Bone Grafts & Substitutes

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Bone Healing

- Positive Factors
  - Good vascular supply at graft site
  - Large surface area
  - Mechanical stability
  - Mechanical loading
  - Growth factors

Bone Healing

- Negative Factors
  - Radiation
  - Tumour
  - Infection
  - Instability
  - Steroids
  - Smoking
  - Malnutrition
  - Diabetes

Mechanical stability – Key factor

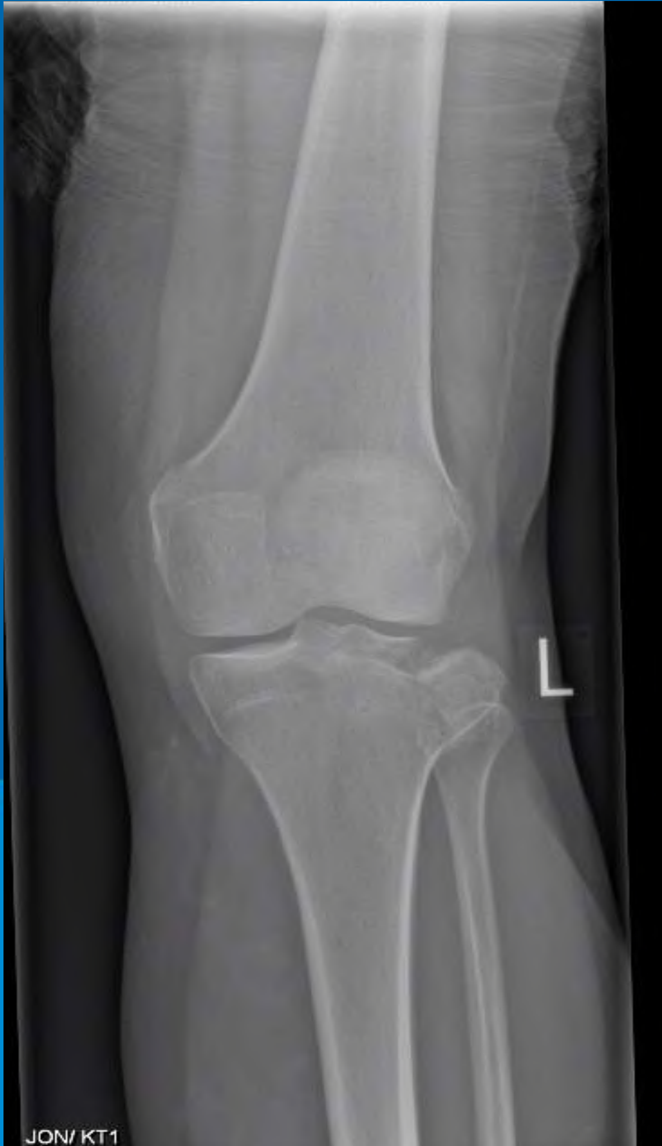
- What type of bone healing?

- **Direct** - rigid / callus free.
  - Lag screw or a compression plate

- **Indirect** – micro motion / callus.
  - Less rigid systems (IM nail / LISS system / periarticular locking plates - span metaphyseal fracture site (Pilon or plateau fractures)

Properties of Graft Material

- Osteogenic – bone formation - no indication of cellular origin (e.g. cancellous autograft)
- Osteoconductive – scaffold provided into which bone growth can occur (e.g. porous calcium phosphate)
- Osteoinductive – recruitment of mesenchymal cells that differentiate into cartilage/bone forming cells (e.g. BMPs)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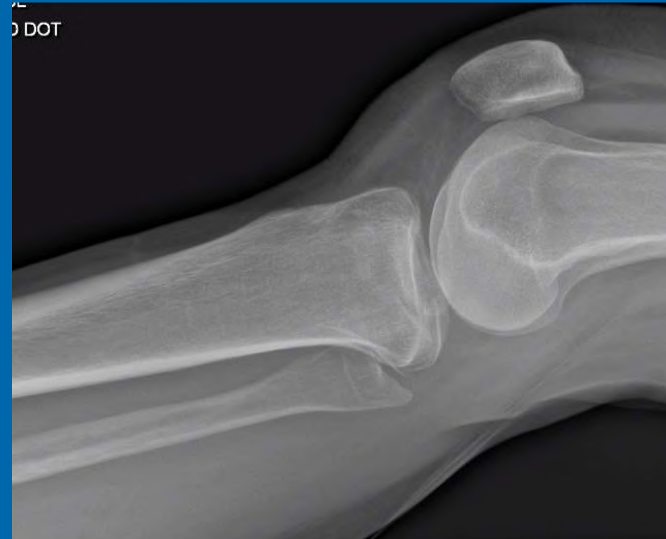

