الجمهورية الجزائرية الديمقراطية الشعبية
Democratic and Popular Republic of Algeria / République Algérienne Démocratique et Populaire
وزارة التعليم العالي والبحث العلمــي
Ministry of Higher Education and Scientific Research
Ministère de l'Enseignement Supérieur et de la Recherche Scientifique
المدرســـة الوطنيـــة العليـــا للبيطــرة ربيع بوشامة
Higher National Veterinary School Rabie Bouchama
École Nationale Supérieure Vétérinaire Rabie Bouchama

N° d'ordre : 053

Projet de fin d'études

En vue de l'obtention du diplôme de **Docteur Vétérinaire**
Domaine : Sciences de la Nature et de la Vie
Filière : Sciences Vétérinaires

THÈME

Management and Treatment of Tibial and Fibular Fractures in Dogs: A Veterinary Perspective

Présenté par :
Bahri Mohammed Rami

Soutenu publiquement, le 03/07/2025 devant le jury composé de :

Dr. Baazizi R	MCA	Présidente
Dr. Bouabdallah R	MCA	Promotrice
Dr. Ghaoui H	MCB	Examinateur

Année universitaire: 2024 / 2025

Acknowledgements

I would like to express my deepest gratitude to **Dr. Bouabdallah**, whose exceptional mentorship, invaluable insights, and consistent encouragement were instrumental in shaping this capstone project. His expertise and dedication significantly guided my research and understanding.

My sincere thanks also extend to the faculty and staff of the veterinary department for providing an inspiring academic environment, crucial resources, and the knowledge foundation upon which this work is built.

A very special acknowledgement goes to the VALHALLA crew (l7pép, Alilou, Smailo, Rouj, Ro). Your unwavering support, both moral and physical, at every step of this project was truly indispensable. Your camaraderie and encouragement made the challenging moments manageable.

Finally, I am grateful to all friends, colleagues, and individuals who, directly or indirectly, contributed to the successful completion of this endeavor. Your collective support has been invaluable.

Dedication

This work is profoundly dedicated to my cherished family, whose unwavering support, enduring patience, and boundless love have been the constant pillars throughout my academic journey. Their belief in my potential has fueled my perseverance, and their sacrifices have made this achievement possible.

BAHRI Mohammed Rami

List of Figures

Figure 1: Left tibia and fibula articulated, lateral aspect (Hermanson et al., 2019). 3
Figure 2: Left tibia and fibula articulated, cranial aspect (Hermanson et al., 2019). 4
Figure 3: Left tibia and fibula disarticulated, caudal aspect (Hermanson et al., 2019). 5
Figure 4: Left tarsus, articulated, craniolateral aspect (Hermanson et al., 2019). 7
Figure 5: Schematic transverse section through left crus (Hermanson et al., 2019). 11
Figure 6: Muscles of left crus. **A**, Superficial muscles, cranial aspect. **B**, Superficial muscles, lateral aspect. **C**, Deep muscles, cranial lateral aspect. **D**, Deep muscles, lateral aspect (Hermanson et al., 2019). 11
Figure 7: Muscles of left crus. **A**, Deep muscles, caudal aspect. **B**, Tibialis caudalis, caudal aspect. **C**, Muscles of crus at stifle joint, lateral aspect. **D**, Muscles of crus, medial aspect (Hermanson et al., 2019). 12
Figure 8: Left crus after removal of the gastrocnemius muscle: caudal view (Done et al., 2009). 15
Figure 9: Left leg after removal of the superficial digital flexor muscle: caudal view (Done et al., 2009). 15
Figure 10: Diagram of the arteries of the pelvis and thigh, medial aspect (Hermanson et al., 2019) 16
Figure 11: Veins of the pelvic limb, medial view (Hermanson et al., 2019). 17
Figure 12: Nerves, arteries, and muscles of the right leg, lateral aspect (Hermanson et al., 2019). 18
Figure 13: Diaphyseal fractures of the tibia. **A**, Simple or incomplete. **A1**, Incomplete tibial or fibula intact; **A2**, Simple oblique tibial; **A3**, Simple transverse tibial. **B**, Tibial wedges. **B1**, One reducible wedge; **B2**, Reducible wedges; **B3**, Nonreducible wedges. **C**, Tibial complex. **C1**, Reducible wedges; **C2**, Segmental; **C3**, Nonreducible wedges (DeCamp et al., 2016). 23
Figure 14: Algorithm for lameness investigation (Scott., 2018). 29
Figure 15: The Fracture Patient Assessment Score (FPAS) (Abercromby., 2016). 32
Figure 16: Optimal splint or cast length for fractures in the dark-shaded areas are shown by the length of the light-shaded areas (DeCamp et al., 2016). 38
Figure 17: Application of the cotton for this heavily padded bandage for the large dog is simplified by splitting Robert-Jones bandage. a 1-pound roll of cotton into two narrower ½-pound rolls. Cast padding may be used in a similar fashion for smaller dogs and cats. **A-C**, Adhesive tape stirrups have been applied to the lower limb and are used for traction while cotton is spiraled proximally. The cotton is carried as high as possible into the groin. One-half to 2 pounds of cotton are necessary to complete the padding, depending on the size of the animal. **D-E**, Multiple spiral layers of elastic gauze are used to compress and conform the cotton. Although firmness is desired, care must be taken not to overtighten the layers in smaller animals. **F**, The bandage is finished by covering the compressed cotton with a protective layer. If desired,

additional stability can be obtained by bending an aluminum splint rod to conform to the Robert-Jones bandage, or strips of fiberglass casting tape or moldable plastic could be used. This splint material is placed before covering the bandage with the protective layer. **G**, The bandage should extend fully to the end of the foot, leaving access to the two middle toes for assessment (DeCamp et al., 2016). 44

Figure 18: Open reduction of fractures. **A** and **B**, Direct application of force to the bone fragments. **C**, Oblique fracture overriding can be reduced by grasping the fragments with a bone holding forceps that is angulated so that each jaw is toward the end of the bone fragment. The forceps is not locked but held by finger pressure only. **D**, By rotating the forceps in the direction shown in C while applying enough pressure to cause the forceps to grasp the cortex, the fragments will slide into reduction. **E**, After reduction, a locking bone-holding forceps is used to maintain temporary reduction of the fragments while fixation is applied (DeCamp et al., 2016). 46

Figure 19: Intramedullary (IM) pinning technique for the tibia. **A**, Transverse fracture of the tibia. **B**, End-on view of the proximal aspect of the left tibia showing both menisci, meniscotibial ligaments, as well as the insertion of the cranial and caudal cruciate ligaments. The circle depicts the approximate location for insertion of an IM pin, immediately cranial to the tibial footprint of the cranial cruciate ligament. **C**, This point, which is located approximately one-third to one-half the distance from the cranial surface of the tibial tubercle to the medial condyle of the tibia, can be “felt” with the tip of the IM pin inserted obliquely in the stifle joint. **D**, With the stifle flexed as much as possible, the pin is inserted through a small medial parapatellar arthrotomy along the medial border of the patellar ligament. The IM pin is then aligned with the medial and caudal cortices of the tibia. **E**, Reduced fracture and IM pin, lateral view. The pin should be inserted as far distally as possible without violating the distal subchondral plate. The IM pin is retracted about ¼ inch (~6 mm) at d’, then cut (d’’). **F**, With a countersink and mallet, the IM pin is returned to the original depth. Sufficient pin is left protruding for removal at the time of clinical union if necessary. The same insertion landmarks and technique are used for interlocking nailing (DeCamp et al., 2016). 50

Figure 20: Angle stable interlocking nail. **A**, Drill jig for placing bolts through the bone and pin. **B**, Measuring tool and placement tool for the interlocking bolt. **C**, Bolts are firmly fixed to the nail hole with no slack or rotational instability (DeCamp et al., 2016). 51

Figure 21: A plate placed on the medial surface of the tibia may function as **(A)** a compression plate for transverse fractures, **(B)** a neutralization plate to support long oblique fractures reconstructed with lag screws, or **(C–D)** a bridging plate with or without an intramedullary pin to span a nonreducible fracture (Fossum et al., 2019). 52

Figure 22: Bone screw types. **A**, Cortical screws are designed to be used for any plate application in the dense diaphyseal bone and may also be used to function as a lag screw. **B**, Cancellous screws are used fixate plate to bone in the metaphyseal region, or to compress fragments of epiphyseal and metaphyseal bone. **C**, Locking screws are designed specifically and only for use with locking plates (DeCamp et al., 2016). 53

Figure 23: Rotational stability may be achieved for intramedullary fixation of tibia fractures by several different means. **A**, Segmental fracture of the tibia with proximal and distal long oblique patterns. **B**, Two double-loop cerclage wires and an intramedullary (IM) pin are often sufficient fixation for cats and small dogs. **C**, Alternatively, lag screws can be used instead of cerclage. To avoid interference, a smaller diameter IM pin should be selected. **D**, Rotational and bending stability can be provided with an angle-stable interlocking nail with two bolts proximal and two bolts distal to an unstable fracture. The longest possible nail should always be selected (DeCamp et al., 2016). 55

Figure 24: **A**, **B**, and **C**, Unilateral (type I) configurations. **D**, **E**, and **F**, bilateral (type II) configurations (DeCamp et al., 2016). 57

Figure 25: Standard circular fixator frame for fracture management (Fossum et al., 2019). 57

Figure 26: **(A)** Transverse or short oblique fractures may be stabilized with an intramedullary (IM) pin and a unilateral external fixator. **(B)** Spiral or oblique fractures may be treated with an IM pin and multiple cerclage wires. **(C)** An interlocking nail may be used to support nonreducible fractures (Fossum et al., 2019). 60

Abbreviations

ABCDE : Airway, Breathing, Circulation, Disability, Exposure

B : Bursa subtendinea m. peronei brevis

CT : Computed Tomography

ESF : External Skeletal Fixation

FPAS : Fracture Patient Assessment Score

IC : Intercondylar

ILN : Interlocking Nail

LCP : Locking Compression Plate

MRI : Magnetic Resonance Imaging

MIPO : Minimally Invasive Plate Osteosynthesis

ROM : Range of Motion

SBTS : Staffordshire Bull Terriers

A : Arteria – artery

M : Musculus – muscle

MM : Musculi – muscles

Abstract

This capstone project provides a comprehensive review of the management and treatment of tibial and fibular fractures in dogs from a veterinary perspective. It begins with a detailed examination of the anatomy and biomechanics of the tibia and fibula, highlighting their structural characteristics, articulations, and functional roles in canine locomotion. The project then explores the various types of fractures that commonly affect these bones, discussing their etiologies, clinical presentations, and diagnostic approaches. Emphasis is placed on current treatment modalities, including both conservative and surgical interventions, with an analysis of indications, techniques, and expected outcomes for each method. The work also addresses post-operative care, potential complications, and considerations for follow-up monitoring to ensure effective healing. Through the integration of recent literature and clinical case studies, this work aims to inform and support veterinary professionals in the management of tibial and fibular fractures in dogs.

Ce projet de fin d'études propose une revue complète de la prise en charge et du traitement des fractures du tibia et du péroné chez le chien, d'un point de vue vétérinaire. Il débute par un examen détaillé de l'anatomie et de la biomécanique du tibia et du péroné, en mettant en avant leurs caractéristiques structurelles, leurs articulations et leurs rôles fonctionnels dans la locomotion canine. Le projet explore ensuite les différents types de fractures qui affectent couramment ces os, en abordant leurs étiologies, leurs présentations cliniques et les méthodes diagnostiques. Une attention particulière est accordée aux modalités de traitement actuelles, incluant les interventions conservatrices et chirurgicales, avec une analyse des indications, des techniques et des résultats attendus pour chaque méthode. Le travail aborde également les soins postopératoires, les complications potentielles, ainsi que les considérations relatives au suivi afin d'assurer une guérison efficace. À travers l'intégration de la littérature récente et d'études de cas cliniques, ce travail vise à informer et à accompagner les professionnels vétérinaires dans la prise en charge des fractures tibiales et fibulaires chez le chien.

يقدم هذا المشروع التخرجي مراجعة شاملة لإدارة وعلاج كسور عظمتي الساق والشظية لدى الكلاب من منظور بيطري. يبدأ المشروع بفحص مفصل للتشريح والميكانيكا الحيوية لكل من الساق والشظية، مع تسليط الضوء على خصائصهما البنيوية، ومفاصلهما، وأدوارهما الوظيفية في حركة الكلاب. ثم يستعرض المشروع الأنواع المختلفة للكسور التي تصيب هاتين العظمتين بشكل شائع، مع مناقشة أسبابها، وأعراضها السريرية، وطرق التشخيص المتبعة. يتم التركيز على الأساليب العلاجية الحالية، بما في ذلك التدخلات التحفظية والجراحية، مع تحليل لمؤشرات كل طريقة وتقنياتها والنتائج المتوقعة منها. كما يتناول العمل أيضًا الرعاية بعد الجراحة والمضاعفات المحتملة، بالإضافة إلى اعتبارات المتابعة لضمان الشفاء الفعال. ومن خلال دمج أحدث الأدبيات والدراسات السريرية، يهدف هذا العمل إلى إثراء معرفة ودعم الأطباء البيطريين في إدارة كسور الساق والشظية لدى الكلا

Summary

Bibliographic Part

Introduction

1- Osteology ... 1

1.1- Tibia ... 1

1.1.1-The Proximal End ... 1

1.1.2- Body of the Tibia Bone ... 2

1.1.3-The Distal End ... 4

1.2- Fibula ... 5

2- Myology ... 6

2.1-Craniolateral Muscles ... 7

2.2-Caudal Muscles ... 10

3- Angiology ... 14

4- Neurology ... 15

5- Biomechanics of the Tibia and Fibula ... 16

1. Classification of Fractures ... 19

2. Tibia and Fibula Fractures ... 22

3. Causal Factors ... 23

4. Predisposing Factors ... 24

1. Diagnostic Assessment in Uncertain Cases ... 26

1.1 Clinical Presentation ... 26

a. General Examination ... 26

b. Signalment ... 26

c. History ... 26

1.2 Diagnosis and Fracture management ... 28

1.2.1 Hands-off examination 28

1.2.2 Hands-on examination 28

2. Emergency Management 30

3. Diagnostic Imaging 30

3.1. Imaging Modalities 31

3.2. Fracture Identification & Radiographic Technique 35

3.3. Radiographic Description of Fractures 36

1. Non-surgical Management of Fractures (External Coaptation) 38

1.1 Principles of External Coaptation 38

1.2 Types of External Coaptation 39

1.3 Indications for Non-Surgical Management 41

1.4 Contraindications & Complications 41

1.5 Application Techniques & Materials 42

1.5.1 Bandages & Splints 42

1.5.2. Casts…. 44

2. Surgical Methods 44

2.1- Principles of Surgical Fracture Repair (Osteosynthesis) 44

2.1.1- Anatomical Reduction 44

2.1.2- Stability Types 45

2.1.3- Implant Selection Criteria 46

2.2- Internal Fixation Techniques 46

2.2.1 Intramedullary Pin/Nail 46

2.2.1.1-Advantages 47

2.2.1.2- Disadvantages 47

2.2.1.3- Types 47

2.2.2- Bone Plates and Screws **49**

2.2.2.1- Screw Biomechanics and Applications **50**

2.2.2.2- Tibia-Specific Surgical Considerations **51**

2.2.2.3- Advantages of Plating Systems **51**

2.2.2.4- Disadvantages and Limitations **51**

2.2.3- Cerclage Wire **52**

2.2.3.1- Clinical Applications and Constraints **52**

2.2.3.2- Technical Application **52**

2.2.3.3- Benefits and Limitations **52**

2.3- External Skeletal Fixation Techniques **53**

2.3.1- Biomechanical Principles **53**

2.3.2- Fixator Types and Configurations **54**

2.3.4- Advantages Over Internal Fixation **55**

2.3.5- Complications and Mitigation Strategies **55**

2.4- Indications for Specific Surgical Techniques **56**

2.4.1- Intramedullary Pinning (Steinmann/Rush Pins) **56**

2.4.2- Interlocking Nails (ILN) **56**

2.4.3- Compression Plating **56**

2.4.4- Locking Plates (LCP) **56**

2.4.5- Cerclage Wiring **56**

2.4.6- External Skeletal Fixation (ESF) **56**

2.4.7- Fibular-Specific Considerations **57**

2.5- Potential Surgical Complications **57**

2.5.1 Infection **57**

2.5.2 Implant Failure 57

3.Criteria for Choosing a Treatment Approach 58

3.1 Fracture-Specific Factors 58

3.2 Patient-Specific Factors 59

3.3 Owner-Specific Factors 59

Introduction

Fractures of the tibia and fibula represent clinically significant orthopedic injuries in small animals, with incidence rates of 14.8-22% among long bone fractures (Phillips, 1979; Butterworth., 2016; Aithal *et al*., 2023). These injuries typically stem from high-energy trauma and frequently present as complex patterns including comminuted, oblique or spiral configurations (DeCamp *et al*., 2016; Hayashi., 2018). Anatomically, the tibia serves as the primary weight-bearing bone of the crus, transmitting 85-90% of axial loads, while the fibula functions as a lateral stabilizer through the interosseous membrane (Hermanson *et al*., 2019; Barone., 1986; Bhamburkar., 2021).

Clinical presentation characteristically includes non-weight-bearing lameness with palpable swelling and crepitation, with open fractures occurring in 12% of diaphyseal and 37% of distal cases (Boone *et al*., 1986; Hayashi., 2018). Diagnostic protocols mandate comprehensive orthopedic examination supplemented by imaging modalities, particularly orthogonal radiographs (Hammond., 2016; Scott., 2018), while advanced techniques like CT or MRI prove indispensable for complex cases (Marolf., 2020; DeCamp *et al*., 2016).

Therapeutic management encompasses both conservative approaches using external coaptation and various surgical interventions including intramedullary pinning, plating, or external fixation (Dyce., 2016; Johnston *et al*., 2018; Fossum *et al*., 2019). Treatment selection requires careful consideration of multiple factors including fracture configuration and patient-specific variables (DeCamp *et al*., 2016; Aithal *et al*., 2023), with vigilant postoperative monitoring crucial to mitigate potential complications (Fossum *et al*., 2019; Jaeger *et* Wosar., 2018).

I - Anatomy and Biomechanics of the Tibia and Fibula

1- Osteology

1.1- Tibia

The tibia is a long, thick bone that lies in the medial part of the crus (the anatomic leg) (Hermanson *et al*., 2019). This long, paired bone articulates proximally with the condyles of the femur and laterally with the fibula at both its proximal and distal ends; distally, it articulates with the tarsus, mainly the talus (Barone., 1986).

The tibia has a shaft (body) and two extremities. The shaft is three sided in the proximal two thirds and flattened craniocaudally in the distal third. It has three surfaces and three borders (Bhamburkar., 2021). The proximal half of the tibia has a triangular cross-section and is more massive than its distal half, which is nearly cylindrical (Hermanson *et al*., 2019).

