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The (soft-tissue) injury—
a high priority consideration

AO Trauma Basic Principles Course

Learning objectives

- Describe the role of soft tissue in fracture healing
- Prioritize the management of soft-tissue injuries
- Apply the management options for fractures with different degrees of soft-tissue injuries
- Outline the etiology, diagnosis, and treatment of compartment syndrome

“The bone is a plant, with its roots in the soft tissue, and when its vascular connections are damaged, it often requires, not techniques of a cabinet maker, but the patient care and understanding of a gardener.”

Girdlestone

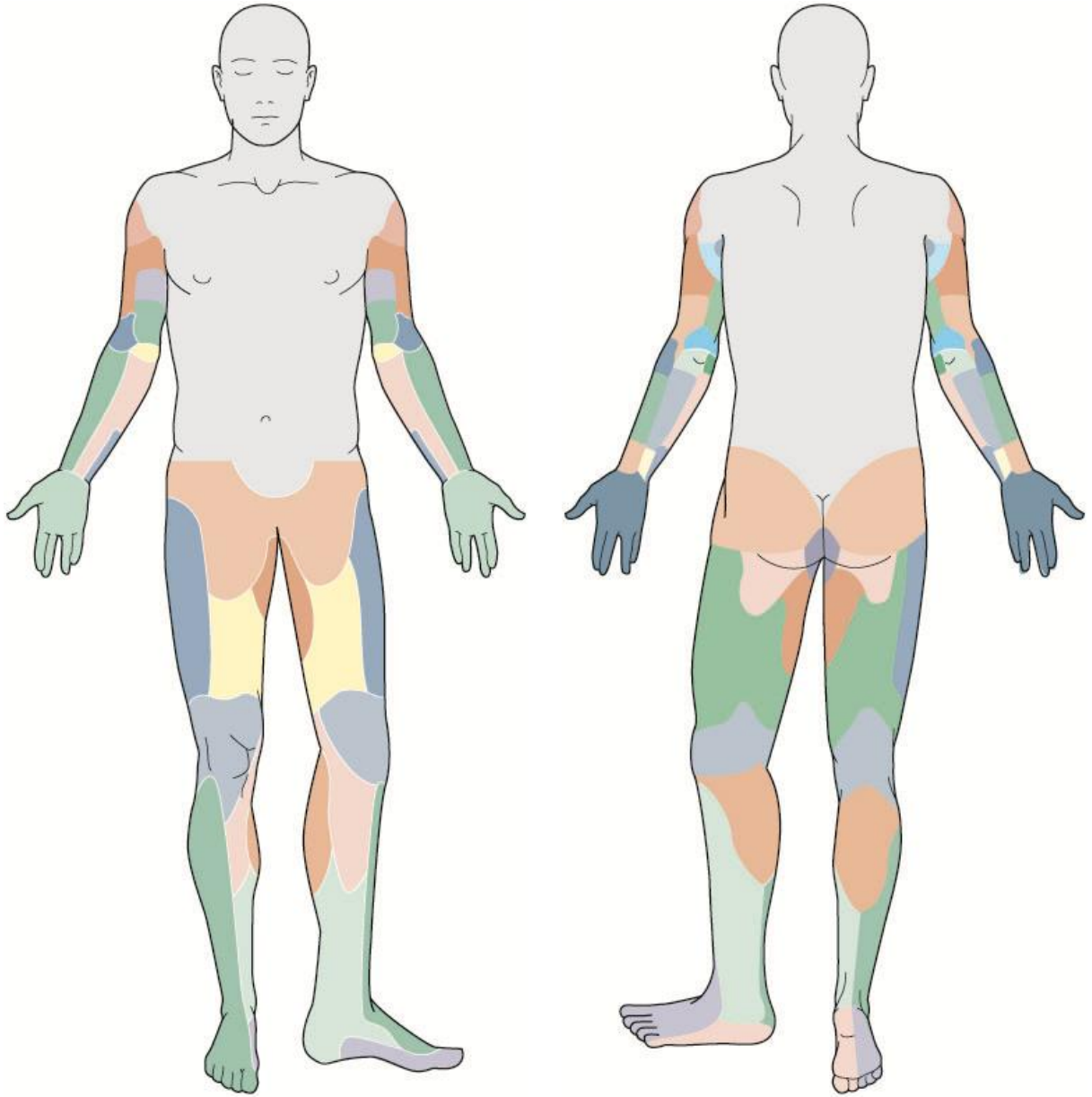
A fracture involves:

