**Chapter -1**

 **Introduction**

Domestic animals like cattle, goats and sheep play a crucial role in the subsistence economy of smallholders in Bangladesh. These ruminants are most popular found throughout the country and are potential resource for supplying high quality meat and milk. Goats are also considered a potential animal genetic resource for poverty alleviation as they are the source of income for many small and landless farmers. There are approximately 257.66 lakh goats, 33.35 lakh sheep and 237.85 lakh cattle in Bangladesh at present (DLS 2015-2016). This huge number of goats is found throughout the country representing 31.36% of the total households. The average number of goat per household is 2.31 and they are mostly reared by landless, small and medium farmers (DLS, 2013).

The above mentioned huge number of goats in Bangladesh are very much susceptible to various diseases and disorders due to the geo-climatic condition as well as rearing system. People reared goats by letting them free for browsing in nearby grasslands and pastures, during which they meet with automobile accidents, attack by dog. Because of their curious and easily excited nature, they also attempt to impossible jumps resulting in traumatic injuries (Suresh, 2016). So goats are very much susceptible to various surgical affections throughout the year in Bangladesh. Among the surgical affections, lameness is one of the condition in which fracture constitutes a major portion of lameness in goat.

Long bone diaphyseal fractures are very common in goats (Smith and Sherman, 2009). Among long bone fractures, femur and metacarpus fractures are the most common orthopedic injuries encountered in young ruminants like goat and calf constituting 32.0% and 24.0% respectively (Singh *et al*., 1995) and metacarpal and metatarsal fractures constituted about 20.9% and 32.2% respectively in ruminants (Thilagar *et al.,* 2002). Metacarpal bone fracture ranks first among all the long bone fracture in calves (Belgi *et al*., 2016). Ferguson *et al.,* 1990 stated 50.0% of the fracture cases seen in cattle are metacarpus and metatarsus fracture. According to Kosetlin *et al.,* 1990 metacarpus fracture are the most common fracture (40.5%) among the extremity fracture in cattle.

Preexisting bone diseases such as osteomyelitis, chronic fluorosis, fibrous osteodystrophy or rickets can predispose to fractures (Smith and Sherman, 2009). Singh *et al*., (2008) reported trauma due to unknown cause as the most common etiology for caprine fractures followed by fall from a height and external violence. According to Kushwaha *et al.,* (2011) the major cause for fracture in goats was being hit by something, followed by fall from a height and external trauma. Tambe *et al*., (2012) reported that majority of the animals were presented with the history of road accidents (51.5%), followed by other reasons like falling, dog bite and fighting.

The primary aim of fracture treatment is to achieve the fastest possible healing and enable the patient to function normally by allowing early walking (Aron, 1998; Shahar, 2000). For this, the aim is to produce anatomical unity between the joints above and below the fractured bone and functioning of the extremity (Piermattei *et al.,* 1997).

There are a lot of techniques available to manage the fractured bone depending upon the condition of the fracture and type of fracture. According to Fossum(2013) the coaptation technique involves external coaptation like Robert jones banadage, metal spoon splint bandage, spica splint bandage, plaster of paris, Ehmer slings, Velpeau slings, external skeletal fixation, cast, circular external fixator etc. and the internal technique involves intramedullary pins, krischner wire, interlocking nails, orthopedic wire, bone plate and screw. External coaptation technique is the easier and simple procedure for the immobilization of fracture which has its applications limited to simple and stable fractures.

The conservative procedure was followed in the past for managing the fracture in farm animals, which consisted of immobilizing the traumatized limb with plaster of paris cast, bamboo splint, polyvinyl chloride (PVC) splint, modified Thomas splint etc. The healing of fractures was often poor due to initial formation of fibrous callus which was not by cartilagenous cells and was proved beyond doubt (Deepu *et al.,*1998) in earlier studies.

For fracture management, different complications are seen. Complications of fracture management involves joint anchylosis, limb bending due to improper bandaging, limb swelling, nonunion, malunion etc. in external immobilization and pin migration, seroma formation are common complications in internal fixation technique. These metals may cause more inflammation if the soft parts are unduly traumatized during its application (Ali *et al.,* 2001). The results of conservative treatment of unstable diaphyseal fractures of long bones are less than desirable in most cases and results in fracture disease (Glyde and Arnett, 2006).

Though there are good number of fracture cases in Bangladesh but still conventional technique is followed for fracture management. Due to inadequate knowledge about fracture management practice, blood circulation may be interrupted to the affected limb that leads to gangrene formation in the fractured limb which may suggest to amputation of the affected limb and sometimes advise to slaughter of the affected cases. So many valuable animals were rendered economiclly nonviable due to improper fracture treatment. In addition to that, there are less number of well published paper on long bone fracture management of goat in Bangladesh.

Therefore, the objectives of research work are as follows:

* To study the occurrence of long bone fracture in goat.
* To evaluate the outcome of fracture mangement techniques.
* To study the complications.

**Chapter-2**

**Review of Literature**

**2.1. Anatomy of the bone of goat limbs**

Anatomy is the branch of biological science that deals with the form and structure of animals. The limbs include forelegs (thoracic limbs) and hind legs (pelvic limbs). The forelegs consist of scapula, humerus, radius ulna and a lower limb made up of carpus, metacarpus and phalanges. The hind legs consist of pelvic girdle, femur, tibia fibula and a lower limb made up of tarsus, metatarsus and phalanges (Getty and Sisson, 1975).

**2.1.1. Anatomy of Humerus**

The humerus is located between the shoulder and the elbow in the upper arm. At the elbow side, it connects to the radius and the ulna, which are the lower arm bones. At the shoulder joint, it connects to the body through the glenoid fossa of the scapula (Getty and Sisson, 1975).

**Blood supply of Humerus**

The main vascular supply to the humerus comes from the anterolateral branch of the anterior humeral circumflex artery. This passes laterally to the biceps and forms the arcuate artery which enters the head of the humerus in the intertubercular groove and branches out into multiple tuberosities (Getty and Sisson, 1975).

**Nerve supply of Humerus**

The axillary nerve is situated on the proximal side of the bone. The radial nerve extends from the back side to the front part of the bone in the spiral groove. If the humerus gets fractured in this section, it will lead to an injury to the radial nerve.

The ulnar nerve is in the distal region of the bone. This nerve is in the front of the medial epicondyle and gets easily damaged during any elbow injuries (Getty and Sisson, 1975).

**2.1.2. Anatomy of Radius and Ulna**

**Radius**

It is larger but not longer of the two bones. It forms elbow joint with the humerus above and carpal bones below. The bone is faintly curved and presents a shaft and two ends.

The long shaft is flattened craniocaudally and curved longitudinally (Getty and Sisson, 1975).

**Ulna**

Ulna is an ill developed long bone, fused with the radius along its postero-lateral aspect. The shaft is roughly prismatic and therefore presents three surface and three borders.

**Blood supply of radius and ulna**

Lateral surface has formed a vascular groove with the same surface of the ulna for the accommodation of interosseous artery.

**Nerve supply of radius and ulna**

Radial nerve and ulnar nerve

**2.1.3. Anatomy of Metacarpal bones**

The shaft is irregularly cylindrical and presents two surfaces. The anterior surface is convex from side to side. At the middle there is a vertical groove along the length of the bone. The posterior surface is flat and broad at both the ends. The proximal end presents two articular facets. The distal end is divided by a cleft into two condyles. Each condyle is divided into two articular area by a ridge (Getty and Sisson, 1975).

**2.1.4. Anatomy of Femur**

The femur is the strongest of the long bones and provides the origin and attachment for many muscles and tendons. It can be divided into three basic parts (Getty and Sisson, 1975).

1. The femoral head is offset from the main shaft of the femur, points in a medial direction and articulates with the acetabulum. It has a hemispherical articular surface with an associated notch, fovea capitis, which provides attachment for the intracapsular ligament. Lateral to the head is the greater trochanter. This process provides attachment to the gluteal muscles (Getty and Sisson, 1975).

2. Femoral shaft provides attachment for the adductor muscles (Getty and Sisson, 1975).

3. Distal extremity consists of the medial and lateral condyles caudally and a trochlea cranially. The trochlea is made up of two ridges and a groove that articulates with the patella to form the femoropatellar joint (Getty and Sisson, 1975).

**Blood supply of femur:** Femoral artery.

**Nerve supply of femur:** Ischiatic nerve.

**2.1.5. Anatomy of Tibia and Fibula**

The tibia is one of the major weight bearing bones of the hind limb and is involved in both the stifle and hock. The tibia can be divided into three distinct sections (Getty and Sisson, 1975).

1. Proximal extremity is three sided and has two condyles which are separated by the popliteal notch on its caudal aspect (Getty and Sisson, 1975).

2. Tibial shaft is craniocaudally compressed. The tibial tuberosity or tibial crest projects cranially from the proximal part of the shaft and is an important palpable landmark.

3. Distal extremity carries the cochlea which has two grooves divided by a ridge. This central ridge is directed sagittally in most species.

The fibula lies laterally to the tibia and proximally doesn't interact with the stifle joint. The fibula consists of a proximal head, a neck, a shaft and a distal extremity/lateral malleoulus.

**2.1.6. Anatomy of Metatarsal**

Metatarsal bone is somewhat larger in size than metacarpal bone. The shaft is four sided. Proximal end of the bone bears a facet at its medial aspect. The dorsal longitudinal groove is more deep and wide than metacarpal bone (Getty and Sisson, 1975).

**2.2. Overall incidence of long fracture in goat**

According to Tambe *et al*., (2012), the overall incidence of the fracture where a retrospective study of fracture cases was done for past 10 years and found that 5.5% of the total presented fractures were of goats.

**2.2.1. Incidence of fracture according to age**

Kushwaha *et al.,* (2011) reported that higher incidence of fracture was recorded in goats below nine months of age. According to Tambe *et al.,* (2012), out of 11 cases of fractures in goats studied, seven belonged to less than three years old group, followed by three to six and six to nine years.

**2.2.2. Incidence of fracture according to sex**

Singh *et al.,* (2008) studied and reported that higher incidence of fracture occurrence in goat was noticed in females than in males. Tambe *et al.,* (2012) also had reported higher incidence of fracture in female goats than in male goats.

**2.2.3. Incidence of fracture according to type of fracture**

Singh *et al.,* (2008) opined that transverse fractures were more common in goat followed by oblique, multiple, epiphyseal, impacted and avulsion fractures. According to Kushwaha *et al.,* (2011) most of the fractures of goat were of closed type with higher incidence for midshaft fracture. This was followed by proximal and distal diaphyseal fractures with equal incidence rate. Regarding the type of fracture, higher incidence was recorded for oblique fractures. Thilagar and Balasubramaniam (1988) reported that distal third diaphyseal fractures (52.4%) of tibia and fibula were more common than fracture of middle third (34.9%) in goat. Among the different types of long bone fractures, the occurrence of oblique fractures was more (42.5%) than over riding (30.2%) and comminuted fractures (18.1%) in goat. Tambe *et al.,* (2012) found out that midshaft diaphyseal fractures were more in goats. Singh *et al.,* (2017) suggested that diaphyseal fracture were highest in number in goats.