1.1.1-The Proximal End

The proximal end of the tibia features relatively flat medial and lateral condyles of approximately equal surface area that articulate with the menisci; the medial condyle is oval while the lateral is nearly circular, both being convex sagittally and concave transversely (Hermanson *et al*., 2019). These condyles arise from the proximal tibial epiphysis (Thrall *et* Robertson., 2023) and are separated by an intercondylar eminence composed of medial and lateral intercondylar tubercles, its bifid summit fitting into the femoral intercondyloid fossa (Bhamburkar., 2021; Barone., 1986). Irregular cranial and caudal intercondylar areas flank the eminence: the cranial intercondylar area serves as the attachment site for the cranial aspect of the femorotibial menisci, while the caudal intercondylar area accommodates the caudal attachment of the medial meniscus and the caudal cruciate ligament (Hermanson *et al*., 2019; Barone., 1986). A rough central intercondylar area on the eminence provides attachment for the cranial cruciate ligament (Barone., 1986). The condyles themselves are more expansive than their articular surfaces (Hermanson *et al*., 2019) and are separated caudally by the popliteal notch, featuring a medial tubercle for the caudal cruciate ligament attachment; the lateral condyle possesses an articular facet for the fibular head (Barone., 1986; Bhamburkar., 2021). Cranially, the large quadrangular tibial tuberosity provides muscle insertion, with the cranial border (formerly the tibial crest) extending distally from it. A depression separating the tuberosity from the lateral condyle deepens to form the cartilage-lined extensor groove, transmitting the tendon of the long digital extensor muscle (Hermanson *et al*., 2019).

1.1.2- Body of the Tibia Bone

The body of the tibia *(corpus tibiae)* has a prismatic shape with three surfaces (lateral, medial, and caudal). These three surfaces are always very distinct in the proximal half, where they are separated by three well-defined borders. They merge towards the distal end, where the borders fade and where the body of the tibia becomes cylindrical (Barone., 1986).

The lateral surface *(facies lateralis)* of the tibia is smooth, wide, and concave proximally; flat in the middle; and narrow and convex distally (Fig01) (Hermanson *et al*., 2019). it gradually inclines to the cranial side of the bone in its distal part (Bhamburkar., 2021).

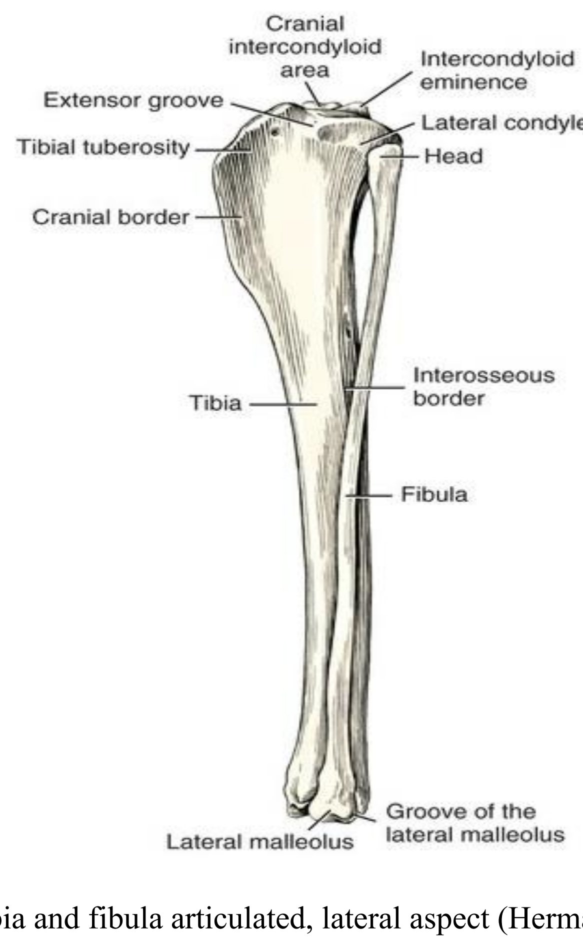

Figure 1: Left tibia and fibula articulated, lateral aspect (Hermanson *et al*., 2019).

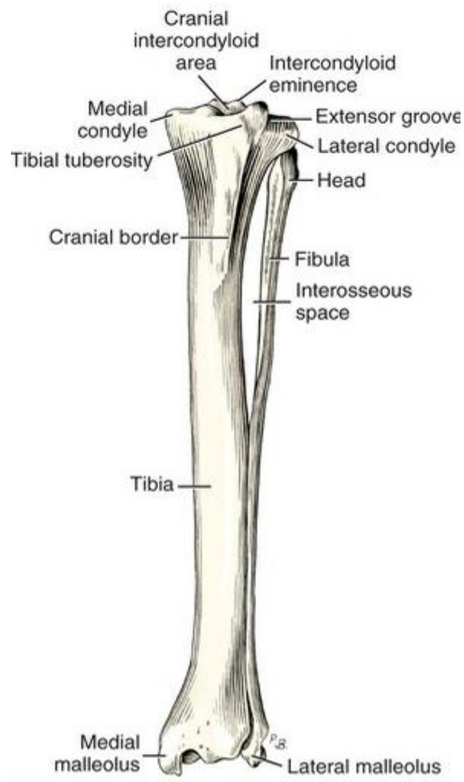

Figure 2: Left tibia and fibula articulated, cranial aspect (Hermanson *et al*., 2019).

The caudal surface *(facies caudalis)* is the widest and best defined. Its proximal surface is triangular, slightly excavated, and mostly smooth, except near the medial border, where it has some muscle insertion rugosities (Fig03) (Barone., 1986).

The proximal fourth of this surface, towards the medial border possesses a narrow triangular area marked by popliteal line for the attachment of popliteus muscle. The rest of the part of this surface is marked by rough lines for the origin of flexor muscles of the hock joint (Bhamburkar., 2021). At the junction of the proximal and middle thirds of the lateral border lies the distally directed nutrient foramen of the bone (Hermanson *et al*., 2019).

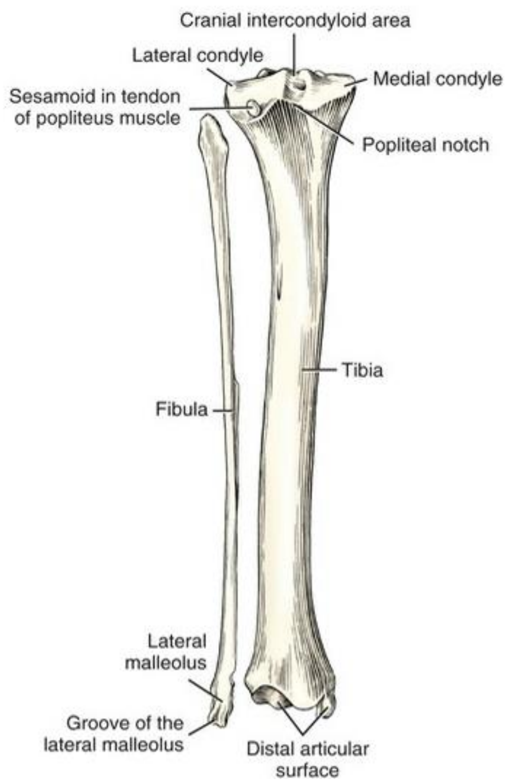

Figure 3: Left tibia and fibula disarticulated, caudal aspect (Hermanson *et al*., 2019).

The lateral border *(margo lateralis)*, also called the interosseous border *(margo interosseus)*, is concave along its length, especially below the proximal end. It helps form a large interosseous space with the fibula (Barone., 1986).

The cranial border *(margo cranialis)* is prominent in its proximal third and is called the tibial crest *(crista tibiae)*. The rest of the extent of the cranial border is rounded and indistinct (Bhamburkar., 2021).

The medial border *(margo medialis)* is the thickest. It's nearly straight and shows some insertion markings in its proximal portion, becoming wider and more rounded as it approaches the distal end (Barone., 1986).

1.1.3-The Distal End

The distal end of the tibia is quadrilateral and slightly more massive than the adjacent shaft (Hermanson *et al*., 2019). It features two concave depressions, the tibial cochleae, separated by an intermediate ridge; these articulate with the talar trochlea to form part of the tarsocrural joint (Thrall *et* Robertson., 2023). A transversely located synovial fossa extends across the intermediate ridge connecting the two grooves. The entire medial aspect of this distal extremity constitutes the medial malleolus (Hermanson *et al*., 2019), which serves as the origin for the short and long parts of the medial collateral ligament, providing medial stabilization to the tarsocrural joint (Thrall *et* Robertson., 2023). Cranially, the distal end presents a stout, pyramid-shaped process, caudal to which lies a semilunar notch. Distally on the fibular surface, a small articular facet (facies articularis malleoli) articulates with the distal fibula (Hermanson *et al*., 2019).

1.2- Fibula

The fibula is a long, thin, laterally compressed bone situated laterally within the crus, serving primarily for muscle attachment rather than significant weight-bearing (Hermanson *et al*., 2019). It articulates proximally with the caudal aspect of the lateral tibial condyle and distally with both the tibia and the talus (Thrall *et* Robertson., 2023; Hermanson *et al*., 2019).

Anatomically, it comprises a proximal head *(caput fibulae)*, neck, body *(corpus fibulae)*, and distal lateral malleolus *(malleolus lateralis)* (Hermanson *et al*., 2019). The proximal head is wide, often spatulate, and flattened transversely (Barone., 1986); its medial surface features a small articular tubercle (facies articularis capitis fibulae) for articulation with the tibia, while the remaining surface is rough for ligamentous and muscular attachments (Hermanson *et al*., 2019; Barone., 1986). The short neck blends indistinctly into the body (Hermanson *et al*., 2019). The body resembles a narrow, elongated blade with a smooth, potentially excavated lateral surface embedded within crus muscles, and a rough medial surface closely opposed to the tibia, featuring a proximally directed nutrient foramen mid-shaft (Barone., 1986; Hermanson *et al*., 2019). Its thin, sharp cranial border *(margo cranialis/interosseus)* defines the interosseous space, confined to the proximal half of the body, where the interosseous membrane attaches (Hermanson *et al*., 2019; Singh B., 2023; Barone., 1986).

Distally, the lateral malleolus extends lower than its medial counterpart (Barone., 1986). Its medial surface contains the articular facet *(facies articularis malleoli)* for articulation with the distal tibia, talus, and craniolateral calcaneus (Hermanson *et al*., 2019). The lateral malleolus features lateral and caudal grooves *(sulci tendinum)*: the caudal groove transmits the tendons of the lateral digital extensor and fibularis brevis muscles, while a cranial groove transmits the tendon of the fibularis longus muscle (Barone., 1986; Hermanson *et al*., 2019). It serves as the origin for the lateral collateral ligament, providing lateral stabilization to the tarsocrural joint (Thrall *et* Robertson., 2023).

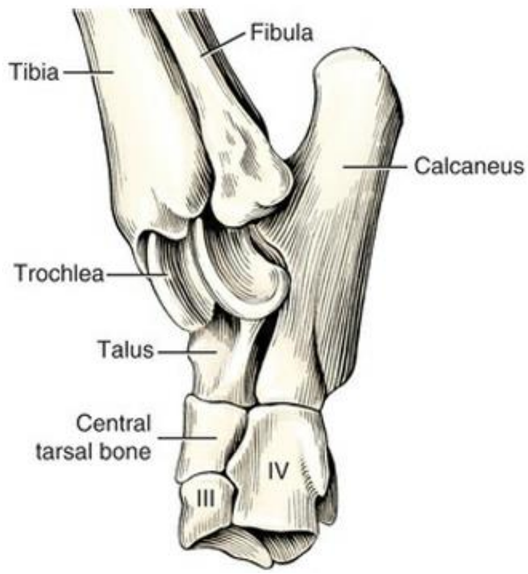

Figure 4: Left tarsus, articulated, craniolateral aspect (Hermanson *et al*., 2019).

2- Myology

On the crus, the muscles lie on the cranial, lateral, and caudal surfaces of the tibia or fibula, whereas the medial surface of the tibia is essentially left free. Flexor and extensor groups are not separated on the crus as they are on the antebrachium (Hermanson *et al*., 2019). The joints of the tarsus and those of the digits, specialized for extension and flexion movements, perform these motions in opposite directions: the tarsus flexes cranially, while the digits flex caudally. This results in a grouping of muscles into two sub-regions, craniolateral and caudal (Barone., 1986). The muscles of craniolateral group are extensors of the digits and flexors of the tarsus. The muscles of the caudal group are flexors of the digits and extensors of the tarsus (Bhamburkar., 2021). These functional muscle groups are mixed on the crus because the tarsal joint is set at an angle opposite to that of the digital joints. The tarsal joint has its flexor surface dorsally, whereas each of the digital joints has its extensor surface dorsally. Therefore, the muscles lying over the dorsal surface must be flexors of the tarsus and extensors of the digital joints (Hermanson *et al*., 2019).

2.1-Craniolateral Muscles

These muscles completely cover the fibula; they are therefore both cranial and lateral (Barone., 1986). The flexors of the tarsal joint that lie on the craniolateral side of the crus are the *mm. tibialis cranialis*, *fibularis (peroneus) longus*, *extensor digitorum longus*, *extensor digitorum lateralis*, and *extensor digiti I longus* (Hermanson *et al*., 2019).

- **M. Tibialis Cranialis**

The *m. tibialis cranialis* functions in tarsal flexion and supination, originating via two heads proximal to the extensor groove on the lateral tibial condyle and cranial tibial border (Bhamburkar, 2021). Its muscle body transitions to a flat tendon in the distal crus, traversing the crural extensor retinaculum alongside the deep peroneal nerve and obliquely crossing the tarsus to insert on the proximal first and second metatarsals (Hermanson *et al*., 2019; Budras *et al*., 2007). This muscle is vascularized by the cranial tibial artery and innervated by the deep peroneal nerve (Bhamburkar, 2021; Barone, 1986).

- **M. Fibularis Longus**

Originating from the lateral tibial condyle, fibular remnant, and lateral collateral ligament (Bhamburkar, 2021), the *m. fibularis longus* facilitates tarsal flexion and pronation. Its elliptical tendon courses distally within a fascial compartment, traverses the lateral malleolar groove within a synovial sheath, and crosses the plantar metatarsus to insert on the medial metatarsal bone (Hermanson *et al*., 2019; Barone, 1986). The superficial peroneal nerve provides innervation, with vascular supply from the cranial tibial artery (Barone, 1986; Bhamburkar, 2021).

- **M. Extensor Digitorum Longus**

Arising from the femoral extensor fossa (Bhamburkar, 2021), the *m. extensor digitorum longus* extends digits II–V while flexing the tarsus. It traverses the tibial extensor groove, diverges from the tibialis cranialis, and forms four terminal tendons enveloped in a synovial sheath before inserting on the distal phalanges (Hermanson *et al*., 2019; Barone, 1986). This muscle is innervated by the deep peroneal nerve and perfused by the cranial tibial artery (Barone, 1986; Bhamburkar, 2021).

- **M. Extensor Digitorum Lateralis**

The *m. extensor digitorum lateralis* originates from the proximal fibula (Budras *et al*., 2007) and enables abduction/extension of digit V. Positioned deep to the fibularis longus, its tendon courses through the lateral malleolar groove within a synovial sheath, merging with the long digital extensor tendon on digit V's proximal phalanx (Hermanson *et al*., 2019; Barone, 1986). Innervation is supplied by the superficial peroneal nerve, with vascularization from the cranial tibial artery (Barone, 1986; Bhamburkar, 2021).

- **M. Extensor Digiti I Longus**

Arising from the cranial fibula and interosseous membrane (Hermanson *et al*., 2019), the *m. extensor digiti I longus* extends digit II (and digit I when present). Its tendon courses medially deep to the long digital extensor, emerges at the tarsus, and typically inserts near the metatarsophalangeal joint of digit II, though it may extend to digit I. The deep peroneal nerve innervates this muscle, which receives blood supply from the cranial tibial artery (Barone, 1986).

- **M. Fibularis Brevis**

Originating from the distal two-thirds of the fibula (Budras *et al*., 2007), the *m. fibularis brevis* contributes to tarsal flexion. Covered by the fibularis longus and extensor digitorum lateralis, its tendon shares a synovial sheath with the latter, passes caudal to it through the lateral malleolar groove, and inserts on the fifth metatarsal base (Hermanson *et al*., 2019; Barone, 1986). It is innervated by the deep peroneal nerve and vascularized by the cranial tibial artery (Hermanson *et al*., 2019; Barone, 1986).

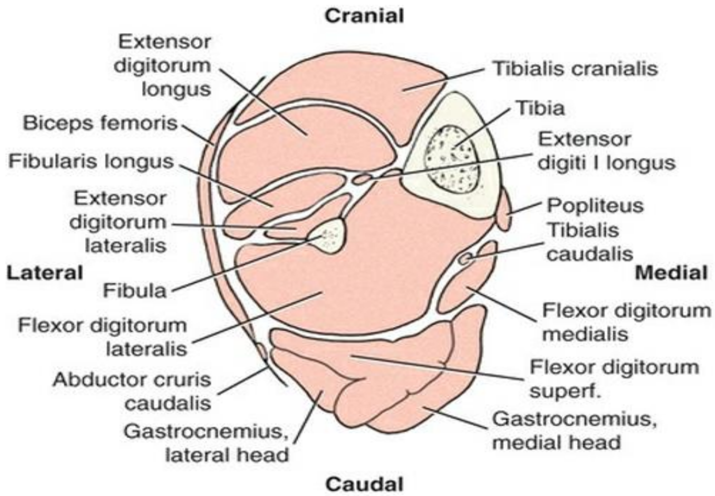

Figure 5: Schematic transverse section through left crus (Hermanson *et al*., 2019).

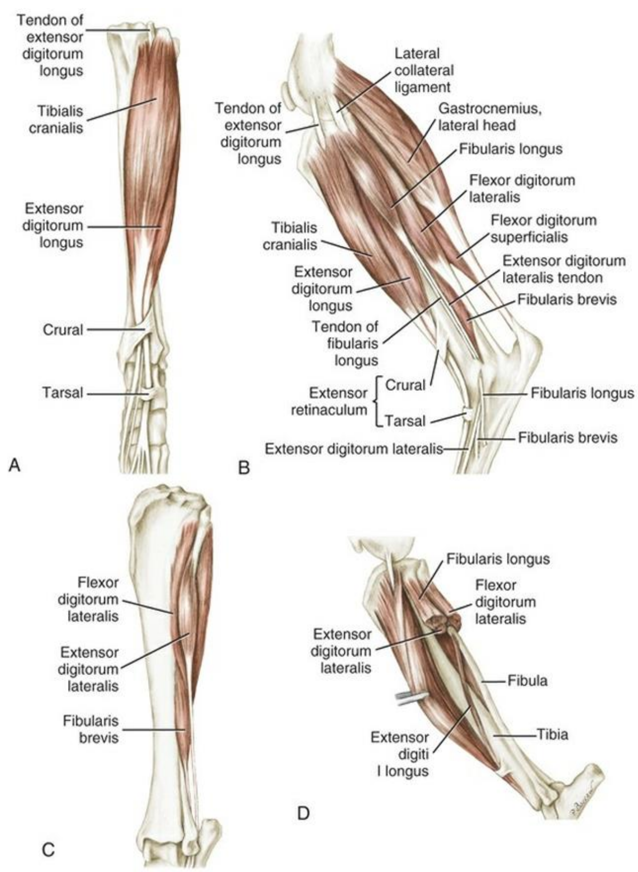

Figure 6: Muscles of left crus. **A**, Superficial muscles, cranial aspect. **B**, Superficial muscles, lateral aspect. **C**, Deep muscles, cranial lateral aspect. **D**, Deep muscles, lateral aspect (Hermanson *et al*., 2019).

