahpaşa with report number 72.

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