**2.2.4. Incidence of fracture according limb involvemnet**

Fractures of forelimb are more commonly encountered than the hind limb fractures (Tulleners, 1986). Singh *et al.,* (2008) noticed higher incidence of fractures on hind limbs in goat. In a report conducted by Lappin *et al.,* (1983), that long bone fractures were found to be more common on right side (57.7%) than left side (42.2%) in goat.

**2.2.4. Incidence of fracture according to bone**

Singh *et al.,* (2008) observed highest incidence on metatarsal bone in goat. Fractures of metacarpal bone occur twice more frequently than metatarsal bone (Tulleners, 1996). In forelimb, the most commonly affected bone was the metacarpal bone. Higher incidence for metatarsal fracture was also reported by Kushwaha *et al.,* (2011) and next highest incidence was for metacarpal and comparatively lesser incidence with femur and tibia. Tambe *et al.,* (2012) reported that higher incidence of fracture was noticed in tibia (27.5%) followed by femur, radius and ulna, metatarsal and metacarpal bone. Lesser incidence was recorded for femur. Bone wise distribution of the incidence was highest in radius and ulna (65.2%) followed by humerus (16.0%) and metacarpal (10.2%) (Fox, 1997) in goat.

**2.3. Etiology of fracture in goat**

External trauma seems to be most important factor in causing the fracture. Higher frequency of hind limb fracture could be fully justified because in vehicular accidents most of the goats are hit from behind (Manjulkar *et al*., 2004). Seguin *et al*. (1997) stated that the etiology of fractures in goat due to auto mobile trauma were 91 (47.8%); other traumatic incidents (26.3%); unknown cause (23.1%) and gunshot injuries (2.6%) recorded in a hospital. According to Kushwaha *et al*., (2011) the major cause for fracture in goats was being hit by something, followed by fall from a height and external trauma. Tambe *et al.,* (2012) reported that majority of the goats were presented with the history of road accidents (51.5%), followed by other reasons like falling, dog bite and fighting.

**2.4. Clinical findings of fracture**

Venugopalan (2009) reported the major clinical signs exhibited by animals with fracture as loss of function of the affected limb, abnormal mobility, deformity, pain and crepitus on palpation. Affected animals deviated from their normal posture and position. Pain was usually absent in pathological fractures.

**2.5. Diagnosis of fracture**

Whittick (1974) explained the importance of visual examination in the diagnosis of fractures. It helped to correlate anamnesis with the lameness observed and also helped to rule out neurological etiology. Visual inspection included the respiratory pattern of the animal, inspection of body integument for open or closed wounds, gait and posture both on recumbency and on ambulation. According to Langley-Hobbs (2003) preoperative orthogonal views of the affected limb including proximal and distal joints was very important before attempting any kind of fracture repair. For bones with curvature, radiographs of normal contralateral bone was also taken. Preoperative radiographic examination helped to confirm the diagnosis of fracture, identify the bone involved, and understand the nature of fracture (number of fragments, direction of fracture line etc.). Joy (2013) reported pain on palpation of fracture site in goats on preoperative evaluation. After treatment with external skeletal fixation, pain was found to have reduced by second week and was absent after four weeks.

**2.6. Principle of fracture treatment**

Schatzker (2005) and Venugopalan (2009) reported AO principles of fracture management as “restoration of anatomy of bone, establishing stability with preservation of blood supply and early mobilization of limb and patient”. Even though this was the original or basic principle proposed by the authors, they suggested that absolute stability was mandatory for only articular or joint related fractures. Diaphyseal fractures had to be treated by giving considerations to length of the bone, its alignment and rotation.

**2.7. Treatment of fracture**

Singh *et al.,* (2006) reported that various factors like type and nature of the fracture, extend of injury inflicted on surrounding soft tissue structures, nerves, blood supply etc. should be considered prior taking decision of treatment. Also body weight and temperament of the animal and cooperation of owner was very important. Complicated surgeries and time consuming fixation techniques might be fruitless unless there was care and cooperation from the side of owner and animal.

Venugopalan (2009) suggested the major steps of fracture treatment as reduction or anatomical alignment of displaced fracture fragments and retension and immobilization by external or internal coaptation techniques.

Venugopal (2015) reviewed and reported the AO/ASIF techniques employed for the treatment of fractures as interfragmentary compression, bone splinting techniques, combination of interfragmentary compression and bone splinting techniques and adaptation osteosynthesis. Adaptation osteosynthesis resulted from anatomical fixation of fracture fragments by using weak implants.

**2.8. Fracture fixation technique**

Singh *et al.,* (2006) reported that a fractured limb should be temporarily immobilized by cotton pads or splints before surgical correction of fractures. This was due to the high possibility of the fracture to become complex or complicated due to the injuries inflicted by sharp edges of fracture fragments to surrounding soft tissues, tendons, ligaments and nerves. Two types of technique were used in goat in case of fracture fixation namely external coaptation and internal intramedullary technique.

**2.8.1. External coaptation technique**

The techniques of external immobilization are cheaper and this makes the treatment feasible for the animals like goats which are of low commercial value (Mbiuki and Byagagaire, 1984; Adams and Fessler, 1996; Tulleners, 1996). Most fractures of lower limbs heal with normal casting (Merck, 2006). The cast serve as an artificial limb to animal. Different types of external immobilizers are used for treatment of fracture in goats such as Plaster of Paris alone (Mbiuki and Byagagaire, 1984), together with modified Thomas splint (Canapp, 2004), Newtech cast and Polyvinyl Chloride sheet (Manjulkar *et al*., 2004), Resin impregnated bandage reinforced with splint and motorbike spokes (Doiphode, 1994) and Polyvinyl chloride mould (Beale, 2004). Schmokel *et al*. (2003) and Schmokel *et al*. (2007) recommended applying a modified Robert Jones bandage for several days and limiting exercise to indoor confinement with leash walk for six to 10 weeks that had fractures stabilized using the MIPO technique.

**2.8.1.1. Application of Robert jones bandage**

The 'Robert Jones' bandage, first described by Major Robert Jones in 1915. The following steps use for Roberts jones bandage:

**Step 1:** Using white bandage tape, place stirrups on the distal 1/3rd of the limb overlapping the toes and extending approximately an equal length from the end of the leg (Brodell *et al*., 1986). Be sure to tab the ends for easy separation later on.

**Step 2:** Wrap the leg lightly with cast padding starting at the toes and moving proximally. Overlap the bandage 50% as wrap and try to get 2 layers of padding (Brodell *et al*., 1986).

Note - it is important not to exceed approximately two layers of cast padding. Excessive padding will cause premature loosening of the bandage as the cotton compresses overtime.

**Step 3:** Wrap the leg tightly with a conforming bandage starting at the toes and moving proximally. This is the step where create compression, however, not as much as it would with the standard Robert Jones bandage (Brodell *et al*., 1986). Overlap the bandage 50% as wrap and make sure the toes are still visible.

**Step 4:** Separate the tape stirrups, rotate them proximally, and secure them to the compression bandage thus creating a barrier and preventing the bandage from slipping down (Brodell *et al*., 1986).

Note – it should always make sure some of the underlying cast padding is visible on the end by the toes.

**Step 5:** Wrap the leg in vet wrap starting at the toes at an angle to cover the distal ends of the bandage and again moving proximally as its progress. Be sure to overlap 50% as apply the material.

**2.8.2. Internal (Intramedullary pinning) fixation technique**

Intramedullary fixation is the most readily used system of internal fixation in small animals (Brinker *et al.*, 1988). In many respects it is the least understood and least sophisticated method. The techniques are adapted for human, and very little research of intramedullary fixation has taken place in veterinary orthopaedics (Palmer *et al*., 1988). In contrast to human orthopaedics where the number of appliances is limited only by one's imagination, the devices used in veterinary medicine include only the Steinmann pin, Kirschner wire, Rush pin, and Kuntscher nail, and of these, the Rush pin and Kuntscher nail are not used extensively (Brinker *et al.*, 1988).

**2.8.3. Indications of Steinmann pinning**

Intramedullary pinning with a single Steinmann pin may be indicated in fractures throughout the length of a long bone. It is best for transverse and short oblique fractures of the middle third of long bones (Brinker *et al.*, 1988). It can be applied in conjunction with cerclage and hemicerclage wiring. Single or multiple Steinmann pins together with cerclage and hemicerclage wiring may be adapted for all types of fracture fixation (Luis *et al.,* 2007).

**2.8.3.1. Surgical approach of Steinmann pinning**

Skin was incised over the diaphyseal part of the femur, and then the fascia lata was incised as close as possible to anterior border of the biceps femoris muscle. The vastus-lateralis and biceps femoris muscle were retracted to expose the femur. Two covered scissors were passed under the femur to protect the under lining structures (Sissener, 2007) from being injured during induction of the fracture.

**2.8.3.2. Method of insertion of Steinmann pinning**

The Steinmann pin is inserted by using a Jacob's chuck. The pin should be introduced at the end of the bone, cross the fracture site, and become embedded in the distal metaphysis of the bone. Retrograde insertion of Steinmann pins is advocated by some and has the advantage of being technically easier to accomplish (Brinker *et al.*, 1988).

The seating of a Steinmann pin is a very important part of its placement. After the pin has been introduced, crossed the fracture site, and reduced the fracture, it should be seated firmly in the distal fragment. The distance traveled by the pin is sometimes difficult to measure and should be planned before introduction into the distal fragment (McLaughlin, 1999). This can be done easily by adjusting the chuck on the pin so that an adequate amount of pin will appear between the chuck and the surface of the skin; this distance is equivalent to the length of the pin that needs to be introduced into the distal fragment (Sissener, 2007). Using this technique, it is relatively easy to establish a firm seating for the Steinmann pin without penetrating the joint surface below the fracture. As seating of the pin is achieved, the rotation that is necessary to insert the pin should be lessened to the point where only longitudinal pressure is applied to push the pin so that it may interdigitate with the cancellous bone (McLaughlin, 1999).

**2.8.3.3. Contraindications of Steinmann pinning**

Single Steinmann pins are usually contraindicated in severely comminuted fractures except when cerclage or hemicerclage wiring is added (Luis *et al.,* 2007). Intramedullary pins are not good devices to use in the presence of sepsis. Insertion of a Steinmann pin into the marrow cavity of a septic fracture may cause the extension of infection throughout the medullary cavity and make the treatment of this infection very difficult. Steinmann pinning should be attempted only when the fracture can be made stable (Olmstead *et al*., 1995). The Steinmann pin should never be allowed to protrude through the skin when it is used for an intramedullary fixation. If this occurs, the pin should be removed and replaced immediately with a larger pin or some other form of fixation that will adequately stabilize the fracture (Olmstead *et al*., 1995). Simply reinserting the same pin after it has penetrated through the skin is not adequate treatment; this may serve only to be the focus for an infectious process, and the pin will usually begin backing out again several days later.

