Objective

- Definition
- Etiology
- Classification
- Evaluation
- Management
  non-operative
  operative
- Prevention

Definition

Non Union

NON UNION OCCURS WHEN A FRACTURE HAVE FAILED TO HEAL IN EXPECTED TIME AND IS NOT LIKELY TO HEAL WITHOUT NEW INTERVENTION

FDA defined nonunion as *"established when a minimum of **9 months** has elapsed since fracture with no visible progressive signs of healing for **3 months**"*

DELAYED UNION

DELAYED UNON OCCURS WHEN A FRACTURE HAS NOT HEALED COMPLETELY IN EXPECTED TIME BUT STILL HAS POTENTIAL TO HEAL WITH INTERVENTION

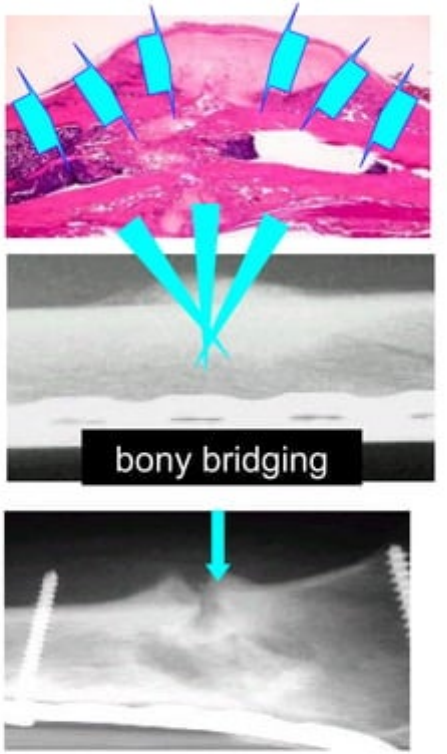
Pseudoarthrosis

Formation of a false joint where a fibro-cartilaginous cavity is lined with synovial membrane

Fracture healing

Stages of fracture healing

- Hematoma formation
- Inflammation and cellular proliferation
- Callus formation
- Consolidation
- Remodeling



Causes of non-union

Poor Vascularity (biology)

Instability

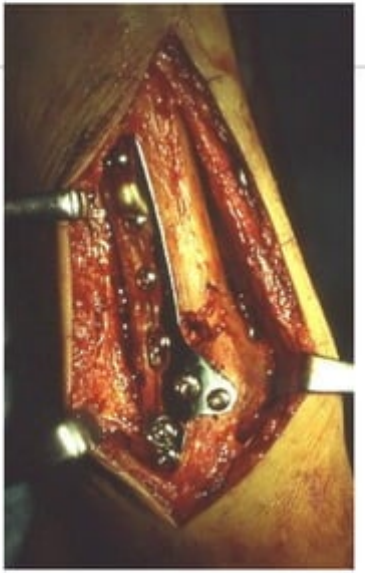
Infection

Host factors

- Diabetes
- Smoking
- NSAIDS
- Malnutrition
- Steroid use
- Rheumatoid disease
- Malignancy

Poor vascularity

Traumatic

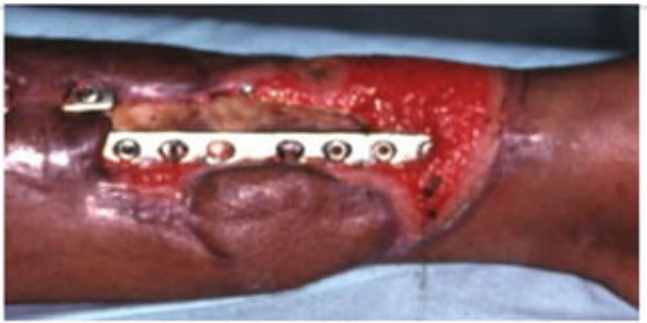


Iatrogenic

instability

Inadequate stabilization:
Resorption of bone at fracture site.

