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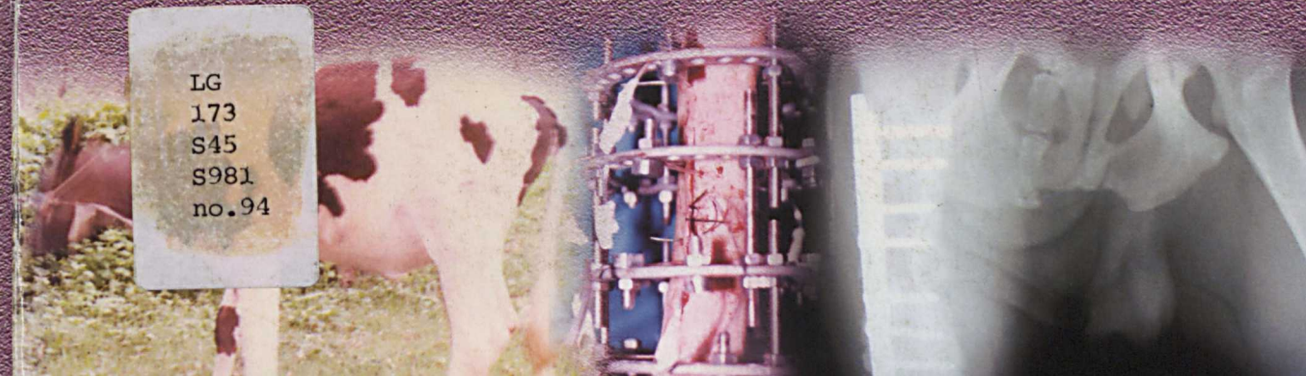
DEVELOPMENT AND INNOVATION IN THE FRACTURE MANAGEMENT OF ANIMALS

Prof. Dr. Sundararajan Thilagar



Diterbitkan di Malaysia oleh
Bahagian Komunikasi Korporat
Universiti Putra Malaysia
43400 UPM Serdang
Selangor, Malaysia

Tel : 603-8946 6003
Fax : 603-8948 7273
e-mail: cco@admin.upm.edu.my

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PROF. DR. SUNDARARAJAN THILAGAR

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S.THILAGAR

Prof.Dr.Sundararajan Thilagar was born in an agricultural family on 14th October 1954 in a village called Alangulam near Thiruppuvanam town of Sivagangai District (Tamilnadu-India). He obtained his B.V.Sc. and M.V.Sc. (Surgery) degrees from the Tamilnadu Agricultural University (India) in 1978 and 1983 respectively. He took his doctorate from the Tamil Nadu Veterinary and Animal Sciences University (India) in the year 1993.

Prof.Dr.S.Thilagar joined as Junior Manager (Veterinary) in the Tamilnadu Dairy Development Corporation, Ooty. Later in 1980, he joined his Almamater as Research associate in the Department of Clinics, Madras Veterinary College. Tamil Nadu Veterinary and Animal Sciences University. As faculty member he worked in various capacities. He became Professor of Surgery in 1994 and served as Head of the Department of Clinics, Veterinary College and Research institute, Namakkal and University Veterinary Teaching Hospital, Madhavaram Chennai. He was instrumental in developing the infrastructural facilities in these two hospitals. Later he worked as Professor and Head, Department of Clinics, Madras Veterinary College Chennai, India from 1999-2003. Prof. Dr.S.Thilagar is currently working as Professor in the Faculty of Veterinary Medicine, UPM since August 2003

Prof. Dr.S.Thilagar has worked in many research schemes particularly in a scheme on Embryo transfer in Goats, funded by the Govt. of Tamilnadu (India) and successfully produced first embryo transferred kids in 1989 the first of its kind in South India. His interest towards need based research in the field of Veterinary Sciences particularly in Veterinary surgery was the prime factor to obtain grants from different external funding agencies like ICAR, Ministry of Rural Development, Govt. of India for many research projects.

Prof.Dr.S.Thilagar had shown interest in the field of diagnosis of spinal injury since 1980 with focus on spinal injury patients and their rehabilitation. The unique opportunities enabled him to be associated in developing an ambulatory cart for a paralyzed cat which was recognized for publication in U.K. and India.

He has written a chapter in one book, co-authored 4 teaching manuals, and has authored 70 research and clinical papers both in national and international journals. Various authors in reputed journals have cited his papers. He has guided 3 M.V.Sc students, 1 MVM and two Ph.D (TANUVAS).Currently guiding one Ph.D student.

Prof.Dr.S.Thilagar is a recipient of the Maruthamuthu Mariyayee Best Teacher Award in 1995 from TANUVAS. For his outstanding Research Contribution in the field of contrast radiology (Myelography) and Rehabilitation Techniques for Handicapped and Veterinary Patients with Spinal Lesions in Veterinary Sciences, the Tamilnadu State Council for Science and Technology awarded TAMILNADU SCIENTIST AWARD (TANSA) for the year 1998 in the field of Veterinary Sciences and also later recognized as Fellow ISVS by the Indian society for veterinary surgery in 2004.

DEVELOPMENT AND INNOVATION IN THE FRACTURE MANAGEMENT OF ANIMALS

ABSTRACT

In the early 1920's, veterinary orthopedic cases were just managed with the help of external coaptation and external fixation devices. In many places conventionally trained persons and veterinarians carried out this practice. Subsquently after a better understanding of fracture biomechanism many internal fixation techniques, have been adopted in animals, providing good success rate of the fracture repair in veterinary practice.After the formation of AO/ASIF, fracture repair has branched out into many channels particularly in dogs ,cats ,horses and exotic pets. The availability of implants also facilitated the increasing demands from the animal owner to take these techniques.