**2.9. Orthopaedic wire techniques**

Orthopaedic wiring of fractures has long been popular in veterinary medicine (Sissener, 2007). Use of orthopaedic wire, like all other techniques, is successful when the indications are proper and the techniques are adequate. The problems associated with orthopaedic wiring and the poor results that are sometimes obtained, can usually be traced to improper technique or indications (Luis *et al.,* 2007).

**2.9.1. Full cerclage wiring**

Full cerclage wiring has been used with presently accepted techniques for approximately 10 years in veterinary medicine (McLaughlin, 1999). Adequate full cerclage wiring requires the use of large heavy-gauge wire of 18 or 20 gauge diameter and some method of adequately molding the wire to the bone (Endo *et al.*, 2003). One of the two most common types used is the ASIF wire loop, with its wire tightener, which was originally intended for temporary fixation of fracture fragments with the ASIF system. This technique has come to be used as a definitive method of fracture fixation in small animals and seems not to pull apart as one might suspect. The other technique is to use heavy- gauge wire and twist the wire in a fashion that allows the wire to tighten over the cortex. With this technique a wire twister or pair of pliers may be used (McLaughlin, 1999).

**2.9.2. Hemicerclage wiring**

The use of hemicerclage wiring has been advocated by many in combination with intramedullary Steinmann pinning (Sissener, 2007). In this technique a large 18-gauge or 20-gauge wire is used to hold fracture fragments or cracks together. The wire is effective in reinforcing longitudinal cracks in the cortex and often in preventing rotation and overriding of oblique fracture fragments. The wire is passed through a small hole in one fracture fragment, passes across the fracture site, and comes out through a small hole in the opposite fracture fragment (Endo *et al.*, 2003). The wire is twisted together in the same manner as described in full cerclage wiring and may ormay not be bent over in place, depending on its application. Sometimes the wire is also placed around the intramedullary device so that the pin is incorporated with the wire in bone-fracture fixation (Sissener, 2007). Many patterns and applications of hemicerclage wiring have been reported in the veterinary literature (Mclaughlin, 1999). They are a definite adjunct in any fracture that is handled with the single Steinmann pin when rotation of the fragments is a possibility or if overriding of the fracture is a complication (Endo *et al.*, 2003).

**2.10. Complications of fracture management**

**2.10.1. Complications of external coaptation**

Complications of external coaptation can be very high in young animals. Fracture disease is a syndrome characterized by joint laxity or stiffness, periarticular fibrosis, degeneration of the joint cartilage, osteopenia and muscle atrophy (Kapatkin, 2000). Other adverse effects of improperly placed limb splintage are valgus and rotational deformity (Beale, 2004). Immobilization of the stifle joint should be avoided, particularly in cases of distal femoral fractures, to minimize risk of devastating complications like quadriceps contracture and genu recurvatum. Prolonged immobilization of the hind limb in a non-weight bearing position causes coxavalga and increased anteversion. Unfortunately the last two conditions are not reversible (Adams and Fessler, 1996). The application of any form of supporting bandages, in the attempt of correcting the hyperextension are inappropriate and should be avoided (Canapp, 2004).

**2.10.2. Complication of internal fixation**

Inadequate technique of Steinmann pin placement with improper seating in the distal fragment or instability of the fracture will lead to the complication of pin migration, the most common problem associated with intramedullary pinning. It is seen in animals where there is instability at the fracture site, allowing the fracture to collapse over the pin, or where there is sufficient motion to cause loosening of the pin at its distal aspect. If the pin loosens, the fracture will usually distract or collapse and angulate (Sissener, 2007). The pin may penetrate the skin through the site of initial insertion and create a tract for infection. If pin migration is a problem, it is evidence of instability at the fracture site and should be corrected immediately. Instability of the fracture, especially of the femur, will allow the formation of rotational deformities, usually an external rotation of the proximal fragment as a result of the pull of the iliopsoasmuscle (McLaughlin, 1999). This complication is very common and can be seen on the lateral radiograph, which shows a femoral head that faces cranially. It will produce an abnormality in gait and should be prevented (Vasseur *et al.,* 1984).

**2.11. Fracture healing**

Aron (1998) opined that fracture healing was a process of bone regeneration. It was divided into well-documented stages: inflammation, connective tissue and fibrocartilage formation (soft callus), bony bridging or mineralization (hard callus), and remodeling. During the remodeling phase, mechanical loading of the bone becomes important, because increasing load stimulates callus remodeling and maturation (Aron, 1998 and Hulse and Hyman, 2003). Progressively increasing the weight bearing forces to accelerate bone healing can be achieved by staged disassembly of the initial fracture repair (Nanai and Basinger, 2005). Johnson and DeCamp (1999) reported that the biological environment at the fracture site had a significant influence on bone healing. Surgical approaches and implants that compromise the surrounding soft tissues and vascular supply ultimately delay bone healing. Ozsoy and Altunatmaz (2003) observed normal healing process of bone fragments that were not aligned properly with external fixation healed in a short time when anatomical alignment was achieved without the need of perfect positioning of the fragments.Fracture healing occurred by either direct or indirect healing process.

**2.11.1. Primary or direct healing process**

Primary bone healing involves a direct attempt by the cortex to re-establish itself after interruption without the formation of a fracture callus.Direct healing was reported when there was anatomical alignment of fractures with absolute stability or stabilized by external or internal coaptation techniques (Hulse and Hyman, 2003). Ozsoy and Altunatmaz (2003) reported that, Primary bone healing is lead by the formation of a so-called cutting cone (consisting of osteoclasts at the front of the cone to remove bone and trailing osteoblasts to lay down new bone) across the gaps to form a secondary osteon.

Primary healing (also known as direct healing) requires a correct anatomical reduction which is stable, without any gap formation also reported Ozsoy and Altunatmaz (2003). Such healing requires only the remodeling of lamellar bone, the Haversian canals and the blood vessels without callus formation. This process may take a few months to a few years.

In fact, this method is employed only after rigid surgical fixation, or in case with a partial crack in the bone, a so-callled "unicortical" fracture (Aron, 1998), where the remaining bone holds everything rigid.

**2.11.2. Secondary or indirect healing process**

Secondary healing (also known as indirect fracture healing) is the most common form of bone healing. Secondary bone healing involves the classical stages of injury, hemorrhage inflammation, primary soft callus formation, callus mineralization, and callus remodeling (Hulse and Hyman, 2003). This method of bone healing closely resembles endochondral ossification (which involves a cartilage template being replaced by bone). It usually consists of only endochondral ossification. Aron (1998) reported that, sometimes intramembranous ossification occurs together with endochondral ossification. Intramembranous ossification, mediated by perisoteal layer of bone, occurs without formation of callus (Hulse and Hyman, 2003). For endochondral ossification, deposition of bone only occurs after the mineralised cartilage. This process of healing occurs when the fracture is treated conservatively using orthopaedic cast or immobilisation, external fixation, or internal fixation (Aron, 1998).

**2.11.3. Complications of fracture healing**

Complications of fracture healing include:

**Infection:** This is the most common complication of fractures and predominantly occurs in open fractures. Post-traumatic wound infection is the most common cause of chronic osteomyelitis in patients. Osteomyelitis can also occur following surgical fixation of a fracture (Suresh, 2016).

**Non-union:** No progression of healing within six months of a fracture occurring. The fracture pieces remain separated and can be caused by infection and/or lack of blood supply (ischaemia) to the bone. There are two types of non-union, atrophic and hypertrophic (Nanai and Basinger, 2005). Hypertrophic involves the formation of excess callus leading to bone ends appearing sclerotic causing a radiological "Elephants Foot" appearance due to excessive fracture ends mobility but adequate blood supply (Johnson and DeCamp, 1999). Atrophic non-union results in re-absorption and rounding of bone ends due to inadequate blood supply and excessive mobility of the bone ends.

**Mal-union:** Healing occurs but the healed bone has 'angular deformity, translation, or rotational alignment that requires surgical correction'. This is most common in long bones such as the femur (Suresh, 2016).

**Delayed union:** Healing times vary depending on the location of a fracture and the age of a patient. Delayed union is characterized by 'persistence of the fracture line and a scarcity or absence of callus formation' on x-ray. Healing is still occurring but at a much slower rate than normal (Suresh, 2016).

**Chapter- 3**

**Materials and methods**

**3.1. Place and duration of the study**

The study was performed at Shahedul Alam Quaderi Teaching Veterinary hospital (SAQTVH), Chittagong Veterinary and Animal Sciences University (CVASU) and the duration of the study was from January 2016 to December 2016.

**3.2. Selection of Cases**

The cases were selected on the basis of following criteria:

**Anamnesis:** Detail anamnesis regarding cause of lameness, limb affected and depth of trauma inflicted, progression of lameness, duration of illness, previous treatments if any were recorded as presumptive diagnosis. Signalment specially breed, age, sex and body weight of the animal were also recorded.

**Clinical Examinations:** After anamnesis both distant and close clinical examination were done in each case. Each animal was observed from a distance while standing, walking and also trotting. Grading of weight bearing, gait of the animal and lameness scoring were analyzed in this phase to identify the affected limb and assess the severity of lameness. Close observation includes palpation of the affected limb to detect pain, swelling and crepitating of the fractured bone in each case.

**Radiological Examination:** For confirmative diagnosis, medio lateral and cranio caudal views of the affected bone were taken to diagnose each case.

**3.3. Study design**

Cases with diaphyseal fractures of humerus, radius ulna, femur, tibia, metacarpal and metatarsal without any concurrent neurological, metabolic or infectious diseases were selected for the study of fracture management and the cases were divided into two groups, group I and group II.

**Group I**

Conventional or external coaptation technique by applying Robert Jones or modified Robert Jones bandage – minimum 6 cases.

**Group II**

Internal fixation technique by applying steinmann pins with or without wires – minimum 6 cases.

**3.4. External coaptation materials used in group-I**

Robert Jones or Modified Robert Jones Bandage was used in group I. It is the combination of bunch of rolled cotton approximately 10-20 cotton roll 3ʺ to 4ʺ in width and 10ʺ to 15ʺ in length (half to one pound, sunny corporation, sun-moon brand, BD), roll gauze (4ʺ, 6ʺ; daffodil brand, BD), crepe bandage (10cm × 4.5m; cigma plus, BD) and adhesive tape (2ʺ, 3ʺ, Health care, Thailand) (Fig. 1).

