RESEARCH ARTICLE

Sokoto Journal of Veterinary Sciences

(P-ISSN 1595-093X/ E-ISSN 2315-6201)

Bada *et al*. /*Sokoto Journal of Veterinary Sciences* (2017) 15: 36 -45.

http://dx.doi.org/10.4314/sokjvs.v15i4.6

Comparative evaluation of pin-in-fiberglass cast and Kirschner-Ehmer external fixative in the management of radius-ulna fractures in dogs

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Abstract

Four adult (two males and two females) dogs were used to comparatively evaluate the effectiveness of pin-in-fiberglass cast with Kirschner-Ehmer type I external skeletal fixative in the management of surgically created radius-ulna fractures in dogs. These dogs were assigned to two groups (A and B) with each group made up of two dogs. The radius-ulna fracture was created in all the dogs under general anaesthesia as follows: Group A, pin-in-fiberglass casting; and Group B, Kirschner-Ehmer type I external fixation. Post-operatively, minimal increase in vital parameters were observed, but were not significant (P>0.05) when compared with pre-operative values in both groups. The haematological indices were within acceptable normal limits for both group (P>0.05). Dogs in both groups bore weight on the operated limb and could walk within 24 hours post-operative. Radiographic evaluation revealed minimal soft tissue swelling and minimal periosteal tissue reaction in both groups. The Kirschner-Ehmer external fixative group attained the faster fracture healing time (7 weeks) compared to the pin-in-fiberglass group (8 weeks). Functional and cosmetic appearances were graded as excellent for both groups. Complications associated with the two techniques were cast sores in the pin-in-fiberglass group while pin loosening and serous pin tract drainage were observed in the Kirschner-Ehmer external fixative group. Thus, it was concluded that pin-in-fiberglass cast could be used as a satisfactory substitute to Kirschner-Ehmer type I external fixative in the management of simple radius-ulna fractures in dogs.

Keywords: Bone, Dog, Fracture, Kirschner-Ehmer external fixative, Pin-in-fiberglass cast, Radius-ulna

Received: 16-12-2016 Accepted: 30-03-2017

Introduction

Traumatic injuries to musculoskeletal system are common problems encountered in companion animal practice which most often arise from automobile accidents, cruelty, gunshot, and other related causes (AbdulRahman *et al.*, 2006). These injuries, mostly fractures are disruptions or discontinuities of the surface of mesothelial organs generally or skeletal structure specifically in animals (Hassan & Hassan, 2003). The radius-ulna are paired bones that connect the elbow to the carpus or wrist joint with the radius being the major weight-bearing bone of the two (Permattei *et al.*, 2006). Bennour *et al.* (2014) reported that when fractures of the lower forelimb occur, both radius and ulna bones are usually affected together. However, it is not uncommon to have a fractured radius and an intact ulna following trauma to a forelimb (AbdulRahman *et al.*, 2006). Fractures of the radius-ulna bones are one of the commonest fractures in dogs which comprises about 17% of the fractures seen in small animal practice Greg (2003), with highest incidence during the breeding season (AbdulRahman *et al.*, 2006).

The primary goal of fracture treatment is to achieve the fastest possible healing time and to enable the patient function normally by allowing early ambulation (Shahar, 2000). Various methods have been used in the management of radius and ulna fractures, however, external fixation methods are primarily suggested (Permattei *et al.*, 2006). External fixation has an extensive history that can be traced back to the days of Hipocrates (Hernigou, 2016) and despite the advances in technology and metallurgy, modern principles of external fixations are still based largely upon its earlier predecessors (Paul, 2003). An amazing variety of fixators are available throughout the world, mostly developed for human use. Because of their size and cost, most are not practical for veterinary use, although some are adaptable, especially those designed for hand or forearm use in humans (Permattei *et al*., 2006). The main components of an external fixator include fixator pins, connecting bars, and clamps (Bini & Syam, 2014). Replacement of conventional clamps and connecting bar system with other materials which may offer significant advantages in the clinical application of external skeletal fixation have been evaluated (Permattei *et al*., 2006). These types of system help reduce the cost of the apparatus, which is always a consideration in veterinary orthopedics.

The aim of this study was to comparatively evaluate the effectiveness of pin-in-fiberglass cast and Kirschner-Ehmer Type I external fixative in radius-ulna fractures stabilization in dogs through the evaluation of clinical and radiographic outcomes.