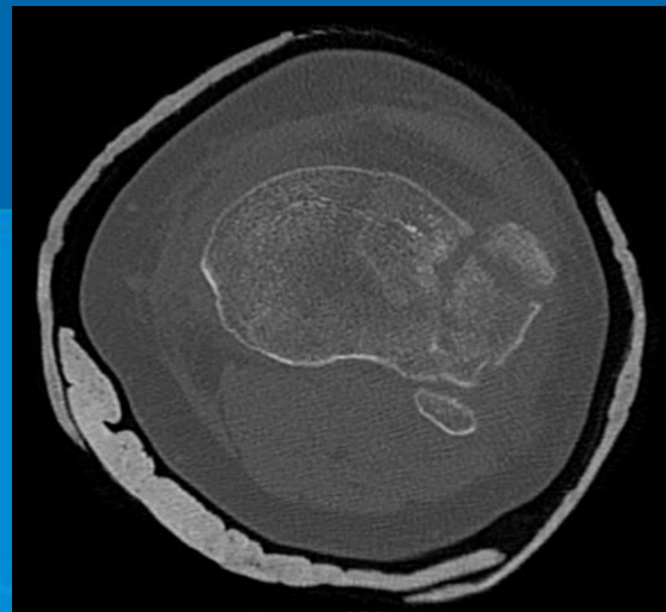

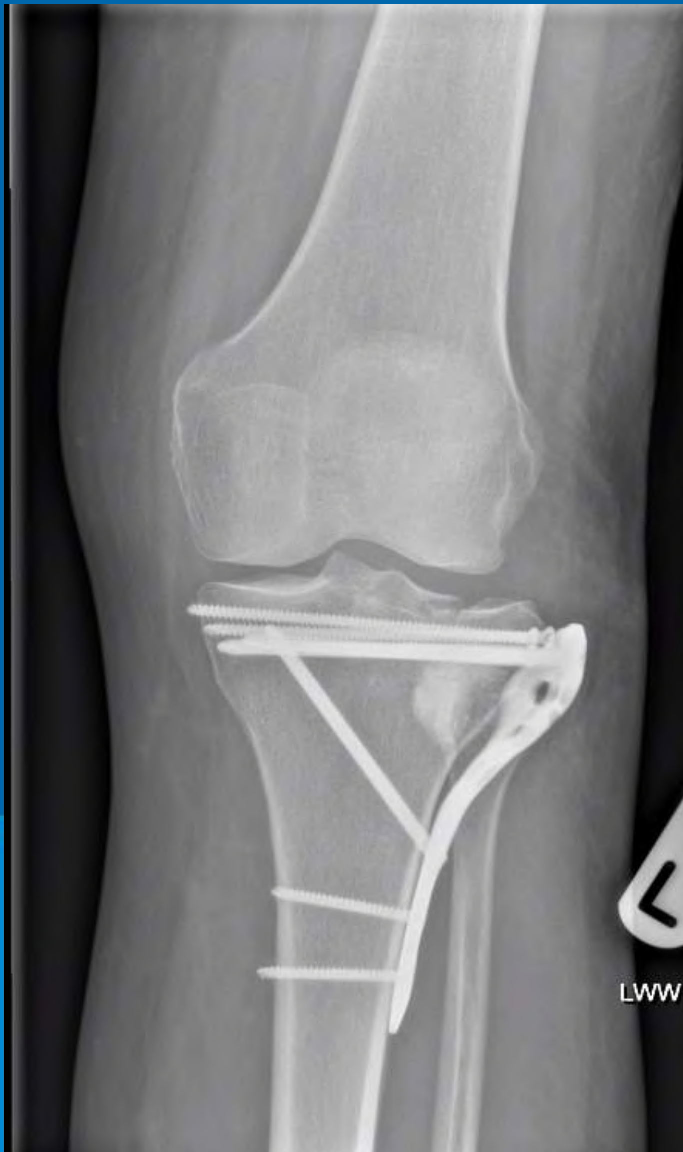
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