Infection



Infection:
Infection and loss of soft tissue covering or osteomyelitis

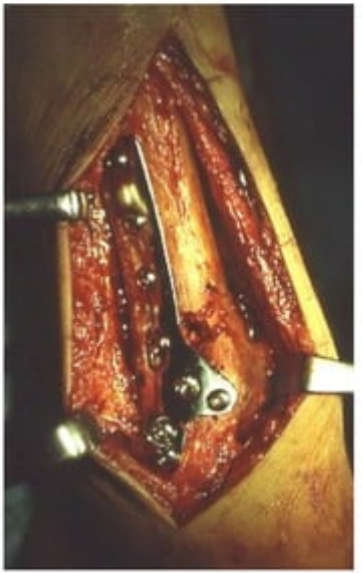
Risk factors

Local Risk factors

- Open Fractures
- High energy fractures with bone devitalization.
- Severe associated soft tissue injury
- Bone loss
- Infection

Iatrogenic Factors:

- Poor reduction
- Unstable fixation
- Bone devitalization



Risk factors…

Systemic Risk Factors

- Malnutrition
- Smoking
- NSAIDs
- Systemic Medical Conditions like Diabetes,
- Chronic alcoholism.

Patient Factors

- **Non Compliance**

Classification

Site

- Diaphyseal
- Metaphyseal:
    - Extraarticular
    - Intraarticular

Callus

- Hypertrophic
- Avascular

Infection

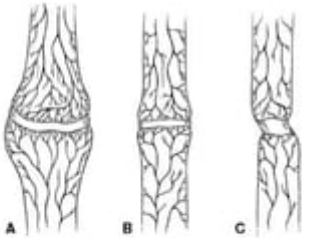
- Aseptic
- Septic

HYPERTROPHIC

1. ELEPHANT FOOT
2. HORSE HOOF
3. OLIGOTROPHIC

AVASCULAR

1. TORSION
2. NECROTIC
3. DEFECT
4. ATROPHIC



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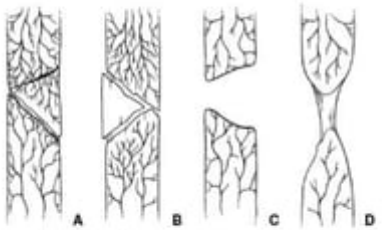

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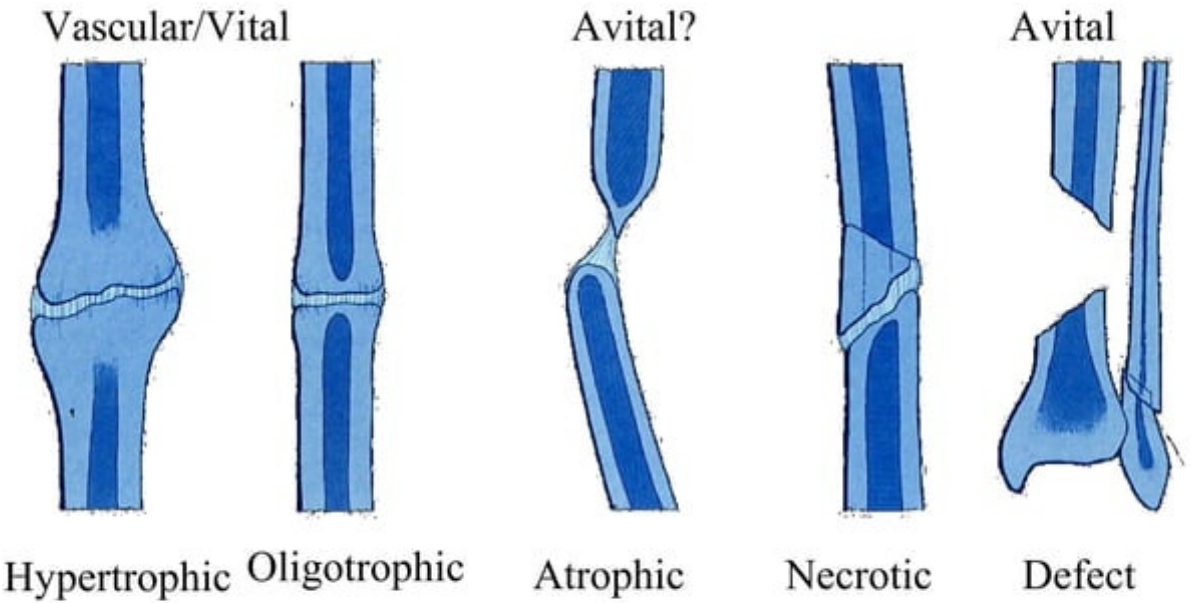