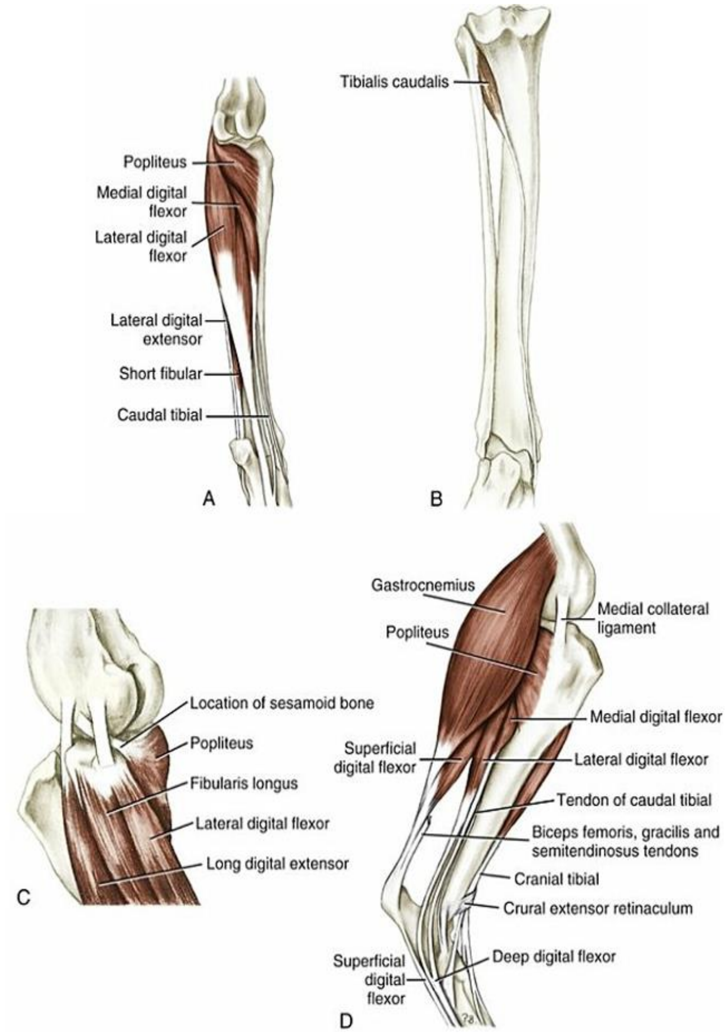

Figure 7: Muscles of left crus. **A**, Deep muscles, caudal aspect. **B**, Tibialis caudalis, caudal aspect. **C**, Muscles of crus at stifle joint, lateral aspect. **D**, Muscles of crus, medial aspect (Hermanson *et al*., 2019).

2.2-Caudal Muscles

On the caudal side of the crus lie the extensors of the tarsal joint and the flexors of the digital joints (Hermanson *et al*., 2019). These muscles are arranged in two layers separated by a strong septum. The superficial layer, that includes the *m. flexor digitorum superficialis* and the *m. gastrocnemius.* The deep layer contains a muscle confined to the proximal part of the region: the *m. popliteus*, along with two strong flexors of the digits (lateral and medial), joined by the *m. tibialis caudalis*. The entire structure is enveloped by the crural fascia (Barone., 1986).

- **M. Gastrocnemius**

Functioning as the primary extensor of the hock joint (Budras *et al*., 2007), the *m. gastrocnemius* originates via lateral and medial heads from the respective femoral supracondyloid crests, with sesamoid bones embedded in each tendon of origin articulating with the femoral condyles (Bhamburkar, 2021; Budras *et al*., 2007). The muscle bellies descend separately over the caudal stifle, fuse midway along the crus, and transition into a strong tendon at the distal tibia (Hermanson *et al*., 2019; Bhamburkar, 2021). This tendon twists with the superficial digital flexor tendon, becomes cranial to it at the tuber calcanei, and contributes to the calcaneal tendon inserting on the tuber calcanei (Barone, 1986; Bhamburkar, 2021). The tibial nerve provides innervation, while vascular supply derives from popliteal and caudal femoral arteries (Bhamburkar, 2021; Barone, 1986). Notably, the tibial nerve and popliteal vessels course between its two heads (Barone, 1986).

- **Common Calcanean Tendon**

The common calcanean tendon *(tendo calcaneus communis)* aggregates insertions onto the tuber calcanei, primarily comprising the gastrocnemius tendon crossed medially by the superficial digital flexor tendon (Hermanson *et al*., 2019). It incorporates contributions laterally from the *m. biceps femoris* and medially from the *mm. semitendinosus* and *gracilis* (Hermanson *et al*., 2019). The structure broadens near the calcaneal tuberosity, forming a fibrous cap before continuing onto the plantar metatarsus (Barone, 1986).

- **M. Flexor Digitorum Superficialis**

Arising conjointly with the lateral gastrocnemius head on the femur and containing the lateral sesamoid bone (Hermanson *et al*., 2019), the multipennate *m. flexor digitorum superficialis* facilitates digital flexion and tarsal extension/stabilization. Initially united with the gastrocnemius, its tendon winds medially around the gastrocnemius tendon to reach the tuber calcanei, where it broadens into a cap-like insertion (Bhamburkar, 2021; Hermanson *et al*., 2019). Distally, it divides into four branches enveloped by the plantar fascia and a plantar annular ligament, inserting on the middle phalanges of digits II–V (Barone, 1986; Hermanson *et al*., 2019). Innervation is supplied by the tibial nerve, with vascularization from medial plantar, caudal femoral, and caudal tibial arteries (Barone, 1986; Bhamburkar, 2021).

- **Mm. Flexor Digitorum Profundi**

Comprising the large *m. flexor digitorum lateralis* (arising from the proximal fibula, tibia, and interosseous membrane) and the smaller *m. flexor digitorum medialis* (originating on the fibular head and popliteal line), these muscles flex the digits (Hermanson *et al*., 2019; Budras *et al*., 2007). The multipennate *m. flexor digitorum lateralis* covers the caudal tibia/fibula, while the *m. flexor digitorum medialis* lies adjacent medially (Barone, 1986; Hermanson *et al*., 2019). Their tendons unite near the talus within the plantar tarsal sheath (formed by the sustentaculum tali and flexor retinaculum) to form the deep digital flexor tendon, which divides into four branches inserting on the distal phalanges of digits II–V (Barone, 1986; Hermanson *et al*., 2019). Both components are innervated by the tibial nerve and vascularized by branches of the caudal tibial artery (Bhamburkar, 2021; Barone, 1986).

- **M. Tibialis Caudalis**

The *m. tibialis caudalis*, when present, extends the tarsus and supinates the pes, originating on the proximal fibula (Hermanson *et al*., 2019). Interposed between the deep digital flexors, its delicate tendon courses cranially to the *m. flexor digitorum medialis* tendon within its own synovial sheath, inserting on the medial tarsal ligaments (Barone, 1986; Hermanson *et al*., 2019). This muscle is innervated by the tibial nerve and supplied by the caudal tibial artery (Barone, 1986).

- **M. Popliteus**

Functioning to flex the stifle and rotate the tibia laterally, the *m. popliteus* originates via a long sesamoid-containing tendon on the caudal lateral femoral condyle, articulating with the lateral tibial condyle (Hermanson *et al*., 2019). Its tendon traverses between the lateral femorotibial ligament and lateral meniscus into the popliteal notch, covering the caudal tibial surface before inserting on the proximal medial tibia (Barone, 1986; Budras *et al*., 2007). The tibial nerve provides innervation, with vascular supply from popliteal, cranial tibial, and caudal tibial arteries (Bhamburkar, 2021; Barone, 1986).

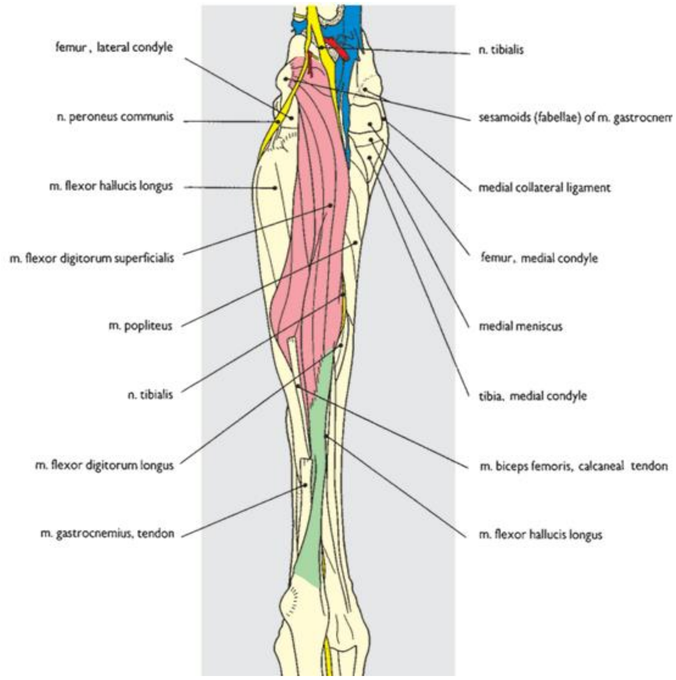

Figure 8: Left crus after removal of the gastrocnemius muscle: caudal view (Done *et al*., 2009).

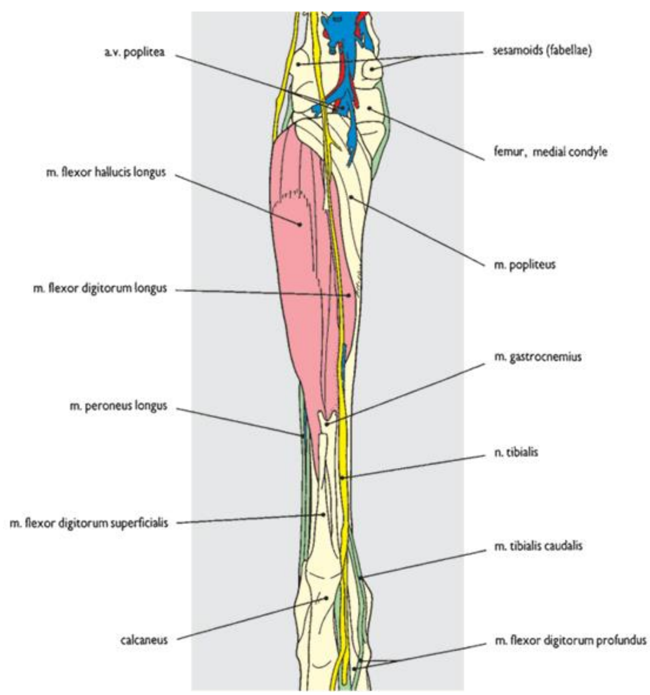

Figure 9: Left leg after removal of the superficial digital flexor muscle: caudal view (Done *et al*., 2009).

3- Angiology

The crus receives its vascular supply primarily from branches of the popliteal artery, which bifurcates into the cranial tibial artery and caudal tibial artery at the distal femur (Barone., 1986; Hermanson *et al*., 2019).

- **Arterial Supply**

- **Cranial Tibial Artery:**

Emerges between the tibia and fibula, descending along the cranial tibial border. It supplies the extensor muscles (e.g., *m. tibialis cranialis*, *m. extensor digitorum longus*), the tibial shaft, and anastomoses with the dorsal pedal artery distally (Bhamburkar., 2021; Hermanson *et al*., 2019).

- **Caudal Tibial Artery:**

Courses caudomedially, supplying the flexor muscles (e.g., *m. flexor digitorum profundus*, *m. tibialis caudalis*), the tibia's nutrient foramen, and the medial malleolar region. It anastomoses with the saphenous artery (Barone., 1986).

- **Nutrient Artery to Tibia:**

Arises from the cranial tibial artery, entering the tibial shaft via a distal-directed foramen at the junction of the proximal/middle thirds (Hermanson *et al*., 2019).

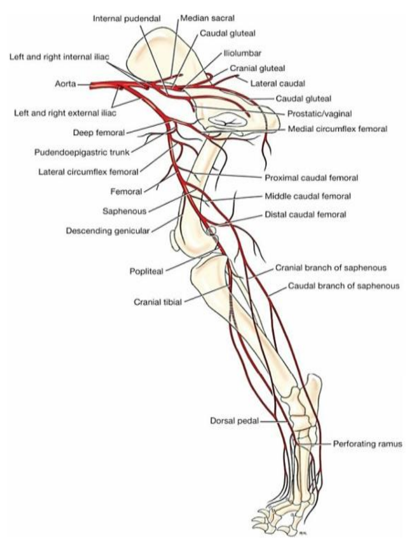

Figure 10: Diagram of the arteries of the pelvis and thigh, medial aspect (Hermanson *et al*., 2019)

- **Venous Drainage**

- **Parallels arterial supply:** cranial and caudal tibial veins drain into the popliteal vein. Superficial drainage occurs via the great saphenous vein (Barone., 1986).

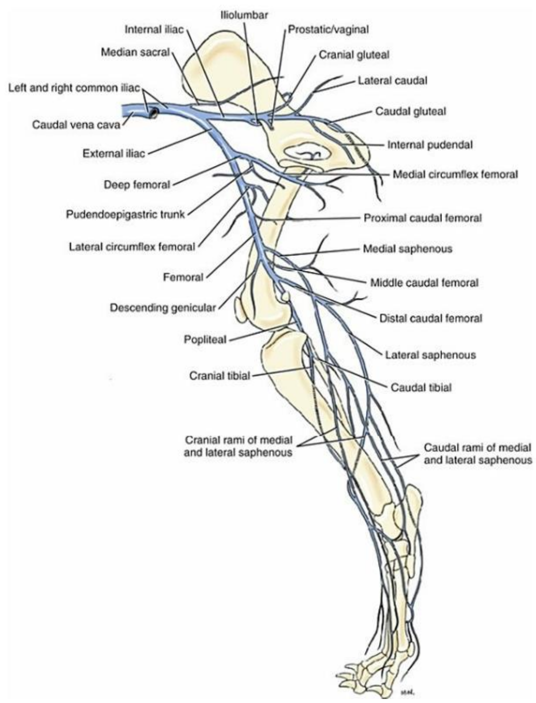

Figure 11: Veins of the pelvic limb, medial view (Hermanson *et al*., 2019).

4- Neurology

Innervation of the crus is governed by terminal branches of the sciatic nerve: the tibial nerve and common fibular (peroneal) nerve (Hermanson *et al*., 2019).

- **Key Nerves:**

- **Tibial Nerve:**

Innervates caudal muscles (e.g., *m. gastrocnemius*, *m. flexor digitorum profundus*). Courses between the heads of *m. gastrocnemius*, supplying sensory branches to the tibia's caudal cortex (Barone., 1986; Bhamburkar., 2021).

- **Common Fibular Nerve:**

Divides into:

  - **Deep Fibular Nerve:** Innervates craniolateral muscles (e.g., *m. tibialis cranialis*, *m. extensor digitorum longus*).
  - **Superficial Fibular Nerve:** Supplies *m. fibularis longus* and *m. extensor digitorum lateralis* (Hermanson *et al*., 2019).

- **Saphenous Nerve (from femoral nerve):**

Provides sensory innervation to the medial tibial surface (Bhamburkar., 2021).

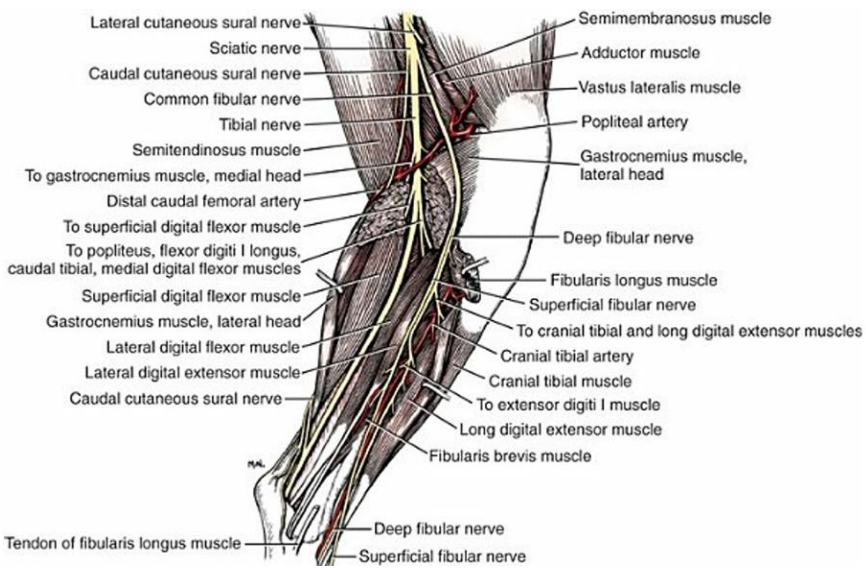

Figure 12: Nerves, arteries, and muscles of the right leg, lateral aspect (Hermanson *et al*., 2019).

5- Biomechanics of the Tibia and Fibula

- **Weight Transmission:**

The tibia bears 85–90% of axial load during stance, transmitting force from the femur to the talus. Its proximal triangular cross-section resists bending; distal cylindrical shape accommodates rotational forces (Hermanson *et al*., 2019; Thrall *et* Robertson., 2023).

The fibula acts as a lateral strut:

- Stabilizes the tibia via the interosseous membrane.
- Provides attachment for muscles controlling tarsal motion (e.g., *m. fibularis longus* aids in tarsal flexion/paw pronation) (Barone., 1986; Bhamburkar., 2021).

- **Joint Function:**

- **Stifle Joint:**

Tibial condyles articulate with femoral condyles via menisci, enabling flexion/extension. The intercondylar eminence limits cranial-caudal displacement, aided by cruciate ligaments (Hermanson *et al*., 2019).

- **Tarsocrural Joint:**

Tibial cochleae and medial malleolus form a mortise with the talus, enabling dorsiflexion/plantarflexion. The lateral malleolus (fibula) prevents talar displacement (Thrall *et* Robertson., 2023).

- **Muscle Leverage:**

- **Craniolateral Muscles:**

m. tibialis cranialis and *m. extensor digitorum longus* act as tarsal flexors during swing phase (Hermanson *et al*., 2019).

- **Caudal Muscles:**

m. gastrocnemius extends the hock via the calcanean tendon; *m. flexor digitorum profundus* flexes digits during stance (Barone., 1986).2

- **Dynamic Stability:**

- The fibula rotates slightly during locomotion, accommodating tibial torsion and distributing load to the lateral malleolus (Singh., 2023).
- **Tibiofibular Syndesmosis:** Distal tibiofibular ligaments prevent splaying during weight-bearing (Hermanson et al., 2019).

II. Classifications, Causes and Risk Factors for Fractures

A fracture is a complete or incomplete break in the continuity of bone or cartilage. A fracture is accompanied by various degrees of injury to the surrounding soft tissues, including blood supply, and by compromised function of the locomotor system (DeCamp *et al*., 2016).

Statistically, the tibia is the long bone that is most infrequently fractured. It is usually associated with fractures of the fibula, except in certain cases (oblique fractures of the middle third in growing patients) (Zaera Polo., 2015).

1. Classification of Fractures

Classification of fractures is useful for a variety of reasons. Accurate description of a fracture enables surgeons to plan and discuss methods of treatment and prognosis, and allows more effective comparison of outcomes (Jones., 2016).

- **Soft tissue involvement**

Depending on the affectation or involvement of soft tissues, the fractures can be classified as follows (Zaera Polo., 2015):

Closed fractures: The fracture does not communicate to the outside (DeCamp *et al*., 2016; Jones., 2016). This is the most frequent type of fracture. They are considered as sterile and do not usually present additional problems regarding vascularisation (Zaera Polo., 2015).