Materials and Methods

Study animals

The conduct of this research was approved by the Ethical Committee on Animal Use and Care of the Ahmadu Bello University, Zaria with reference number ABUCAUC/2016/031. The study was conducted in the Department of Veterinary Surgery and Radiology, Ahmadu Bello University, Zaria, Nigeria. Four clinically healthy Nigerian indigenous dogs of same age (ten months) and different sexes were used for this study. The dogs weighed between 9 and 11 Kg. The animals were acclimatised for a period of 8 weeks during which physiological vital parameters (temperature, pulse rate, and respiratory rate) and haemogram of all the animals were obtained as baseline data. The animals were divided into two groups (A and B) and each group comprised of two dogs; a male and a female. Group A dogs underwent pin-in-fiberglass cast technique and group B dogs underwent Kirschner-Ehmer type I external skeletal fixation technique.

The animals were sedated using atropine sulphate injection 0.1% (Amopin® Yanzhou Xierkangtai Pharma Ltd, China) (0.02 mg/kg) intravenously (IV) and chlorpromazine hydrochloride injection 2.5% (Pauco Chlorpromazine HCL Injection®, Pauco Pharmaceutical Ltd, Nigeria) (4 mg/kg) IV and the surgical site (elbow to carpus) was shaved and scrubbed with soap, water and 0.05% chlorhexidine. Following this, general anaesthesia was induced with thiopental sodium 10% (15 mg/kg) IV. The dog was then intubated with appropriate sized endotracheal tube post induction to maintain patent airway. Ketamine Hydrochloride (22 mg/kg) (Pauco Ketamine Injection®, Kwality Pharmaceutical Ltd, India) intramuscularly was employed for maintenance of anesthesia.

A closed radius-ulna fracture was created in all the dogs as described by Marturano *et al. (*2008) using a modified Marturano fracture device. The modified Marturano fracture device was constructed like a guillotine manually operated without any electrical component. It has a heavy striker with a blunt rectangular tip made of steel covered with rubber pad. The area extending from the wrist joint to the elbow joint of the right fore limb was padded using a sterile surgical drape. The limb was held to the device by two assistants. An external blow using the striker of the device was then manually dropped from a height onto the mid-section of the forearm over the radius and ulna bones without violating the skin to create closed, complete fractures of the radius and ulna. Two standard radiographic views (anterior-posterior and lateral) were taken to verify the fractures generated.

Surgery

The fracture manipulation, and reduction were carried out as described by Ann & Dianne (2005). In the pin-in-fiberglass cast group, two threaded positive profile transfixation pins each (fully threaded pin, Shanz Screw 3.5 x 200 mm, stainless steel, Asco, India) were drilled using an electrical drill (at < 150 rotation per minute) cranio-caudally into the proximal and distal fracture segments of the fractured radius-ulna bones at about 30 degrees to exit the skin at the opposite side (Plate I). Orthopedic cast padding was then applied in double thickness (Plate II) which was overlaid with Fiberglass cast material (Perfect Cast® Hospital and Home Care UK) fenestrating the protruding transfixation pins until the whole length of the projecting transfixation pins have been incorporated and covered by the cast. The cast extended from proximal radius to distal radius (Plate III). For the Kirschner-Ehmer type I external skeletal fixation group, the application of the fixator was done as described by Permattei *et al. (*2006). The most proximal and distal positive profile transfixation pins (Front threaded pin, Shanz Screw 3.5 x 200 mm, stainless steel, Asco, India) were drilled cranio-caudally first into the proximal and distal segments of radius-ulna bones at about 35 degree without exiting the skin in the opposite side (Plate IV). A single connecting bar (Connecting Rod 4.0 mm x 300 mm, Asco, India) was then loosely attached to the pins using the clamps (Small Single Pin Clamp 4.0 x 3.5 mm) with the remaining number of “open” clamps in the

Plate I: Four transfixation pins inserted into the fracture segments in a cranio-caudal direction exiting the skin at the opposite side

Plate II: Orthopedic Cast padding applied on the limb fenestrating the protruded pins

Plate III: Fiberglass cast applied unto the cast padding fenestrating and incorporating the pins

Plate IV: The most proximal and distal transfixation pins inserted obliquely first and connected to a cross bar by clamps (arrows)

middle (Plate IV). The fractures were then reduced and the two end clamps tightened. The remaining two fixation pins were then drilled through the open clamps into the fractured bones and the construct tightened adequately (Plate V). Immediately after surgery, Elizabethan collar was applied on the dogs and a compression bandage, similar to a modified Robert-Jones bandage was applied on the operated limb for both groups to protect fixative and to minimise postoperative swelling (Plate VI).