**3.5. Internal fixation materials used in group-II**

**3.5.1. Instrumentation and implants**

**3.5.1.1. Basic orthopedic instruments for internal fixation**

Basic orthopedic instruments used in this study were pointed reduction forceps, self centering bone holding forceps, serrated reduction forceps, Hohmann reduction forceps, Senn retractor, periosteal elevator, wire passer, rasp, pin cutter and wire cutter cum twister (Fig. 2).

**3.5.1.2. Orthopedic implants**

Trocar pointed Steinmann pins were used in all the animals of group II. Pins occupying 70-80 % of diameter of medullary canal were selected for the study. The appropriate size (3.5 mm, 4 mm, 4.5 mm and 5.5 mm in diameters and 150 mm, 200 mm, and 250 mm in length) of the pins was selected by measuring the diameter from the lateral radiograph of the respective contralateral bone. Wires (20G, 22G) also used in group-II (Fig. 3) especially for oblique fracture management.

**3.6. Imaging tools**

**3.6.1. Computed radiography (CR) X-Ray**

CR-30X scanner (AGFA) was used to read the exposed radiographic cassette. After scanning image was seen in monitor (Fig. 4). In addition, a portable X-ray machine was used to generate X-ray and focused on those cassettes with wearing radio protective lead apron and thyroid collar (Fig. 5). Two different sized cassettes (Fig. 6) were used; i) 35 cm X 43 cm and ii) 24 cm X 30cm.

CR X-Ray was used to assess radiographic score of pre and post-fracture evaluation of group-I and II cases.

**3.6.2. C-arm fluoroscopic unit**

A high frequency mobile X-ray image intensifier television system (Allengers- HF49R) (Fig. 7) with 230 mm diameter image intensifier with voltages between 40-110 kV at variable tube currents between 0.1 to 3 mA was used for fluoroscopy. The

main control units with mobile trolley contains an operating console, lifting column, tragarm and holder for C-arm, image intensifier tube with CCD camera and HF single

tank with iris collimator. The X-ray tube had a stationary anode with a nominal kV of 110 kV. There are two monitors, one each for LIH and stored memory display with a temporary storage capacity of up to 4 images. The unit was connected to a desktop computer in which the images were further processed and stored using iMagic software. In this study, C-arm was used during internal fixation technique to acquire appropriate insertion of pin in all the cases and external coaptation technique to acquire better anatomical reduction and alignment of fracture fragments.

**3.7. Fracture Management techniques**

**3.7.1. External Coaptation technique for group I**

**3.7.1.1. Application of Robert Jones/ modified Robert Jones bandage**

**Patient preparation**

Goat was restrained on either left or right lateral recumbancy depending on affected limb. The affected limb should be on upper position. The cases were sedated by Diazepam at the dose rate of 0.5mg/kg (inj. Sedil®, Square Pharmaceuticals Ltd. BD) for proper applying the bandage if necessary.

Two adhesive tape stirrups to cranial and caudal surfaces of the foot from carpus or tarsus to 6 inches beyond the hoof were applied. Cotton padding (approximately 10-20 rolled cotton 3ʺ to 6ʺ thickness) was applied around the limb through internal rotation at least above and below the affected bone ensuring that the extremity (hoof) was visible to detect any limb swelling. Following at least two to three layers of roll gauze was firmly wrap through internal rotation over the cotton to compress it. Then inversion of the tape stirrups and stick to the outer layer of the gauze was done. Elastic bandage was wrapped through internal rotation over the outer surface of the bandage. Lastly adhesive tape was wrapped over the elastic bandage.

**3.7.1.2. Removal of bandage**

In group I animals, bandages were removed on 30-45th days of fracture stabilization on the basis of lameness scoring and radiographic assessment score with the help of bandage cutter.

**3.7.2. Intramedullary pinning technique for group II**

**3.7.2.1. Patient preparation**

The cases (group II) were completely off feed for 12 hours. Clipping and shaving above hip joint to below stifle joint in femur and above shoulder joint to below knee joint in humerus was done of the affected limb. The extremity was wrapped firstly with unsterile gauze and finally wrapped with sterile gauze just before the surgery. Operated part was made sterile by using 10% povidone iodine followed by 70% alcohol.

**3.7.2.2. Surgeon’s preparation**

To minimize microbial contamination, surgeons prepared themselves aseptically before surgery; scrub suit should be worn rather than regular clothes.

After wearing disposable cap and mask, rinsing of hands vigorously with antiseptic solution (7.5% povidone iodine) with scrub brush well under running water and transfer the brush to scrubbed hand and arm. Repeat the process on other arm and hand. After that drying the arms and hand by using sterile towel should be performed. Sterile gowning followed by sterile gloving should be done just before surgery.

**3.7.2.3. Anaesthesia of the patient**

Patient was restrained on lateral recumbancy. Sedation was performed by using Diazepam at the dose rate of 0.5mg/kg (inj. Sedil®, Square Pharmaceuticals Ltd. BD). The operated site was desensitized by using 2% Lidocaine HCl at 1ml/ sq.cm (Inj. Jasocaine®, Jayson Pharmaceuticals Ltd. BD).

**3.7.2.4. Surgical approach**

There were mainly two types of intramedullary pin insertion technique: 1. Normograde insertion and 2. Retrograde insertion. In this study, retrograde insertion technique was performed.

Retrogade intramedullary pinning technique was followed in all the cases of group II.

In case of humerus, skin incision was given cranio lateral to the midshaft of the humeral diaphysis close to the brachialis muscle. Brachial fascia also incise along the same line being careful to isolate and protect the cephalic vein. Incise the brachial fascia along the border of the brachiocephalicus muscle and the lateral head of triceps muscle. After isolating radial nerve an incision was given through the periosteal insertion of the superficial pectoral and brachiocephalicus muscles at their insertion of humeral shaft. Reflecting these two muscles cranially and brachialis muscle caudally to expose the proximal and central humeral shaft. To gain further exposure of the distal humeral shaft reflect the brachialis muscle cranially and the lateral triceps muscle caudally [Fig. 24(b), 26(b), 29(b)]

Great care should be taken to adequately visualize and protect the radial nerve which lies superficial to the brachialis muscle and deep to the lateral head of triceps muscle.

Intramedullary pin of 75–80% of the medullary diameter was directed proximally toward the craniolateral cortex until it exits through the greater tubercle, after which it is withdrawn proximally until the distal pin tip was flushed with the fracture. The pin is directed distally in the marrow cavity to pass along the caudomedial cortex of the shaft and anchors well down in the medial condyle, at least the level of the epicondyle. During insertion of the pin into the distal segments, the two segments were hold firmly in the reduced position with one or two self locking bone forceps. In order to ensure passage of the bone down into the medial condyle, the bone fragments are bowed slightly medially at the fracture site. For anchorage of the pin proximal to the supratrochlear foramen, it was allowed to follow the center of the medullary canal until resistance was felt, then driven slightly farther to secure bone anchorage without entering the foramen. These pins were all usually cut as close to the bone as possible, leaving just enough pin protruding to allow removal after healing into the proximal fracture segment via the fracture site.

In case of femur, skin incision was given craniolateral border of the thigh. The incision should be given slightly more cranial than lateral since the exposure plane will be at the cranial border of biceps muscle. Superficial leaf of the fascia lata was incised along the cranial border of the biceps femoris muscle. Retract the biceps femoris muscle caudally to expose the vastus lateralis muscle. Fascial septum of vastus lateralis muscle was incised in its insertion point of caudal lateral border of femur. Vastus lateralis muscle was reflected from the surface of the femur to expose the femoral diaphysis.

After exposing both the proximal and distal parts of fracture fragments freshening was done with peri-osteal elevator. Intramedullary pins of 75–80% of the medullary diameter were driven from the fracture site proximally through the medullary canal into the trochanteric fossa. Care should be taken to have the proximal fracture fragment adducted (parallel to the table) and in the angulation and directed along the craniolateral surface of the medullary cavity. These entire precautions help keep emergence of the pin away from the femoral head and sciatic nerve. After which it is withdrawn proximally until the distal pin tip was flushed with the fracture. The pin is directed distally in the marrow cavity to pass along the caudomedial cortex of the shaft and anchors well down in the medial condyle, at least the level of the epicondyle. During insertion of the pin into the distal segments, the two segments were hold firmly in the reduced position with one or two self locking bone forceps. These pins are all usually cut as close to the bone as possible, leaving just enough pin protruding to allow removal after healing into the proximal fracture segment via the fracture site [Fig. 25(b), 27(b), 28(b)]

**3.7.2.5. Closure of surgical site**

The separated muscle bellies were apposed and subcuticular sutures were applied using 1-0 chromic catgut. The skin incision was apposed in interrupted cross mattress sutures using braided silk. Immediately following surgery, the suture line and the pin exit point were covered with cotton seal soaked with 10% povidone iodine (Povisep®, Jayson Pharmaceuticals Ltd. BD) and applied soft cotton bandage.

**3.7.2.6. Post operative care**

Streptomycin and penicillin (SP Vet®, Acme Laboratories Ltd. BD) at the rate of 10mg/kg and 20000 IU/kg body weight was given intramuscularly at 24 hours interval in all goats of group II up to 5th post operative day. Meloxicam (Mel Vet®, Acme laboratories Ltd. BD) @ 0.5 mg/kg subcutaneously and pheniramine maleate (Antihista-Vet®, Square Pharmaceuticals Ltd. BD) @ 1 mg/kg intramuscularly were administered up to 3rd and 5th post operative days, respectively.

Skin sutures were removed on the 8th to 10th post operative day. Restricted movement was advised up to 2 weeks following surgery. Passive flexion and extension exercise was advised for the operated limb after two weeks.

**3.7.2.7. Removal of implants**

In group II, the intramedullary (Steinmann) pin was removed on 45th post operative day on the basis of lameness scoring, radiographic assessment score and or if any complication arises. The implants were removed by using Diazepam (Sedil®, Square Pharma Ltd. BD) @ 0.5 mg/kg intravenously. The intramedullary pin was removed by making a small stab incision on the skin at the point of exit of the intramedullary pin and with the help of artery forceps or needle holder. A simple interrupted suture was placed at the stab wound with silk.

**3.8. Parameters studied for fracture management**

**3.8.1. Lameness grade**

A lameness grade was assigned before and after fracture management (day 1, 15, 30 and 45) on the basis of severity of clinical signs in group I and group II animals to assess the response to treatment. Clinical lameness score (0-5) was given as follows (Cook *et al.,* 1999).

0 – No observable lameness.

1 – Intermittent, mild weight bearing lameness, if any change in gait.

2 – Consistent, mild weight-bearing lameness with little change in gait.

3 –Moderate weight-bearing lameness – obvious lameness with noticeable “head bob” and change in gait.

4 – Severe weight-bearing lameness – “hoof touching” only.