Open fractures: The fracture site communicates to the outside (DeCamp *et al*., 2016; Jones., 2016). The skin has been damaged, from the exterior or from the interior (Zaera Polo., 2015). These fractures are contaminated or infected, and healing at best may be complicated and delayed (DeCamp *et al*., 2016).

* *Gustilo Type II:* Open fracture with a wound >1 cm, moderate soft tissue damage, and minimal contamination. Adequate soft tissue coverage of bone remains.

Gustilo Type III: Severe open fracture with extensive soft tissue damage, contamination, and bone exposure requiring reconstruction (Fossum *et al*., 2019; Jones., 2016).

- **Number of fragments**

Simple fracture: The bone has been fractured into two fragments. This is the “typical” fracture in which there is only one fracture plane (DeCamp *et al*., 2016; Jones., 2016; Zaera Polo., 2015).

Multifragmental fractures (comminuted/complex fractures): They have one or more completely separated fragments of intermediate size. These fractures can be further described as follows: wedge fracture, reducible wedges, nonreducible wedges, multiple or segmental fracture (DeCamp *et al*., 2016; Jones., 2016; Zaera Polo., 2015).

- **Wedge Fracture:** A wedge fracture is a multifragmental fracture with some contact between the main fragments after reduction.
- **Reducible Wedges:** Reducible wedges are fragments with a length and width larger than one third the bone diameter.
- **Nonreducible Wedges:** Nonreducible wedges are fragments with a length and width less than one third the bone diameter.
- **Segmental Fracture:** The bone is broken into three or more segments; the fracture lines do not meet at a common point (DeCamp *et al*., 2016; Zaera Polo., 2015).

- **Direction of the fracture plane**

The direction of the fracture plane is important as it determines if the weight borne will transform with greater or lesser intensity in displacement from one direction or another from the fracture site (Jones., 2016).

Transversal fracture: The fracture plane courses more or less perpendicular to the longitudinal axis of the bone (Jones., 2016; Zaera Polo., 2015).

Oblique fracture: The fracture line is equal to or greater than 30 degrees to the long axis of the bone (Jones., 2016). Depending on the amplitude of said angle, they can be:

- Short oblique fractures, if the angle tends towards perpendicularity.
- Long oblique fractures, if they tend to be parallel with the longitudinal axis of the bone (DeCamp *et al*., 2016; Zaera Polo., 2015).

Spiral fracture: It is a special case of oblique fracture in which the fracture line curves around the diaphysis (DeCamp *et al*., 2016; Jones., 2016).

Regarding comminuted fractures with total instability, the direction of the fracture lines is irrelevant (Zaera Polo., 2015).

- **Nature of the fracture**

The extent of damage can be described as follows:

Incomplete fracture: It is called a greenstick fracture in young animals because of the bending of the nonfractured cortex. Fissure fractures exhibit fine cracks that penetrate the cortex in a linear or spiral direction (DeCamp *et al*., 2016). In other words, part of the bone remains intact (Jones., 2016).

Complete fracture: It describes a single circumferential disruption of the bone (DeCamp *et al*., 2016). That is to say, the cortex is completely broken with separation of the fragments (Jones., 2016).

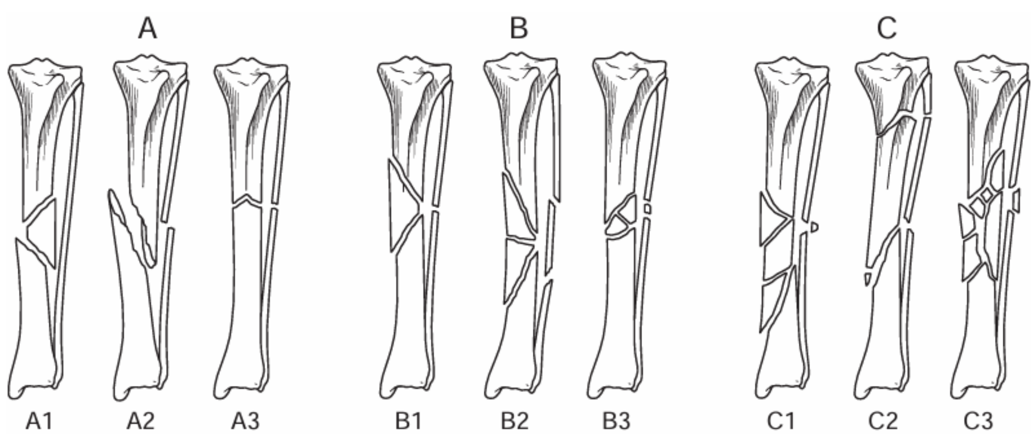

Figure 13: Diaphyseal fractures of the tibia. **A**, Simple or incomplete. **A1**, Incomplete tibial or fibula intact; **A2**, Simple oblique tibial; **A3**, Simple transverse tibial. **B**, Tibial wedges. **B1**, One reducible wedge; **B2**, Reducible wedges; **B3**, Nonreducible wedges. **C**, Tibial complex. **C1**, Reducible wedges; **C2**, Segmental; **C3**, Nonreducible wedges (DeCamp *et al*., 2016).

2. Tibia and Fibula Fractures

Tibial and fibular fractures account for 14.8% of canine fractures (Phillips, 1979; Butterworth, 2016) and 17-22% of long bone fractures in dogs. Concurrent tibia-fibula fractures are most common, though isolated tibial fractures occur in one-third of cases (typically from falls), while isolated fibular fractures are rare (2-3%) (Aithal *et al*., 2023).

Open fractures are more prevalent in animals >1 year, representing 12% of diaphyseal fractures and 37% of distal fractures (Boone *et al*., 1986; Hayashi, 2018). Most tibial fractures involve the diaphysis, particularly the proximal and middle thirds. Young dogs frequently exhibit incomplete diaphyseal/metaphyseal fractures or physeal fractures (Aithal *et al*., 2023).

- **Fractures of the Proximal Region**

In the vast majority of cases these involve physes of skeletally immature patients (Butterworth., 2016).

Tibial tuberosity avulsion and physeal fracture are the two most common types of proximal fractures (Hayashi., 2018).

Avulsion of the tibial tubercle: This injury is seen almost exclusively in animals less than 10 months of age. The Greyhound and terrier breeds are over-represented, with Staffordshire Bull Terriers being commonly affected in one study (Gower *et al*., 2008).

Separation of the proximal tibial physis: This is a relatively uncommon injury seen only in immature patients. It is associated with caudal rotation of the tibial plateau and craniomedial displacement of the proximal tibial metaphysis (Butterworth., 2016).

***Avulsion Fracture:** A fragment of bone, which is the site of insertion of a muscle, tendon, or ligament, is detached as a result of a forceful pull (DeCamp *et al*., 2016).

Fracture of the proximal fibula: These fractures occur rarely in isolation. If they result from a lateral blow to the limb then there may be pain or swelling on the lateral aspect of the stifle and pain on joint manipulation.

- **Fractures of the Diaphysis**

Tibial fractures dominate clinically over fibular fractures in combined injuries, as the fibula bears minimal weight; isolated fibular shaft fractures often warrant conservative management

(Butterworth, 2016). Mid-diaphyseal fractures are most frequent (64%), surpassing proximal (20%) and distal (15%) locations (Hayashi, 2018). Oblique/spiral and comminuted fractures are prevalent patterns (Hayashi, 2018). Stabilizing the tibia typically realigns and protects the fibula; an intact fibula can augment tibial fixation (Butterworth, 2016). Diaphyseal fracture configurations include incomplete (5–19%), transverse (6–14%), oblique/spiral (21–44%), comminuted (34–53%), and segmental (1–3%), with reported incidences varying across studies (Boone *et al*., 1986; Unger *et al*., 1990; Hayashi, 2018).

- **Fractures of the Distal Region**

Skeletally immature patients commonly sustain physeal fractures, while adults more frequently experience malleolar avulsions at tarsocrural collateral ligament origins (Butterworth, 2016). Physeal and malleolar fractures are the primary distal types. Studies report varying incidences: physeal (31%), malleolar (58%), and metaphyseal (9%) fractures (Boone *et al*., 1986; Hayashi, 2018); alternatively, simple non-articular/physeal (60%) and malleolar (28%) fractures (Unger *et al*., 1990; Hayashi, 2018).

3. Causal Factors

Direct violence: fractures are usually a result of road traffic accidents, but other causes include dog fights and trapping a paw whilst moving at speed (Butterworth., 2016).

Indirect violence: The force is transmitted through bone or muscle to a distant point where the fracture occurs (e.g., fracture of femoral neck, avulsion of tibial tubercle, fracture of condyles of the femur).

Diseases of Bone: Some bone diseases cause bone destruction or weakening to such a degree that trivial trauma may produce a fracture (e.g., bone neoplasms, nutritional disturbances affecting bone) (DeCamp *et al*., 2016). In these cases the bone breaks with a lower force than would be required to fracture a healthy bone (Jones., 2016).

Pathological fractures account for less than 3% of all fractures encountered in dogs in small animal practice (Boulay *et al*., 1987) (Calvo., 2016).

4. Predisposing Factors

- **Breed**

Non-descript (stray/street) dogs exhibit the highest incidence of tibial fractures due to greater exposure to vehicular trauma, followed by Labradors and Golden Retrievers (Radha *et al*., 2023; Kumar *et al*., 2020). Staffordshire Bull Terriers (SBTs) demonstrate breed-specific susceptibility to tibial tuberosity avulsion fractures (86% of cases), potentially linked to genetic predisposition and regional lineage concentration in South London (Gower *et al*., 2008). German Shepherds, Pomeranians, and Pugs are also overrepresented (Kumar *et al*., 2020).

- **Sex**

Males account for 60.1–61.8% of tibial fractures, attributed to both higher population numbers and behavioral traits (increased aggression/territoriality leading to road accidents) (Radha *et al*., 2023; Kumar *et al*., 2020).

- **Age**

Juvenile dogs demonstrate the highest susceptibility to tibial fractures, with distinct age-related risk patterns. Puppies aged 0–6 months exhibit peak incidence (29.1%), attributable to heightened activity levels, underdeveloped bone density, and increased vehicular trauma exposure (Radha *et al*., 2023). Adolescents (6–24 months) represent 41.4% of cases, where developmental bone fragility increases fracture risk under mechanical stress (Kumar *et al*., 2020). Staffordshire Bull Terriers (SBTs) show a specialized predisposition to tibial tuberosity avulsion fractures at 3–10 months (median: 5 months), coinciding with skeletal immaturity and physeal vulnerability (Gower *et al*., 2008).

III. Clinical Presentation and Diagnosis

1. Diagnostic Assessment in Uncertain Cases

1.1 Clinical Presentation

a. General Examination

The animal's general health should be ascertained before focusing on the orthopedic complaint. The entire examination varies with case complexity, a history of recent trauma, the intended use of the animal (e.g., breeding, showing, racing, hunting), and economics dictated by owners (DeCamp *et al*., 2016).

b. Signalment

Any age, breed, or sex of dog or cat may be affected. Young animals more often sustain vehicular trauma (Fossum *et al*., 2019). Breed, sex, and age are significant factors influencing fractures in dogs. Non-descript young male dog has a higher risk of fractures due to its developing bones and increased exposure to trauma from roaming and accidents (Bhushan *et al*., 2020).

c. History

In taking a full and comprehensive history, the clinician should start with general questions and progress to more specific ones relevant to the key concerns of the client. Leading questions should be avoided since it is a natural tendency for clients to say what they think that the clinician wants to hear and this information may be unintentionally inaccurate or misleading (Duerr., 2020). Specific historical information is useful for ruling out categories of orthopedic problems. This information includes occurrence of trauma, owner identification of limb(s) involved, description of the lameness or gait abnormality, chronological progression of the problem, efficacy of treatments tried, and variability with weather, exercise, and arising from recumbency (DeCamp *et al*., 2016). Affected animals usually present with non–weight-bearing lameness after trauma. Owners may be unaware that the trauma has occurred (Fossum *et al*., 2019). Other features such as fever, inappetence, lethargy, and weight loss may indicate some systemic problem, such as inflammatory joint conditions or internal injury from trauma (DeCamp *et al*., 2016).

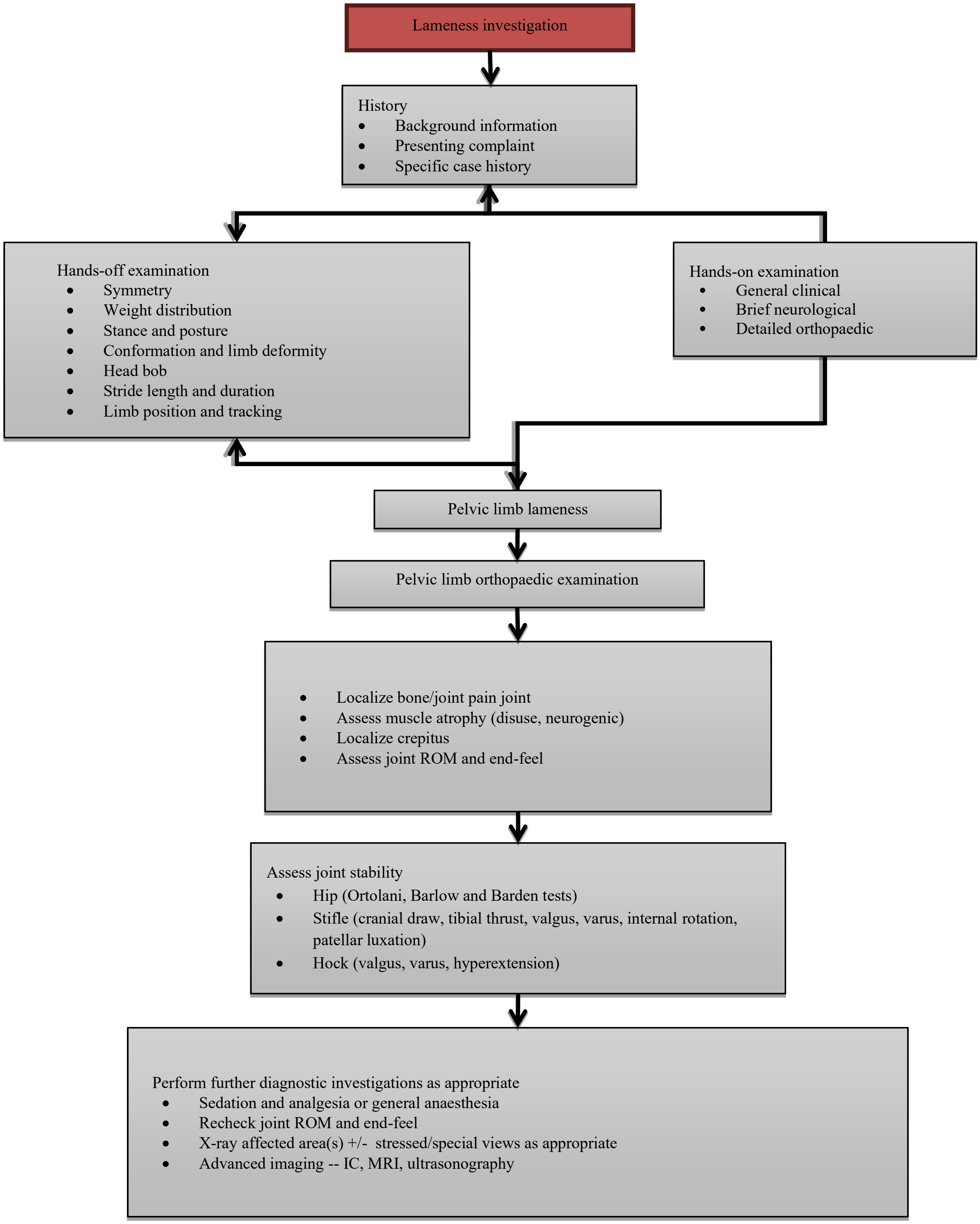

Figure 14: Algorithm for lameness investigation (Scott., 2018).

1.2 Diagnosis and Fracture management

1.2.1 Hands-off examination

- **Gait Analysis**

Lameness represents diminished locomotor function, manifesting as movement difficulty, stiffness, or impaired rising/jumping (Scott, 2018). Initial assessment begins with *observation at rest*: animals may subtly shift weight away from painful limbs during standing or prefer sitting with bilateral pelvic injuries (Aithal *et al*., 2023). Evaluation should start unobtrusively during free movement in the exam room to capture natural behavior before clinical stress alters presentation (Duerr, 2020; DeCamp *et al*., 2016).

Observation in motion evaluates walking/trotting gaits, with tight circles or stair climbing often revealing subtle lameness (Duerr, 2020). Key indicators include:

- Shortened stride, head elevation during limb impact
- Toe-dragging, circumduction, or abnormal limb rotation
- Stumbling, ataxia, or abnormal sounds (clicks/snaps)

Neurologic deficits (e.g., toe-scuffing, crisscrossing) distinguish neurologic from orthopedic causes, while reduced joint motion suggests articular pathology (DeCamp *et al*., 2016; Duerr, 2020). Standardized lameness scales improve consistency in documenting findings over time (DeCamp *et al*., 2016).

1.2.2 Hands-on examination

- **General clinical examination**

A comprehensive clinical assessment precedes fracture management decisions, with localization and diagnosis of complete long bone fractures being relatively straightforward through clinical examination, though incomplete fractures pose diagnostic challenges (Aithal *et al*., 2023). Examination requires tailoring to patient size: medium and large dogs are best assessed on non-slip flooring to ensure relaxation, while small dogs may be examined on elevated surfaces. General health evaluation identifies comorbidities influencing treatment (Scott, 2018). Classic fracture signs include acute non-weight-bearing lameness, limb shortening, deformity, palpable swelling, crepitation, and pain; open fractures may present with soft tissue loss (Fossum *et al*., 2019; Aithal *et al*., 2023).

- **Routine neurological assessment of lameness**

A brief neurological screen is routinely performed, expanding to a full examination if history, gait analysis, or clinical findings suggest neurological involvement. Critical components include lateral limb hopping and paw replacement testing – delayed correction of paw position indicating abnormality (Scott, 2018). This facilitates anatomical localization of neurological dysfunction (Bartner, 2020).

- **Orthopaedic examination**

Examination must be systematic and thorough, commencing with non-painful areas to preserve patient cooperation and progressing proximal-to-distal with contralateral limb comparison (Scott, 2018; von Pfeil & Duerr, 2020). Key tibial/fibular landmarks include: the entirely palpable cranial/medial tibial surface; the distally palpable fibula near the lateral malleolus; the tibial tuberosity cranially; and the gastrocnemius bellies/common calcaneal tendon insertion caudally (Scott, 2018). Palpation seeks swelling, crepitus, or discontinuity while minimizing manipulation to avoid distress (Aithal *et al*., 2023; Abercromby, 2016). Vascular integrity is confirmed via distal limb warmth/capillary refill (though shock reduces reliability), while neurological function must be assessed to prognosticate limb utility (Abercromby, 2016; von Pfeil & Duerr, 2020).

- **Fracture Assessment Scoring**

Post-diagnosis, fractures are evaluated through a tripartite scoring system: Mechanical factors (anticipated forces dictating required fixation stability) (Abercromby, 2016; Fossum *et al*., 2019); Biological factors (local soft tissue damage/systemic health predicting healing timeline) (Abercromby, 2016); and Clinical factors (owner compliance, patient behavior, home environment guiding aftercare) (Abercromby, 2016; DeCamp, 2003). This framework informs implant selection and surgical strategy (Fossum *et al*., 2019).