Postoperatively, Diclofenac sodium injection (4mg/kg) (Diclowin®, Chupet Pharm. Ltd, China) was given for 5 days to relieve pain. Procaine penicillin injection (20,000 IU/kg) (Gossipain® Shanxi Federal Pharmaceutical Ltd., China) and Streptomycin (20mg/kg) (Paulio® Shandong Reyoung Pharmaceutical Ltd., China) were given for 7 days.

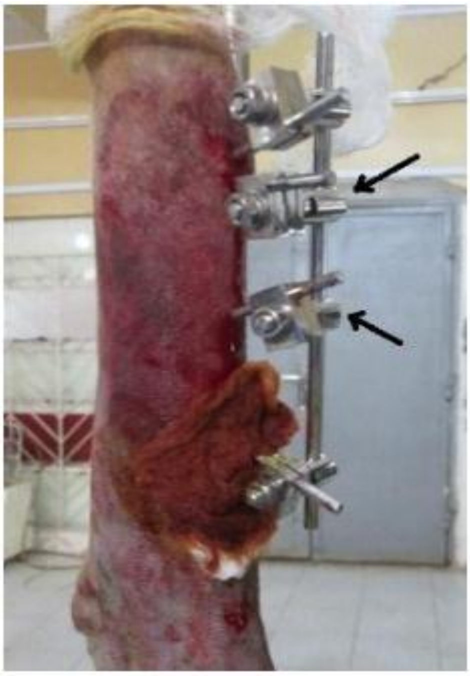

Plate V: The middle pins inserted through the remaining two open clamps (arrows) and connected to the bar with clamps

Plate VI: A modified Robert-Jones bandage applied on the operated limb overriding the fixative to protect it and to minimize postoperative swelling

Clinical evaluation

Physiological vital parameters of rectal temperature, respiratory rate, and pulse rate were monitored daily throughout the duration of fracture healing. Haemogram for each dog was evaluated at weekly intervals. Time of first weight bearing was noted and lameness was assessed at weekly intervals and graded as present or absent. The fractured limbs were radiographed and re-positioning was checked for alignment and success of the reduction was evaluated as described by Gian *et al. (*2009). The reduction was considered to be excellent if there was 100% stump contact with absence of axial deviation; good, if there was stump contact between 50% and 100% and /or axial deviation not >10^{o}; sufficient, if there was stump contact between 10% and 50% and/or axial deviation not>30^{o} ; Insufficient, if stump contact < 10% and/or axial deviation >30^{o}. The radiograph of the fractured limb was repeated after every two weeks intervals. The condition of the fracture callus formation was evaluated during the postoperative period and bone healing was evaluated, and radiographic results graded as described by Gian *et al.* (2009). Early complications were noted and categorized as described by Gian *et al. (*2009). Complications were considered to be minor if they were managed without additional procedures under general anesthesia, and were considered to be major if they required additional procedures or substantial modification under general anesthesia. The fixators were removed when the fractures were determined to have healed and the functional and cosmetic results were evaluated, and clinically graded as described by Fox *et al. (*1995). They were graded as excellent if the limb is functionally normal and similar in appearance to the contralateral normal limb; good if the limb showed slight lameness only after extensive exercise, or minor difference from the contra lateral normal limb; fair if the limb showed slight to moderate lameness but consistent weight bearing, or noticeable difference from the contra lateral normal limb, or poor if the animal showed non-weight bearing lameness, or marked, disfigured alteration from the contralateral normal limb.

Data analysis

Physiological parameters and hematological values were summarised and presented in graphs, while radiographs are presented in pictorially.