Vascular/Vital
Avital?
Avital
Hypertrophic
Oligotrophic
Atrophic
Necrotic
Defect

Paley et al

Type A<2cm of bone loss

A1 (Mobile deformity)

A2 (fixed deformity)

A2-1 stiff w/o deformity

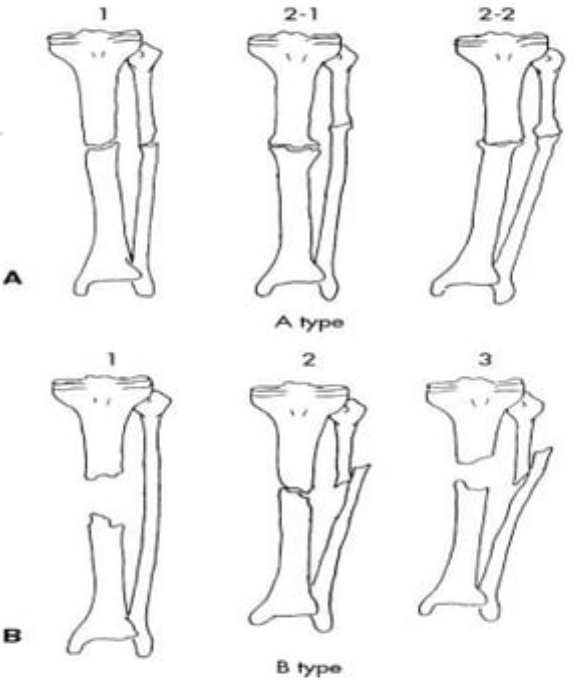
A2-2 stiff w/ fixed deformity

Type B>2cm of bone loss

B1 w/ bony defect

B2 loss of bone length

B3 both



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Diagnosis

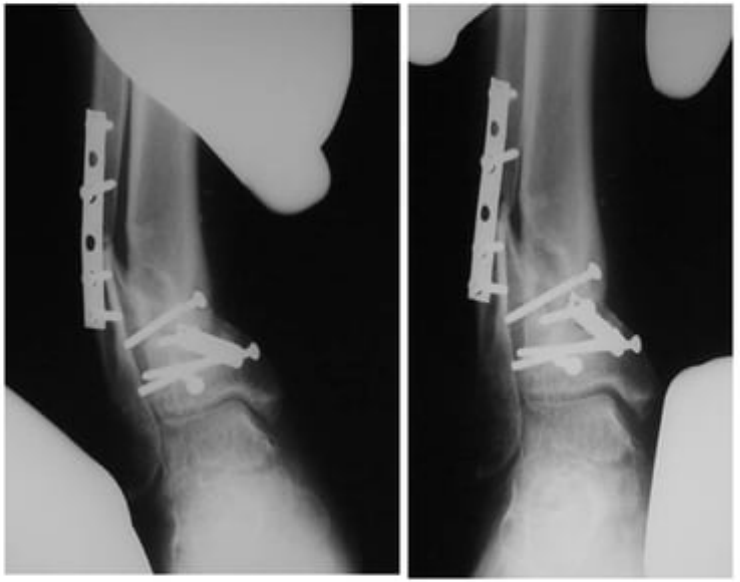
- Persistent Pain
- Non physiologic motion
- Progressive deformity
- No radiographic evidence of healing
- Implant failure

Radiologic evaluation

- Standard radiographs are often diagnostic
- 45 degree oblique films can increase diagnostic accuracy
- Despite additional projections, the potential for false-positive results for fracture healing remains.
- Serial Radiological Assessment is necessary.