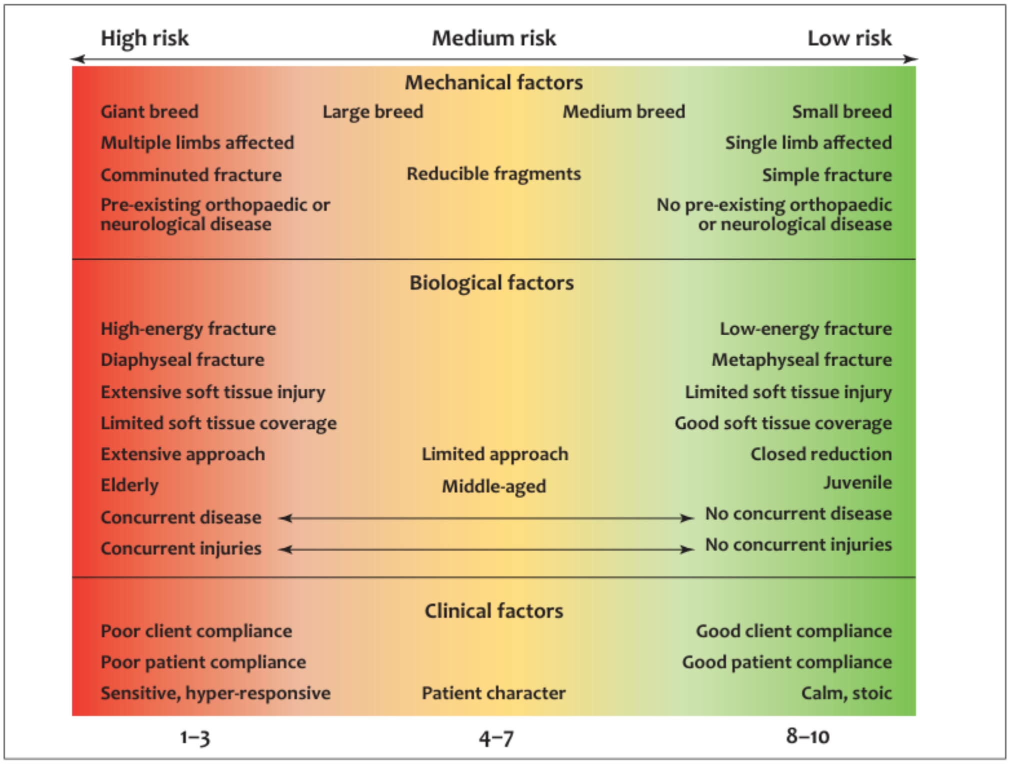

Figure 15: The Fracture Patient Assessment Score (FPAS) (Abercromby., 2016).

2. Emergency Management

A rapid but thorough initial examination must be performed and a detailed history taken. Priority is given to any life-threatening injuries; the first few minutes after arrival are pivotal to survival of the severely traumatized patient (Abercromby., 2016). Most fracture presentations are simple, acute and have a clear history or there is a high index of suspicion (e.g. the animal has been missing) of external trauma (Hobbs *et* Pead., 2018). Once the 'ABCDE' of emergency medicine has been managed (airway, breathing, circulation, disability, exposure), further more detailed examination and assessment are pursued (Abercromby., 2016).

3. Diagnostic Imaging

It is essential for fracture diagnosis, classification, treatment planning, and monitoring healing progression (Hammond, 2016). Radiography confirms fracture presence, type, and location, guiding surgical planning (Aithal *et al.*, 2023). Orthogonal views of areas identified during orthopedic examination are mandatory, with medio-lateral or latero-medial views being the minimum requirement for limb assessment (Scott, 2018; Aithal *et al.*, 2023). While plain radiography typically suffices for fracture confirmation, advanced techniques like digital radiography or CT improve accuracy for detecting occult fractures and are increasingly utilized in small animal practice (Aithal *et al*., 2023). However, advanced imaging should be reserved for carefully selected cases following thorough clinical evaluation and lameness localization, not as a diagnostic shortcut (Scott, 2018).

3.1. Imaging Modalities

All of the diagnostic imaging modalities available to veterinary practitioners have a role to play in imaging musculoskeletal cases, but radiography, as the most widely available and arguably the easiest to perform, remains the mainstay of imaging of musculoskeletal disease (Maddox., 2018). Diagnostic imaging modalities for investigation of fractures include radiography, magnetic resonance imaging, ultrasonography and nuclear scintigraphy (Hammond., 2016). Computed tomography (CT) is increasingly being used, particularly for conditions affecting bones, while ultrasonography, magnetic resonance imaging (MRI) and scintigraphy (nuclear medicine) are all able to provide additional specific and complementary information (Maddox., 2018).

- **Radiography**

This remains the most commonly used modality, due to both its widespread availability and the excellent bone imaging it provides (Hammond., 2016). It is extremely useful for detecting and evaluating fractures, as well as for assessing fracture fixation and healing. In general, two orthogonal (90 degrees to each other) views of an area are taken (DeCamp *et al*., 2016).

However, disadvantages of radiography include ionizing radiation and the possibility of underdiagnosis of certain disease processes. It is important for the clinician to remember that normal radiographs of a limb or body part do not exclude disease, and additional advanced imaging may be required for diagnosis (Marolf., 2020).

- **Computed Tomography**

CT generates cross-sectional radiographic images reconstructed computationally, utilizing a gantry with rotating x-ray tube and detector array to eliminate structural superimposition (DeCamp *et al*., 2016; Maddox, 2018).

- **Magnetic Resonance Imaging**

MRI produces images via electromagnetic excitation of tissue protons, offering superior soft tissue and articular cartilage resolution as the gold standard for soft tissue injury assessment (Marolf, 2020; DeCamp *et al*., 2016).

- **Ultrasonography**

Ultrasonography employs high-frequency sound waves, primarily evaluating soft tissue pathologies (e.g., tendon ruptures) or trauma-associated conditions (e.g., bladder rupture) rather than osseous structures (Hammond, 2016; Maddox, 2018). It visualizes bone surfaces, callus formation, and vascularization at fracture sites, sometimes detecting healing earlier than radiography (Risselada *et al*., 2005; Risselada *et al*., 2007). Advantages include no ionizing radiation and feasibility in awake patients, but results are operator-dependent (Marolf, 2020).

3.2. Fracture Identification & Radiographic Technique

Radiographic evaluation of suspected fractures requires imaging areas indicated by clinical signs and orthopedic examination, with at least two orthogonal views essential for comprehensive three-dimensional assessment of the injury (Hammond, 2016; Maddox, 2018). Traumatic fractures typically manifest as altered bone contour with cortical/medullary disruption, evidenced by radiolucent fracture lines (Hammond, 2016). Standard technique employs a vertical primary X-ray beam and tabletop setup, utilizing a grid for tissue thickness >10 cm; lateral views position the affected limb lowermost (mediolateral orientation) adjacent to the cassette (Maddox, 2018). Subtle or incomplete fractures may require repeat radiographs after 7–10 days to permit fracture line widening through remodeling (Hammond, 2016). Contralateral limb radiographs provide comparative reference for anatomy, implant sizing, or pre-contouring (Maddox, 2018), while fragment override appears as increased opacity on one view but requires orthogonal confirmation for spatial interpretation (Hammond, 2016).

3.3. Radiographic Description of Fractures

When a fracture is identified on a radiograph, various features of the fractured bone and surrounding soft tissue should be considered to maximize the information regarding the fracture and ensure the correct treatment protocol is initiated (Hammond., 2016).

- Determining the age of the fracture.
- Assessing whether the fracture is pathological.
- Evaluating the possibility of an open fracture.
- Identifying if the fracture is complete or incomplete.
- Assessing the number of fracture fragments present..
- Describing the direction of the fracture lines.
- Determining articular involvement.
- Assessing the maturity of the patient.
- Looking for evidence of avulsion (Hammond., 2016).

IV. Treatment Options

1. Non-surgical Management of Fractures (External Coaptation)

External coaptation conservatively immobilizes fractures using bandages, splints, or casts without invasive techniques (Aithal., 2023). These devices approximate bone fragments through uniform pressure distribution (DeCamp *et al*., 2016), providing excellent outcomes for stable fractures when properly selected (Dyce., 2016; Aithal., 2023).

Bandaging restricts joint motion, reduces weight-bearing forces, minimizes swelling, and prevents self-trauma (Marcellin-Little., 2018), but is only indicated for highly stable fractures in young patients where biological healing compensates for reduced stability (Zaera Polo., 2015).

1.1Principles of External Coaptation

Coaptation facilitates secondary bone healing via callus formation rather than rigid fixation (Dyce, 2016). It primarily restricts joint mobility to reduce pain (Marcellin-Little., 2018), though its effectiveness varies by force type: cylinder casts neutralize bending well but poorly resist compression, torsion, shear, or distraction (DeCamp, 2003; Dyce., 2016).

Consequently, oblique/comminuted fractures risk reduction loss under weight-bearing (DeCamp., 2003), making coaptation unsuitable for inherently unstable injuries (Dyce., 2016). Devices also protect soft tissues from contamination and manage exudate through absorption and compression (DeCamp., 2003; Marcellin-Little., 2018).

Padding must be carefully balanced, as excess permits fragment mobility, while insufficient padding causes pressure sores or necrosis (DeCamp., 2003; Zaera Polo., 2015; Aithal., 2023). Proximal stifle fractures are anatomically contraindicated due to poor cast-bone coupling (Dyce., 2016).

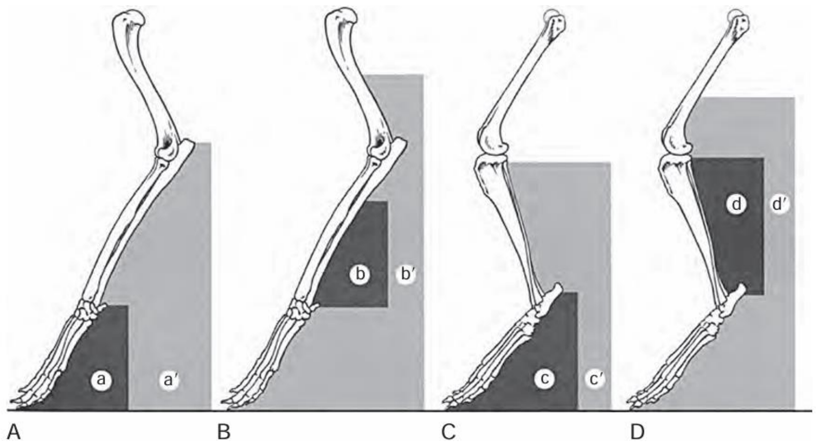

Figure 16: Optimal splint or cast length for fractures in the dark-shaded areas are shown by the length of the light-shaded areas (DeCamp *et al*., 2016).

1.2. Types of External Coaptation

In choosing between the various types of bandages, splints, and casts, it is important to reflect on the somewhat conflicting basic principles of orthopedic bandaging versus external coaptation. The challenge is to balance a patient's needs for soft bandaging with the strict stiffness requirements for bone splinting (DeCamp *et al*., 2016).

- **Bandages**

An orthopaedic bandage serves many useful functions that can augment and support the healing processes of soft tissue and bone. The four primary functions of a bandage are protection, absorption of draining material, compression of soft tissue, and stabilization (DeCamp., 2003).

- **Robert Jones Bandage**

It is used for temporary immobilization of a fractured limb and to help decrease swelling (Aithal., 2023; DeCamp., 2003; DeCamp *et al*., 2016; White *et* Sylvestre., 2019). This bulky, cotton-gauze wrapping is typically used before or after surgery for temporary limb splintage (DeCamp., 2003; DeCamp *et al*., 2016; Fossum *et al*., 2019).

Limitations: Thick cotton padding loosens after application and contributes to instability at the fracture site (DeCamp., 2003). The bandage often slips down to the level of the stifle, causing it not to function as well; it can cause skin lesions along the caudal surface of the stifle area and on the patella (White *et* Sylvestre., 2019).

- **Modified Robert Jones Bandage (The soft-padded bandage)**

The Modified Robert Jones bandages decreases joint motion after surgery, thus decreasing the pain resulting from joint motion in the early postoperative period. It helps control swelling of the operated area (DeCamp., 2003; Marcellin-Little., 2018). Soft padded bandages are used when excessive compression of the tissue is not desired (Fossum *et al*., 2019).

Soft-padded bandages have three layers: an inner (contact) layer of cast padding or rolled cotton (for larger dogs) stabilized by a second layer of rolled gauze and an outer layer that can be made of self-adhesive rubberized tape (Marcellin-Little., 2018). It can incorporate splints or casts to increase its rigidity (Aithal., 2023).

Limitations: Less immobilization of the limb is achieved because the thinner layer of padding is more flexible (DeCamp., 2003).

- **Splints**

A splint is something less than a full cast and typically is molded only to one or multiple aspects of the limb (Aithal., 2023; DeCamp *et al*., 2016). They are indicated in stable closed fractures distal to the proximal 1/3 of the tibia (mostly with intact fibula) (Aithal., 2023).

Rigid materials such as fiberglass, plastic, and splint rods provide the mechanical strength and stiffness required in external coaptation, but these may also endanger the splinted limb if used improperly (DeCamp *et al*., 2016).

- **Lateral Splint**

A great advantage of this splint is that good stability may be achieved (DeCamp *et al*., 2016).

- **Caudal Splint (Spoon Splint)**

Ensure better stifle immobilization (Marcellin-Little., 2018).

Such splints are not suitable for long-term use (soft tissue lesions and poor immobilization) (DeCamp *et al*., 2016).

- **Casts**

Casts are generally considered to be molded tubular structures with minimal padding that if removed, would form a mold from which a casting of the limb could be made. As a general rule, custom molded casts and splints are more efficient stabilizers of the bones and joints than premade ones (DeCamp *et al*., 2016).

A cast typically comprises several layers: a contact layer (generally stockinette), a padding layer, a compression layer and the circumferential cast material (Dyce., 2016).

- **Full Cast**

Materials: Plaster of Paris, fiberglass, or polypropylene substrates.

The classic casting material is plaster of Paris, but with the development of synthetic casting materials, its use has declined. Synthetic casts made of fiberglass or polypropylene substrate impregnated with water-activated polyurethane resin have considerable advantages over plaster casts (DeCamp., 2003; Fossum *et al*., 2019).

Application: A full leg-cast encloses the limb from the toes to the midshaft femur (DeCamp., 2003).

Advantage: The stability achieved is adequate fixation for healing of many fractures and joint conditions (DeCamp., 2003; Fossum *et al*., 2019).

- **Bivalved Cast**

Structure: Full cast cut into two halves and secured with straps (DeCamp., 2003).

Purpose: Allows swelling management (DeCamp., 2003; White *et* Sylvestre., 2019).

Advantage: Preferred over full casts in acute phases (Fossum *et al*., 2019).

1.3. Indications for Non-Surgical Management

Non-surgical management is indicated for fractures below the mid-diaphysis of the tibia (distal to the stifle) and other straight bones (e.g., metacarpus, radius-ulna) (Aithal., 2023). Ideal candidates include stable fractures (greenstick, transverse configurations) with minimal displacement, particularly in immature animals where intact periosteum enhances stability (Dyce., 2016; Fossum *et al*., 2019). Rapidly healing fractures are preferred to minimize cast-related complications (Aithal., 2023). The intact fibula serves as an internal brace, resisting axial collapse at the fracture site (Dyce., 2016; Zaera Polo., 2015).

Closed reduction achieves near-anatomical alignment without open surgery, preserving soft tissue integrity (Aithal., 2023; Dyce., 2016). For transverse fractures, >50% reduction on orthogonal radiographs is acceptable; perfect apposition is neither common nor essential (DeCamp., 2003; Dyce., 2016). This technique suits non-displaced/incomplete fractures distal to the stifle (DeCamp., 2003; Fossum *et al*., 2019). Goals include eliminating rotational/angular deformities, verified via proximal joint radiographs to ensure parallel articular surfaces (Fossum *et al*., 2019). Reduction must be completed before cast application, as devices cannot correct alignment post-placement (DeCamp., 2003). General anesthesia facilitates manipulation but rarely achieves perfect reduction due to soft tissue interposition or fracture forces. Post-reduction radiographs are mandatory, with surgical intervention required if alignment deteriorates during weight-bearing (DeCamp., 2003). Delayed management risks irreducibility from muscle contracture or callus; juveniles tolerate greater displacement due to superior healing capacity (Dyce., 2016; DeCamp., 2003).

Cost considerations: While perceived as economical, cast materials often exceed expenses of simple surgical stabilization (e.g., ESF). Associated complications (pressure sores, malunion) may incur further costs (Dyce., 2016).

1.4. Contraindications & Complications

Coaptation carries significant risks: it may cause early limb disuse leading to long-term dysfunction, permanent joint stiffness, and tissue complications including skin irritation, bruising, ischemic injuries, and impaired bone healing (Marcellin-Little, 2018). Additional complications encompass pressure ulcers, peripheral edema, cast migration, delayed union, malalignment, and nonunion (Dyce, 2016).

Generally, external coaptation is not indicated in open fractures with soft tissue injury (Aithal., 2023).

1.5. Application Techniques & Materials

1.5.1. Bandages & Splints

For bandaging, the animal is properly restrained in lateral recumbency, and the affected limb is held upwards. In hindlimbs, the stifle joint is held partially extended. Help can be taken from an assistant to keep the limb in extended position using an anchor tape/adhesive tape applied along the limb extremity or a cotton bandage tied around and above the toes (Aithal., 2023; DeCamp., 2003).

When applying a bandage, it is best to leave the two middle digits exposed in order to better assess the bandage for tension and the development of potential complications as well as minimizing the creation of an interdigital dermatitis (DeCamp *et al*., 2016; White *et* Sylvestre., 2019).

- **Donuts**

Donuts are used to protect the skin over protuberant areas of the limb from being damaged by the bandage (White *et* Sylvestre., 2019).

- **Stirrups**

Orthopedic bandages can be bulky and stirrups will help to keep the two middle digits exposed and the distally located bandage materials from shifting (DeCamp *et al*., 2016; White *et* Sylvestre., 2019).

- **Contact Layer**

If there is a wound or incision, an appropriate contact layer is selected to cover it (White *et* Sylvestre., 2019).

- **Padding Layer**

It is done by wrapping an even layer of cotton roll around the limb, starting from the distal end, including the fractured bone, and up to above the joint proximally (Aithal., 2023). The bandage (cast padding or cotton) is started at the digits and the material unraveled in a proximal direction with each turn over lapping the previous one by approximately 50% (White *et* Sylvestre., 2019).

- **Compressive Layer**

The compressive layer is applied over and started in the same manner as the cast padding layer (White *et* Sylvestre., 2019). Because this layer will compress the bandage, it is important to start distally and move proximally (Aithal., 2023; White *et* Sylvestre., 2019).

- **Protective Layer**

The final layer is applied/started in the same fashion as the previous two. The working tension was applied with the conforming gauze layer so the protective layer is applied with just enough tension for it to fit smoothly and evenly over the bandage (White *et* Sylvestre., 2019). An adhesive tape is wrapped around the limb in a circular fashion intermittently to secure the bandage (Aithal., 2023).