The topic is discussed from the history of fracture repair, the status of its use in animals, classification of fracture, biomechanism of fracture, factors responsible for bone healing fracture, enhancing factor for fracture healing and different fixation techniques (both external and internal).

HISTORY OF VETERINARY ORTHOPEDICS

Earlier to 1920's orthopedic patients were mostly only fracture cases managed with plaster of paris, tripolith dressing, pitch and corn starch paste in small animals and Tar pitch in large animals. The first advancement in veterinary orthopedics came in 1920 when fluoroscopy and radiography of the skeleton was introduced. Each of these substances, were mixed with water and made into a paste that was used to saturate bandages of gauze, muslin and cheesecloth. The bandages were then wrapped over the cotton padding and supported with splints that were from material like wood tongue depressors, wire, gauze, cardboard, flexible wooden strips and bamboo.

In spite of improved traction and splinting techniques, the fluoroscope and radiographs revealed complicated fractures still resisted complete reduction and healed in a mal-aligned fashion. More sophisticated and adoptable methods were sought to achieve satisfactory results. Surgical intervention to the site of the injury was a feasible approach but the complication of sepsis was a common problem. Asepsis was achieved after the discovery of antibiotics against infection and the importance of sterilization in 1928 was the second breakthrough in the field of veterinary surgery including orthopedic surgery.

In 1940, a third breakthrough occurred that added confidence to successful fracture repair due to additional antibiotics. From 1940-1960 many fractured bones were stabilized with metallic materials such as piano wire, bicycle spokes wire, stainless steel rod and tantalum and processed animal tissues such as bovine bone and tendon were tried in the medullary cavity. The use of metallic and animal materials, encouraging as it was, brought new problems, primarily associated with tissue reaction, metal oxidation, and metal fatigue. In the mid 1960 bone plating become the successful technique after introduction of AO system of implant from Switzerland. Since then many types of implants were used in the field of veterinary orthopedics and its application is slowly spreading to pet animals, food animal, exotic pets and equine.

Veterinary orthopedics, which began as fracture repair enlarged into orthopedic disease of genetic origin, biomechanics and other many disciplines. The future should continue to expand the horizons of orthopedics. The humble beginnings can be traced to three major steps made by radiography, sterile technique and antibiotics. Further development in the field of orthopedics is mainly due to the establishment of AO.

STATUS OF FRACTURE REPAIR IN ANIMAL SPECIES

Dogs and cats: Fractures in dogs and cats are easy to repair hence many internal and external fixations are primarily adopted in dogs and cats and applied in practice. Pet owners are demanding best suitable techniques in recent days, thus providing a strong platform for the field of veterinary orthopedics to grow further. Many innovative methods are feasible in small animals.

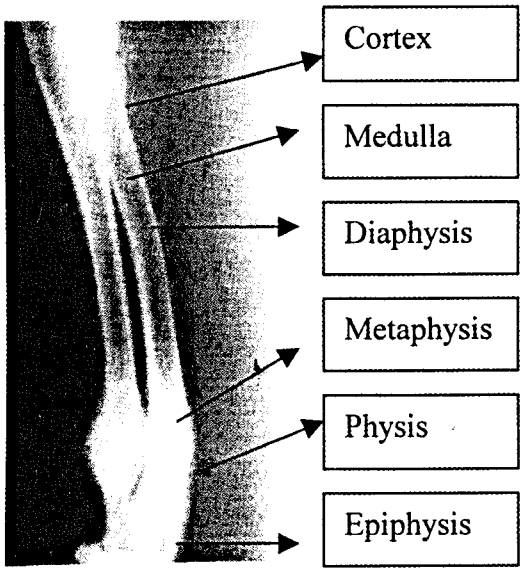
Equines: Equine fractures are more difficult to repair and heal more slowly. As recently as 30 years ago, most horses with severe fractures were euthanized or, at best, retired, largely because you couldn't ask a horse to stay in bed or use crutches to keep his weight off of a fracture while it healed. Today, internal fixation, using screws and bone plates, permits a horse to stand on a broken leg while it heals, often making previously life-threatening fractures treatable. Additionally, new anesthetics and methods of bringing a horse out of anesthesia greatly reduce the probability of developing new fractures and re-fractures during recovery. However, it's still an anxious time when a horse whose fracture has just been repaired gets to his feet.

Due to increasing competitive intensity, fractured legs in performance horses are more common than ever. The chance of a successful repair often depends largely on how the horse is handled before he gets to the operating table. If a horse is forced to walk on the broken bone or if he's transported to the hospital without a proper splint, what began, as a relatively simple fracture might be irreparable.

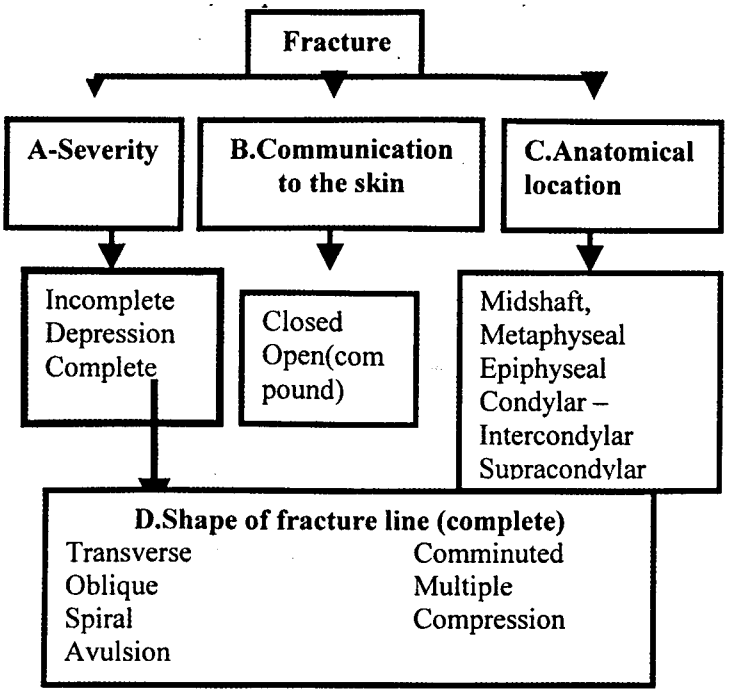
Farm Animals: In the past simple forms of orthopedic treatments have been used to treat long bone fractures in farm animals. In the last decade three major factors have advanced ruminant orthopedics better understanding of bone physiology and biomechanics, related fracture repair, the availability of implants and equipments to treat animals. This has increased the scope of mechanical support by internal fixation techniques in appropriate situation. More than that the economic value and potential of skeletal ruminants have increased due to advances in assisted reproduction technology and clients have demanded that conditions once thought irreparable be treated.