5 – Non-weight-bearing.

**3.8.2. Radiographic assessment**

Radiographs were taken before and after fracture management (day 1, 15, 30 and 45) in group I and group II animals to assess the response to treatment. Post fracture management radiographs were evaluated and scored for reduction and fracture alignment. Score for fracture reduction and alignment (0-3) was given as follows (Cook *et al.,* 1999).

0 - Anatomical reduction.

1 - Minimal (<1mm) malreduction.

2 - Moderate (1-3mm) malreduction.

3 - Severe (>3mm) malreduction.

**3.9. Post fracture management complications**

Post fracture management complications were studied and recorded, if any.

**3.10. Data analysis**

Data obtained from the study was imported to the Microsoft Excel-2007 and then transferred to the statistical software STAT/IC-11.0 for calculating percentage of different variables.

**Chapter- 4**

**Results**

**4.1. Incidence of long bone fracture**

**4.1.1. Overall incidence of long bone fracture**

From January 2016 to December 2016 a total of 2439 clinical cases of goat were recorded of which 1.59% (N=39) cases were fracture in goat (Table 1).

**Table 1: Overall incidence of long bone fracture**

|  |  |  |
| --- | --- | --- |
| **Criteria** | **No. of Animal** | **Percentage (%)** |
| Total clinical cases of goat | 2439 | - |
| Total no. of long bone fracture cases in goat | 39 | 1.59 |

**4.1.2. Incidence of long bone fracture according to breed**

Among 39 long bone fracture cases, 25.6% (N=10) was jamunapari, 58.9% (N=23) was cross, and 15.5% (N=6) was black Bengal goat (Table 2). Higher incidence was found in cross breed (58.9%) whereas lower incidence was found in black Bengal goat (15.5%).

**4.1.3. Incidence of long bone fracture according to age**

Out of 39 long bone fracture cases, 46.1% (N=18) was below 6 months, 41.1% (N=16) was 6 months to 1year, 5.1% (N=2) was 1year to 1.6 years and 7.7% (N=3) was above 1.6 years (Table 2). Higher incidence was found in below 6 months whereas lower incidence was found in 1 to 1.6 years of age.

**4.1.4. Incidence of long bone fracture according to sex**

Among 39 long bone fracture cases, 59% (N=23) was male, and 41% (N=16) was female (Table 2).

**Table 2: Incidence of long bone fracture according to breed, age, sex**

|  |  |  |  |
| --- | --- | --- | --- |
| **Criteria** | **Classification** | **No. of Animal** | **Percentage (%)** |
| According to breed | Jamunapari | 10 | 25.6 |
| Cross | 23 | 58.9 |
| Black Bengal | 06 | 15.5 |
| According to age | >6m | 18 | 46.1 |
| 6m to 1y | 16 | 41.1 |
| 1y to 1.6y | 02 | 5.1 |
| Above 1.6y | 03 | 7.7 |
| According to sex | Male | 23 | 59.0 |
| Female | 16 | 41.0 |

**4.1.5. Incidence according to the nature of long bone fracture**

Within long bone fracture cases (N=39), 100% were closed fracture (Table 3).

**4.1.6. Incidence according to type of long bone fracture**

Out of long bone fractures, 100% (N=39) was complete fracture. Again the complete fractures 84.6% (n=33) was oblique, 10.3% (n=4) transverse, 5.1% (n=2) spiral fractures (Table 3). Higher incidence was found in oblique fracture (84.6%) whereas lower incidence was found in spiral fracture (5.1%).

**4.1.7. Incidence according to the limb involvement**

Among the total long bone fracture cases, 48.7% (N=19) involved in fore limbs and 51.3% (N=20) involved in hind limbs. Within the affected hind limbs 40.0% (n=8) in left limb, 60.0% (n=12) in right limb. Again, among the affected forelimbs, 36.8% (n=07) was in left limb, 63.2% (n=12) in right limb (Table 3).

**4.1.8. Incidence according to different bones involved**

Among the affected hind limbs 30% (n=6) in femur, 50% (n=10) in metatarsal bone, and 20% (n=4) was in tibia-fibula. Within the affected forelimbs, 84.2% (n=16) was in metacarpal bone, 5.3% (n=1) in radius-ulna bone and 10.5% (n=2) in humerus (Table 3). Higher incidence was found in metacarpal bone (84.2%) whereas lower incidence was found in radius-ulna bone (5.3%) in fore limb. Again in hind limb higher incidence was found in metatarsal bone (50.0%) whereas lower incidence was found in tibia fibula (20.0%).

**4.1.9. Incidence according to the location of long bone fracture**

Out of 39 long bone fractures, 79.5% (N=31) was diaphyseal fractures and 20.5% (N=8) was epiphyseal fractures. Among the diaphyseal fractures 71.0% (n=22) was in mid diaphyseal fractures, 6.4% (n=2) was in proximal diaphyseal fractures and 22.6% (n=7) was in distal diaphyseal fractures. Higher incidence was found in mid diaphyseal fracture (71.0%) whereas lower incidence was found in proximal diaphyseal fracture (6.4%) (Table 3).

**Table-3: Incidence of long bone fracture according to nature, type, limb and bone involvement, and location of fracture**

|  |  |  |  |
| --- | --- | --- | --- |
| **Criteria** | **Classification** | **No. of Animal** | **Percentage (%)** |
| According to nature of fracture | Closed | 39 | 100 |
| Open | 00 | - |
| According to type of fracture | **Complete** | **39** | **100** |
| Oblique | 33 | 84.6 |
| Transverse | 04 | 10.3 |
| Spiral | 02 | 5.1 |
| **Incomplete** | **00** | **00** |
| According to limb involvement | **Fore limbs** | **19** | **48.7** |
| Left limbs | 07 | 36.8 |
| Right limbs | 12 | 63.2 |
| **Hind limbs** | **20** | **51.3** |
| Left limbs | 08 | 40 |
| Right limbs | 12 | 60 |
| According to bone involved | **Fore limbs** | **19** | **48.7** |
| Metacarpal | 16 | 84.2 |
| Radius ulna | 01 | 5.3 |
| Humerus | 02 | 10.5 |
| **Hind limbs** | **20** | **51.3** |
| Femur | 06 | 30.0 |
| Metatarsal | 10 | 50.0 |
| Tibia fibula | 04 | 20.0 |
| According to location of fracture | **Diaphyseal** | **31** | **79.5** |
| Mid | 22 | 71.0 |
| Proximal | 02 | 6.4 |
| Distal | 07 | 22.6 |
| **Epiphyseal** | **08** | **20.5** |

**4.2. Causes of long bone fracture**

Out of 39 long bone fracture cases in goats, maximum fracture cases; n=20 (51.3%) were caused due to fall down during jumping and minimum fracture cases; n=3 (7.7%) were caused due to dog bite. Other fracture cases were due to automobile accident; n=11 (28.2%) and indirect violence; n=5 (12.8%) (Table 4).

**Table 4: Causes of long bone fracture**

|  |  |  |
| --- | --- | --- |
| **Causes of fracture** | **No. of goat** | **Percentage** |
| Fall down during jumping | 20 | 51.3 |
| Automobile accident | 11 | 28.2 |
| Indirect violence | 5 | 12.8 |
| Dog bite | 3 | 7.7 |

**4.3. Fracture Management study**

**4.3.1. Clinical cases of long bone fracture management by external coaptation technique in group-I**

**Table 5: Clinical summary in group-I**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Case no.** | **Signalment** | **Body weight(kg)** | **Bone affected** | **Type of fracture** |
| 1 | JP,5m,M | 12 | Lt. Metatarsal | Short oblique proximal diaphyseal fracture |
| 2 | C,3m,M | 12 | Lt. Metatarsal | Transverse mid diaphyseal fracture |
| 3 | BB,8m,M | 18 | Lt. Metatarsal | Transverse proximal diaphyseal fracture |
| 4 | C,7m,M | 20 | Rt. Metatarsal | Short Oblique mid diaphyseal fracture |
| 5 | C,3m,M | 10 | Lt. Metacarpal | Transverse mid diaphyseal fracture |
| 6 | JP,6m,M | 17 | Lt. Metacarpal | Transverse mid diaphyseal fracture |
| 7 | C,4m,M | 20 | Rt. Metatarsal | Short oblique Proximal diaphyseal fracture |
| 8 | JP,11m,M | 28 | RT. Tibia | Transeverse metaphyseal fracture |

Rt= Right, Lt= Left, JP= Jamunapari, BB= Black Bengal, Cross= BB x JP, m= Months, yr= Year

**4.3.2. Clinical cases of long bone fracture management by internal fixation technique in group-II**

**Table 6: Clinical summary in group-II**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Case no.** | **Signalment** | **Body weight****(kg)** | **Bone affected** | **Type of fracture** | **Materials/ implant used** |
| 1 | JP, 4m, M | 20 | Rt. Humerus | Short oblique proximal diaphyseal | Steinmann pin 4.5mm + 18G 2 cerclage wires |
| 2 | JP, 3.5m, F | 20 | Rt. Femur | Oblique over-riding mid diaphyseal | Steinmann pin 4.5mm + 18G 2 cerclage wires |
| 3 | C, 2yr, F | 22 | Lt. Humerus | Oblique over-riding mid diaphyseal | Steinmann pin 4.5mm + 18G 3 cerclage wires |
| 4 | C, 5m, F | 14 | Lt. Femur | Complete transverse proximal diaphyseal | Steinmann pin 4.0mm |
| 5 | JP, 4m, F | 12 | Rt. Femur | Oblique mid diaphyseal | Steinmann pin 4.0mm |
| 6 | JP, 1yr, M | 25 | Lt. Humerus | Long Oblique over-riding mid diaphyseal | Steinmann pin 4.5mm + 18G 2 cerclage wires |

Rt= Right, Lt= Left, IMP= Intramedullary Pinning, BB= Black Bangle, JP= Jamnapari, Cross= BB x JP, m= Months, yr= Year.

**4.4. Evaluation of the fracture management technique**

**4.4.1. Parameters studied**

**4.4.1.1. Lameness grading in clinical cases of group-I and II**

Before fracture management case no. 2, 3, 4, 5 of group I and all the cases of group II were non weight bearing lameness (grade 5) (table 7). After fracture management in day 1 all the cases of group I and II were mild weight bearing lameness, hoof touching only (grade 4). Gradual improvement in weight bearing was noticed between 15th days to 45th days in all the cases except case no. 8 of group I and case no. 5 in group II. No observable lameness (grade 0) was found in day 45 in all the cases except case no. 8 of group I and case no. 6 in group II. Case no. 8 of group I and case no. 5 of group II showed mild weight bearing lameness with change in gait (grade 2) in 45th day of observation which indicates delayed union of the fractured fragments. [Fig. 8, 9, 10, 11, 12, 13, 14, 15, 24(a), 24(c), 24(d), 25(a), 25(c), 25(d), 26(a), 27(a), 27(c), 28(a), 29(a)].