- **Adding a Splint**

When additional stability is required, place the splint between the compressive (conforming gauze) and protective (cohesive bandage) layers. It must span the entire fracture length, running from the toes distally **to** a point proximally beyond the fracture site, extending specifically to the tibial tuberosity while including the stifle joint (Aithal., 2023). Secure it with porous tape and an additional gauze layer, wrapping both distal and proximal ends to prevent shifting during weight-bearing (White *et* Sylvestre, 2019). In hindlimbs, position the splint along the cranial surface of the crus to accommodate the tibia's anterior placement and avoid interference from the common calcaneal tendon (Aithal., 2023).

Figure 17: Application of the cotton for this heavily padded bandage for the large dog is simplified by splitting Robert-Jones bandage. a 1-pound roll of cotton into two narrower ½-pound rolls. Cast padding may be used in a similar fashion for smaller dogs and cats. **A-C**, Adhesive tape stirrups have been applied to the lower limb and are used for traction while cotton is spiraled proximally. The cotton is carried as high as possible into the groin. One-half to 2 pounds of cotton are necessary to complete the padding, depending on the size of the animal. **D-E**, Multiple spiral layers of elastic gauze are used to compress and conform the cotton. Although firmness is desired, care must be taken not to overtighten the layers in smaller animals. **F**, The bandage is finished by covering the compressed cotton with a protective layer. If desired, additional stability can be obtained by bending an aluminum splint rod to conform to the Robert-Jones bandage, or strips of fiberglass casting tape or moldable plastic could be used. This splint material is placed before covering the bandage with the protective layer. **G**, The bandage should extend fully to the end of the foot, leaving access to the two middle toes for assessment (DeCamp *et al*., 2016).

1.5.2. Casts

General anesthesia is recommended for closed fracture reduction and cast application, with the dog in lateral recumbency (Aithal., 2023; DeCamp., 2003; Fossum *et al*., 2019). The limb must be clean and dry before reduction via traction and digital pressure guided by radiographs. Apply tape stirrups medially/laterally to prevent cast migration (DeCamp., 2003; Dyce., 2016).

Apply stockinette extending 1-2 inches beyond intended cast margins, stretched taut to prevent wrinkles (DeCamp., 2003; Fossum *et al*., 2019). Place protective donuts over the calcaneus using cast padding (DeCamp., 2003). Wrap cast padding in 50% overlapping layers from toes proximally, securing donuts beneath and limiting to ≤2 layers for optimal stability (DeCamp., 2003; Fossum *et al*., 2019).

Wear gloves to handle synthetic casting tape (DeCamp., 2003; Aithal., 2023). Immerse tape in cold water, squeeze, shake excess, and immediately apply from toes with 50% overlap (Aithal., 2023; DeCamp., 2003; Fossum *et al*., 2019). Work rapidly (5-7 minute set time), avoiding wrinkles over limb contours. Enclose toes but leave ends open for monitoring, with padding extending 1 cm beyond tape. Apply extra tension at thigh musculature, terminating tape 1 cm from padding edge (DeCamp., 2003).

After hardening, secure rolled-down stockinette/padding with adhesive tape and affix twisted stirrups distally (DeCamp., 2003; Dyce., 2016; Fossum *et al*., 2019). For bivalved casts, apply second tape layer before final securing (DeCamp., 2003).

2. Surgical Methods

2.1- Principles of Surgical Fracture Repair (Osteosynthesis)

Surgical fracture repair is governed by foundational biomechanical and biological principles that optimize bone healing while minimizing complications. These principles, derived from decades of veterinary orthopedic research, prioritize *anatomical reduction*, *stable fixation*, and *biological preservation* to restore function (Aithal., 2023; DeCamp *et al*., 2016).

2.1.1- Anatomical Reduction

Precise restoration of bone alignment and joint surfaces is critical. For tibial fractures, this involves:

- **Direct Reduction:** Open visualization and fragment manipulation using bone clamps.
- **Indirect Reduction:** Closed techniques (traction, ligamentotaxis) preserving soft tissue attachments.

Compromised reduction increases risks of malunion and post-traumatic arthritis (Johnston *et al*., 2018; Fossum *et al*., 2019).

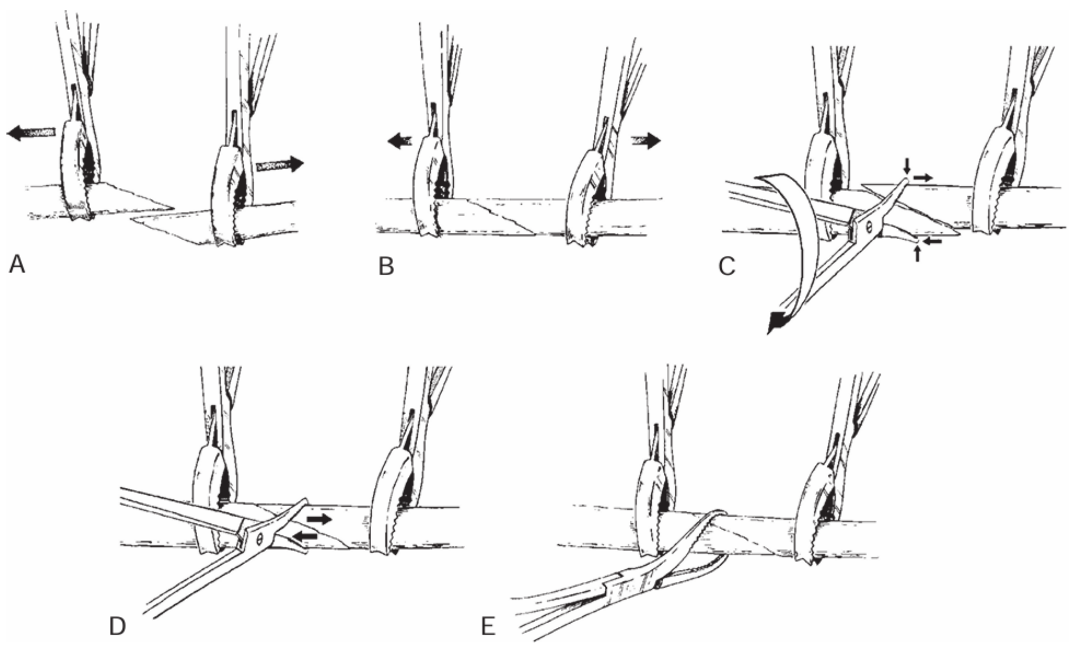

Figure 18: Open reduction of fractures. **A** and **B**, Direct application of force to the bone fragments. **C**, Oblique fracture overriding can be reduced by grasping the fragments with a bone holding forceps that is angulated so that each jaw is toward the end of the bone fragment. The forceps is not locked but held by finger pressure only. **D**, By rotating the forceps in the direction shown in C while applying enough pressure to cause the forceps to grasp the cortex, the fragments will slide into reduction. **E**, After reduction, a locking bone-holding forceps is used to maintain temporary reduction of the fragments while fixation is applied (DeCamp *et al*., 2016).

2.1.2- Stability Types

Absolute stability achieves rigid fixation through interfragmentary compression (e.g., lag screws, compression plates), eliminating motion to enable primary bone healing without callus. It is reserved for simple, reconstructible fractures like transverse tibial breaks but requires extensive dissection and risks stress concentration (DeCamp *et al*., 2016).

Relative stability permits controlled micromotion via flexible fixation (e.g., IM pins, bridging plates), stimulating secondary bone healing with callus formation. This biological approach suits comminuted tibial fractures where anatomical reconstruction is impossible but demands careful postoperative load management (DeCamp *et al*., 2016; Johnston *et al*., 2018).

2.1.3- Implant Selection Criteria

Implants must counteract dominant fracture forces:

- **Bending:** Neutralized by plates/ILN
- **Rotation:** Controlled with locking screws
- **Compression:** Resisted by interlocking nails
- **Distraction:** Prevented with tension band wiring

Selection considers fracture location, patient size, and bone quality (DeCamp *et al*., 2016; Johnston *et al*., 2018).

2.2- Internal Fixation Techniques

Internal fixation of fractures by open reduction provides good alignment and rigid fixation of the bone segments (Aithal., 2023). The primary reason to choose internal fixation for treating a fracture is to hold the fragments rigidly until they are healed while allowing the patient to move the limb and to bear weight (Johnston *et al*., 2018; Roe., 2003).

Internal fixation methods are invasive, they require a surgical approach to the bone (Johnston *et al*., 2018; Roe., 2003). It can be achieved either by intramedullary fixation techniques like pinning/ nailing or by extramedullary techniques like bone plating. Screws, wires, and staples are generally used as ancillary fixation devices along with plates and nails (Aithal., 2023).

The increased tissue damage from the surgical approach and fragment manipulation may prolong healing. Implants remain inside the body and can potentiate infection. The advantages and disadvantages of the various possible approaches must be balanced to optimize an individual patient's care (Roe., 2003).

2.2.1 Intramedullary Pin/Nail

Despite its limitations, intramedullary (IM) Steinmann pins remain the most commonly and widely used for fracture fixation in veterinary practice (Aithal., 2023; DeCamp *et al*., 2016). Nail/IM pin can be used either alone or along with other ancillary techniques (Aithal., 2023). Improvements in IM pinning have developed with better understanding of the biomechanical considerations necessary for successful bone healing, especially in combination with other fixation techniques, including cerclage wire, external skeletal fixators, and bone plates (Aithal., 2023; DeCamp *et al*., 2016).

Due to their central position within the medullary cavity, IM pins can resist bending forces well and maintain alignment (Aithal., 2023; Johnston *et al*., 2018; Moores., 2016; Roe., 2003). The technique of IM pinning is simple and needs minimum instruments (Aithal., 2023).

The key element for successful application of both pinning and wiring techniques is an acute awareness of their shortcomings in stabilizing fractures. Once these deficiencies are recognized and counteracted, pins can be successfully used in many routine fractures, with minimal complications (DeCamp *et al*., 2016). The use of an intramedullary pin alone, however, provides no resistance to axial compression or rotation and is therefore not recommended for clinical use (Moores., 2016).

2.2.1.1-Advantages

There are many potential advantages of pin and wire fixation over bone plates for the veterinary surgeon. Pin and wire fixation is much less expensive than bone plate fixation (DeCamp *et al*., 2016).

Most pin and wire fixations require little surgical exposure, resulting in less tissue trauma and vascular damage and enhanced healing. In general, pins and wires can be applied in less time than needed for plates; this factor saves money and decreases anesthesia time (Aithal., 2023; DeCamp *et al*., 2016).

2.2.1.2- Disadvantages

Pins and wires definitely have disadvantages compared with plates, with most relating to the biomechanical factors. If bone fragments are too small to be reduced and stabilized, pin and wire fixation may not be as stable as a plate (DeCamp *et al*., 2016).

Pins do not resist forces aligned with (compression) or around (rotational) their axes well because there is little friction between the bone and the smooth surface of the pin. Rarely, if ever, is an intramedullary pin used as the sole implant for repair of a shaft fracture. Fractures that are fairly transverse or have any level of comminution are not stable when repaired using an intramedullary pin alone (Johnston *et al*., 2018; Roe., 2003).

2.2.1.3- Types

- **Steinmann Pins**

Solid stainless steel pins occupying 60-70% of medullary canal diameter.

Indications: Transverse or short oblique midshaft tibial fractures (DeCamp *et al*., 2016; Johnston *et al*., 2018).

Limitations:

- Zero rotational stability (requires cerclage/ESF tie-in) (Moores., 2016).
- Risk of pin migration in comminuted fractures (Aithal., 2023).

Tibial Insertion: Medial aspect of proximal tibia (avoid tuberosity) (Johnston *et al*., 2018).

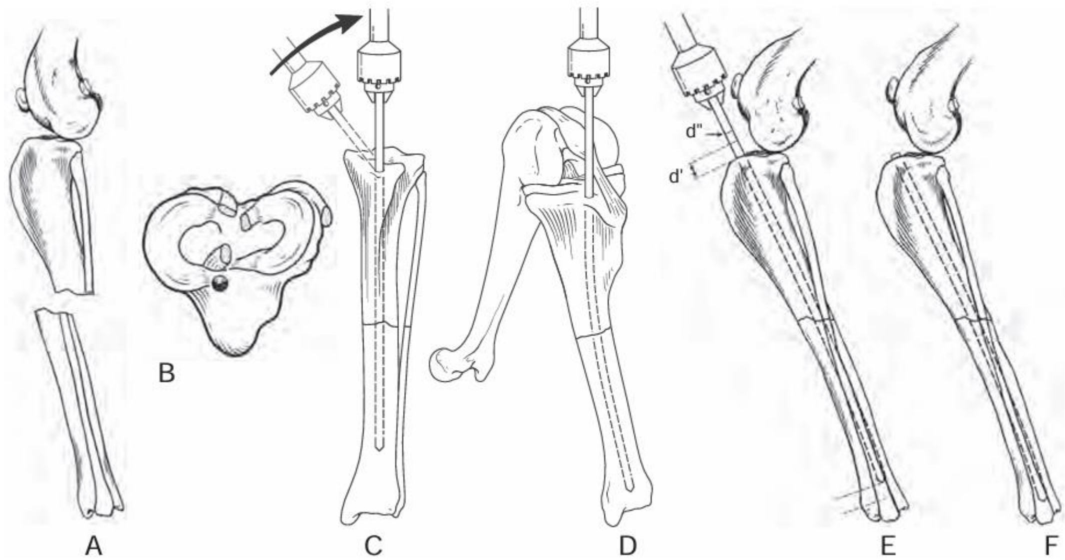

Figure 19: Intramedullary (IM) pinning technique for the tibia. **A**, Transverse fracture of the tibia. **B**, End-on view of the proximal aspect of the left tibia showing both menisci, meniscotibial ligaments, as well as the insertion of the cranial and caudal cruciate ligaments. The circle depicts the approximate location for insertion of an IM pin, immediately cranial to the tibial footprint of the cranial cruciate ligament. **C**, This point, which is located approximately one-third to one-half the distance from the cranial surface of the tibial tubercle to the medial condyle of the tibia, can be "felt" with the tip of the IM pin inserted obliquely in the stifle joint. **D**, With the stifle flexed as much as possible, the pin is inserted through a small medial parapatellar arthrotomy along the medial border of the patellar ligament. The IM pin is then aligned with the medial and caudal cortices of the tibia. **E**, Reduced fracture and IM pin, lateral view. The pin should be inserted as far distally as possible without violating the distal subchondral plate. The IM pin is retracted about ¼ inch (~6 mm) at d', then cut (d''). **F**, With a countersink and mallet, the IM pin is returned to the original depth. Sufficient pin is left protruding for removal at the time of clinical union if necessary. The same insertion landmarks and technique are used for interlocking nailing (DeCamp *et al*., 2016).

- **Rush Pins**

Elastic pins leveraging three-point endosteal contact.

Indications: Distal tibial metaphyseal fractures (e.g., avulsions near hock) (DeCamp *et al*., 2016; Johnston *et al*., 2018).

Biomechanics:

- Allow controlled micromotion to stimulates callus formation (Moores., 2016).
- Unsuitable for unstable/axial load fractures (Aithal., 2023).

- **Interlocking Nails (ILN)**

Locked nails with proximal/distal screws.

Indications (gold standard): Comminuted tibial shaft fractures (Johnston et al., 2018; DeCamp *et al*., 2016).

Mechanical Advantage:

- Converts shear forces to compressive forces at the screw-bone interfaces (Moores., 2016).
- Resists bending, rotation and collapse (Aithal., 2023).

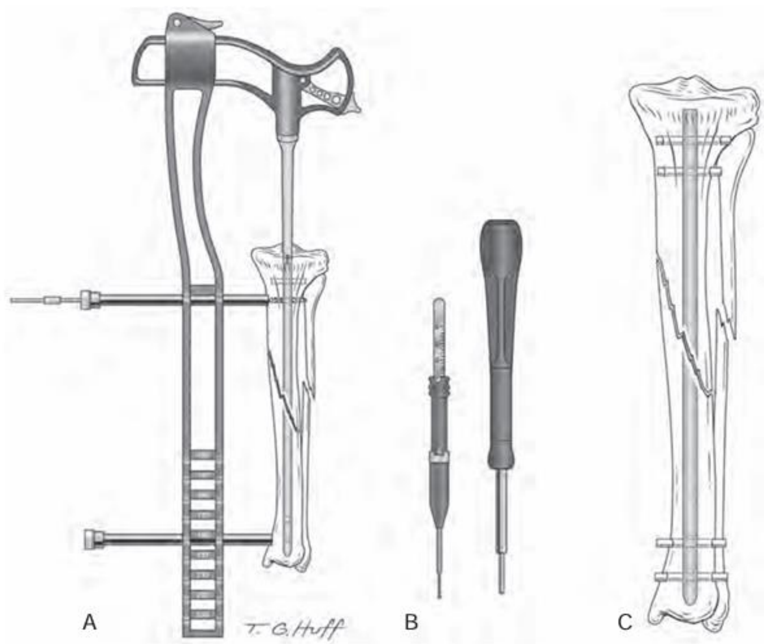

Figure 20: Angle stable interlocking nail. **A**, Drill jig for placing bolts through the bone and pin. **B**, Measuring tool and placement tool for the interlocking bolt. **C**, Bolts are firmly fixed to the nail hole with no slack or rotational instability (DeCamp *et al*., 2016).

2.2.2- Bone Plates and Screws

Bone plates and screws represent a cornerstone of internal fixation for tibial and fibular fractures, providing rigid stabilization through extramedullary load-sharing constructs. These implants enable precise anatomical reduction and immediate postoperative weight-bearing by resisting bending, compression, and rotational forces via screw-bone interfaces (Johnston *et al*., 2018; Aithal., 2023). The biomechanical versatility of plating systems accommodates diverse fracture patterns: compression plates achieve absolute stability through interfragmentary compression in simple transverse or oblique fractures, while locking plates (LCP) function as fixed-angle devices for comminuted fractures or osteopenic bone, minimizing soft tissue disruption via minimally invasive techniques (DeCamp *et al*., 2016; Moores., 2016). Neutralization or bridging plates further extend applications by protecting lag screws or spanning unstable zones with butterfly fragments, ensuring structural integrity during healing (Johnston *et al*., 2018).

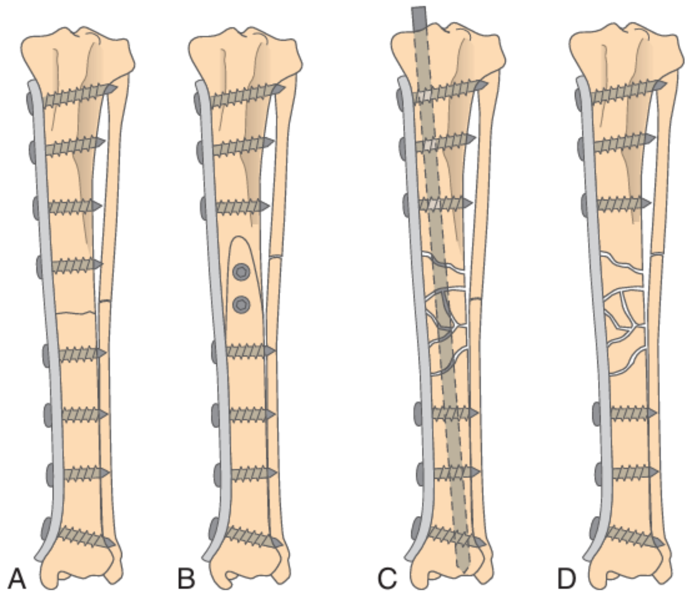

Figure 21: A plate placed on the medial surface of the tibia may function as **(A)** a compression plate for transverse fractures, **(B)** a neutralization plate to support long oblique fractures reconstructed with lag screws, or **(C–D)** a bridging plate with or without an intramedullary pin to span a nonreducible fracture (Fossum *et al*., 2019).