Radiologic evaluation…

- Stress radiograph gives the status of stability of the fixation.
- It also confirm the clinical diagnosis

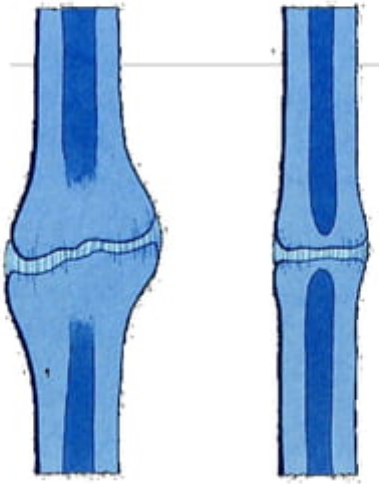


Varus stress Valgus stress

Radiologic evaluation

- **Computed Tomography:** A definitive diagnostic tool having 100% sensitivity but lack of specificity (62%)

Hypertropic nonunion



Elephant foot Horse hoof

Biology: good , viable , vascular

Stability: lacking

Treatment:

- Provide stability
- Correct deformity, if present
- No bone graft required

atropic nonunion

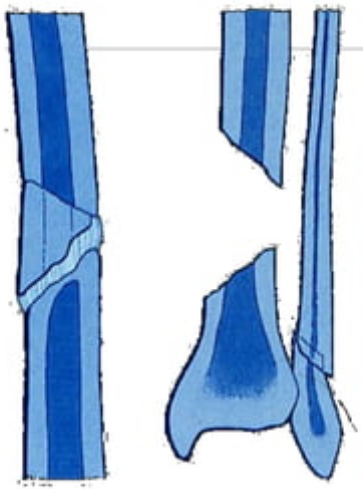
Atrophic

Biology: Poor , avascular , nonviable

Stability: lacking

Treatment:

- Provide stability
- Bone graft
- Debridement
- Excision of non vital bone



Biology: None

Stability: lacking?

Treatment:

- Provide stability
- Bone graft
- Other reconstruction

NON OPERATIVE TREATMENT

- Indirect intervention
- Weight bearing And external stabilization
- Electrical stimulation
- Ultrasound stimulation
- Extracorporal shock wave therapy
- Parathyroid harmone
- Gene therapy

Indirect intervention

Cesaation of smoking

Control of diabetes/ metabolic disorder

Maintaining nutrition

Long term use of NSAIDS, steroids , chemotherapic agents etc

Immunosuppresive drugs

Weight bearing and external stabilization

- Application of weight bearing in functional brace

Mechanism = stimulation of osteoblastic activity by mechanical loading

Mainly used in hypertrophic

- External supportive devices have little role in

Atrophic non union

Pseudoarthrosis

Malaligned nonunions

Infected non unions

Electrical stimulation

Internal application

Direct current = surgical implantation and potentially surgical removal of stimulation device

External application

Mechanism = alteration of electrical potential at the fracture site .There by reducing osteoclastic related bone resorpstion , increase osteoid formation and stimulate angiogenesis.

1. Capative coupling – 24 hrs per day
2. Pulsed electromagnetic field stimulation – 12 hrs per day
3. Combined magnetic field - 30` min per day

Ultrasound stimulation

Low intensity pulsed ultrasound is of low energy

Frequency of 1.5mhz a signal burst width of 200 micro sec a repetation 1 mhz an intensity of 300mW/cm

Mechanism = stimulate ossification

Extracorporal shock wave therapy

High energy

Requires regional anaesthesia

Enhance biomechanical properties of bone and angiogenesis

Parathyroid hormone

Regulator of calcium metabolism

Pth binds to osteoblasts stimulating release of mediators that in turn stimulate osteoclasts to resorb bone thus help in acute fracture healing and non union

Gene therapy

- Aspirated iliac crest stem cells has been shown to enhance the activity of osteoconductive grafts.