Results

The post-operative mean value of the vital parameters for both groups showed a slight deviation from the pre-operative mean values (Figure 1, 2 & 3). There was an immediate rise in mean rectal temperature which was observed to reach a peak of 39.50 ± 0 on day 2 for the pin-in-fiberglass group and 39.25 ± 0.07 on day 4 for Kirschner-Ehmer external fixative group. Post-operative fluctuation in the mean pulse rate and respiratory rate values in the two groups coincided with the changes observed in the mean rectal temperature for both groups. The differences in

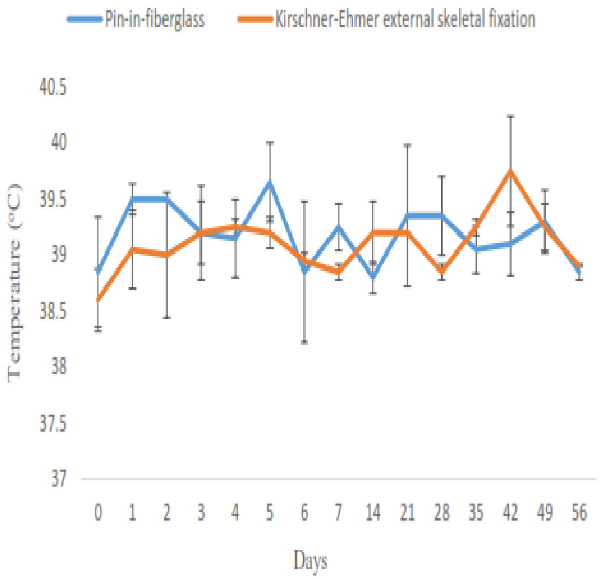

Figure 1: Mean pre- (Day 0) and post-operative temperature change in the Pin-in-fiberglass and Kirschner-Ehmer external skeletal fixation groups

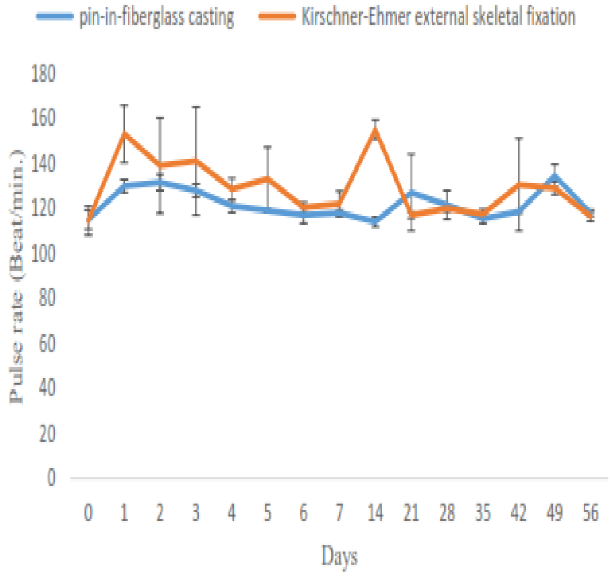

Figure 2: Mean pre- (Day 0) and post-operative pulse rate of the Pin-in-fiberglass and Kirschner-Ehmer external skeletal fixation groups

the vital parameters between both groups was not statistically significant (p>0.05). The mean packed cell volume (PCV) of the pin-in-fiberglass cast group (Figure 4) decreased slightly from 38.5 ± 0.5 on the day of surgery to 37 ± 0.1 on day 7 post-operative. By week 4 post surgery, the PCV of the group had risen to 38 ± 0.5 which was maintained within a normal range until the termination of the study. The Kirschner-Ehmer external fixative group also showed a slight drop in mean PCV (Figure 4) from 37.5 ± 1.5 on the day of surgery to 36.5 ± 1 on day 7 post-surgery. Improvement in the mean PCV of the group was noticed at week 4 post-surgery with value at 37.5 ± 1 which was maintained within the normal range until the termination of the study. A sharp rise in mean WBC was noticed in both groups within the first 7 days post-surgery from the initial values on the day of surgery (Figure 5). However, in all the groups, this increase in the mean WBC was short lived as a decline in the mean WBC was later noticed which stabilised at week 4 to a normal range which remained stable within this normal range until the termination of the study. The differences in the haemogram values between both groups was not statistically significant (p>0.05). Fractures in dogs of both groups were closed, transverse with minimal spikes and chips except for one dog in the Kirschner-Ehmer external fixative group (group B) in which the fracture was distal one-third. Immediate post-operative radiograph showed that fracture reduction was achieved in all the dogs of both groups and were graded as good (Gian *et al.*, 2009) (Plate VII & VIII). Post-operatively after anaesthetic recovery, all the dogs in both groups abducted their limbs. However, the mean time of first ground contact with the fractured limb post-surgery was noted