2.2.2.1- Screw Biomechanics and Applications

Screw selection is critical for optimizing fixation strength. Cortical screws feature fine threads and high core diameter, providing superior pull-out resistance in the dense cortical bone of tibial shafts (Johnston *et al*., 2018). Cancellous screws utilize coarse threads and reduced core diameter to maximize purchase in metaphyseal trabecular bone, making them ideal for proximal/distal tibial fractures (Aithal., 2023). Lag screws uniquely convert shear forces to compression when placed perpendicular to fracture planes, creating absolute stability for oblique fractures, though they require protection from bending forces via neutralization plates (DeCamp *et al*., 2016).

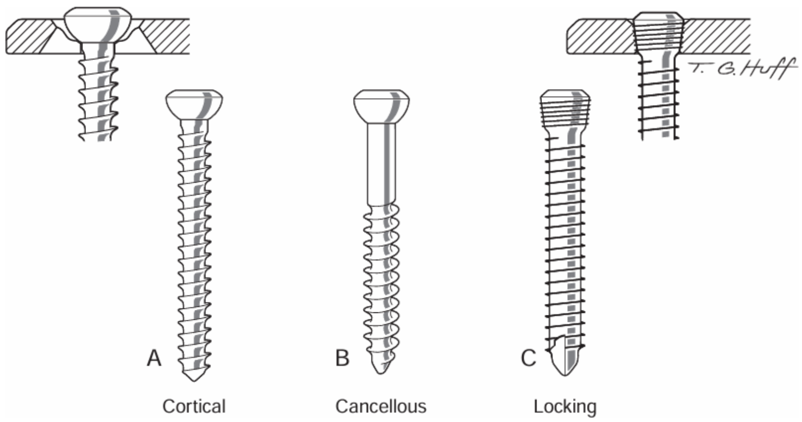

Figure 22: Bone screw types. **A**, Cortical screws are designed to be used for any plate application in the dense diaphyseal bone and may also be used to function as a lag screw. **B**, Cancellous screws are used fixate plate to bone in the metaphyseal region, or to compress fragments of epiphyseal and metaphyseal bone. **C**, Locking screws are designed specifically and only for use with locking plates (DeCamp *et al*., 2016).

2.2.2.2- Tibia-Specific Surgical Considerations

The medial approach to the tibial shaft remains the gold standard for plating, allowing direct fragment visualization while avoiding neurovascular structures (Johnston *et al*., 2018). For distal fractures, pre-contoured locking plates facilitate epiphyseal screw placement without joint penetration. Fibular fixation is rarely indicated unless lateral malleolar involvement compromises tarsal stability, as the fibula primarily functions as a tension band for the tibia (Aithal., 2023; DeCamp *et al*., 2016).

2.2.2.3- Advantages of Plating Systems

Plates offer unparalleled benefits for complex tibial fractures. Anatomical restoration of joint surfaces prevents post-traumatic arthritis, while rigid fixation enables immediate functional loading, thus reducing complications like muscle atrophy or joint contracture (Johnston *et al*., 2018). Locking plate technology permits minimally invasive application (MIPO), preserving fracture hematoma and vascularity to accelerate healing (Aithal., 2023). The adaptability of modern systems accommodates diverse scenarios, from compression fixation of simple fractures to bridging of irreparable comminution (Moores., 2016).

2.2.2.4- Disadvantages and Limitations

Significant drawbacks include extensive soft tissue dissection in conventional approaches, which may devitalize bone fragments and elevate infection risks (5-15% in contaminated wounds) compared to external fixation (DeCamp *et al*., 2016). Locking constructs can induce stress shielding, leading to cortical atrophy under the plate; particularly problematic in geriatric patients with poor bone quality (Johnston *et al*., 2018). Financial barriers also exist, as locking systems require specialized instrumentation costing 2-3 times more than basic implants (Aithal., 2023).

2.2.3- Cerclage Wire

Cerclage wiring serves as an adjunctive fixation method primarily indicated for long oblique or spiral fractures of the tibial shaft, where it enhances stability by converting detrimental shear forces into beneficial compressive forces across fracture lines. By applying full circumferential loops around anatomically reduced bone fragments, cerclage wires increase interfacial friction to prevent fragment displacement. However, they lack intrinsic resistance to bending or torsional loads and thus require supplemental stabilization with intramedullary pins or neutralization plates to achieve clinical efficacy (DeCamp *et al*., 2016; Johnston *et al*., 2018).

2.2.3.1- Clinical Applications and Constraints

In tibial fracture management, cerclage wires are only appropriate when the fracture length exceeds twice the bone diameter, ensuring sufficient cortical grip without risking fragment splintering. Their application is contraindicated in comminuted fractures due to inadequate fragment capture and in osteopenic bone where wire cut-through may occur. While rarely used for isolated fibular injuries, cerclage may supplement tibial fixation in distal fractures involving the lateral malleolus to restore tarsal stability (Aithal., 2023; Johnston *et al*., 2018).

2.2.3.2- Technical Application

Successful cerclage application demands strict adherence to biomechanical principles. Precise anatomic reduction must precede wire placement, with loops spaced no closer than 5mm apart and maintained at least 10mm from fracture edges to avoid stress risers (Moores., 2016; DeCamp *et al*., 2016).

2.2.3.3- Benefits and Limitations

The primary advantages of cerclage wiring include minimal cost, preservation of local vascularity compared to plating techniques, and effective reduction of fracture gaps to under 1mm. Conversely, wires cannot function as standalone implants due to poor load-bearing capacity, with reported failure rates of 15-30% through breakage or slippage. Overtightening during application may further compromise bone perfusion, delaying healing or promoting nonunion (Aithal., 2023; Johnston *et al*., 2018).

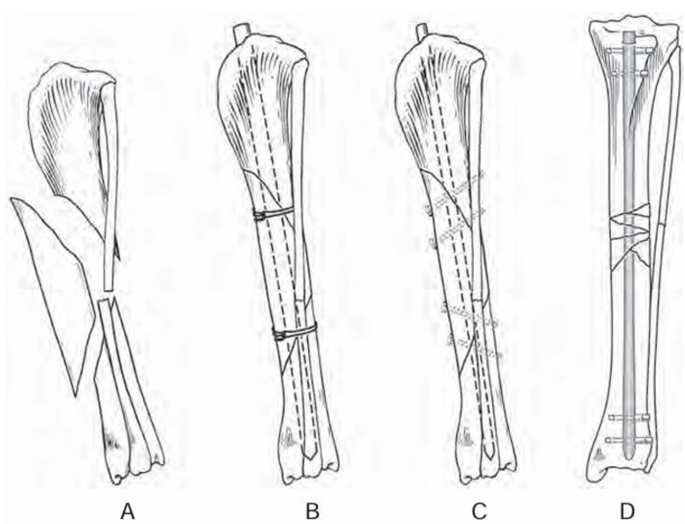

Figure 23: Rotational stability may be achieved for intramedullary fixation of tibia fractures by several different means. **A**, Segmental fracture of the tibia with proximal and distal long oblique patterns. **B**, Two double-loop cerclage wires and an intramedullary (IM) pin are often sufficient fixation for cats and small dogs. **C**, Alternatively, lag screws can be used instead of cerclage. To avoid interference, a smaller diameter IM pin should be selected. **D**, Rotational and bending stability can be provided with an angle-stable interlocking nail with two bolts proximal and two bolts distal to an unstable fracture. The longest possible nail should always be selected (DeCamp *et al*., 2016).

2.3- External Skeletal Fixation Techniques

External skeletal fixation (ESF) employs percutaneous pins connected to external frames to stabilize fractures while preserving fracture biology (DeCamp *et al*., 2016). This technique is indispensable for open tibial fractures with contamination (Gustilo Type II/III) (Fossum *et al*., 2019), comminuted fractures where anatomical reconstruction is unattainable (Johnston *et al*., 2018), and cases with compromised soft tissues (e.g., severe trauma) (Aithal., 2023). ESF functions as a load-sharing construct, permitting staged destabilization as healing progresses (DeCamp *et al*., 2016).

2.3.1- Biomechanical Principles

Stability hinges on pin-bone interface integrity, optimized by positive-profile pins that maximize thread-bone purchase (Marcellin-Little., 2003). Frame stiffness increases with higher pin density (≥2 pins/fragment), decreased bar-to-bone distance (2–3 cm), and double-bar configurations in dogs >20 kg (Jaeger *et* Wosar, 2018).

2.3.2- Fixator Types and Configurations

Three primary ESF configurations are utilized in tibial fracture management:

- **Type I Linear Fixators**: Unilateral frames for simple distal tibial fractures (DeCamp *et al*., 2016).
- **Type II Linear Fixators**: Bilateral frames resisting bending/torsion in comminuted midshaft fractures (Jaeger *et* Wosar., 2018).
- **Circular Fixators (Ilizarov)**: Tensioned wires (1.5–2.0 mm) for fractures with bone loss or infection (Marcellin-Little., 2003).

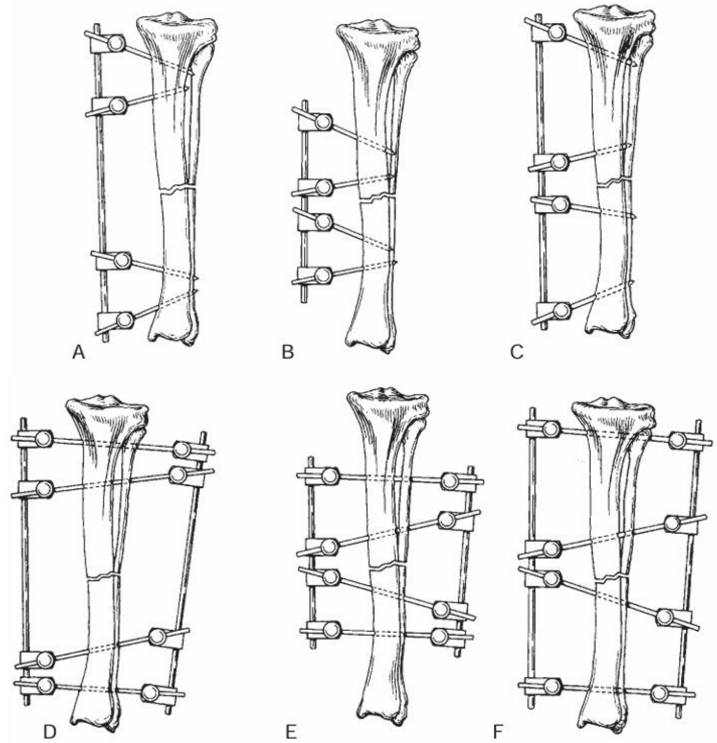

Figure 24: **A**, **B**, and **C**, Unilateral (type I) configurations. **D**, **E**, and **F**, bilateral (type II) configurations (DeCamp *et al*., 2016).

Figure 24*:*

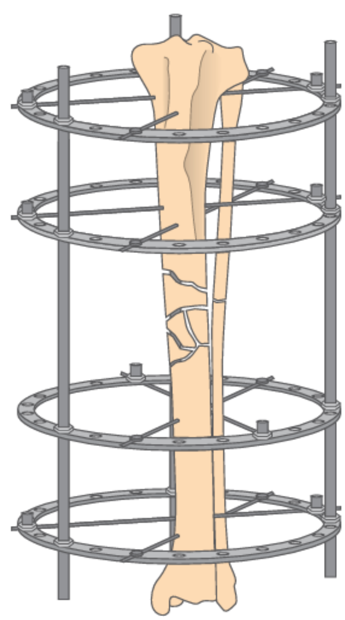

Figure 25: Standard circular fixator frame for fracture management (Fossum *et al*., 2019).

2.3.4- Advantages Over Internal Fixation

ESF minimizes soft tissue dissection, preserving periosteal blood supply (critical in high-energy trauma). The system's adaptability allows postoperative adjustments for alignment corrections. Unlike internal implants, ESF components can be removed incrementally to promote callus maturation. In infected fractures, pin tracts facilitate exudate drainage, reducing sepsis risk compared to enclosed plating systems (DeCamp *et al*., 2016; Marcellin-Little, 2003).

2.3.5- Complications and Mitigation Strategies

- **Pin Tract Infections (15–30% incidence):** Manifest as purulent discharge or peri-pin swelling. Prevention includes daily cleaning with 0.05% chlorhexidine and avoidance of excessive skin motion. Management requires oral antibiotics and pin removal if unresolved (Jaeger *et* Wosar, 2018).
- **Pin Loosening:** Often caused by thermal necrosis during drilling. Low-speed drilling with saline irrigation minimizes bone damage.
- **Frame Failure:** More common in dogs >20 kg. Double-bar configurations and larger diameter pins (≥3.5 mm) mitigate this risk (DeCamp *et al*., 2016).

2.4- Indications for Specific Surgical Techniques

2.4.1- Intramedullary Pinning (Steinmann/Rush Pins)

Indicated for non-comminuted transverse midshaft fractures (Johnston *et al*., 2018). Steinmann pins require cerclage adjuncts for rotational stability; contraindicated in oblique fractures (Moores., 2016). Rush pins suit distal metaphyseal avulsions (DeCamp *et al*., 2016).

2.4.2- Interlocking Nails (ILN)

Gold standard for comminuted tibial shaft fractures (Johnston *et al*., 2018). Biomechanically superior in large breeds (>20 kg) but contraindicated near articular surfaces (<2 cm) (DeCamp *et al*., 2016).

2.4.3- Compression Plating

Optimal for simple transverse fractures via interfragmentary compression (Johnston *et al*., 2018). Avoid in contaminated wounds (Fossum *et al*., 2019).

2.4.4- Locking Plates (LCP)

Preferred for comminuted proximal/distal fractures or osteopenic bone. MIPO technique preserves blood supply (Aithal., 2023).

2.4.5- Cerclage Wiring

Cerclage wires serve strictly as adjuncts in long oblique fractures. They convert shear forces to compression but provide no standalone stability. Its use is prohibited in comminuted fractures or osteopenic bone due to fragment splintering and cut-through risks (DeCamp *et al*., 2016; Aithal., 2023).

2.4.6- External Skeletal Fixation (ESF)

ESF is the technique of choice for open fractures (Gustilo Type II/III) with severe contamination or soft tissue loss, as percutaneous pins minimize implant seeding and permit wound access (Jaeger *et* Wosar., 2018). ESF is relatively contraindicated in uncooperative patients or owners unable to manage daily pin care (Fossum *et al*., 2019).

2.4.7- Fibular-Specific Considerations

Isolated fibular fixation is rarely indicated except in distal lateral malleolar fractures destabilizing the tarsus. Tension band wiring or lag screws restore tarsocrural joint integrity but are avoided in proximal fractures where fibular nonunion does not impede function (Johnston *et al*., 2018).

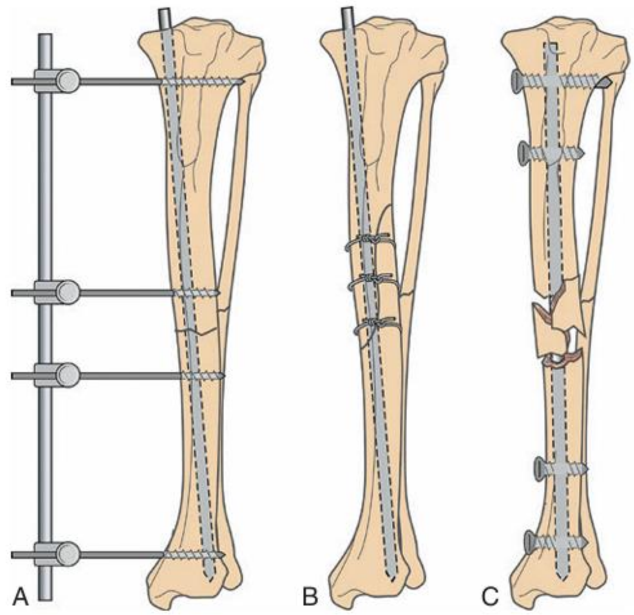

Figure 26: (A) Transverse or short oblique fractures may be stabilized with an intramedullary (IM) pin and a unilateral external fixator. **(B)** Spiral or oblique fractures may be treated with an IM pin and multiple cerclage wires. **(C)** An interlocking nail may be used to support nonreducible fractures (Fossum *et al*., 2019).

Figure 26:

2.5- Potential Surgical Complications

2.5.1 Infection

Infections occur in 5–15% of internal fixations and 15–30% of external fixations, often due to biofilm formation on implants or soft tissue compromise. Open fractures (Gustilo Type II/III) and prolonged surgery (>90 min) significantly elevate risk. Prophylaxis requires pre-operative antibiotics and strict aseptic technique. Early debridement is critical for contaminated cases (Fossum *et al*., 2019; DeCamp *et al*., 2016).

2.5.2 Implant Failure

- **Plates/Screws:** Failure manifests as screw pull-out in osteopenic bone or excessive loading.
- **IM Pins:** Bending/migration occurs with inadequate canal fill (<60%).
- **ESF:** Pin breakage follows thermal necrosis from high-speed drilling.

Prevention: Canal fill ≥70% for pins; low-speed drilling with irrigation for ESF; plate length ≥3× fracture length (Johnston *et al*., 2018; Moores., 2016).

2.5.3 Neurovascular Injury

Common peroneal nerve injury (15–20% risk in craniolateral approaches) and saphenous vessel damage (medial approaches) are most prevalent. Immediate repair is essential for sharp transections; neuropraxia typically resolves in 4–6 weeks (Piermattei *et al*., 2006).

3.Criteria for Choosing a Treatment Approach

Selecting the optimal management strategy for tibial and fibular fractures requires synthesizing fracture characteristics, patient-specific variables, owner constraints, and clinical resources into an evidence-based decision matrix (DeCamp *et al*., 2016; Aithal., 2023).

3.1 Fracture-Specific Factors

Location & Pattern:

- **Proximal Tibia:** Locking plates (angular stability) or circular ESF (articular involvement) (Johnston *et al*., 2018; Jaeger *et* Wosar., 2018).
- **Midshaft:** Interlocking nails (comminution) or compression plating (simple transverse) (DeCamp *et al*., 2016; Moores., 2016).
- **Distal:** Trans-articular ESF or minimally invasive plating (epiphyseal sparing) (Aithal., 2023; Johnston *et al*., 2018).

Stability & Displacement:

- Non-displaced fractures may tolerate external coaptation; unstable fractures demand rigid fixation (Johnston *et al*., 2018; Dyce., 2016).

Open vs. Closed:

- **Gustilo Type I/II:** ESF (percutaneous, wound accessible) (Fossum *et al*., 2019).
- **Gustilo Type III:** Staged protocols (debridement → delayed ILN/plating) (Fossum *et al*., 2019; Aithal., 2023).

3.2 Patient-Specific Factors

Age & Skeletal Maturity:

- **Juveniles:** External coaptation or flexible fixation (Rush pins) to preserve physes (DeCamp *et al*., 2016; Moores., 2016).
- **Geriatrics:** Locking plates (osteopenia-compatible) (Johnston *et al*., 2018; Aithal., 2023).