- There are few commercially available Recombinant BMP proved to be effective treating nonunions.

Surgical management

Principle of surgical management

Cure infection if present

Correct Deformity if significant

Provide stability through implants

Add biologic stimulus when necessary

OPERATIVE

- Timing of operative intervention
- Plate and screw fixation
- IM nailing
- External fixation
- Arthroplasty
- Amputation
- Arthrodesis
- Fragment excision and resection arthroplasty
- Osteotomy
- Synostosis

Timing of operative intervention

Difficulty in establishing the optimal time to intervene surgically in treatment of non union parallels the difficulty in the diagnosis of non union

Standardized protocol

Waiting for 6 months before reoperation

Treat infection before operating

Adding stability

Plate and screw fixation

Intramedullary Devices

External Fixation

Choice of internal fixation depends on-

Type of nonunion.

Condition of the soft tissues and bone

Size and position of the bone fragments

Size of the bony defect.

Plate and screw fixation

- Plates provide a powerful reduction tool
- Surgical technique should strive for absolute stability
- Locking plates have improved stability and fixation strength
- Other relative indications:
  - Absent medullary canal
  - Metaphyseal nonunions
  - When open reduction or removal of prior implants is required

- Multiple Indications for plate
  - Broken implants require that removal
  - Metaphyseal nonunion
  - Significant deformity
- Technique
  - Blade properly positioned in the distal fragment
  - Reduction obtained by bringing plate to the shaft
  - Absolute stability with lag screw
  - Nonunion was not exposed

FIGURE 27-17 An open distal femur fracture treated with debridement and lateral plating resulted in a large segmental defect **(A)**. High varus stresses on the eccentrically placed plate **(B)** resulted in plate fracture prior to union despite bone grafting **(C)**. Nonunion repair with revision plating and additional autologous bone graft led to fracture union **(D)**.

union, either at baseline or created by surgical means such

IM Nail

- 3 forms

1. Pre existing nail
2. Exchange nail
3. Dynamization

- Ideal case – Femur or tibia with an existing canal and no prior implants
- Exchange nailing provides a good option for the tibia and femur
- Special equipment is often necessary to traverse sclerotic canals

External fixation

- Largest indication is a temporary stabilization following infection debridement
- Also useful in correction of stiff deformity and lengthening

- ✓ Monofocal
  - Compression
  - Sequential distraction-compression
  - Distraction
  - Sequential compression-distraction
- ✓ Bifocal
  - Compression-distraction lengthening
  - Distraction-compression transport (bone transport)
- ✓ Trifocal
  - Various combinations