Exotic Pets: Exotic pets represent a very heterogeneous group of species involving mammals, birds and reptiles. The increasing numbers have resulted in many veterinarians to specialize on their treatment in traumatic injury. In smaller patients (less than 100gm) bandages, splints may be the only method for fracture repair method. Surgical methods are frequently used in larger patients weighing more than 100gms.

Bone anatomy: The structures like cortex, medulla, and the anatomical region called diaphysis, metaphysis, physis and epiphysis are very important structures thus plays vital part in fracture repair management and as well as choosing right fixation techniques. Cortex is the outer layer of the bone which is thin in food animals compare to other animals. Animals having thick cortex is ideal patients for internal fixation techniques. Physis is part to be considered in immature animals fracture repair to avoid any further damage to growth plate thus may affect the growth of an animal. All these information were concluded from much innovative research study.



Classification of fractures: Fractures in animals are classified and described based on the communication to the skin and bone, shape of the fracture lines, anatomical location of the fracture and severity. This classification is self explanatory to match the suitable techniques of fixation, which is suited for the cases. The genesis of the classification is also a result of many fracture repair techniques applied in animals.



Incidence of fracture:

***In dogs*:** Regarding the incidences of bones involved, fracture of radius and ulna was more prevalent (31.9%) followed by that of tibia and fibula (31.9%) and femur (14.7%) Thilagar et al., (1988) *(Table1)*.Similar pattern was recorded by Archibald , (1974).

In Food animal (Ruminant) Metacarpus fractures are the most common ones seen in ruminants. Metacarpus and metatarsus fractures comprise 50% of all. The incidence of long bone fractures were metatarsus (28.2%), metacarpus (26%) and tibia (14.6%) Thilagar et al .,2003b) *(Table 2)* Similar pattern of incidence was also observed by Ferguson, (1982); Dass et al., (1985) and Aithal,(1999) Higher incidence of fractures in distal bones of the limbs is probably attributed to less soft tissue coverage and vulnerability to fracture during automobile accidents.

In horse: Distal limb is the most commonly affected site in all types of race particularly metacarpal and metatarsal bone (Nixen ,1986 and Mc Kee,1995)

Principles of fracture fixation: The following principles are important in fracture management and considered to be vital which generated many new innovative methods in fracture repair in animals

- Anatomic reduction of fracture fragments
- Stable fixation
- Preservation of blood supply to the bony fragments and surrounding soft tissues
- Early active pain free mobilization of the muscles and joints

Table 1: Incidence of fractures in dogs (percentage) in relation to bone and locations (S.Thilagar et. al. 1988)

Bone involved	Right				Left				
	Upper third	Middle third	Lower third	Total	Upper third	Middle third	Lower third	Total	Grand total
Radius ulna	1(2.6%)	26(66.6%0	12(30.8%)	39(61.0%)	2(8.0%)	15(60.0%)	8(32.0%)	25(39%)	64(31.9%)
Tibia fibula	3(10.7%)	8(18.6%)	17(60.7%)	28(45.2%)	4(11.8%)	14(41.2%)	16(47.0%)	34(48%)	62(31.9%)
Femur	4(33.3%)	5(41.7%)	3(25.0%)	12(40.0%)	1(5.6%)	6(33.3%)	11(61.1%)	18(60%)	30(14.7%)
Humerus	-	3(60.0%)	2(40.0%)	5(55.6%)	0	3(75.0%)	1(25.50%)	4(44.4%)	9(4.4%)
Pelvis	-	-	-	-	-	-	-	-	12(5.9%)
Metacarpal	-	-	-	6	-	-	-	-	6(2.9%)
Metatarsal	-	-	-	1	-	-	-	2	3(1.5%)
Patella	-	-	-	1	-	-	-	-	1(0.5%)
Digits	-	-=	-	-	-	-	-	1	1(0.5%)

Table 2: Incidence of fractures based on the type in ruminants (S.Thilagar et al 2003b,)

Limb	Bone Involved	Caprine				Bovine			
		Transverse	Oblique	Comm inuted		Transverse	Oblique	Comminuted	Total
Fore Limb	Humerus	2	8	-	10	1	3	-	4
	Radius &Ulna	19	11	-	30	4	2	-	6
	Metacarpus	18	16	24	58	1	3	9	13
Hind Limb	Femur	5	12	3	20	-	2	3	5
	Tibia& Fibula	4	10	8	22	2	5	7	14
	Metatarsus	4	13	27	44	7	4	9	20
Total		52	70	62	184	15	19	28	62
Percentage		28.3	38.0	33.7		24.2	30.6	45.2	

Types of bone fracture forces:

Tension, compression, bending and rotation are the forces to be considered by the surgeon in choosing an implant for fixation. The primary forces present may vary with the location and extent of the fracture. In many occasions implants must be combined to adequately counter all forces in a specific fracture.