- Skin
- Subcutaneous fat
- Muscle
- Periosteum
- Bone

Vascular anatomy of the skin

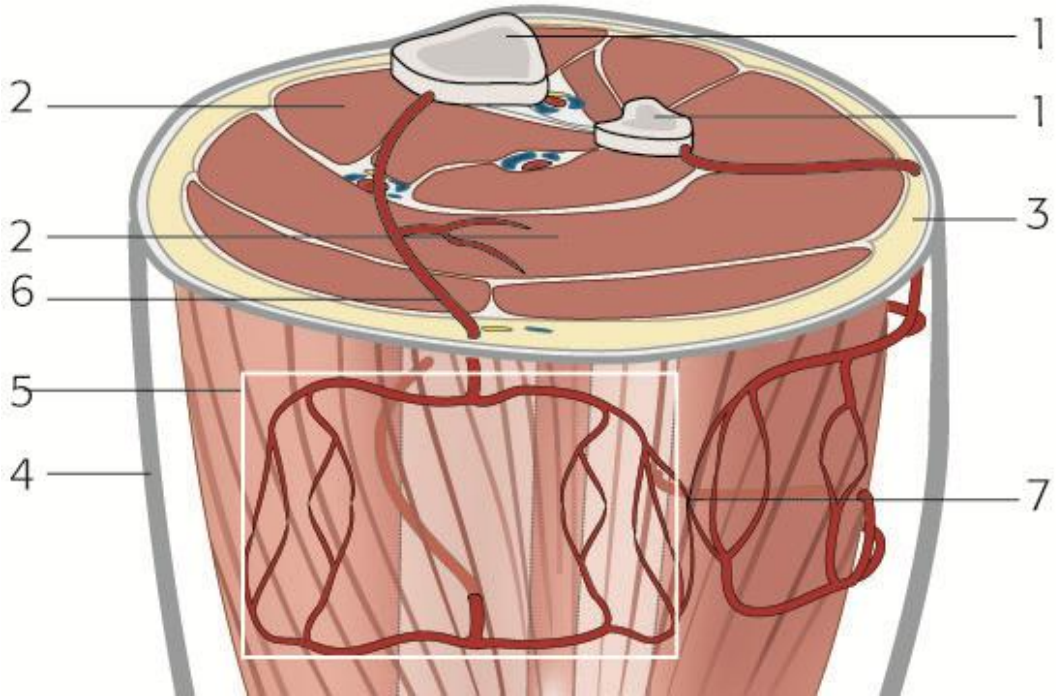
Angiosomes

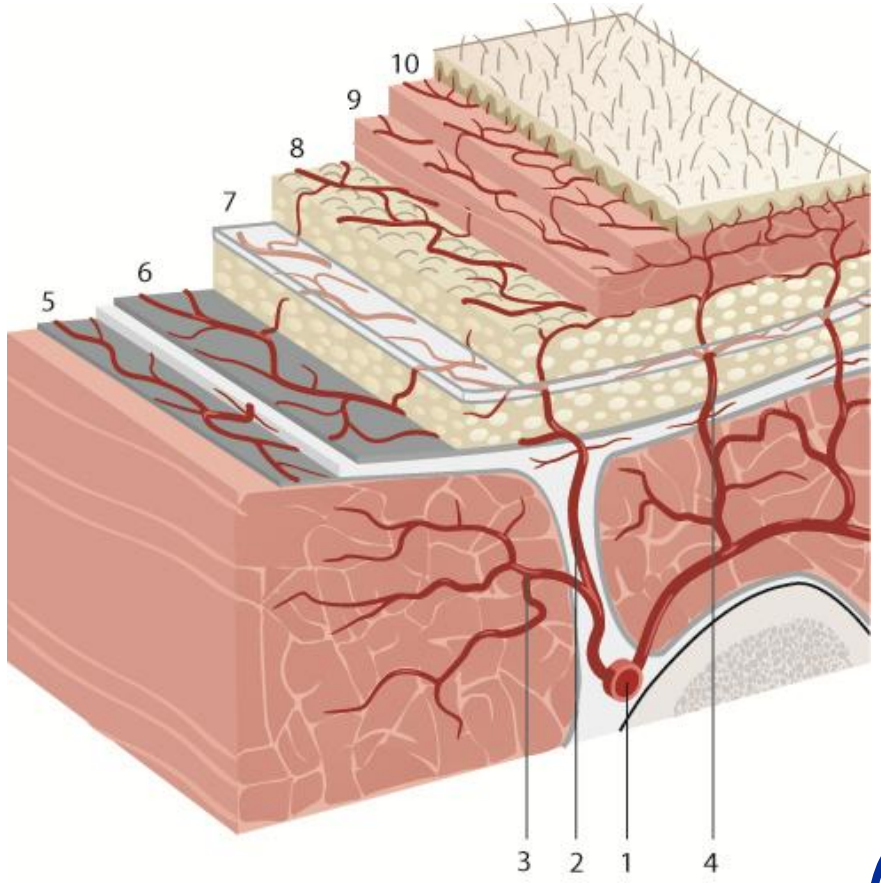
- Represent discrete, but interconnected, areas of skin, which are supplied by a named source vessel
- Very similar to dermatomes



Vasculature of the skin

Vascular supply to the skin is directly related to perforators that come through muscle from named arteries





Blood supply to muscle

- Usually comes from named vessels
- Various patterns of vascular supply
  - Single pedicle (proximal)
  - Dominant pedicle and multiple minor pedicles
  - Two dominant pedicles
  - Segmental pedicles