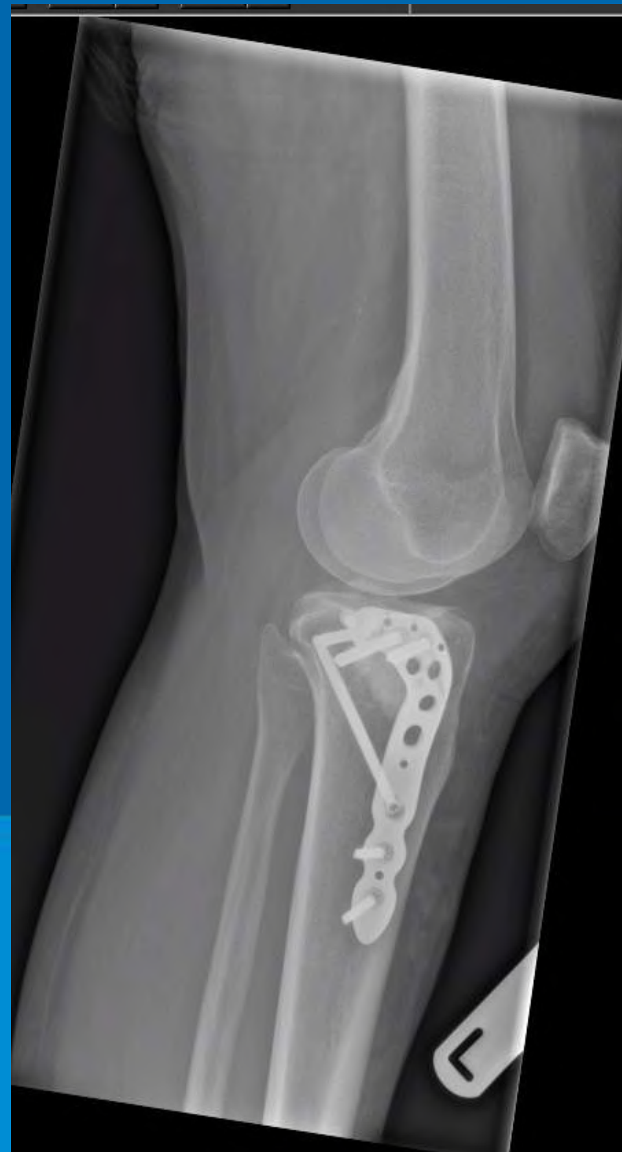
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