**Table 7: Lameness grades in group I and II**

|  |  |  |  |
| --- | --- | --- | --- |
| **Group** | **Case no** |  | **Lameness grade** |
| **Before bandage/ pre operative** | **After bandage/Post operative** |
| **Day1** | **Day 15** | **Day 30** | **Day 45** |
|  I | 1 | 4 | 4 | 3 | 1 | 0 |
| 2 | 5 | 4 | 3 | 1 | 0 |
| 3 | 5 | 4 | 3 | 1 | 0 |
| 4 | 5 | 4 | 3 | 1 | 0 |
| 5 | 5 | 4 | 3 | 1 | 0 |
| 6 | 4 | 4 | 3 | 1 | 0 |
| 7 | 4 | 4 | 3 | 1 | 0 |
| 8 | 4 | 4 | 4 | 3 | 2 |
|  II | 1 | 5 | 4 | 3 | 1 | 0 |
| 2 | 5 | 4 | 3 | 1 | 0 |
| 3 | 5 | 4 | 3 | 1 | 0 |
| 4 | 5 | 4 | 3 | 1 | 0 |
| 5 | 5 | 4 | 3 | 2 | 2 |
| 6 | 5 | 4 | 3 | 1 | 0 |

**4.4.1.2. Fracture reduction, alignment, healing evaluation of clinical cases in group-I and II**

Radiographic assessment score was given on pre and post fracture management of day 1, 15, 30 and 45 in group I and II animals. In case no.1, 4, 5, 8 of group I and all the cases of group II severe malreduction (grade 3) were seen before fracture management. Anatomical reduction (grade 0) was found in all the cases of group I and II in day 1 after fracture management except case no. 4, 5 and 8 in group I animals. In post fracture management day 15, minimal mal reduction (grade 1) was observed in all the cases of group I and group II except case no 8 of group I. Moderate mal reduction (grade 2) was found in case no 8 of group I in 45th post fracture management day.

Progressive secondary bone healing was noticed in all the cases of group I and group II on post fracture management day 15 onward except case no 8 of group I. [Fig. 16, 17, 18, 19, 20, 21, 22, 23, 24(c), 24(d), 25(c), 25(d), 26(a), 26(c), 27(a), 27(c), 28(a), 29(a), 29(c)].

**Table 8: Radiographic assessment score in group I and II**

|  |  |  |  |
| --- | --- | --- | --- |
| **Group** | **Case no.** | **Before bandage / Pre-operative** | **Fracture reduction and alignment** |
| **After bandage / Post operative** |
| **Day1** | **Day15** | **Day 30** | **Day 45** |
| I | 1 | 3 | 0 | 1 | 0 | 0 |
| 2 | 1 | 0 | 1 | 0 | 0 |
| 3 | 2 | 0 | 1 | 0 | 0 |
| 4 | 3 | 2 | 1 | 0 | 0 |
| 5 | 3 | 2 | 1 | 0 | 0 |
| 6 | 2 | 0 | 1 | 0 | 0 |
| 7 | 2 | 0 | 1 | 0 | 0 |
| 8 | 3 | 2 | 2 | 2 | 2 |
| II | 1 | 3 | 0 | 1 | 0 | 0 |
| 2 | 3 | 0 | 1 | 0 | 0 |
| 3 | 3 | 0 | 1 | 0 | 0 |
| 4 | 3 | 0 | 1 | 0 | 0 |
| 5 | 3 | 0 | 1 | 0 | 0 |
| 6 | 3 | 0 | 1 | 0 | 0 |

**4.4.2. Post-bandage complications in group I**
Mal union and abnormal gait were seen in one case (case 8) (Fig. 30).

**4.4.3. Post-operative complications in group II**
Wire loosening (Fig. 31) in case no 2 and Pin tract discharge, pin migration (Fig. 32) in case no 5 was noticed.

**Chapter-5**

**Discussion**

**5.1. Incidence of long bone fracture**

**5.1.1. Overall incidence of long bone fracture**

A total number of 2439 different clinical cases were registered in the Shahedul Alam Quadery Teaching Veterinary Hospital, Chittagong Veterinary and Animal Sciences University (CVASU), during the study period. Out of 2439 cases, 39 cases of goat were found long bone fracture. The incidence of long bone fracture was found to be 1.59%. These finding was similar to the finding of Kumar (2016) who reported an incidence of 82.0%. Rajhans (2013) and Singh *et al.,* (2015) also reported that the overall incidence of fracture was 90.0% and 95.0%, respectively in all goats. However, Arora (1996) reported that overall incidence of fracture was 12.2%. The variation in incidence of fracture may be attributed to change in location and time of study.

**5.1.2. Incidence of long bone fracture according to breed**

Out of 39 long bone fracture cases, 58.9% was cross breed, 25.6% was jamunapari and 15.5% was black Bengal. The higher incidence of long bone fracture was in cross breed may be due to more intensity of the local people to rear cross breed in Bangladesh.

**5.1.3. Incidence of long bone fracture according to age**

Among 39 long bone fracture cases, 46.1% (N=18) was below 6 months, 41.1% (N=16) was 6 months to 1year, 5.1% (N=2) was 1year to 1.6 years and 7.7% (N=3) was above 1.6 years. These findings are similar with the results of Singh *et al.,* (2017), who found that total 30 cases of fracture in goats, the highest percentage of fracture was recorded in animals of age below 9 months (60.0%), followed by age group of 3 - 5 years (23.3%) and age group of 9 months - 3 years (16.6%). Similar findings were also reported by Patel (2014), Gupta (2015) and Kumar (2016), who also reported highest incidence of fracture in goats below 9 months of age. In present study, the higher incidence of fracture in young goats may be because of their more population and activeness curious and easily excited nature, they also attempt to impossible jumps resulting in traumatic injuries, which makes them more prone for fracture either due to automobile accident or falling.

**5.1.4. Incidence of long bone fracture according to sex**

The long bone fracture was found to be more common in male 59.0% (N=23) than female goats 41.0% (N=16). The observation was similar with the findings of Singh (2015), who found that male (53.3) was vulnerable than female one (46.6%). These finding was similar with the findings of Philip *et al.,* (1998), Gupta (2015), Singh(2015) and Kumar (2016). Higher incidence in male can be attributed to the fact that, males are more active than female, which predispose them to the factors responsible for causing the fracture.

**5.1.5. Incidence according to the nature of fracture**

Closed fractures were found higher (100.0%) than open fractures (0%) in one year’s incidence of long bone fracture in goat. Similar result was found by Newton (1998) and Tulleners (1996). However, a survey on small animal fracture by Wong (1984) reveals open fractures were the highest in number than closed fractures in Malaysia. Causes of higher incidence of close fracture in present study are due to fall down of the affected cases from small distance that causes fewer traumas in affected limb.

**5.1.6. Incidence according to types of long bone fracture**

In the present study, all fracture cases were revealed complete in nature. Types of fracture observed during the study period were oblique (84.6%), transverse (10.6%) and spiral (5.1%). These results are similar with the study of Singh *et al.,* (2017), who found that types of fracture observed were oblique (46.6%), transverse (46.6%) and spiral (6.6%). Similar findings have also been reported by Arora (1996), Patel (2014) and Kumar (2016) in goats. A plausible explanation of high incidence of oblique fracture might be when a force less than optimal breaking force of bone, acts tangentially on any object it get distributed un-proportionately with more force on near cortex and less force on far cortex leading to break of the nearby cortex and tear in the cortex which is away, thus creating oblique fracture in goats. However, Manjulkar *et al.,* (2004) recorded highest incidence of transverse fracture.

**5.1.7. Incidence according to the limb affected**

Result of this study revealed that the total long bone fracture cases, 48.7% (N=19) was involving fore limb and 51.3% (N=20) was involving hind limb. Among the affected hind limbs 40% (n=8) in left one and 60% (n=12) in right one. Again, the affected forelimbs, 36.8% (n=07) was in left and 63.2% (n=12) in right one. Singh *et al*., (2017) also reported very similar result for leg affected among 30 cases of goats, more number of fractures was recorded in hind limbs (63.3%) than fore limbs (36.6%). Similar findings were also reported by Ganesh *et al.,*(1994) and Aithal *et a.,*(1998) in goats. Singh *et al.,* (1983) opined that most of the fractures were caused by automobile accidents, where the animals were most likely to get injury from behind as the animals were slow to react from their hind quarters.

**5.1.8. Incidence according to different bone involved**

In the present study, highest number of fracture was recorded in metacarpal (84.2%) followed by metatarsal (50%), femur (30%), tibia-fibula (20%), humerus (10.5%) and radius ulna (5.3%). Similar finding was also reported by Kumar (2016) reported highest number of fracture in metacarpal followed by metatarsal in goats. In contrary to this, Singh *et al*., (1983) highest number of fracture was recorded in tibia-fibula (36.6%) followed by metatarsal (23.3%), radius-ulna (16.6%), humerus (10.0%), metacarpal (6.6%) and femur (6.6%). The more number of fractures in metacarpal may be attributed to tendency of goats to suddenly flee from source of trauma like automobile or projectile stick. Being cranial part of the body, there are more chances of metacarpal to be trapped with a source of trauma.

**5.1.9. Incidence according to location of fracture**

On the basis of location, out of 39 long bone fractures, highest number was recorded 79.5% (N=31) as diaphyseal fractures and 20.5% (N=8) were as epiphyseal fractures. Again among the diaphyseal fractures 71.0% (n=22) were mid diaphyseal fractures, 6.4% (n=2) proximal diaphyseal fractures and 22.6% (n=7) distal diaphyseal fractures. Similar findings was reported by Singh *et al*., (2017) highest in diaphysis (56.6%) followed by distal third (33.3%) and proximal third (10.0%). Similar findings were also reported by Arora (1996) and Gupta (2015) in goats. This may be due to the fact that the mechanical pressure is very much concentrated in diaphysis than epiphysis (Beale, 2004). But according to Canapp (2004), epiphyseal fractures were the highest in number in most accidental fractures.

**5.2. Causes of long bone fracture**

There are a number of causal agents that causes fracture of bones either directly or indirectly. Piermattei *et al.,* (2016) stated that 75.0 to 85.0% of all fractures are caused by automobile accidents. Other causes of fracture involve indirect violence, different bone diseases like bone neoplasm, nutritional disturbance that affect bone. In present study, major cause of fracture of goats was fall down during jumping (51.3%). Other causes were automobile accident (28.2%), indirect violence (12.8%) and dog bite (7.7%).