Muscular blood supply

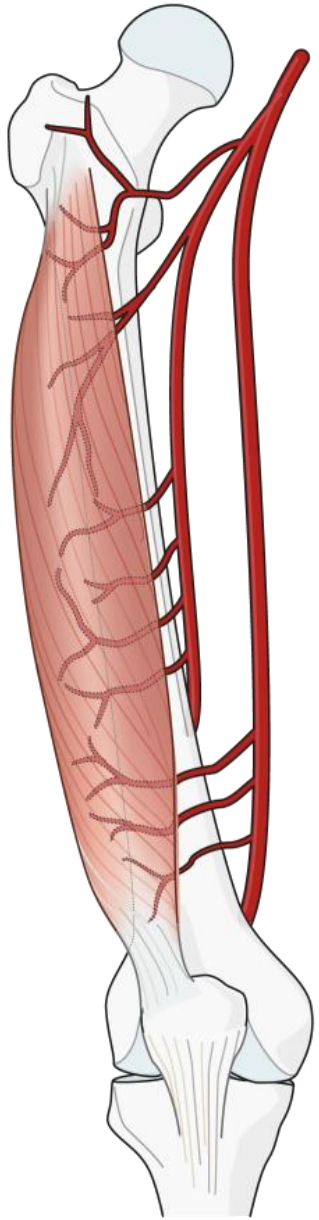
Single pedicle

- Gastroc, rectus femoris, tensor fascia lata

Muscular blood supply

Single major/multiple minor

- Vastus lateralis, soleus, brachioradialis, gracilis



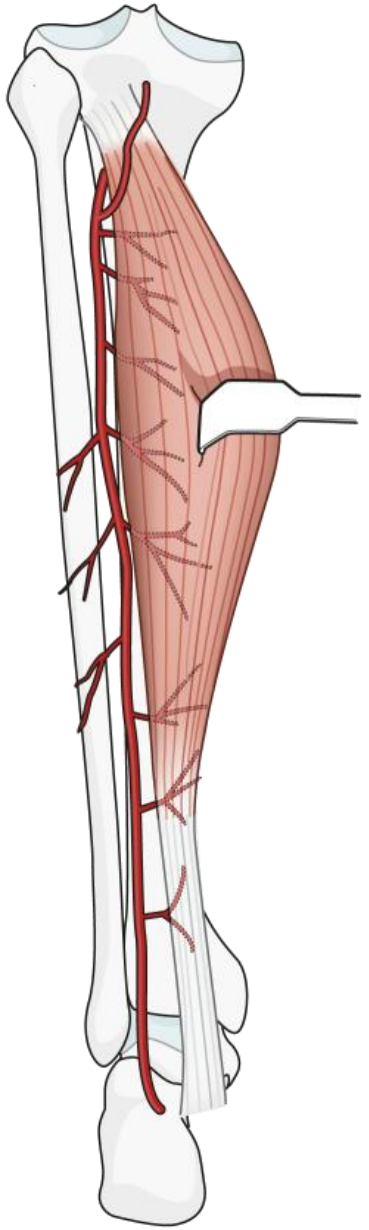
Muscular blood supply

Double pedicle

- Gluteus maximus

Segmental pedicles

- Tibialis anterior, EHL, EDL, FHL, FDL



Blood supply to bone

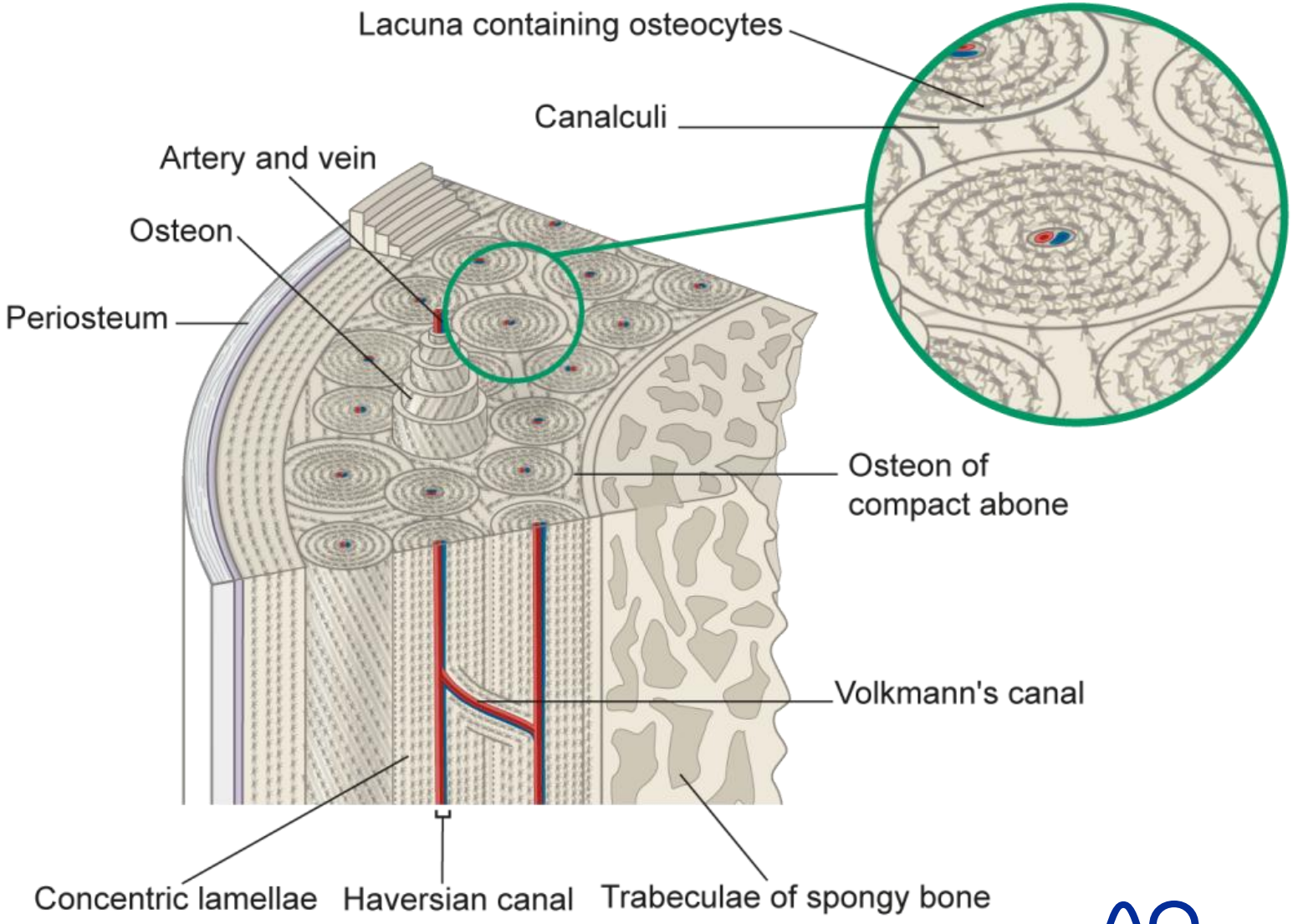
Outer 1/3 of bone

- Supplied by periosteal vessels that arise from named arteries which enter only at the sites of ligamentous or heavy fascial attachment
- However, all of these vessels are thin-walled and probably represent venules or capillaries

Blood supply to bone

Inner 2/3 of bone

- Supplied by nutrient artery that then divides into arterioles which supply entire endosteum



Extraosseus blood supply

- In fractures, the blood supply to the callus forms from the ruptured periosteal capillaries (where they exist) and torn muscle capillaries in the vicinity of the fracture
- Endosteal blood supply reconstitutes from endosteal arterioles
- Persists until medullary circulation regenerates
- May easily be disrupted by lack of stability at the fracture
- Cannot replace the intramedullary circulation

Role of soft tissue

- Skin is the primary barrier to infection
- Muscle
  - Provides blood supply to skin
  - Functions to provide locomotion
  - Improves blood drainage from dependent areas
- Periosteum
  - Provides blood supply to bone (outer 1/3)
  - Provides osteoprogenitor cells to bone

How do we assess soft-tissue injuries?