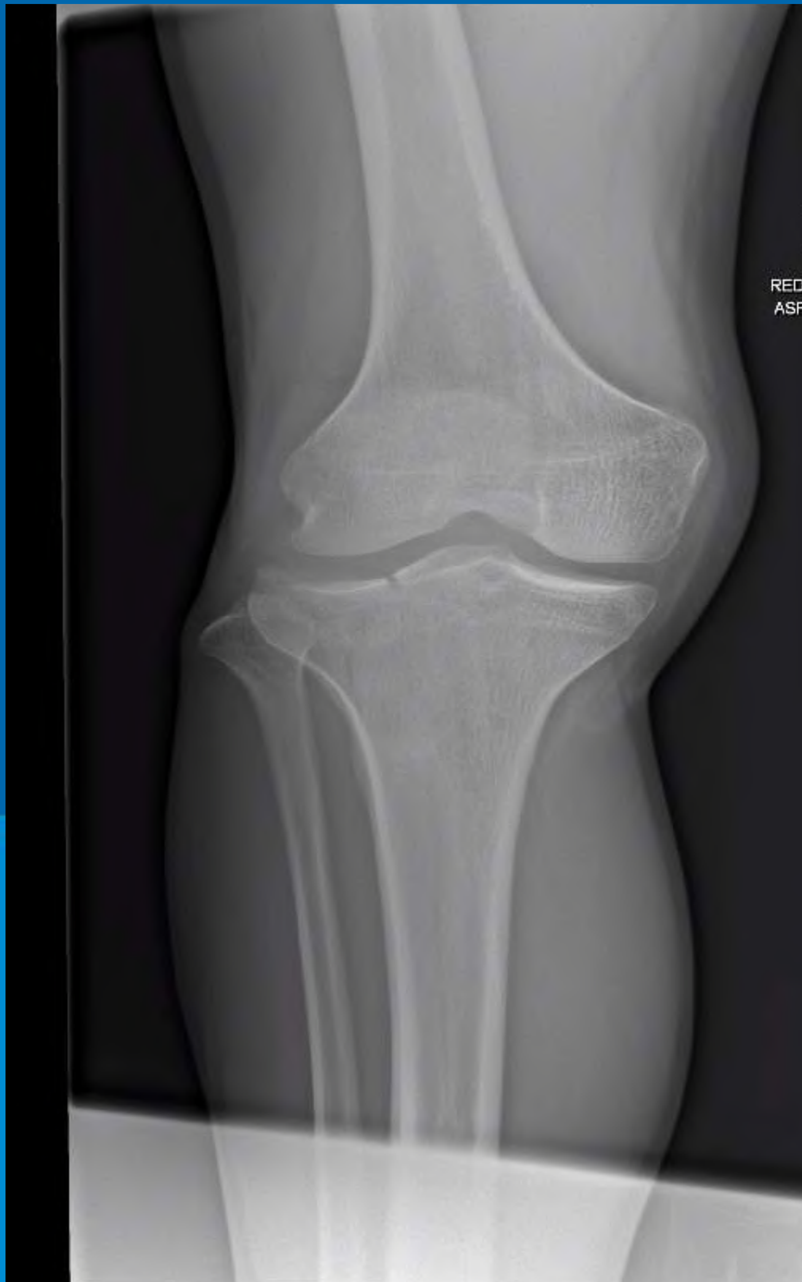
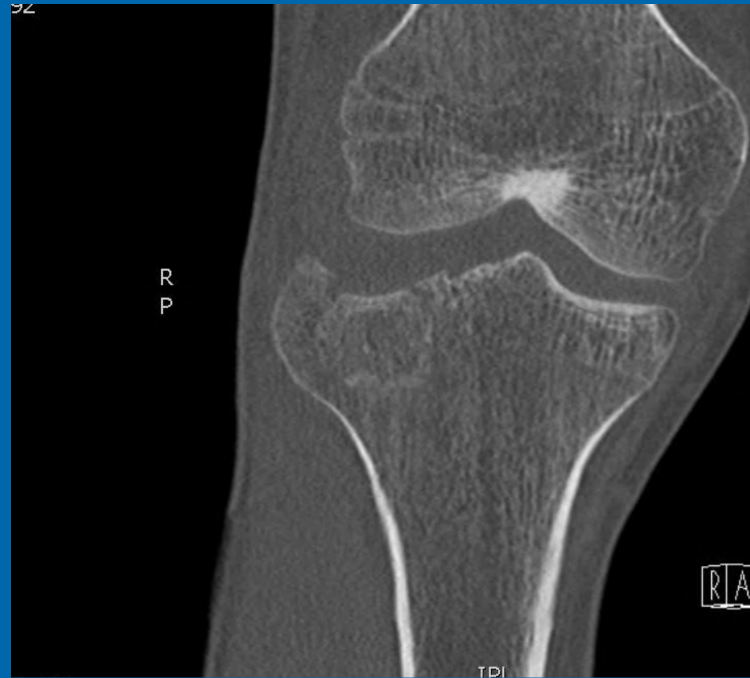
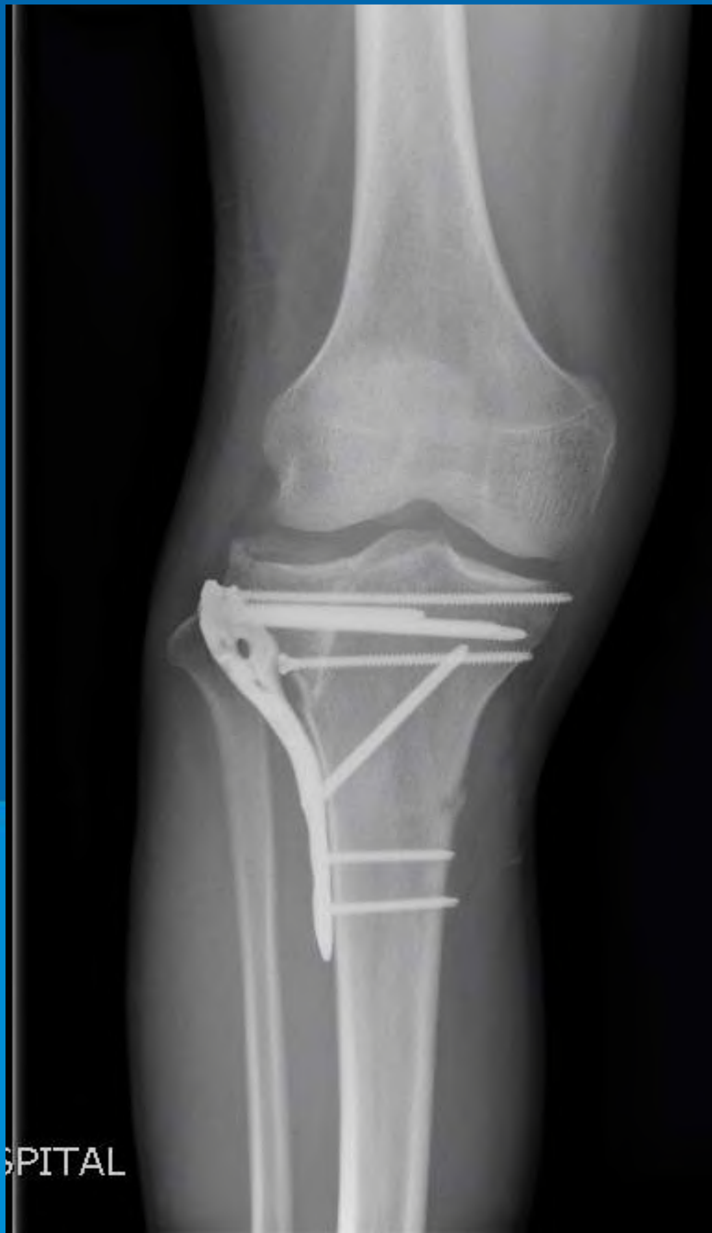