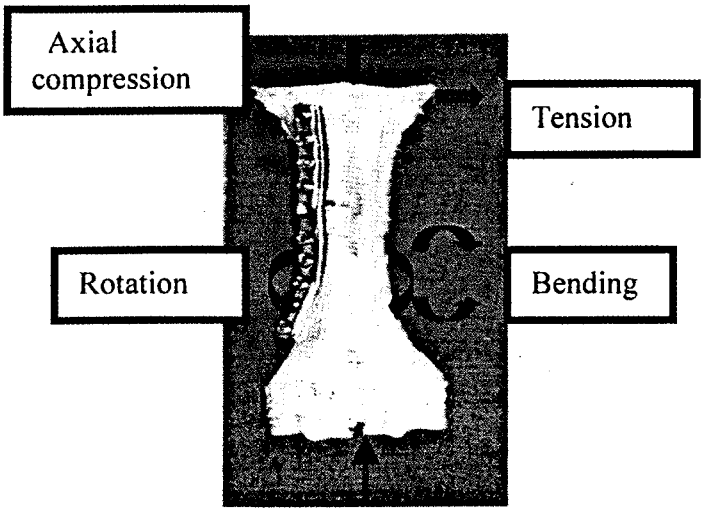


Figure 1. Types forces that are seen at fracture site

Goals of fracture fixation

The goals of fracture treatment are to encourage quick healing, restore function to affected bone and its associated surrounding soft tissues and obtain a cosmetically acceptable appearance. Before selecting treatment regimens and fixation devices, the criteria of a-Early ambulation and b-Complete return of the affected part to function is focused in fracture repair and its management.

Fracture healing:

Fracture healing varies depending on biological and mechanical factors that influence the sequence of cellular events occurring in fracture healing. The biological factors are fracture location which can be given as in cortical bone, cancellous bone, physeal cartilage and circulation and tissue injury. The mechanical factors mean the stability of bone segments and fragments after fixation device placement. For the sake of simplicity, fracture healing can be divided into three phases as *inflammatory phase*, reparative *phase* and *remodeling phase.*

Inflammatory phase: After fracture the blood vessels at the fracture site get damaged which results in blood clot formation and necrosis of the bone at the fracture site due to osteoclast death. This provokes migration of polymorph nuclear leukocytes followed by macrophages.

Reparative phase: Formation of Collagen, cartilage and bone. New bone is formed at the subperiosteal region and cartilage in other areas

Remodelling phase: Remodelling phase takes place for prolonged time. The cellular module that controls remodeling resorption unit, consisting of osteoclast followed by osteoblast which resorb bone and establish haversian systems

Factors that influence Fracture healing:

Fracture healing can be modified by any endogenous or exogenous factor that has on influence on the metabolic function of cells. The external factors are

a- The degree of local trauma
b- Degree of bone loss
c- The type of bone (cortical and cancellous)
d- Degree of immobilization and Infections
f- Local malignancy in the bone
g- Local pathogenic non malignancy lesions
h- Avascular necrosis
i- Intraarticular fracture-fibrinolysis of synovial fluid

New Innovation in Bone healing: Delayed union and Non-union are the complication in cases of interruption in the healing process. Einhorn, (1995) observed that 10% of the fracture would necessitate further surgical procedure because of non-healing and bone defect. Management of such bone defect by Autologus bone cancellous bone graft replaced by alternative treatments by physical or biological methods for the past 35 years.

Two approaches are being practiced with regards to enhancing bone healing. The ***physical strategy*** includes the use of mechanical stimulation, electromagnetic fields, and low intensity ultrasound.

The ***biological approach*** involves the use of **osteoconductive biomaterials, osteoinductive biomaterials** comprising a combination of growth regulatory molecules with carriers and **osteogenic biomaterials** made of scaffold seeded with osteocompetent cells. (i) The osteoconductive materials are calcium based ceramics-hydroxyapatite, tricalcium phosphate, bioactive glasses and natural coral exoskeleton derived from marine reefs-Calcium carbonate. These materials are found to be unsuitable for large defects of bone in clinical scenario. (ii) Osteoinductive materials growth factors which stimulate tissue repair which originate from the blood clot and bone. Platelet derived growth factors

(PDGF) and TGF-β are derived from the clot. The growth factors includes BMPs (h-BMP, rh-BMP2, 7), TGF-β, PDGF IGF-IIGF-II and basic and acidic fibroblast growth factors are released from the bone matrix. These materials are also found to be suitable for large segmental defects of bone in clinical scenario. Carriers;Poly ±-polyhydroxyester foams(polyglycolic and polylactic acids(PGA-PLA),collagen, alginate or calcium phosphate polymers) are used as carriers for the growth promoters.(iii)Osteogenic materials composed of a scaffold loaded with osteocompetent cells like bone marrow stromal fibroblast(BMSF) are experimented. Delivered using many carriers and useful even for necrotic areas and larger defects. (Hannouche et al .,2001)

Different methods of fixation of fractures

All fixations procedures are classified under these three categories.

I Limb splinatge: Limb splintage is a method applying or splinting externally ex: Coaptation splints, casts, modified Thomas splint. First to introduce in veterinary practice still in use especially in food animals and few other animals having stable fracture and transverse fractures without much deviation.

II-Bone splintage: Method in which implants are either inserted in to the medullary canal or applied on the periosteum to stabilize the fracture ends ex: Intramedullary pin, external skeletal fixator, bone plate

III-Compression: This Technique is usually used as additional fixation procedure with other splintage techniques in order to counteract all fracture forces.ex:lag screw, cerclage/ inter fragmentary wire, tension band wire and compression plate.

Effect of Fracture forces for different techniques:

The table furnished under(Table3) gives an idea how these techniques counter the different forces of bone fracture .Choosing the techniques is based on the benefits of forces can be nullified not by the facilities available in the hospital. Recent concept is to adopt suitable techniques by considering and giving maximum benefits for the fracture case.