Degree of bone injury implies level of injury to soft tissue

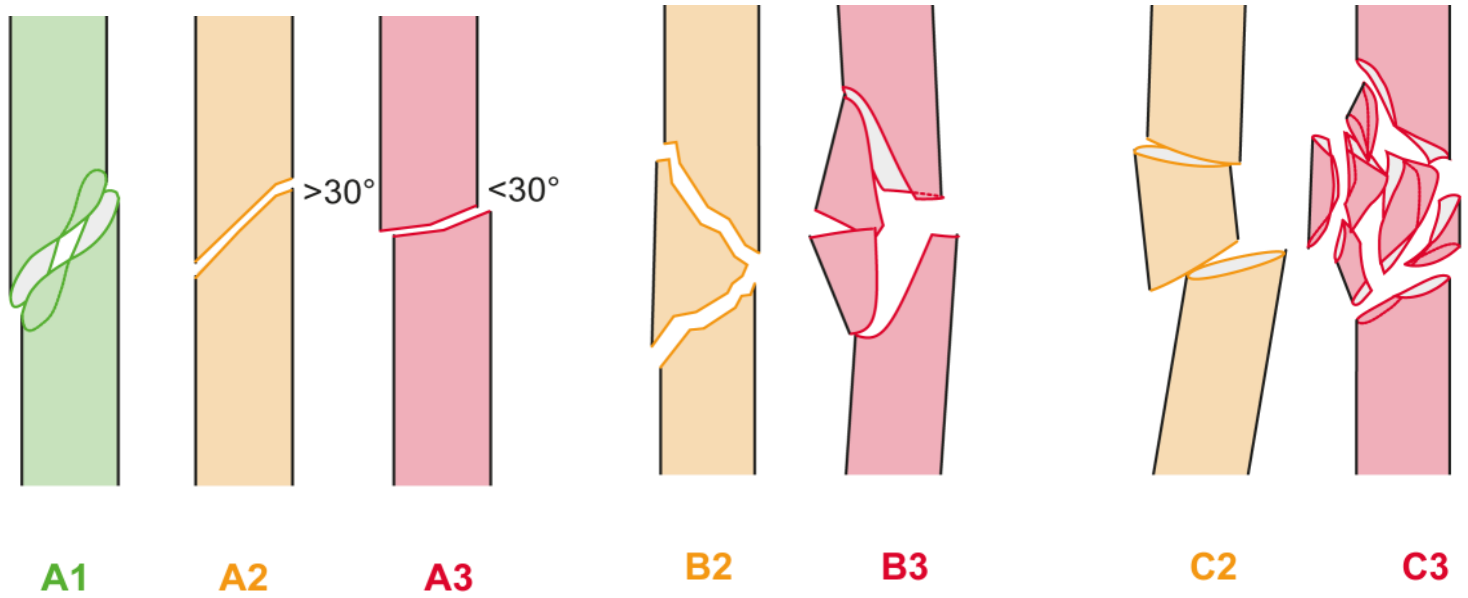
- Uncommon for severe fracture to have little soft-tissue injury
- Not uncommon for severe soft-tissue injury to have innocuous bone injury