**5.3. Fracture management technique**

**5.3.1. External coaptation technique**

8 cases with diaphyseal fractures of long bones were treated with external coaptation technique (Modified Robert Jones bandage). Diaphyseal fractures of the metacarpal, metatarsal, radius ulna and tibia were subjected to external coaptation. The selection concurred with suggestion made by McPherron *et al*., (1992). Modified Robert Jones Bandage was used in group I. In group I, long bone fractures involving metacarpal, metatarsal, radius ulna and tibia after treating with modified Robert Jones bandage showed good outcome. Piermattei *et al.,* (1997) also stated that when mechanical instability was present, the bone underwent a healing process producing external callus that functioned as a mechanical supporting structure.

**5.3.2. Internal fixation technique**

Duhautois (2003) suggested that, mid shaft diaphyseal fractures of humerus and femur were subjected to intramedullary pinning or internal fixation technique. Awatif *et al.,* (2006) discussed about the successful use of intramedullary pinning technique for correction of diaphyseal fractures in caprines. The technique was more reliable than external casting or splinting for femoral fractures and animals showed complete absence of lameness in six weeks with no complications. Singh *et al.,* (2006) reported intramedullary pinning as a sound and economical method for the internal fixation of fractures.

Pins were available in different diameters and strength of the pin was proportional to its diameter. Pins were able to provide good axial stability but less rotational stability. The technique was successful in repairing fractures of humerus and femur in sheep, goats and young calves (Singh *et al.,* 2006).

Diameter of the Steinmann pin used progressively increased according to the body weight of the animal. Intramedullary pin diameters are considered to be important for fixing fracture in goat. The intramedullary pin occupied 70 to 80 % of medullary canal diameter which are sufficient to withholding fracture (Brinker *et al.,* 1988).

Open reduction and retrograde insertion of intramedullary pins were found to be appropriate for proper alignment of fracture fragments and provided stable fixation in all cases. Johnson and DeCamp (1999) reported that the penetration of intramedullary pin in the large mass of femur predisposed to pin tract drainage because of increased motion between the pin and soft tissue. They also observed that excessive tension at the pin soft tissue interface resulted in increased inflammation, tissue necrosis and secondary infection. They suggested the placement of pin in healthy soft tissue area with limited soft tissue mass between muscle bellies through a 1 cm long soft tissue releasing incision to facilitate blunt dissection of soft tissue down to the level of bone for pin insertion. The observations concurred with Aron and Dewey (1992) and Johnson and DeCamp (1999).

**5.4. Evaluation of fracture management technique**

**5.4.1. Lameness grade**

Scoring technique was adopted for the evaluation of lameness. Lameness scores proposed by Kaler *et al.,* (2009) was modified accordingly and was used to record individual lameness scores at the time of presentation. Group I and group II animals showed no observable lameness on the 45thpost-operative day except presence of moderate weight bearing lameness in one case of group I, and one case of group II. This may be consequence of fixation failure and/or re-fracture. This is in agreement with the findings of Dueland *et al*., (1999) who reported that lameness grade for subsequent post-operative weeks gradually decreased in intramedullary pinning technique with excellent limb function in 93.0% of the cases.

**5.4.2. Radiographic evaluation**

Fracture reduction and alignment are gradually improved in group I and group II animals on 30th and 45thpost-operative day. This might be due to stable anatomical environment and direct bone healing. This is in accordance with studies of Dueland *et al*. (1999). However one case of group I got minimal mal reduction on 45thpost-operative day. This might be due to fixation failure as a result of chronic inflammatory reaction due to pin-soft tissue motion or increased patient activity. Similar activity presented by some noble work (Harari, 1992a; Johnson and DeCamp, 1999). But there is no such report found comparing external and internal fixation techniques regarding fracture reduction and alignment.

**5.5. Complications of fracture management**

Denny and Butterworth (2000) reported malunion, non-union of fracture ends, delayed union, fracture disease, fracture associated sarcoma, osteomyelitis and fat embolism as additional complications of fracture healing. They have also described radiographic features of delayed union as persistent fracture line with signs of healing, uneven fracture surfaces, open medullary cavity and absence of sclerosis. Radiographic features of non-union included closed medullary cavity, smooth fracture surfaces and sclerosis.

Case no. 8 of group-I showed delayed healing (radiographic assessment score 2) which is similar to Rovesti (2005) who defined delayed union as a fracture that took longer time to heal than anticipated. Clinically it was diagnosed by the persistence of pain and non-usage of limb for a longer period after the occurrence of fracture. Radiographic appearance was often similar to normal healing, but with delayed appearance of callus with persistent fracture line.

 Venugopal (2015) reported that fracture diseases were characterized by muscle atrophy, tissue adhesions, osteoporosis and joint stiffness.

Pin tract migration from bone and soft tissue would have caused trauma to surrounding soft tissue mass. Motion produced pin tract discharge for longer period. Case no. 5 from group-II had pin tract discharge. Canapp (2004) revealed that pin tract discharge is almost the common clinical signs of long bone fixing.

**Chapter-6**

**Conclusions**

The present research work reveals the following conclusions:

* Higher incidence of long bone fracture was found in cross breed (58.9%), below 6 months of age (46.1%) and male (59.0%) compare to female goat.
* Mid diaphyseal (71.0%), oblique fracture (84.6%) is more common than other type of fracture and metacarpal bone is more (84.2%) prone to fracture than other bone.
* Most common causes of fracture were due to fall down (51.3%).
* Long bone especially metacarpal, metatarsal, tibial oblique and transverse fracture can be successfully managed by Modified Robert Jones bandage in field condition.
* Long bone specially humerus and femur oblique, over riding fracture can be successfully treated by intramedullary pinning technique with wiring.
* In both groups, fracture management needs technical skills which can minimize complications.
* Owner cooperation is also very important for successful outcome of fracture management.

**References**

Adams, SB and Fessler, JF. 1996. Treatment of fractures of the tibia and radius-ulna by external coaptation. Veterinary Clinics of North America: Food Animal Practice, 12:181-198.

Aithal, HP, Singh, GR and Bisht, GS. 1998. Incidence of fractures in different domestic animals – A twenty year survey analysis. 22nd Indian Society for Veterinary Surgery Symposium, Bhubneshwar, 5-7 November, 30-32.

Ali, TMO, Ibrahim, KEE and Elton, H. 2001. Animal diseases diagnosed at the University of Khartoum Veterinary Teaching Hospital (1995-1998). Journal of Veterinary Science and Animal Husbandry, 40:38.

Aron DN and Dewey CW. 1992. Application and postoperative management of external skeletal frxators. Veterinary Clinics of North America: Small Animal Practice, 22: 69-97.

Aron, DN. 1998. Stages of bone healing and practical techniques for fractures. In: Current techniques in small animal surgery (4thed.), Edited by Bojrab MJ, Williams & Wilkins, Baltimore, 872-873; 934-935.

Arora, S. 1996. Clinical and radiological evaluation of fractures in goats. M.V.Sc. & A.H. thesis (Surgery and Radiology), Rajasthan Agriculture University, Bikaner.

Awatif, ME., Ali, OS. And Shnain, HM. 2006. Kirschner intramedullary pinning for femoral fractures in caprine. Surgery Journal, 1:75-77.

Beale, BS. 2004. Orthopedic clinical techniques femur fracture repair. Clinical Techniques in Small Animal Practice, 3:134-150.

Belgi, A., Akin, İ., Gülaydin, A and Yazici, MF. 2016. The treatment of distal metacarpus fracture with locking compression plate in calves. Turkey Journal Veterinary Animal Sciences, 40: 234-242.

Brinker WO, Hohn RB and Prieur WD. 1988. Manual of Internal Fixation in Small Animals.Springer, pp. 180-187.

Brodell, JD, Axon, DL and Evarts, M. 1986. The Robert Jones bandage. The journal of Bone & Joint Surgery, 68(5):776-779.

Canapp, SO. 2004. External fracture fixation. Clinical Techniques in Small Animal Practice, 19: 14-119.

Cook, JL, Tomlinson, JL and Reed, AL. 1999. Fluoroscopically guided closed reduction and internal fixation of fractures of the lateral portion of the humeral condyle: prospective clinical study of the technique and results in ten dogs. Veterinary Surgery, 28: 315-321.

Denny, HR and Butterworth, SJ. 2000. A guide to canine and feline orthopaedics (4th ed.). Blackwell Science, Oxford, pp. 18; 132.

DLS, 2013. Expansions and Activities. Department of Livestock Services, Government of the people’s Republic of Bangladesh. Annual Report-2013.

DLS, 2015-16. Expansions and Activities. Department of Livestock Services, Government of the people’s Republic of Bangladesh. Annual Report-2015-16.

Deepu, PM, Thilagar, A, David, WP. And Murali MB. 1998. Comparative evaluation of ilizarov technique and PVC splint reinforced cost for the management of compound fracture of metatarsus in calves. Indian Veterinary Journal, 82: 1159-1162.

Doiphode, JM. 1994. Comparative study of different types of splintage in the treatment of long bone fractures of sheep and goat. Indian Veterinary Journal, 71:70-72.

Dueland, RT, Johnson, KA, Roe, SC, Engen, MH and Lesser, AS. 1999. Interlocking nail treatment of diaphyseal long-bone fractures in dogs. Journal of the American Veterinary Medical Association, 214: 59-66.

Duhautois, B. 2003. Use of veterinary interlocking nails for diaphyseal fractures in dogs and cats: 121 cases. Veterinary Surgery, 32: 8-20.

Endo, D, Nakamura, K, Maeda, H and Matsushita, T. 2003. Interlocking intramedullary nail method for the treatment of femoral and tibial fractures in cats and small dogs, The Journal of Veterinary Medical Science, 60: 119-122.

Fox, DB. 1997. Orthopedic Examination of the Forelimb in the Dog. Journal of the American Animal Hospital Association, 33 (6): 528-532.

Fossum, TW. 2013. Small animal surgery (4th ed.). Edited by Mosby. pp. 789-790; 857-858; 706-707.

Ferguson J, Dehghani S and Petrali, S. 1990. Fractures of the femur in newborn calves. Canadian Veterinary Journal, 31: 289-291.

Ganesh, TN, Sathish, T, Thilager, S, Kumar, RB, Ameerjan, K, Pattabiraman, SR. and Balasubramanian, NN. 1994. Retrospective study on incidence and anatomical locations of orthopaedic problems in large animals. 17th Indian Society for Veterinary Surgery Congress, Mathura, 45-48.

Getty, R and Sisson, S. 1975. Sisson and Grossman's The Anatomy of the Domestic Animals (5thed). Vol, 2, Edited by Cynthia Ellenport Rosenbaum, N. G. Ghosal, Daniel Hillmann. pp 120-350.

Glyde M and Arnett R. 2006. Tibial fractures in the dog and cat: options for management. Iris Veterinary Journal, 59:290-295.