Table3- Effect of Fracture forces against different fixation techniques: Forces Not neutralize (-) =Forces neutralize (+)

Types of of fixation	Types of techniques	Forces				
		Compression	shear	Bending	Tension	Rotational
I-Limb Splintage	Coaptation devices	-	-	+	-	+
II-Bone Splinatage	Intramedullary pin	-	-	+	-	
	Multiple pin	-	-	+	-	+
	Interlock nail	+	+	+	+	+
	Bone plate	+	+	+	+	+
	External fixator	+	+	+	+	+
III-Compression fixation	Lag screw, cerclage wire, screws	+	+	+	+	+

I-External coaptation: External coaptation in the form of cast/splints is commonly applied in ruminant and equine fracture patients but less used in pet animal fracture cases. External coaptation is used as temporary stabilization and at times for permanent for much long bone fracture in these animals .Casts alone provide minimal axial stability, motion at a fracture site secondary to weight bearing can result in fragment displacement, collapse, prolonged pain and delayed healing (Adams and Fessler, 2000).Due to its less cost, this technique is still practiced in cattle and horses and exotic pets.

Cast material:ex: Fiberglass cast, plaster of paris,poly urethane impregnated fiberglass cast Thomas splint cast combination .*Splinte*:ex. PVC splint -The prognosis for long term, pain free survival is excellent for closed fracture and fair for open fractures managed in this manner. The callous forming result of external cooptation is abundant compared to other fixation technique (Deepu Philip Mathew et. al ., 2005)

Figure 2. Fracture limb immobilized with PVC splint and callus formed

Half limb cast with transfixation. Transfixation casts or so called walking casts ,are useful for providing increased axial stability over that provided by external coaptation alone.Transfixation provides ,a method for transferring weight form the proximal skeleton to the cast thus unloading the bone in the distal portion of the limb. Casts with transfixation are useful for severely comminuted fracture. Positive profile centrally threaded 1/4 inch –diameter pins can be used in ruminants and horses weighing 200kg (Adams and Fessler, 2000).and Fubini and Ducharme, 2004)

External skeletal fixation devices: External skeletal devices can be used in cases of fractures involving all long bones, the mandible, and for bridging joints. Useful particularly in stable, unstable fracture, open fracture, osteotomies and fixation delayed union and nonunion fractures, arthrodesis of certain joints and stabilization of certain joints following ligament or tendon reconstruction Stability is achieved through the use of multiple percutaneous transcortical pins interconnected externally to form a rigid frame. External fixation is more commonly practiced in ruminants and small animals than in horses,

because pins strong enough to bear a horse's weight often require drilling excessively large holes in the bones.

i-Linear fixator

Type 1A one plane unilateral (half –pin splint or unilateral frame). The pins only pass through one skin surface but penetrate both cortices. Minimum of two pins per fragment are used attached to the same connecting bar or some times connected to a second connecting bar by extending the pin which provides more strength..

Type II Bilateral one plane (full pin splintage or bilateral frame). The pins pass through the skin, both cortices and through the skin on the opposite side of the limb. The pins are connected to the bars on each side of the limb (two bars) useful in radius /ulna and tibia. Not useful for femur and humerus due to interference of the medial bar.

Type III bilateral two planes (three dimensional/two –plane bilateral frames). Is on in which it consists of a type II splint (full pin splint) with a half splint applied to the anterior side of the bone at 90 degrees to the full pin splint

ii-Ring fixator (complete/partial): Flexible kirshner wires are used as fixation pins. The rings are connected one to the next by several threaded connecting bars. Ring fixators are a used to construct limb lengthening procedures, corrective osteotomies and multiple piece fractures. In a detailed study on transverse fractures firm bridging with moderate external callus of the defect with cartilaginous cells and adequate vascularization was observed in dogs (Chaudari et.al., 1997) and in ruminants (Olkay et al. 1999 and Deepu Philip Mathews 2005).

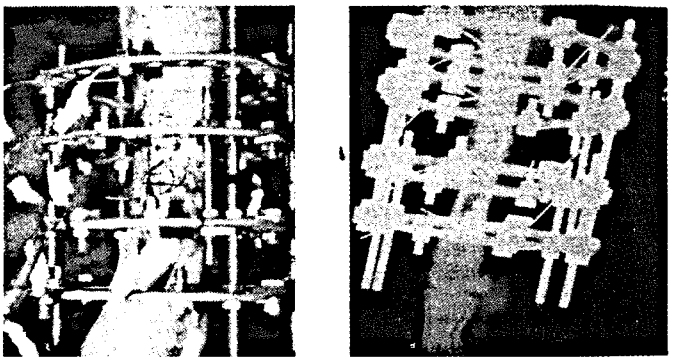


Figure 3. Ring fixator for metacarpal fracture repair in a calf

Internal fixation:

Implant materials: Materials that are implanted for internal fixation should be strong, ductile, wear and fatigue resistant, to, maintain fixation, i.e. maintain mechanical

properties during the healing period, be chemically stable for a given period, should not cause allergy and should not affect the infection resistance of the tissue or the organism. Metals, their alloys, polymers, ceramics and composites are the materials used for construction of implants .Since 1900 the metals are used Stainless steel. Titanium Alloy. Cobalt Chrome and Shape memory materials.

In 1926. 18% chromium, 8% nickel stainless steel was introduced into surgical applications. Which was more corrosion resistant for body fluids than the vanadium steel initially introduced by Sherman for his fracture fixation plates. Later in 1926, 18-8SMo stainless steel, which contained a small percentage of molybdenum, to improve the corrosion resistance in salt water, was introduced. This alloy became known as 316 stainless steel. The next alloy to be introduced into orthopedic practice was titanium and its alloys. In 1947 possible applications for titanium surgical implants were considered Titanium's lightness and good mechanical and chemical properties are salient features for implant applications .Bone plates can also be fabricated using shape memory alloys, in particular nickel titanium. Using a bone plate made out of NiTi surgeons follow the same procedure as is used with conventional bone plates.