Assessment of soft-tissue injury

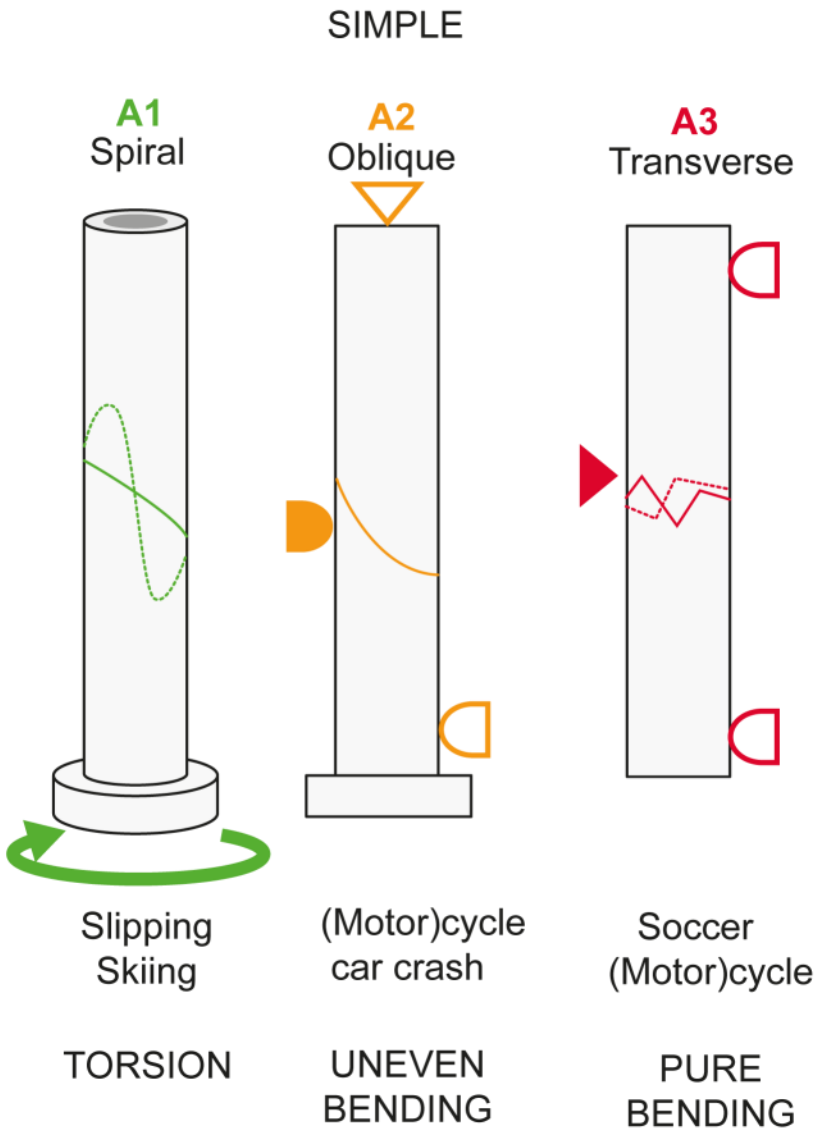
Mechanism of injury can also give clues

Fracture mechanisms of the diaphysis

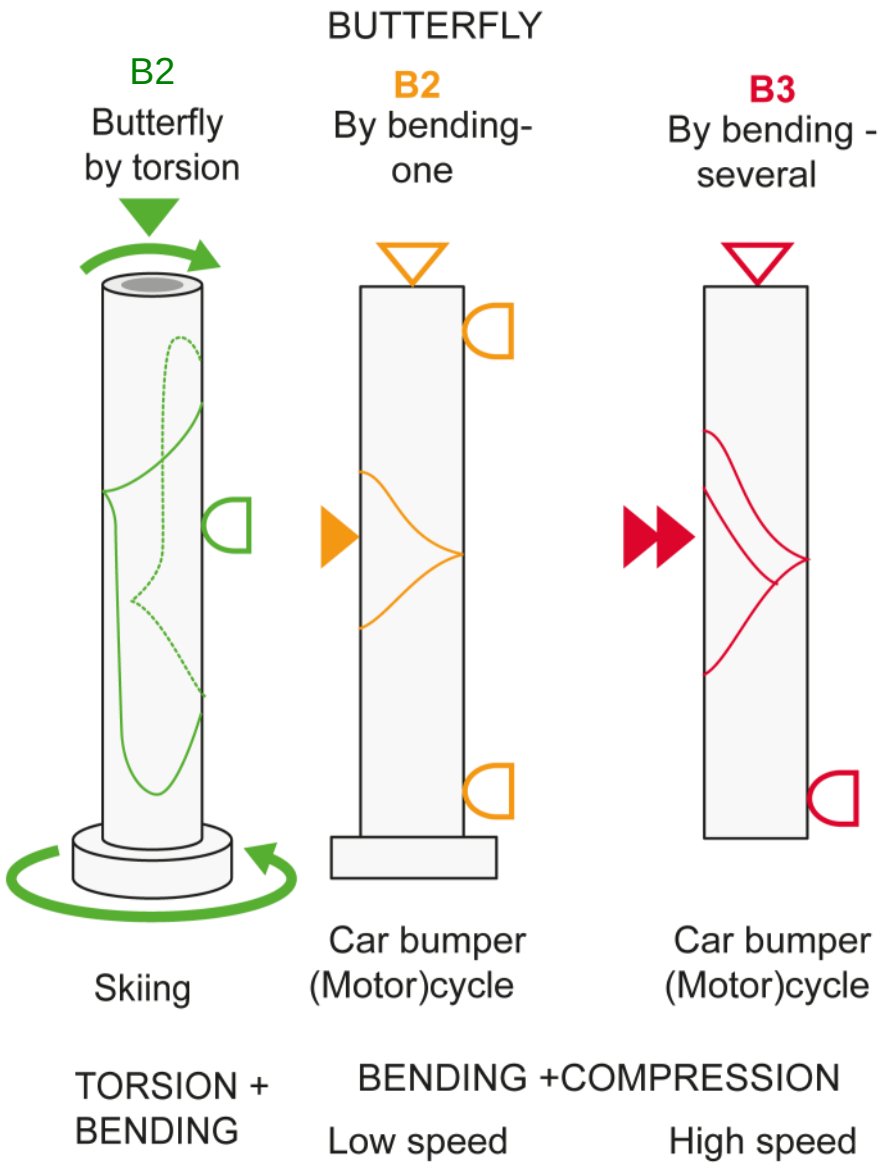
- Torsion (skiing)
- Bending (indirect)
- Compression (fall from a height)
- Contusion (direct, bumper injury)
- Combinations



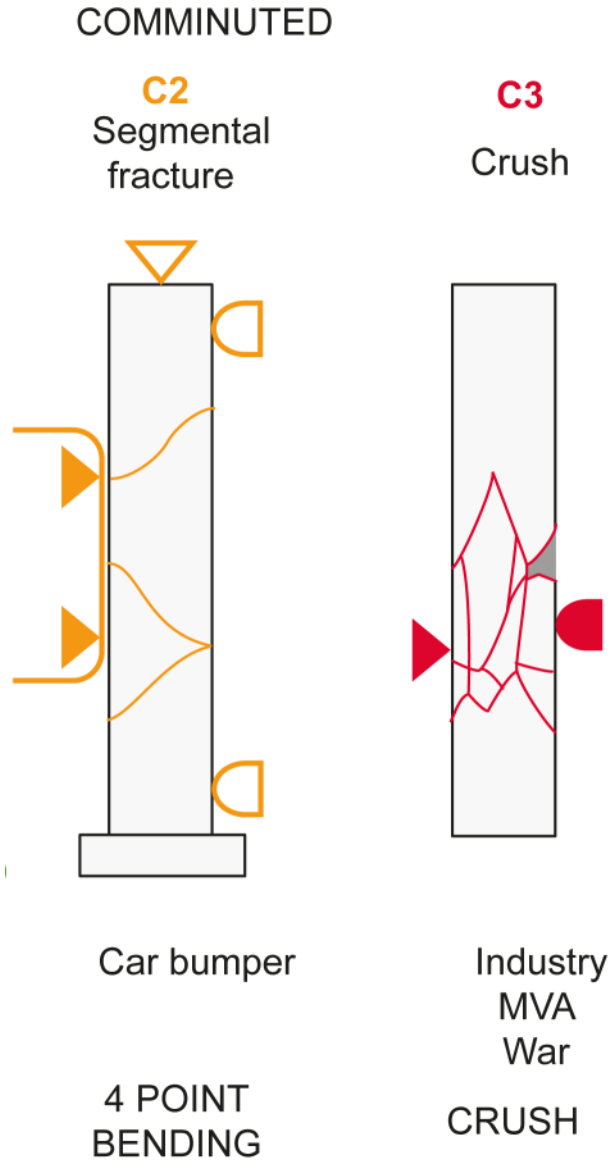
Low-energy fracture patterns



Medium-energy fracture patterns



High-energy fracture patterns



Classification of closed fractures

Tscherne and Oestern, 1982

C 0

- No, or no significant, soft-tissue trauma
- Simple fracture
- Indirect mechanism