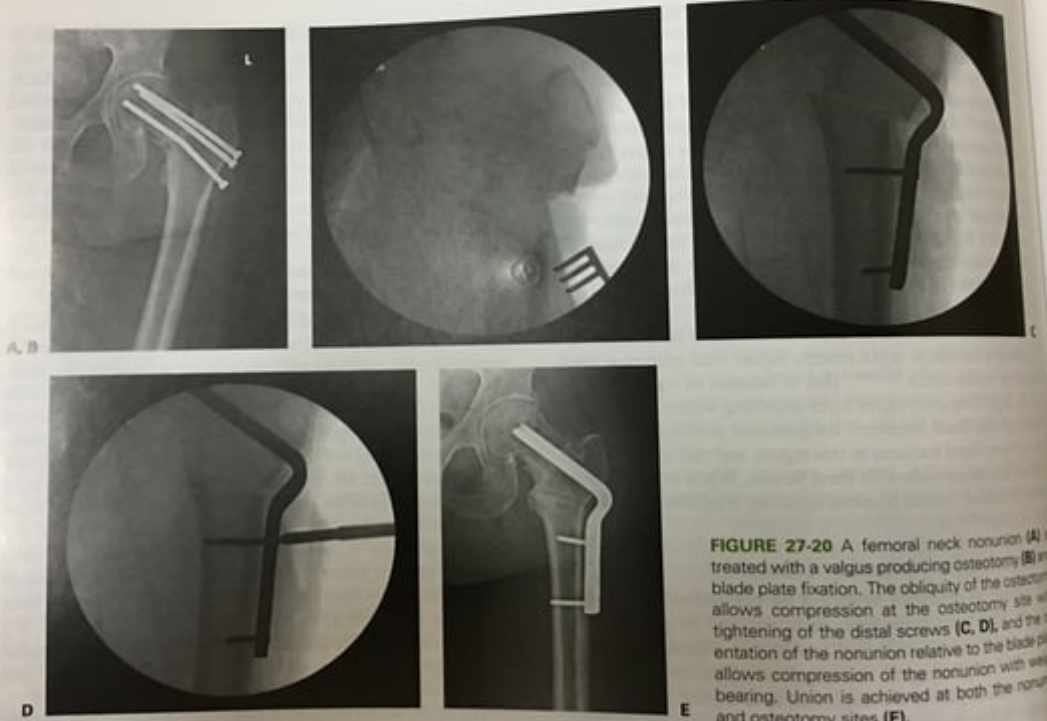


FIGURE 27-20 A femoral neck nonunion **(A)** is treated with a valgus producing osteotomy **(B)** and blade plate fixation. The obliquity of the osteotomy allows compression at the osteotomy site with tightening of the distal screws **(C, D)**, and the orientation of the nonunion relative to the blade plate allows compression of the nonunion with weight bearing. Union is achieved at both the nonunion and osteotomy sites **(E)**.

BONE GRAFT

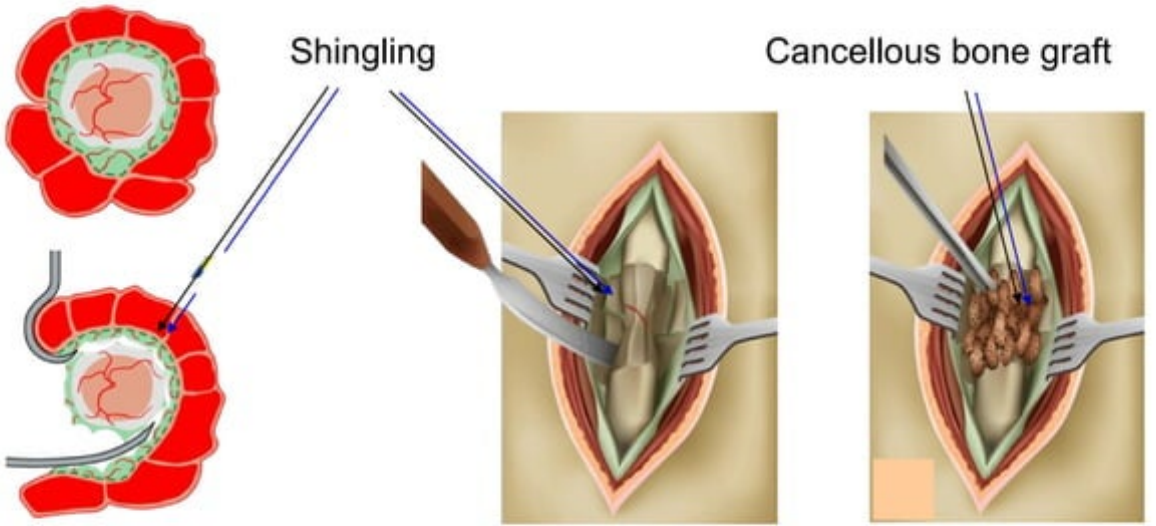
Gold standard for biological and mechanical purposes.

Properties of Autograft:

Osteogenic	a source of vital bone cells
Osteoinductive	recruitment of local mesenchymal cells
Osteoconductive	scaffold for ingrowth of new bone

Bone graft can also be allograft.