Composites: Bone plates made of braided composites, because of their low stiffness, is subjected to considerable strain when subjected to loading. If the magnitude of strain is large, it is possible that matrix and fibre could experience relative displacement leading to fracture Because of the disadvantages of metallic fixation the use of bio-absorbable devices in bone fracture fixation was suggested already in 1960's. Such devices retain their strength several weeks or months in vivo, support the healing fracture and are finally metabolized after fracture healing.

The advantages of bioabsorbable implants in bone surgery are significant: there is no need for removal operation, and osteoporosis associated with rigid metallic implants can be avoided or at least reduced and the bone itself heals better. The avoidance of removal procedures leads to financial benefits, psychological advantages, and it increases operative capacity .The main disadvantage of current biodegradable materials is the premature loss of mechanical properties before the healing process is complete. In addition PLGA undergoes an autocatalytic degradation process which results in an accelerated degradation that leads to hollowing of the implant and its catastrophic failure Although several composite bone plates were developed using UD laminates and discontinuous short fibers to serve as alternatives for the conventional stainless-steel AO compression plates, there still remain a number of improvements to be addressed from a mechanical viewpoint.

Intramedullary Fixation. Intramedullary pins (or Nail) fixation for fracture treatment in small animals started in the 1940 slowly gained popularity this techniques are the most common type of internal fixation(Brinker et al.,1997) Pins do not counteract rotational forces or shear forces, and the cortices of avian bones are quite thin so they don't provide much purchase to hold IM pins. Additional methods of internal fixation may be utilized

in addition to the IM pin to help counteract rotation and shear forces. Cerclage and hemicerclage wires, external fixators or stack pinning may all be employed. Cross pins may be used to stabilize metaphyseal fractures. Pins like Steinmann pins, Kirshner wires, Rush pin Kuntscher nail and interlocking nails have been used in animals. Rush Pins and kuntscher and interlocking nails (6mm diameter) are that not commonly practiced due its demerits.

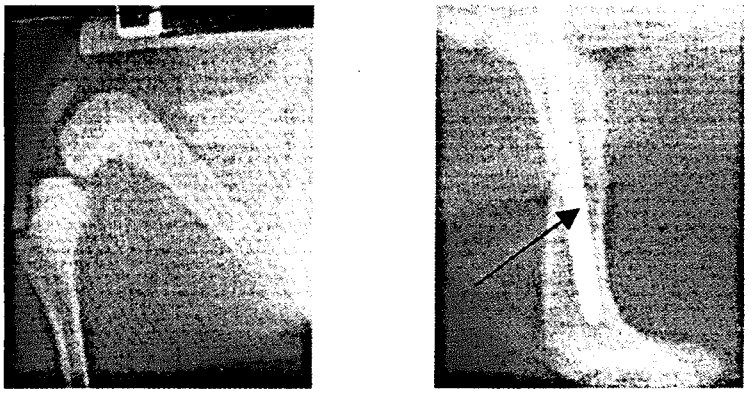


Figure 4. Radiograph of a transverse femur fracture immobilized with IM pin in a dog

Interlocking nails: Since early 1950 various improved IN have been developed for treating long bone fractures in dogs.(Tass Dueland et. al., 1999). Large diameter pins are inserted in the medullary cavity of fractured bone and locked in place by using screws placed perpendicularly through the cortex, pin and other cortex. Screw is inserted proximally and distally. More applicable in femur, humerus and tibia (long bones).Fixation of Diaphyseal fractures with IN provides stability against axial, bending and torsional loads. This technique overcomes rotational stability and pin migration and collapse of comminuted fracture during weight bearing when compared to intramedullary pinning.

Cross pinning: Cross pinning affords rigid stabilization of the fracture segments by providing multiple pins and varying angles of fixation. This technique is applicable to metaphyseal fracture more commonly in pet animals because of the cancellous nature of the bone, the broad contact area between opposing segments, and the close proximity of the fracture to the articular surfaces. The frequency of fractures at this location has been attributed to the inherent weakness of the metaphyseal growth plate relative to the adjacent ligaments and osseous structures (Salter and Harris, 1963; Alcantara and Stead, 1975).

At least two small Steinmann pins or kirschner wires are used to stabilize the fracture. This technique provides excellent result of distal femoral physeal fracture in canine and feline patients. With minimal hardware implantation, axial and rotational stability is achieved. Both K-wires and intramedullary pin have been used as cross pin in immature dogs and cats (Northway, 1973., Sumner Smith and Dingwall, 1973., Milton et al., 1980.,

Hardi and Chambers 1984) .The diameter of the trocar pointed intramedullary Steinmann pins used in these cats varied from 1.6mm-1.8mm in diameter.(Thilagar et .al., 2006)

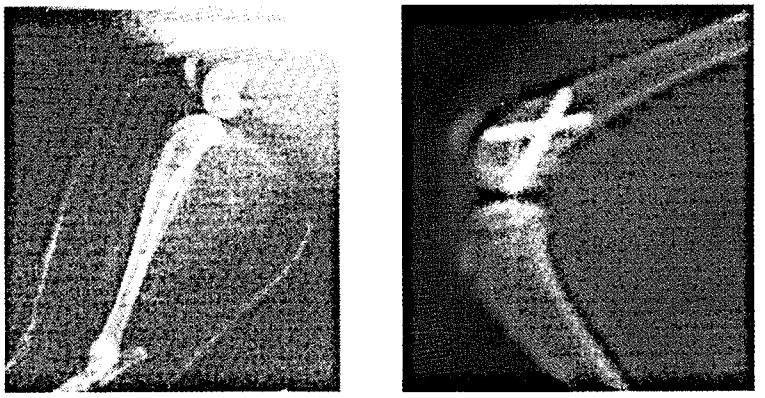


Figure 5. Lateral radiograph of Salter Haris type fracture in a cat immobilized using two small IM pin