Breed & Size:

- **Large breeds (>25 kg):** ILN/plating (load-bearing capacity) (Moores., 2016; Johnston *et al*., 2018).
- **Toy breeds:** ESF (minimal soft tissue dissection) (DeCamp *et al*., 2016).

3.3 Owner-Specific Factors

- **Financial Capacity:**

ESF costs 40% less than locking plates; external coaptation is least expensive but higher revision risk (Aithal., 2023; DeCamp *et al*., 2016).

- **Compliance:**

ESF requires daily pin care; non-compliant owners favor internal fixation (Jaeger *et* Wosar., 2018; Fossum *et al*., 2019).

Discussion

The management of tibial and fibular fractures in dogs demands a comprehensive integration of anatomical principles, biomechanical understanding, and clinical decision-making. The tibia's critical function as the primary weight-bearing structure, transmitting 85-90% of axial loads from the femur to the talus, directly correlates with its high susceptibility to traumatic injury (Hermanson *et al*., 2019; Barone, 1986). This vulnerability is clinically manifested in the predominance of mid-diaphyseal fractures, which constitute approximately 64% of tibial injuries according to epidemiological studies (Boone *et al*., 1986). Concurrently, the fibula serves as an essential lateral stabilizer through its interosseous membrane connection, with particular significance in distal fractures involving the lateral malleolus where it maintains tarsocrural joint integrity (Hermanson *et al*., 2019; Hayashi, 2018). Breed-specific predispositions further complicate clinical management, exemplified by Staffordshire Bull Terriers exhibiting an 86% incidence of tibial tuberosity avulsions, likely attributable to unique tibial crest morphology and biomechanical loading patterns (Gower *et al*., 2008; Bhamburkar, 2021).

Diagnostic protocols continue to emphasize orthogonal radiography as the foundational imaging modality, though advanced techniques like computed tomography (CT) and magnetic resonance imaging (MRI) have proven indispensable for evaluating complex articular fractures, occult injuries, and preoperative planning (Hammond, 2016; Marolf, 2020). Treatment selection requires careful stratification based on fracture characteristics and patient factors. Conservative management through external coaptation remains viable for stable, non-displaced fractures in juvenile patients, where biological healing potential compensates for reduced mechanical stability (Dyce, 2016). However, surgical intervention is typically mandated for unstable configurations, with implant selection governed by biomechanical requirements and biological preservation principles. Intramedullary fixation illustrates this decision-making complexity; while Steinmann pins offer simplicity and cost-effectiveness for transverse midshaft fractures, their standalone application provides no resistance to axial compression or rotational forces, rendering them biomechanically inadequate for clinical use without supplemental stabilization (Moores, 2016; DeCamp *et al*., 2016). This limitation necessitates adjunctive techniques such as cerclage wiring for long oblique fractures or external fixator tie-ins for comminuted patterns to achieve sufficient stability (Johnston *et al*., 2018).

Contemporary surgical options demonstrate specialized advantages tailored to specific fracture challenges. Interlocking nails (ILN) have emerged as the gold standard for comminuted tibial shaft fractures due to their load-sharing design that effectively resists bending, rotation, and collapse through locked proximal and distal bolts (DeCamp *et al*., 2016; Moores, 2016). Locking compression plates (LCP), particularly when applied via minimally invasive plate osteosynthesis (MIPO) techniques, provide angular stability essential for metaphyseal fractures and osteopenic bone while preserving fracture hematoma and vascularity (Aithal *et al*., 2023; Johnston *et al*., 2018). External skeletal fixation (ESF) remains the technique of choice for Gustilo Type II/III open fractures with severe contamination, as percutaneous pins minimize implant seeding risk while permitting ongoing wound management (Jaeger *et* Wosar, 2018; Fossum *et al*., 2019). The critical decision between internal and external fixation often hinges on multiple factors beyond fracture morphology, including patient size (with ESF preferred for toy breeds to minimize soft tissue dissection), owner compliance (given ESF's demanding pin care requirements), and financial constraints (as ESF costs approximately 40% less than locking plate systems) (DeCamp *et al*., 2016; Aithal *et al*., 2023).

Despite technological advances, persistent complications underscore the need for meticulous technique and postoperative vigilance. Pin tract infections complicate 15-30% of ESF cases, while implant failure rates of 5-15% plague internal fixation, often stemming from biofilm formation on implants or excessive loading in compromised bone (Fossum *et al*., 2019; DeCamp *et al*., 2016). Future research should prioritize breed-specific biomechanical studies to refine implant selection, long-term outcome comparisons between fixation methods, and evidence-based rehabilitation protocols to optimize functional recovery (Butterworth, 2016; Aithal *et al*., 2023). This integrated approach—grounded in anatomical reality, biomechanical principles, and evidence-based clinical practice—forms the essential foundation for successful management of these complex orthopedic injuries (DeCamp *et al*., 2016; Aithal *et al*., 2023).

References

1- **Abercromby R.,** *Preoperative assessment of the fracture patient*, In: BSAVA Manual of Canine and Feline Fracture Repair and Management, 2016, 2nd edition, pages 49-52. BSAVA, British Small Animal Veterinary Association.

2- **Aithal H.P, Pal A, Kinjavdekar P, Pawde A.M.,** *Basic Considerations*, In: Textbook of Veterinary Orthopaedic Surgery, 2023, pages 40-41. Springer Nature.

3- **Aithal H.P, Pal A, Kinjavdekar P, Pawde A.M.,** *Management of Specific Fractures in Small Animals*, In: Textbook of Veterinary Orthopaedic Surgery, 2023, pages 194-199. Springer Nature.

4- **Aithal H.P, Pal A, Kinjavdekar P, Pawde A.M.,** *Principles of Fracture Fixation Techniques*, In: Textbook of Veterinary Orthopaedic Surgery, 2023, pages 66-92, 105-126. Springer Nature.

5- **Bartner L.,** *The Neurologic Examination*, In: Canine Lameness, 2020, page 48. John Wiley & Sons, Inc.

6- **Barone R.,** *Artères du Bassin, de la Queue et du Membre Pelvien*, Anatomie comparée des mammifères domestiques, Tome cinquième: Angiologie, 1986, 3e édition, pages 397-401. Editions Vigot Frères, Paris.

7- **Barone R.,** *Ceinture et Membre Pelviens*, Anatomie comparée des mammifères domestiques, Tome premier: Ostéologie, 1986, 3e édition, pages 669-681. Editions Vigot Frères, Paris.

8- **Barone R.,** *Muscles de la Ceinture et du Membre Pelviens*, Anatomie comparée des mammifères domestiques, Tome deuxième: Arthrologie et myologie, Partie 2: Myologie, 1986, pages 913-945. Editions Vigot Frères, Paris.

9- **Bhamburkar R.V.,** *Anatomy of Hind Limb*, *In:* Veterinary Anatomy- the Regional Gross Anatomy of Domestic Animals, 2021, pages 681-682, 719-740. NIPA-New India Publishing Agency, New Delhi.

10- **Boone E.G., Johnson A.L., Hohn R.B.,** *Distal tibial fractures in dogs and cats*, In: J Am Vet Med Assoc, 1986, 188:36.

11- **Boone E.G., Johnson A.L., Montavon P., *et al*.,** *Fractures of the tibial diaphysis in dogs and cats*, In: J Am Vet Med Assoc, 1986, 188:41.

12- **Boulay JP, Wallace LJ and Lipowitz AJ.,** *Pathological fracture of long bones in the dog*, In: Journal of the American Animal Hospital Association, 1987; 23, 297–303.

13- **Budras K.D, McCarthy P.H, Fricke W, Richter R, Horowitz A, Berg R.,** *Pelvic Limb*, In: Anatomy of the Dog, 2007, 5th edition, pages 82- 85. Schlütersche Verlagsgesellschaft mbH & Co.

14- **Butterworth S.J.,** *The Tibia and Fibula*, In: BSAVA Manual of Canine and Feline Fracture Repair and Management, 2016, 2nd edition, page 301. BSAVA, British Small Animal Veterinary Association.

15- **Calvo I.,** *Pathological Fractures*, In: BSAVA Manual of Canine and Feline Fracture Repair and Management, 2016, 2nd edition, page 112. BSAVA, British Small Animal Veterinary Association.

16- **DeCamp C.E.,** *External Coaptation*, In : Textbook of Small Animal Surgery Vol 2, 2003, 3rd edition, pages 1835- 1847. SAUNDERS, an imprint of Elsevier Science.

17- **DeCamp C.E, Johnston S.A, Déjardin L.M, Schaefer S.L.,** *Fractures: Classification, Diagnosis, and Treatment*, In: Brinker, Piermattei, and Flo's Handbook of Small Animal Orthopedics and Fracture Repair, 2016, 5th edition, pages 24-27, 33-35, 40-45, 49-58, 64-90. Elsevier, St. Louis, Missouri.

18- **DeCamp C.E, Johnston S.A, Déjardin L.M, Schaefer S.L.,** *Fractures of the Tibia and Fibula*, In: Brinker, Piermattei, and Flo's Handbook of Small Animal Orthopedics and Fracture Repair, 2016, 5th edition, pages 670-705. Elsevier, St. Louis, Missouri.

19- **DeCamp C.E, Johnston S.A, Déjardin L.M, Schaefer S.L.,** *Orthopedic Examination and Diagnostic Tools*, In: Brinker, Piermattei, and Flo's Handbook of Small Animal Orthopedics and Fracture Repair, 2016, 5th edition, pages 1-3, 14-18. Elsevier, St. Louis, Missouri.

20- **Done S.H, Goody P.C, Stickland N.C, Evans S.A, Baines E.A.,** *The hindlimb*, In: Color Atlas of Veterinary Anatomy, Vol 3: The Dog & Cat, 2009, 2nd edition, page 358-365. Mosby Elsevier.

21- **Duerr F.M.,** *Subjective Gait Evaluation*, In: Canine Lameness, 2020, pages 5-6. John Wiley & Sons, Inc.

22- **Dyce J.,** *Non-surgical management of fractures*, In: BSAVA Manual of Canine and Feline Fracture Repair and Management, 2016, 2nd edition, pages 142- 147. BSAVA, British Small Animal Veterinary Association.

23- **Fossum T.W, Cho J, Dewey C.W, Hayashi K, MacPhail C.M, Huntingford J.L, Quandt J.E, Radlinsky M.G, Willard M.D, Schulz K.S, Yu-Speight A.,** *Management of Specific Fractures*, In: Small Animal Surgery, 2019, 5th edition, page 1121- 1133. Elsevier, Philadelphia, PA.

24- **Fossum T.W, Cho J, Dewey C.W, Hayashi K, MacPhail C.M, Huntingford J.L, Quandt J.E, Radlinsky M.G, Willard M.D, Schulz K.S, Yu-Speight A.,** *Principles of Fracture Diagnoses and Management*, In: Small Animal Surgery, 2019, 5th edition, page 981-985, 995- 1022. Elsevier, Philadelphia, PA.

25- **Fossum T.W, Cho J, Dewey C.W, Hayashi K, MacPhail C.M, Huntingford J.L, Quandt J.E, Radlinsky M.G, Willard M.D, Schulz K.S, Yu-Speight A.,** *Principles of Orthopedic Surgery and Regenerative Medicine*, In: Small Animal Surgery, 2019, 5th edition, page 957- 965. Elsevier, Philadelphia, PA.

26- **Hammond G.,** *Imaging of fractures*, In: BSAVA Manual of Canine and Feline Fracture Repair and Management, 2016, 2nd edition, pages 37- 40. BSAVA, British Small Animal Veterinary Association.

27- **Hayashi K., Kapatkin A.S.,** *Fractures of the Tibia and Fibula*, In: Veterinary Surgery: Small Animal, 2018, 2nd edition, pages 1176- 1192. Elsevier, St. Louis, Missouri.

28- **Hermanson J.W, de Lahunta, Evans H.E.,** *The Heart & Arteries*, In: Miller and Evans' Anatomy of the Dog, 2019, 5th edition, pages 1141- 1147. Elsevier, St. Louis, Missouri.

29- **Hermanson J.W, de Lahunta, Evans H.E.,** *The Muscular System*, In: Miller and Evans' Anatomy of the Dog, 2019, 5th edition, pages 624-637. Elsevier, St. Louis, Missouri.

30- **Hermanson J.W, de Lahunta, Evans H.E.,** *The Skeleton*, In: Miller and Evans' Anatomy of the Dog, 2019, 5th edition, pages 348-356. Elsevier, St. Louis, Missouri.

31- **Hermanson J.W, de Lahunta, Evans H.E.,** *The Spinal Nerves*, In: Miller and Evans' Anatomy of the Dog, 2019, 5th edition, pages 1485-1488. Elsevier, St. Louis, Missouri.

32- **Hermanson J.W, de Lahunta, Evans H.E.,** *The Veins*, In: Miller and Evans' Anatomy of the Dog, 2019, 5th edition, pages 1200- 1208. Elsevier, St. Louis, Missouri.

33- **Hobbs S.L, Pead M.,** *Acute management of orthopaedic and external soft tissue injuries*, In: BSAVA Manual of Canine and Feline Emergency and Critical Care, 2018, 3rd edition, pages 276- 292. BSAVA, British Small Animal Veterinary Association.

34- **Jaeger G.H, Wosar M.A.,** *External Skeletal Fixation*, In: Veterinary Surgery: Small Animal, 2018, 2nd edition, pages 691- 712. Elsevier, St. Louis, Missouri.

35- **J. A. Gower, N.J.Bound, A. P. Moores.,** *Tibial tuberosity avulsion fracture in dogs: a review of 59 dogs*, In: Journal of Small Animal Practice, 2008; 49, 340–343.

36- **Johnson K.A.,** *The Hindlimb*, In: Piermattei's Atlas of Surgical Approaches to the Bones and Joints of the Dog and Cat, 2014, 5th edition, pages 424- 438. Elsevier, St. Louis, Missouri.

37- **Johnston S.A, von Pfeil D.J.F, Déjardin L.M, Roe S.C, Weh J.M.,** *Internal Fracture Fixation*, In: Veterinary Surgery: Small Animal, 2018, 2nd edition, pages 654-690. Elsevier, St. Louis, Missouri.

38- **Jones G.C.,** *Fracture classification and description*, In: BSAVA Manual of Canine and Feline Fracture Repair and Management, 2016, 2nd edition, pages 7, 8. BSAVA, British Small Animal Veterinary Association.

39- **Kumar B.B, Sharma A.K, Reetu, Kumar P, Kumar C, Kumar R.,** *Study on incidence of fractures with respect to breed, age, sex, type and location of fractures and bone involved*, In: Journal of Entomology and Zoology Studies, 2020; SP-8(2): 21-24.

40- **Maddox T.W.,** *Imaging*, In: BSAVA Manual of Canine and Feline Musculoskeletal Disorders: A Practical Guide to Lameness and Joint Disease, 2018, 2nd edition, pages 22-24. BSAVA, British Small Animal Veterinary Association.

41- **Marcellin-Little D.J.,** *Bandaging, External Coaptation, and External Devices for Companion Animals*, In: Veterinary Surgery: Small Animal, 2018, 2nd edition, pages 737-742. Elsevier, St. Louis, Missouri.

42- **Marcellin-Little D.J.,** *External Skeletal Fixation*, In: Textbook of Small Animal Surgery Vol 2, 2003, 3rd edition, pages 1818- 1832. SAUNDERS, an imprint of Elsevier Science.

43- **Marolf A.J.,** *Diagnostic Imaging Techniques in Lameness Evaluation*, In: Canine Lameness, 2020, pages 125- 132. John Wiley & Sons, Inc.

44- **Moores A.P.,** *Biomechanical basis of bone fracture and fracture repair*, In: BSAVA Manual of Canine and Feline Fracture Repair and Management, 2016, 2nd edition, pages 20- 30. BSAVA, British Small Animal Veterinary Association.

45- **Phillips IR.,** *A survey of bone fractures in the dog and cat*, In: Journal of Small Animal Practice, 1979; 20, 661–674.

46- **Piermattei D.L., Johnson K.A., Dee J.F.,** *The Hindlimb*, In: Atlas of Surgical Approaches to the Bones and Joints of the Dog and Cat, 2006, 4th edition, pages 408-426. Elsevier, St. Louis, Missouri.

47- **Radha M. S., B. N. Nagaraja, K. M. Srinivasa Murthy, M. H. Girish, Anilkumar M. C.,** *Incidence of tibial fractures in dogs*, In: The Pharma Innovation Journal, 2023; SP-12(6): 160-162.

48- **Risselada M, Van Bree H, Kramer M, Duchateau L, Verleyen P, Saunders J.H.,** *Ultrasonographic Assessment of Fracture Healing After Plate Osteosynthesis*, In: Veterinary Radiology & Ultrasound, 2007, 48, 368–372.

49- **Risselada M, Van Bree H, Kramer M, Verleyen P, de Rooster H, Taeymans O.,** *Ultrasonographic and radiographic assessment of uncomplicated secondary fracture healing of long bones in dogs and cats*, In: Veterinary Surgery, 2005,34, 99–107.

50- **Risselada M, Van Bree H, Kramer M, Verleyen P, Saunders J.H.,** *Power Doppler assessment of the neovascularization during uncomplicated fracture healing of long bones in dogs and cats*, In: Veterinary Radiology and Ultrasound, 2006 47, 301–306.

51- **Roe S.**, *Internal Fracture Fixation*, In: Textbook of Small Animal Surgery Vol 2, 2003, 3rd edition, pages 1798- 1817. SAUNDERS, an imprint of Elsevier Science.

52- **Scott H.,** *Lameness examination*, In: BSAVA Manual of Canine and Feline Musculoskeletal Disorders: A Practical Guide to Lameness and Joint Disease, 2018, 2nd edition, pages 7- 20. BSAVA, British Small Animal Veterinary Association.

53- **Singh B.,** *General Anatomy*, In: Dyce, Sack and Wensing's Textbook of Veterinary Anatomy, 2023, 5th edition, page 82. Elsevier, St. Louis, Missouri.

54- **Thrall D.E, Robertson I.D.,** *The Pelvic Limb*, In: Atlas of Normal in the Radiographic Anatomy and Anatomic Variants in the Dog and Cat, 2023, 3rd edition, pages 161, 167. Elsevier, St. Louis, Missouri.

55- **Unger M., Montavon P.M., Heim U.F.A.,** *Classification of fractures of long bones in the dog and cat*, In: Introduction and clinical application, 1990, 3:41. Vet Comp Orthop Traumatol.

56- **von Pfeil D.J.F, Duerr F.M.,** *The Orthopedic Examination*, In: Canine Lameness, 2020, pages 31- 38. John Wiley & Sons, Inc.

57- **White J, Sylvestre A.M.,** *Bandages and Splints*, In: Fracture Management for the Small Animal Practitioner, 2019, pages 19- 27, 39- 55. John Wiley & Sons, Inc.

58- **Zaera Polo J.P.,** *Classification of Fractures*, In: Bone surgery in small animals: Resolution of the most frequent fractures, 2015, pages 14-18. Servet editorial, Grupo Asis Biomedia, S.L.

59- **Zaera Polo J.P.,** *Hindlimb Fractures*, In: Bone surgery in small animals: Resolution of the most frequent fractures, 2015, pages 194- 206. Servet editorial, Grupo Asis Biomedia, S.L.

60- **Zaera Polo J.P.,** *Osteosynthesis Systems and Biomechanics*, In: Bone surgery in small animals: Resolution of the most frequent fractures, 2015, pages 34- 86. Servet editorial, Grupo Asis Biomedia, S.L.