Classification of closed fractures

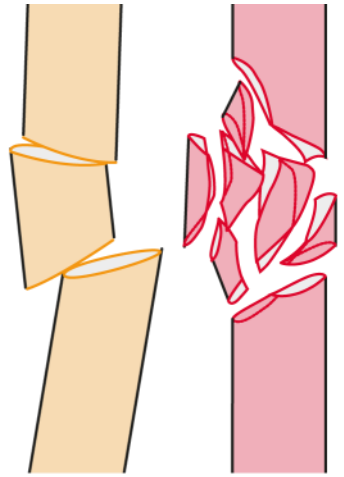
C I

- Soft-tissue contusion
- Fracture pattern usually simple

Classification of closed fractures

C II

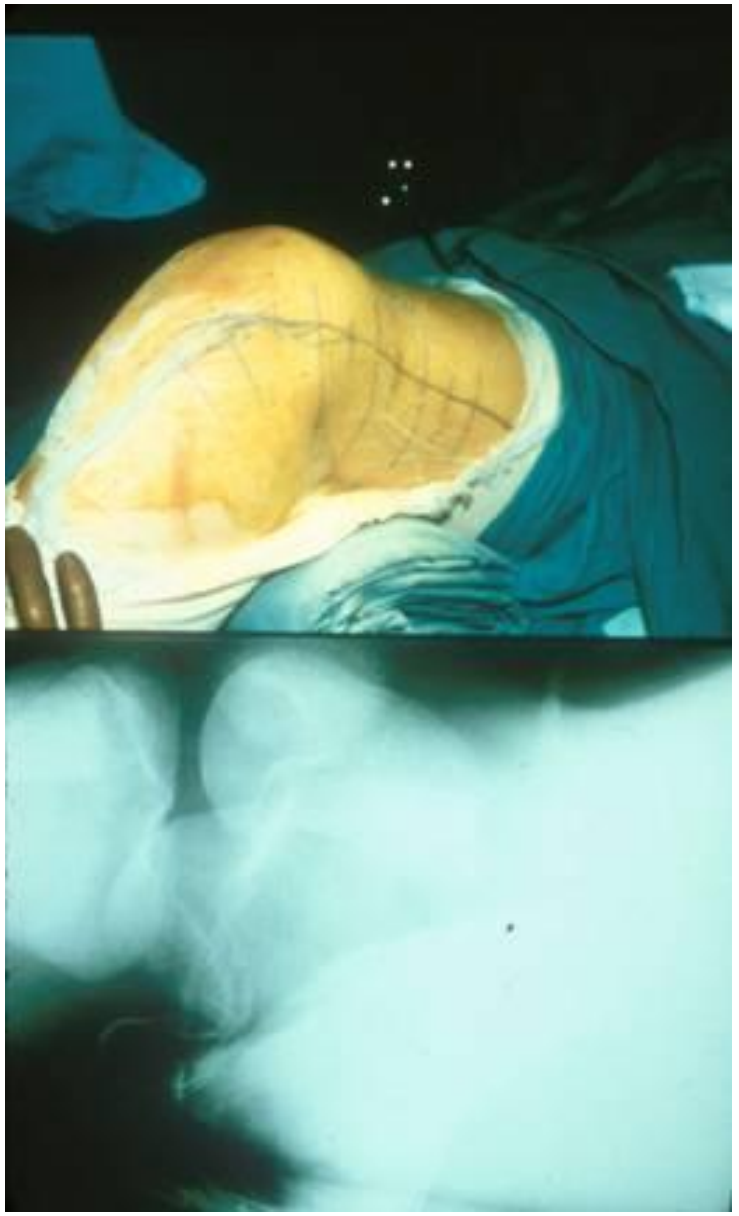
- Deep erosion
- Contusion—localized
- Tangential trauma
- Compartment syndrome possible
- Complex fracture (two levels)
- Direct mechanism



Classification of closed fractures

C III

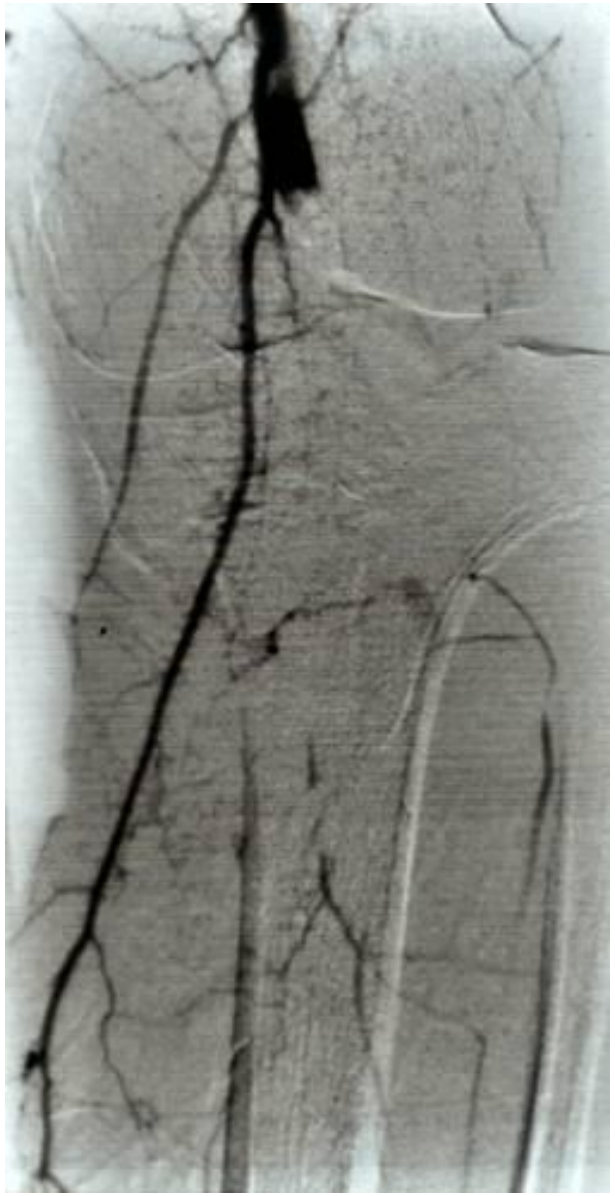
- Deep erosion
- Contamination
- Contusion—diffuse
- Tangential trauma
- Manifestation of compartment syndrome
- Complex fracture
- Direct mechanism



Classification of closed fractures

C IV

- Deep erosion
- Contamination
- Contusion
- Tangential trauma
- Shear injury
- Manifestation of compartment syndrome
- Complex fracture
- Direct mechanism
- Vascular injury with reconstruction



Open fracture classification

Gustilo	
Type I	• Low energy • Minimal soft-tissue damage • Wound < 1 cm
Type II	• Higher energy • Laceration > 1 cm • No flaps/crushing minimal contamination • Slight comminution
Type IIIA	• High energy • Adequate soft-tissue coverage despite flaps/lacerations • Comminution/segmental fracture
Type IIIB	• High energy • Extensive soft-tissue stripping • Inadequate cover • Massive contamination
Type IIIC	• Vascular injury requiring repair

Classification of open fractures

Gustilo-Anderson (Modified)

Type I

- No gross contamination
- “Inside-out”

Type II

- No gross contamination
- Small wound
- Little periosteal stripping

Classification of open fractures

Gustilo-Anderson (Modified)

Type III

- Large skin defect
- Skin defect that requires coverage (type IIIB)
- Large amount of periosteal stripping
- Vascular injury that requires repair (type IIIC)
- Gross contamination or prolonged delay in removing contamination (> 6 hours)
- Shotgun, high-energy ballistic injury, most blast injuries, farm-yard injury

Tips

Size matters, but not that much

- Contamination, high-energy weapons, farm yard injuries are automatically at least a type IIIA even if the wound is < 10 cm

AO soft-tissue classification

Integumentum closed (IC)