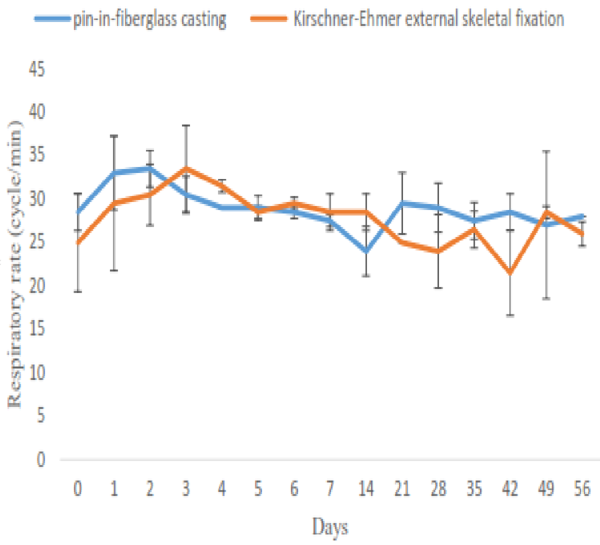

Figure 3: Mean pre- (Day 0) and post-operative respiratory rate of the Pin-in-fiberglass and Kirschner-Ehmer external skeletal fixation groups

subsequently for all the animals. The mean time for first weight bearing on the operated limbs by the dogs was 1 ± 0 and 1 ± 0 days for pin-in-fiberglass, and Kirschner-Ehmer external fixative, group respectively. One week post-operative, the animals in the pin-in-fiberglass cast group were able to bear partial weight on the fractured limb with a display of moderate lameness and at week 5 post-operatives. The dogs were able to bear full weight and run with the operated limb with slight lameness. In Kirschner-Ehmer external fixative group also, the dogs were also able to bear weight on the fractured limbs with a display of slight lameness after a week post-operative and at week 4 post-operative. The animals in this group were able to run with the fractured limb accompanied with slight lameness except for one dog which showed moderate lameness. The fixatives were

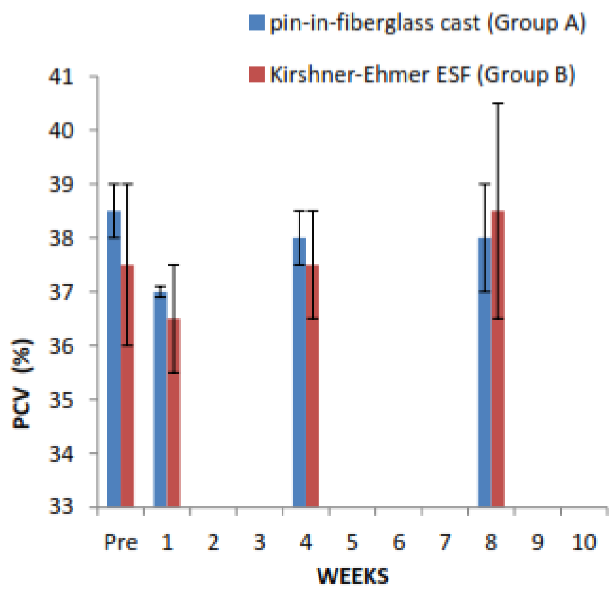

Figure 4: Mean Pre (week 0) and Post-operative packed cell volume (PCV) count plotted against the number of weeks for dogs of Group A, and B (Pin-in-fiberglass cast, and Kirschner-Ehmer external fixative) respectively (Normal PCV value: 35-55 %)

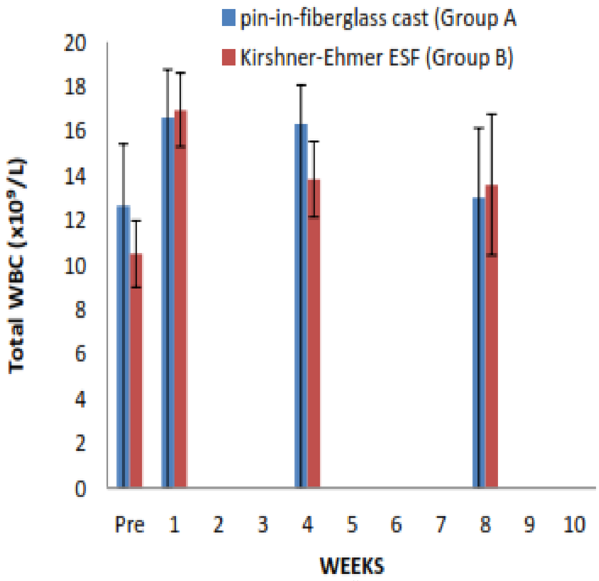

Figure 5: Mean Pre (week 0) and Post-operative total white blood cell (WBC) count plotted against the number of weeks for dogs of Group A, and B, (Pin-in-fiberglass cast, and Kirschner-Ehmer external) respectively (Normal WBC count: 6-17 X10^9/L)