Decortication (Judet, 1972)



Muscle pedicle bone graft
Enhance the healing response
creating well-vascularized bed

BONE GRAFT SUBSTITUTES

Often unnecessary in hypertrophic cases with sufficient inherent biologic activity

- Options
  - Aspirated stem cells (with or without expansion)
  - Demineralized Bone Matrix
  - Autogenous Cancellous Graft
  - Platelet rich plasma
  - Growth Factors
    - Platelet derived
    - Recombinant BMPs

Articular non union

Potential causative factor is inadequate compression of the articular fracture gap leading to prolonged exposure to synovial membrane

Ideal situation of repair

1. Joint arthrosis
2. Joint instability
3. Stiffness

Therefore soft tissue contracture release or early post operative rom exercise

Segmental bone loss

They are due to high velocity injury or infected non union

Surgical options include

1. Autogenous bone graft
2. Free vascularized bone graft
3. Bone transport

A critical sized defect is generally regarded as the that requires surgery

It depends on particular bone involved , location within the bone , surrounding tissue , host biological response

Infected non union

- Contaminated implants and devitalized implants must be removed

- **Infection treated:**
  - Temporary stabilization (external fixation)
  - Culture specific antibiotics
  - +/- local antibiotic delivery (antibiobic beads)

- Secondary stabilization with augmentation of osteogenesis (cancellous grafting)

Active Treatment –

The objective of the active method is to obtain bony union early and shorten the period of convalescence and preserve motion in the adjacent joints.

Polymethyl Methacrylate Antibiotic Beads-

Heat-stable antibiotics, such as tobramycin and gentamicin, can be mixed with PMMA and used locally to achieve *200 times* the antibiotic concentration achieved with intravenous administration.

Prevention

- Good reduction
- Bone grafting
- Firm stabilization
  - ✓ biomechanical stability and
  - ✓ biological vitality of the bone.