- IC 1 = no skin injury
- IC 2 = contusion without skin laceration
- IC 3 = local degloving
- IC 4 = extensive, closed degloving
- IC 5 = necrosis due to deep contusion

Rüedi, Border, Hanson, Tscherne

AO soft-tissue classification

Integumentum open (IO)

- IO 1 = skin perforated from inside out
- IO 2 = skin perforation from outside < 5 cm
- IO 3 = local degloving, contusion > 5 cm
- IO 4 = loss of skin, deep contusion
- IO 5 = open degloving

Rüedi, Border, Hanson, Tscherne

AO soft-tissue classification

Neurovascular injury (NV)

- NV 1 = no injury
- NV 2 = isolated nerve injury
- NV 3 = local vascular injury
- NV 4 = combined neurovascular injury
- NV 5 = sub/total amputation

Rüedi, Border, Hanson, Tscherne

AO soft-tissue classification

Muscle and tendon injury (MT)

- MT 1 = no injury
- MT 2 = isolated (one group)
- MT 3 = two or more groups
- MT 4 = loss of muscle groups, tendon
- MT 5 = compartment/crush syndrome

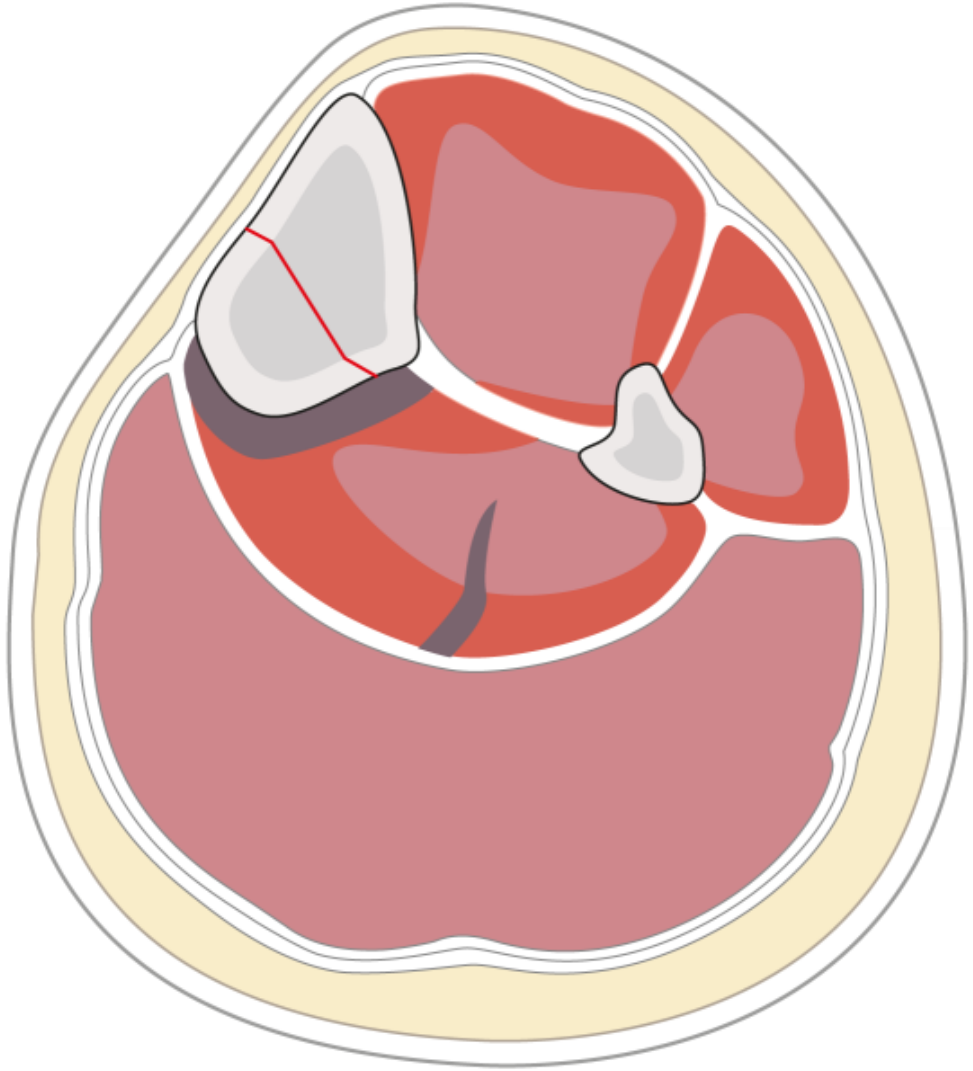
Rüedi, Border, Hanson, Tscherne

Compartment syndrome

- Increasing volume in a nonexpandable space
- Increasing pressure > arteriolar pressure
- Hypoxia
- (Muscle) necrosis
- Critical pressure $P_{diast} - P_{comp} < 30$ mm Hg
- Decreasing arteriovenous difference
- Reperfusion can occur (AMP to hypoxanthine)

Compartment syndrome diagnosis is clinical

- Unrelenting, bursting pain
- Unreleased by analgesia
- Swollen compartment
- Passive stretch pain
- Sensory deficit?
- Pulses always palpable

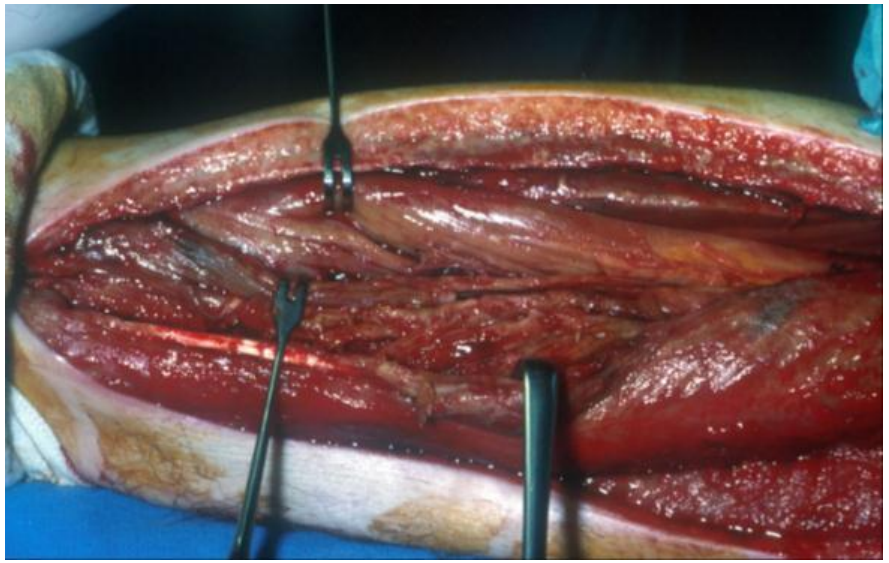


Compartment pressure measurement

- Critical measurement is the difference between compartment pressure and patient's systolic pressure
- Invaluable in unconscious or anesthetized patients
- Trends are more useful than single readings
- NOT a substitute for clinical diagnosis