Plate VII: Postoperative lateral view radiograph of radiu-ulna fractures managed with pin-in- fiberglass cast (Group A, day 0) with apparent fracture gaps (arrow)

Plate VIII: Postoperative lateral view radiograph of radius-ulna fractures managed with Kirschner-Ehmer external fixative (Group B, day 0) with apparent fracture gaps (arrow)

removed at the week 8 and 7, post-operative for the pin-in-fiberglass cast and Kirschner-Ehmer external fixative group respectively. Postoperative radiographic follow-ups for both groups, at second week post reduction showed no remarkable difference from the day zero radiograph of the radius-ulna fractures with (Fractures with) no periosteal reaction with a reduction in size of fracture line (Plate X). Radiographically, the fractures in the pin-in-fiberglass cast groups were evidence of reduction in the size (of) fracture line. However minimal soft tissue and periosteal reaction were evident in all the groups. At week 4, the pin-in-fiberglass cast showed a decline in fracture lines with minimal periosteal reaction (Plate IX). In the Kirschner-Ehmer external fixative group also, there was evidence of minimal observed to heal at 8 weeks post-operative (Plate XI) and 7 weeks post-operative for the Kirschner-Ehmer external fixative group (Plate XII)

Plate IX: Postoperative lateral view radiograph of radius-ulna fractures managed with pin-in fiberglass cast (Group A, 4 weeks). Fracture lines declined with increased callus formation (arrow)

Plate X: Postoperative lateral view radiograph of radius-ulna fractures managed with Kirschner-Ehmer external fixative (Group B, 4 weeks). Fracture lines declined and callus formation continued (arrow)

Plate XI: Postoperative lateral view radiograph of radius-ulna fractures managed with pin-in fiberglass cast (Group A, 8 weeks). Complete disappearance of fracture lines, decline in external callus size. Bones started to reform their shapes

Plate XII: Postoperative lateral view radiograph of radius-ulna fractures managed with Kirschner-Ehmer external fixative (Group B, 7 weeks). Complete disappearance of fracture line, and decline in external callus (arrow) Bones started to reform their shape

respectively. After the removal of the fixative device, the functional and cosmetic result in comparison with the contralateral limbs were evaluated and were graded as excellent for both groups.

Various complications were seen in both groups. In pin-in-fiberglass cast group, cast related complications were noticed. Cast sores were noticed at week 6 post-operative at the proximal aspect of the forelimb which was located cranially and caudally, distal to the olecranon in one dog. In the Kirschner-Ehmer external fixative group, there was pin loosening and serous drainage from pin holes of the proximal segments at week 5 post-operative in one dog.

Discussion

The primary aim of fracture repair is to achieve the fastest possible healing and enable the patient to function normally by allowing early walking (Aron, 1998; Shahar, 2000). The healing of fractures of the radius-ulna bones managed by two different reduction techniques was comparatively evaluated. The rise in temperature of the dogs in both group post-surgery which peaked at day 2 and 4 for the pin-in-fiberglass cast and Kirschner-Ehmer external fixative group respectively, and return back to normal on subsequent days may be attributed to increase in basal metabolic rate of the dogs due to pains. Both groups showed a slight drop in PCV within first week of post-operative. This could be attributed to intra operative blood loss observed in less invasive surgery like external skeletal fixation (Slatter, 1985). The moderate leukocytosis observed in both groups one week post-operative was attributable to tissue damage and inflammatory response following surgery (Gerstenfeld *et al.,* 2003), which according to Bush (1991) could manifest even as early as the first 12-36 hours after surgery.