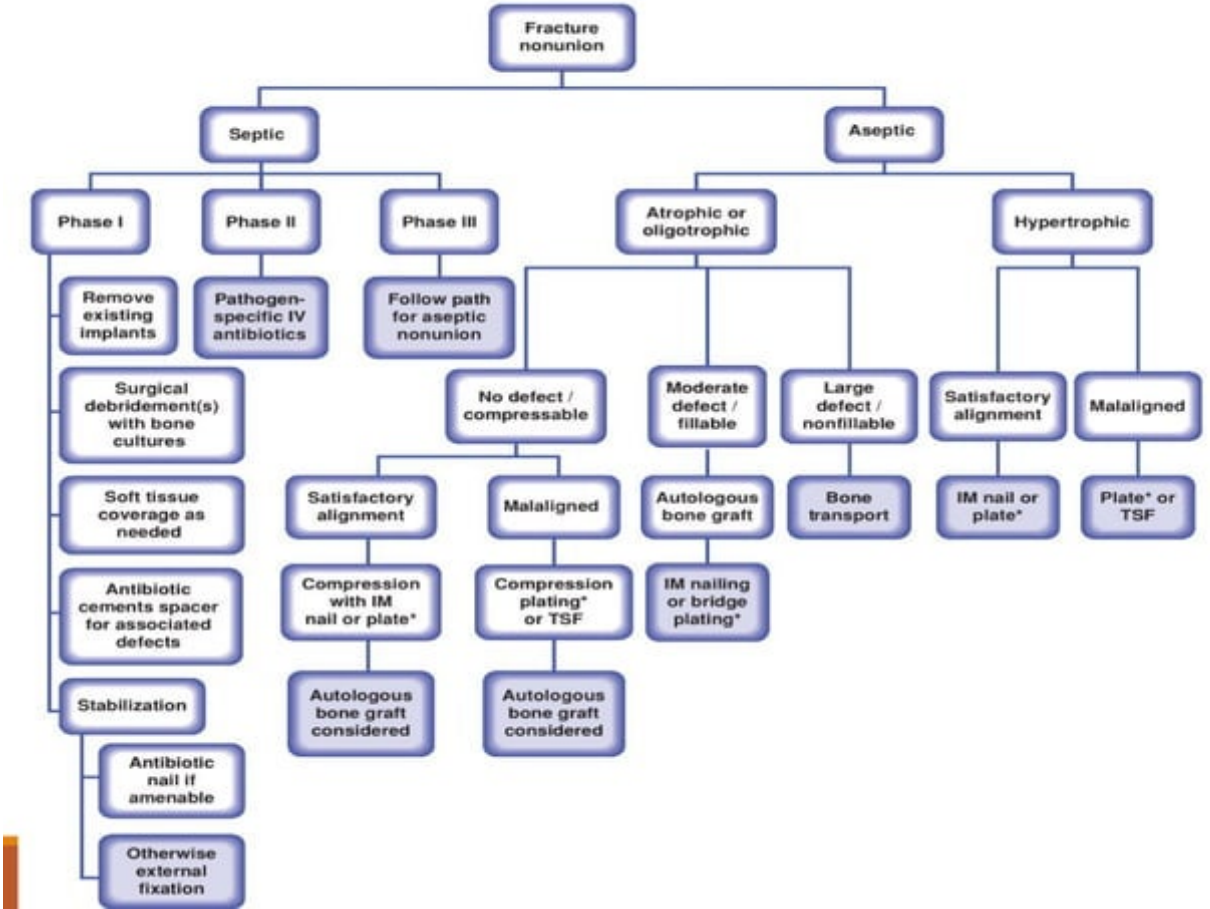
summary

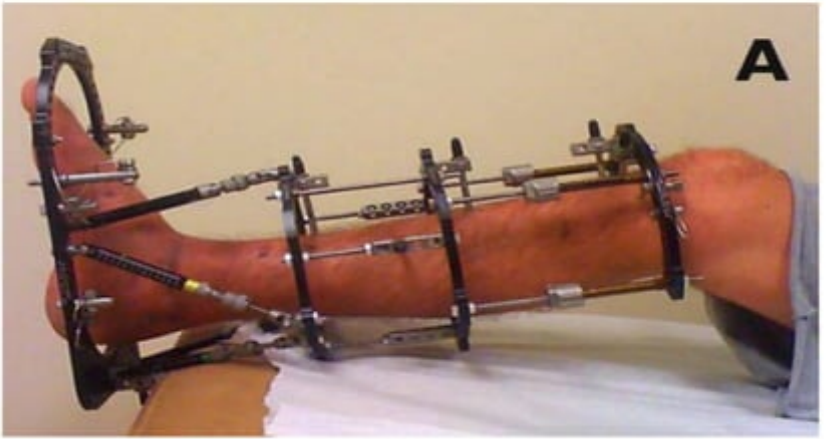
Principles of treatment applied based on types of nonunion:

- stabilization
- enhancement of biology
- eradication of infection if any

How to prevent delayed unions/nonunions:

- biological fixation in original operation
- early recognition of delayed union


Fracture nonunion
Septic
Aseptic
Phase I
Phase II
Phase III
Atrophic or oligotrophic
Hypertrophic
Remove existing implants
Pathogen-specific IV antibiotics
Follow path for aseptic nonunion
Surgical debridement(s) with bone cultures
Soft tissue coverage as needed
Antibiotic cements spacer for associated defects
Stabilization
Antibiotic nail if amenable
Otherwise external fixation
No defect / compressable
Moderate defect / fillable
Large defect / nonfillable
Satisfactory alignment
Malaligned
Satisfactory alignment
Malaligned
Autologous bone graft
Bone transport
IM nail or plate*
Plate* or TSF
Compression with IM nail or plate*
Compression plating* or TSF
IM nailing or bridge plating*
Autologous bone graft considered
Autologous bone graft considered



THANK YOU…