TENSION BAND WIRE AND SCREWS

This technique is used to neutralize the distracting forces placed on certain fractured bones and bony prominences in dogs and cats. Act as compression forces against distraction forces (Schatzker,1991).Useful in cases osteotomies of the olecranon process, trochanter major (Excision arthroplasty), fractures of the tubercalcis, medial and lateral tibial maleolli and a detached tibial tuberosity.The K-wires- neutralize shearing forces and the tension band wire neutralize bending loads and distraction forces. The fracture or osteotomy segments or reduced and the K-wires are passed through the segment, across the fracture line and into the main portion of the bone. These two wires are passed in parallel to each other as possible. Then a transverse hole is drilled such that a figure of eight wire will cross at or just distal to the fracture line. The orthopedic wire is then passed through the hole and around the protruding tips of the K-wires in a figure of eight pattern and the wire is tightened. This Technique provides better stability and osteosynthesis when compared to screws for fractures certain bones and bony prominences (Annie Philip, 1994).

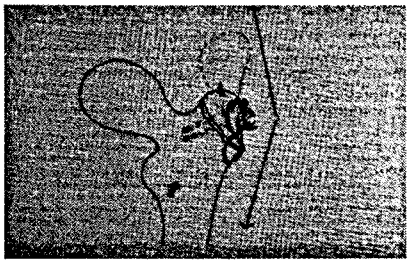


Figure 6. Schematic diagram of Tension band techniques.

Lag Screws are passed from the fracture segments to the main segment either using washer or without washer. This technique is useful in small and larger animals. Both techniques offer perfect stabilization but the breakage of small fragments was observed while using screws for avulsion fractures.

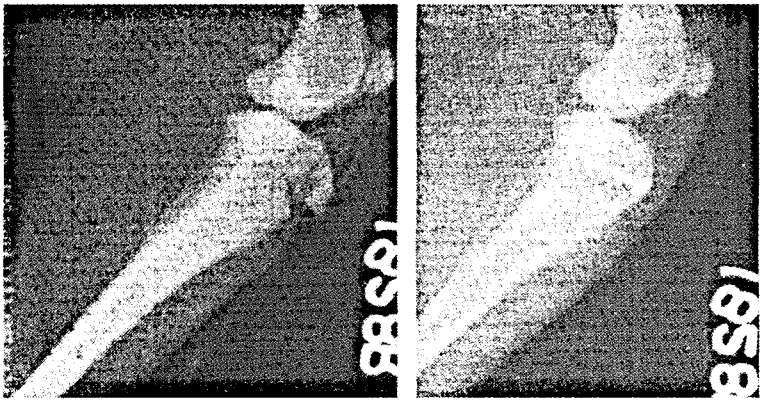


Figure 7. Tibial tuberosity avulsion immobilized using lag screw in a dog

Orthopedic wire:

Cerclage means to encircle or wrap into bundle. The orthopedic wires must be placed as tightly as possible around the bone and not entrap soft tissue (muscle, nerve, vessels) between the wire and the bone. Loose wire may not provide a stable fixation and disrupt the periosteal vascularity needed for fracture healing. useful in small animal. This technique refers to a flexible wire that completely (cerclage) or partially (hemicerclage) passes around the circumference of a fractured bone and then is tightened to provide static interfragmentary compression of bone fragments. It is always used with other method of fixation on any type of diaphyseal fracture. In general, cerclage wire for the fixation of fracture fragments should be placed approximately 5mm form the ends of the fragments and 1cm from each other.

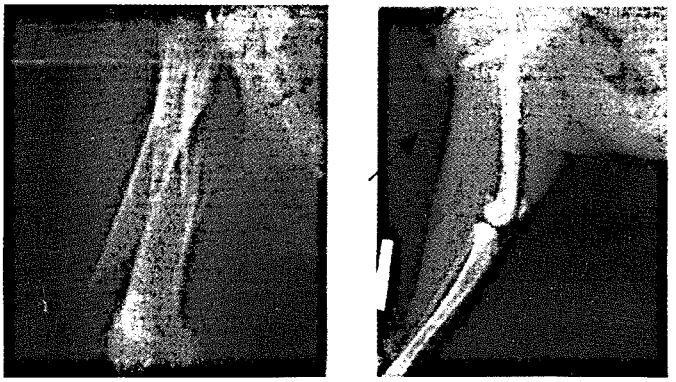


Figure 8. Comminuted fracture repaired using cerclage wire and IM pin in cat

Interfragmenatry compression: Compression in-between the separated fragments can be achieved by wires and position screws *Interfragmentary compression by wires* is commonly practiced in small animals. Utilized i-to prevent rotation of short oblique or transverse fracture. ii-to secure bone fragments.iii-to stabilize fissure fractures wires does not circle the bone. This is the least secure and consistent form of internal fixation. It should be reserved for smaller dogs and cats. This can be combined with transfixation pin to achieve rotational stability .The cruciate and horizontal mattress patterns are more effective in preventing rotational forces. (Blass et al.,1985).