The early weight bearing of the dogs in the pin-in-fiberglass cast group and good joint mobility within the first 24 hours post-operative was comparable to the Kirschner-Ehmer external fixative group in which it was also observed that the dogs were able to bear weight with good joint mobility within the first 24 hours post-operative. This early weight bearing observed could be attributed to the optimum stabilization and better load sharing ability of the fixative devices (Nnaji *et al.*, 2015), and also the analgesic effect provided by the Diclofenac Sodium therapy. According to Ozsov & Altunatimaz (2003) early weight bearing observed is important development with respect to avoiding possible complications such as joint stiffness, bone and muscle atrophy, by allowing early return to function of the extremities.

The evidence of early callus formation and fracture gap bridging at 8 week in the pin-in-fiberglass cast group was comparable to Kirschner-Ehmer external fixative groups which healed at 7 weeks. These could be ascribed to the less interfragmentary distance and a good interfragmentary stability offered by the pin-in-fiberglass cast technique post fracture reduction. While it was reported (Harari *et al.*, 1996; Permattei *et al.*, 2006) that fractures treated with external fixators healed with very minimal external callus formation. In this study, the pin-in-fiberglass technique showed very minimal callus size which suggests minimal interfragmentary movement at the fracture sites. The post-operative radiographic rechecks were difficult with external fixators, because of the superposition of the fixator elements onto the fracture (Kowalski *et al*., 1996) which we also encountered in this study with the Kirschner-Ehmer external fixative group. Repeated exposures were required, often with some degree of obliquity to avoid interference from the fixator, with a subsequent increase in X-ray exposure cost and time required by the procedure. But because of the radiolucency property of the fiberglass cast, such radiographic interference was minimal from every angle in the pin-in-fiber glass cast group.

The absence of any early complication in the first 2 weeks post-operative suggested an adequate and proper application of the fixative devices in the two groups. According to Tomlinson (1991), early complication such as edema distal to the cast was the most important indication of wrongly applied cast which was not observed in the pin-in-fiberglass glass group. This may be partly due to the minimal and uniform tension that was employed during the application of the cast. However, the cast sores observed at the later time could be associated with the dogs spilling their drinking water on themselves which soaked the cast padding thus causing rub sores by the cast edges. The sores were treated by tucking in more cotton wool padding around the open end of the cast along with daily cleaning of the injury using 0.05% chlorhexidine gluconate (Purit® SaroLifecare Ltd, Ibadan, Nigeria). The sore healed after five days of treatment. The serous drainage from pin holes especially those of the proximal fragments in the Kirschner-Ehmer external fixative group was as a result of pin loosening at the bone-pin interface which was the weakest link in the external skeletal fixation have been reported (Permattei *et al.*, 2006). The fact that these complications occurred in the pins placed in the proximal fragments suggested that these may be a result of the area being covered with a more prominent muscle mass found in the proximal aspect of the forearm when compared to the distal part and also the higher activities of the dogs due to advancement in healing at the fracture sites (Ozsov & Altunatimaz, 2003; Sereda *et al.*, 2009). This was taken care of by loosening the clamps of the affected pins, squeezing the pins together, and re-tightening the clamps under sedation. This was followed by daily cleaning of the Skin-pinhole interface with 0.05% chlorhexidine gluconate. Drainages resolved before week 6 post-operative. One would expect that such complication of pin loosening should be seen in the pin-in-fiberglass cast, but such was not observed post removal of the cast in this study. This was attributed to the flexibility in pin positioning since all the four transfixation pins did not necessarily have to be inserted in a linear fashion unlike in the Kirschner-Ehmer external fixator, which made it possible to identify safe corridor for pin insertion thus avoiding area with prominent muscle mass. Type I external fixators can be applied to radius- ulna fracture cases of all ages (Lewis *et al*., 1993).

Likewise in this study, location of the fractures especially in the dog with its fractures located at the distal one-third did not cause any problem with respect to application of the fixator or the healing of the fracture as both dogs with radius-ulna fractures in the Kirschner-Ehmer external fixative group healed at the same time. The fact that radius-ulna fractures to which pin-in-fiberglass cast were applied using the closed method healed in a short period without major complications, once again proved the significance of biological fixation.

In this study, in which pin-in-fiberglass glass cast was comparatively evaluated with a type I Kirschner-Ehmer external fixative in the management of radius-ulna fractures in dogs, early return to function of the extremities, sufficient fracture stability, minimal callus formation, short healing period, minimal technicalities in its application, minimal complications, excellent functional and cosmetic result concludes that pin-in-fiberglass cast should be used as a satisfactory substitute to type I Kirschner-Ehmer external fixatives in appropriate cases.

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