Gupta, S. 2015. Fracture healing using biphasic calcium phosphate with dynamic compression plating in goats. M.V.Sc. & A.H. thesis (Surgery and Radiology), Nanaji Deshmukh Veterinary Science University, Jabalpur.

Harari J. 1992a. Complications of external skeletal fixation. Veterinary Clinics of North America: Small Animal Practice, 22: 99-107.

Hulse, D and Hyman, B. 2003. Fracture biology and biomechanics. In: Textbook of small animal surgery. (3rded.). Edited by Slatter, D. Saunders, Philadelphia, pp. 1785-1789; 1791-1792.

Johnson, AL and DeCamp, CE. 1999. External skeletal fixation-linear fixators. Veterinary Clinics of North America: Small Animal Practice, 29: 1135-1152.

Joy, B. 2013. Uniplanar external skeletal fixation for the management of long bone fractures in goats. MVSc Thesis, Kerala Veterinary and Animal Sciences University, Pookode, 78-86.

Kaler, J, Wassink, GJ and Green, LE. 2009. The inter and intra observer reliability of a locomotion scoring scale for sheep. Veterinary Journal, 180(2): 189-194.

Kapatkin A. 2000. Conservative versus surgical treatment of metacarpal and metatarsal fractures in dogs. Veterinary and Comparative Orthopaedics and Traumatology, 13: 123-127.

Koestlin RG, Nuss K, Elma E. 1990. Metacarpal and metatarsal fractures in cattle. Treatment and results, Tieraerztl Prax, 131-144.

Kumar D. 2016. Efficiency of bone substitutes for fracture healing in goats.Ph.D. Thesis (Surgery and Radiology), Nanaji Deshmukh Veterinary Science University, Jabalpur.

Kushwaha, RB, Gupta, AK, Bhadwal, MS, Kumar, S. and Tripathi, AK. 2011. Incidence of fractures and their management in animals: A clinical study of 77 cases. Indian Journal of Veterinary Surgery, 32(1):54-56.

Langley-Hobbs, S. 2003. Biology and radiological assessment of fracture healing. In Practice, 25(1):26-35.

Lappin, MR, Aron, DN, Herron, HL and Malnati, G. 1983. Fractures of the radius and ulna in the dog. Journal of the American Animal Hospital Association, 19:643-650.

Luis, M, Martínez, R, Judith, B, Halling, KB, Wilkins, K and Schulz, K. 2007. Use of a circular external skeletal fixator for stabilization of a comminuted diaphyseal metatarsal fracture in an alpaca. Journal of the American Veterinary Medical Association. 230(7): 1044-1048.

Manjulkar, GP, Mehesare, SP, Pathak, VP and Dandge, BP. 2004. Use of PVC sheets as an immobilizing coat in small ruminants- a novel approach. Veterinary Indian Association, 4: 44-48.

Mbiuki, SM and Byagagaire, SD. 1984. Full limb casting: A treatment for tibial fractures in calves and goats. Veterinary medicine: Small Animal Clinician, 79:243-244.

McLaughlin, RM. 1999. Internal fixation. Veterinary Clinics of North America: Small Animal Practice, 29: 1097-1116.

McPherron, MA, Schwarz, PD and Histand, MB. 1992. Mechanical evaluation of halfpin (type 1) external skeletal fixation in combination with a single intramedullary pin. Veterinary Surgery, 21: 178-182.

Merck. 2006. The Merck Veterinary Manual (8thed.), Merck and Inc., White House Station, New Jersey, U.S.A, pp. 1220-1280.

Nanai, B and Basinger, RR. 2005. Use of a new investigational interlocking nail supplement in the repair of comminuted diaphyseal tibia fractures in two dogs. Journal of the American Animal Hospital Association, 41: 203-208.

Newton, CD. 1998. Algorithm for bone healing and clinical timeline for fractures. In: Current Techniques in Small Animal Surgery (4th ed.), Edited by Bojrab MJ, Williams and Wilkins, Philadelphia, pp. 865-872.

Olmstead, ML. Egger, EL, Johnson, AL and Wallace, LJ. 1995. Principles of fracture repair. In: Small Animal Orthopaedics, Edited by Olmstead, St. Louis, Mosby, pp. 111-159.

Ozsoy, S and Altunatmaz, K. 2003. Treatment of extremity fractures in dogs using external fixators with closed reduction and limited open approach. Veterinary Medicine, 48: 133-140.

Palmer, RH, Aron, DN and Purinton, PT. 1988. Relationship of femoral intramedullary pins to the sciatic nerve and gluteal muscles after retrograde and normograde insertion. Veterinary Surgery, 17: 65-70.

Patel, S. 2014. Comparative study on plaster of paris and hybrid cast for long bone fracture in goats. M.V.Sc. & A. H. thesis (Surgery and Radiology), Nanaji Deshmukh Veterinary Science University, Jabalpur.

Piermattei, DL, Flo, GL and Brinker. 1997. Handbook of Small Animal Orthopedics and Fracture Repair. WB Saunders Company, Philadelphia, pp. 586-594.

Philip, D., Ameerjan, K., Thilagar, S and Archibald, WA. 1998. A retrospective study of bone and joint disorders in farm and pet animals. 22nd Indian Society for Veterinary Surgery Symposium, Bhubneshwar, 5-7 November, 20-22.

Rajhans, M. 2013. Stabilistion of splinters of long bone fracture in dogs. M.V.Sc. & A.H. thesis (Surgery and Radiology), Nanaji Deshmukh Veterinary Science University, Jabalpur.

Rovesti, GL. 2005. Delayed unions. In: AO principles of fracture management in the dog and cat. Edited by Johnson AL, Houlton JEF, Vannini R, Stuttgart: Thieme, pp. 394-402.

Schatzker, J. 2005. Introduction, AO philosophy and principles. In: AO principles of fracture management in the dog and cat. Georg ThiemeVerlag, New York, pp. 15-19.

Shahar, R. 2000. Relative stiffness and stress of type I and type II external fixators: Acrylic versus stainless steel connecting bars-a theoretical approach. Veterinary Surgery, 29(1): 59–69.

Schmokel, HG, Hurter, K and Schawalder, P. 2003. Percutaneous plating of tibial fractures in two dogs. Veterinary and Comparative Orthopaedics and Traumatology, 16: 191-195.

Schmokel, HG, Stein, S, Radhe, H, Hurter, K and Schawalder, P. 2007. Treatment of tibial fractures with plates using minimally invasive percutaneous osteosynthesis in dogs and cats. Journal of Small Animal Practice, 48:157-160.

Seguin, B, Harari, J, Wood,RD and Tillson, DM. 1997. Bone fracture and sequestration as complications of external skeletal fixation. Journal of Small Animal Practice, 38: 81-84.

Singh, AP. Mirakhur, KK. and Nigam, JMA. 1983. Study on the incidence and anatomical locations of fractures in canine, caprine, bovine, equine and camel. Indian Journal of Veterinary Surgery., 4(1): 61-66.

Singh, AP, Singh, GR and Singh, P. 1995. Fractures. In: Ruminant Surgery (1st ed.), Edited by Tyagi RPS and Singh J. CBS Publishers, New Delhi, pp. 365.

Singh, AP, Singh, G. and Singh, P. 2006. Fractures. Edited by Tyagi, RPS. and Singh, J., Ruminant Surgery. (1sted.). CBS Publishers and Distributers, New Delhi, pp. 344-345.

Singh, V, Dudi, PR, and Gahlot, TK. 2008. Clinical Study on Efficacy of Two Selected External Immobilisation Techniques for Long Bone Fracture Repair in Goats (Capra hircus). Intas Polivet, 9(1): 89-96.

Singh, R. 2015. Composite mesh guided tissue regeneration for fracture repair in dogs. Ph.D. thesis (Surgery and Radiology), Nanaji Deshmukh Veterinary Science University, Jabalpur.

Singh, D, Singh, R, Chandrapuria, VP. and Vaish, R. 2017. Occurrence Pattern of Different Types of Fracture in Bovine, Caprine and Canine. Journal of Animal Research, 7 (4):745-749.

Sissener, T. 2007. Principles of intramedullary pinning techniques in small animal practice. Companion Animal, 12:19-26.

Smith, CM and Sherman, DM. 2009. Goat Medicine (2nded.). Edited by Wiley-Blackwell, Iowa, p. 870.

Suresh, D, 2016. Clinical and radiographical evaluation of healing of fracture of long bones in goats treated with bioceramic implants. M.V.Sc Thesis, Faculty of Veterinary and Animal Sciences Kerala Veterinary and Animal Sciences University, Kerala.

Tambe, NY, Patel, TP, Mistry, JN, Patel, PB. and Patel JB. 2012. Retrospective study on the incidence of fractures in animals. Intas Polivet. 13(2): 364-366.

Thilagar, S and Balasubramaniam, NN. 1988. A retrospective study on the incidence and anatomical locations in 204 cases of fractures in dogs. Cheiron. 17: 68-71.

Thilagar, S, Ganesh TN, George RS, Radhakrishnana, C and Kuraresan, A. 2002. A retrospective study on fracture in ruminants. Indian Journal of Veterinary Surgery, 23: 70-71.

Tulleners, EP. 1996. Metacarpal and metatarsal fractures in cattle. Veterinary Clinics of North America: Food Animal Practice, 12: 199-200.

Vasseur, PB, Paul, HA and Crumley, L. 1984. Evaluation of fixation devices for prevention of rotation in transverse fractures of the canine femoral shaft: an in-vitro study. American Journal of Veterinary Research. 45: 1504-1507.

Venugopal, SK. 2015. AO/ASIF principles and techniques for fracture management. In: Souvenir cum Compendium on National Congress on Canine Practice; 17th to 19th June, 2015, Hotel KanhaShyam, Allahabad, India. 4:84-87.

Venugopalan, A. 2009. Essentials of veterinary surgery (8thed.). Oxford and IBH Publishing Co., New Delhi, pp. 166-173.

Whittick, WG. 1974. Canine orthopaedics. Edited by Lea and Febiger, Philadelphia, pp.66-67.

Wong, WT. 1984. A survey of fractures in the dog and cat in Malaysia. Veterinary Record, 115:273-274.

**Biography**

DR. Mir Md. Afzal Hossain is a candidate for the degree of MS in Surgery, under the department of Medicine and Surgery, Chittagong Veterinary and Animal Sciences University (CVASU). He has passed the Secondary School Certificate (SSC) in 2006 and then Higher Secondary Certificate (HSC) in 2008. He has obtained his Doctor of Veterinary Medicine (DVM) Degree in 2014 (held on 2015) from Chittagong Veterinary and Animal Sciences University (CVASU), Bangladesh. Now, He is working as Veterinary surgeon at Sahidul Alam Quadary Teaching Veterinary Hospital (SAQTVH) in Chittagong Veterinary and Animal Sciences University. He has published several scientific articles in national and international journals. He has great interest on small and large animal surgery.