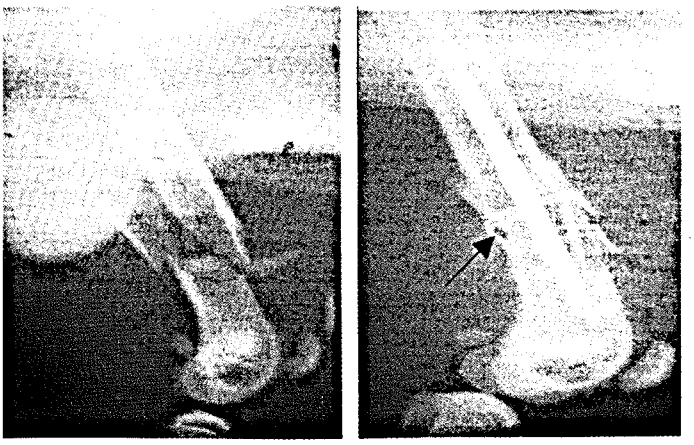


Figure 9. Mulitple fracture of femur in a young dog immobilized with IM pin, cerclage wire and Interfragmentary wire

Interfrgamentary compression by bone screws: In dogs and cats interfragmentary compression by lag screw and position screws are routinely practiced to compress ephiphyseal, metaphyseal and diphyseal fragments. Both cortical and cancellous screws are used. In large animals it is not that commonly practiced since ruminant neonatal bones have a low bone density and thin bone cortices and their ability to support and sustain implants such as intramedullary pins and screws is a primary concern .Recent studies have evaluated various screws holding power in calf bones (Kirpenstein et. al., 1992; Thilagar et al., 2003a and Thilagar et al., 2005) and proved effective in stabilization.

BONE PLATE

Bone plates are adaptable to most long bone fracture, multiple complex fractures post operative complicated fractures. The species more involved is dogs, followed by horses and ruminants. Not much preferred in young animals. Few reports are available on the usage of plates (0.7mm) plates with 0.25mm screws in exotic pets. but not widely practiced. Bone plate can counter all the forces created at the fracture site. Many types of bone plates are available ex C shaped for acetabulam, T shapes mini for lower radius ulna, Least Dynamic Compression plates.The use of Bone plate is depends on the body weight

of an animal. Various size of Single plate application is possible in cases weighing below 60 kgs.(Brinker et.al., 1997) .The animal weighing heavily (horse ,cattle) requires double plating and the outcome of the results are very good in animals weighing below 200kg in horses (Auer.1999 and in small size ruminants (goats -cattle) (Fessler and Adam,1985; Tulleners 1986;Thilagar et.al, 2003a Thilagar et.al. 2005) .Current use of LCDCP(Least contact dynamic compression plate gives better results compared to DCP in experimental studies because less contact to the cortex.

Principle of bone plate fixation:
Plates should be applied to the tension side of the bone

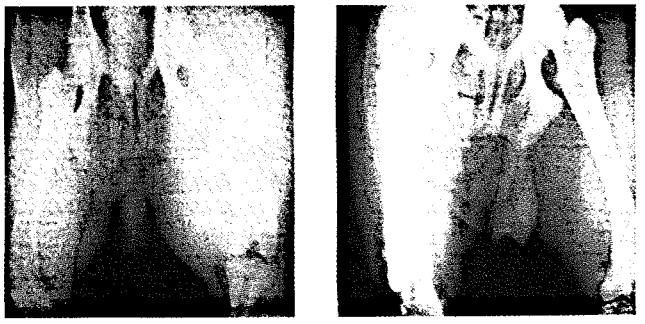
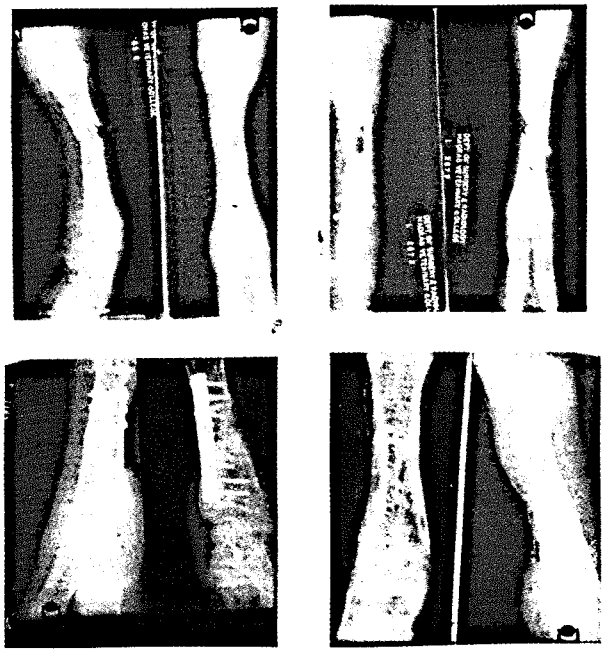


Figure 10. 8holes DCP in a dog (45kg) for a transverse fracture of femur



Post operative 90 days Post implant removal

Figure 11. DCP (Butterfly) in a calf (80Kg) for a comminuted fracture of metatarsus and position screw (S.Thilagar et al 2005)

Minimum of two screws (four cortices) should be used on each side (proximal and distal) of the fracture in small animals but three to four screws is ideal for compression and neutralization plates and mandatory for bridging plate. The Minimum distance between fracture lines and screws is 4-5mm or at least equal to the diameter of the screw. Long plate is more effective than the short plate or plate just short of the entire length of the bone.Plate should be applied and contoured to the bone surface very closely i.e. 1mm gap.

Plate function:Bone plate can be applied as a ***compression plate, neutralization plate or a buttress plate.*** In compression plate the fracture fragments are fixed by compression. Specially designed screw holes that allow compression of the bone if the screw is inserted. Neutralization plates is applied to the fracture bone to have neutralization effect, main fragments are rigidly fixed usually with screw. Buttress plate is used shore up the fragment of bone thus maintaining length and functional angle.

Bone plate removal: It is better to remove the plate after some period which varies based on the age of the animal. In veterinary practice response to the removal of plate is poor.

Animal age	Post operative period
0-3months	4 weeks
3-6months	2-3months
6-12months	3-5months
Above 1 year	5-14months

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