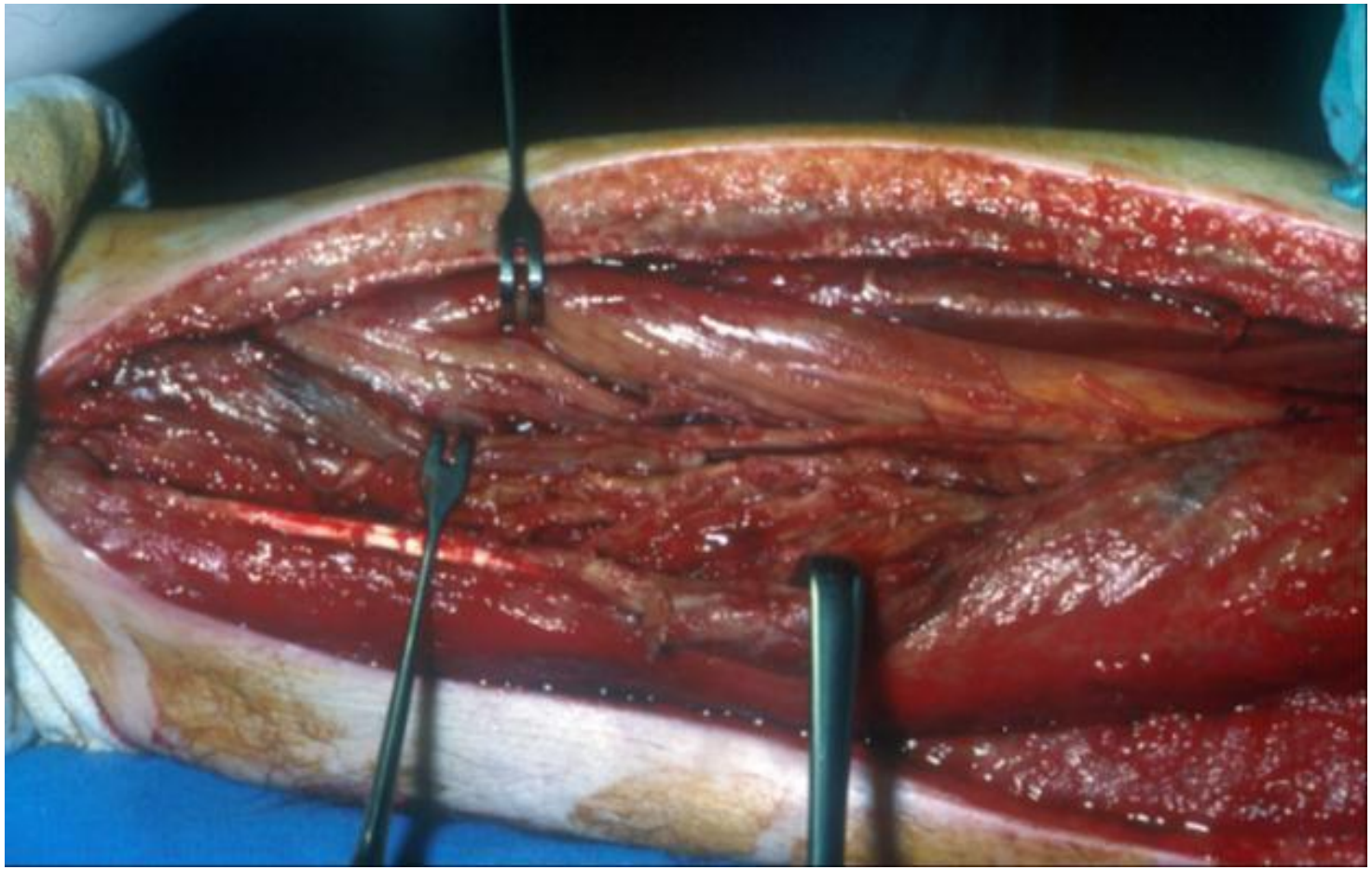
Compartment syndrome treatment

- Remove all compressing casts
- Lay the extremity flat
- Dermatofasciotomy > 30 mm Hg
  - Lateral perifibular
  - Bilateral
- Open all four compartments



Evaluation of muscle viability

- Color
- Contractility
- Consistency
- Capillary bleeding



Techniques for soft-tissue handling

Incisions

- “Minimally invasive” ≠ small incision
  - If small incision does not allow adequate visualization, excessive retraction is often used
  - Proper placement of incision is more critical when using small incisions
  - Small incisions do not ensure that the surgeon does not strip the bone
- Do not skive the skin—incise the skin perpendicular to the skin

Techniques for soft-tissue handling

Retraction

- Avoid retracting more than required to provide visualization
- Relax retraction whenever not needed
- Avoid self-retaining retractors when possible because they are easily set and forgotten

Techniques for soft-tissue handling

Forceps

- Use a very gentle touch—do not squeeze tissue
- Use as a retractor
- Avoid the use of large forceps (eg, Smith-Peterson) on the skin

Techniques for soft-tissue handling

Dissection

- Avoid horizontal dissection planes whenever possible (especially between the subcutaneous tissue and fascia)
- Gentle pressure on the skin edge may allow visualization of bleeders which may then be specifically cauterized
- Sharp dissection with a knife should be used when possible (rather than cutting with scissors which crushes soft tissues)
- Avoid multiple passes with scissors or scalpel through tissues

Techniques for soft-tissue handling

Bone exposure

- Preserve periosteum whenever possible
- Use least aggressive bone holding clamps as possible
- **Pay attention**

Take-home messages

- Soft tissue plays a critical role in preventing infection, supplying vasculature to bone, and in function
- Soft-tissue injury must be appreciated when deciding how to approach a fracture
- Soft tissue must not be further injured by careless surgical dissection
- Compartment syndrome is a surgical emergency
- A high index of suspicion and early diagnosis is key to successful treatment