Younger, better quality bone

Less of a metaphyseal defect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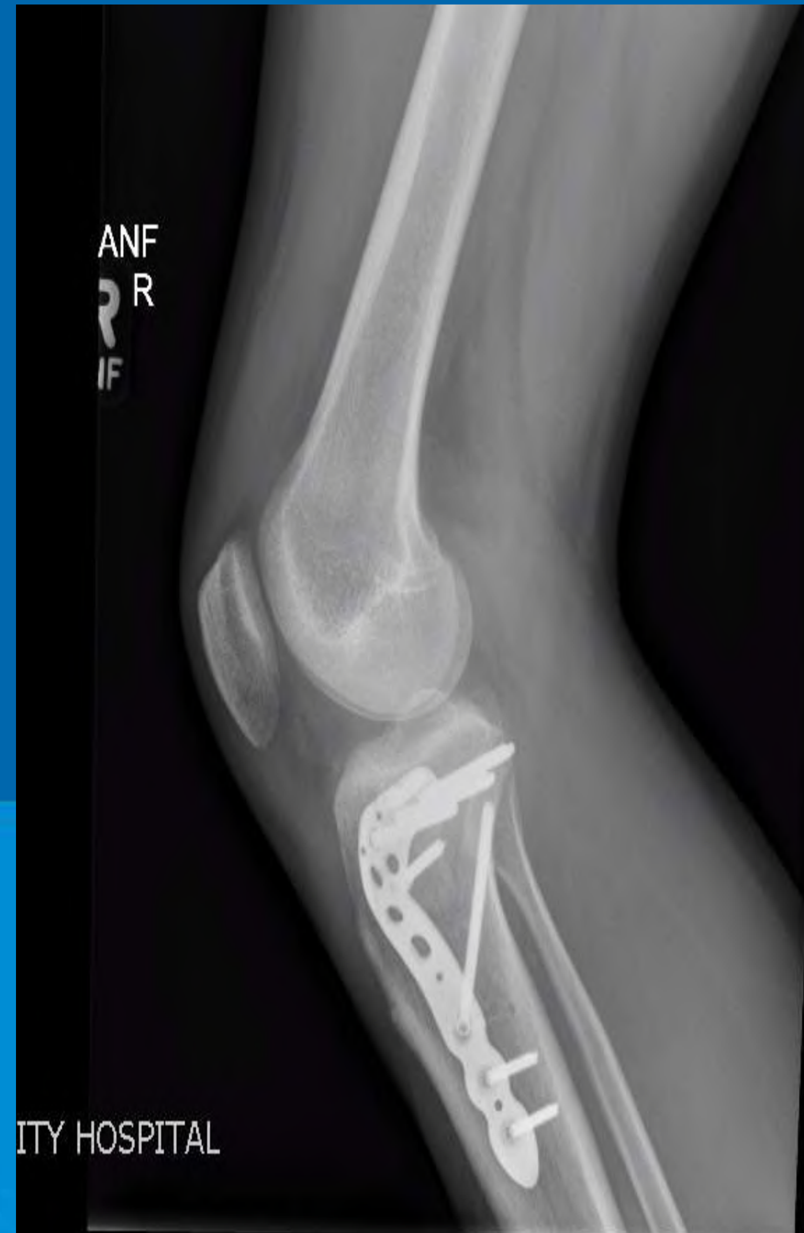
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3 roles of bone graft materials

All measured against the gold standard -
Autogenic Bone Graft (ABG)

- Bone graft extender – increases volume
  - ABG has limited volume
- Bone graft enhancer – improves healing rates
  - compared to ABG
- Bone graft substitute – replaces the use of ABG

Healing Environment

- Biological roles of the graft depend upon the healing environment

- Example: Tibial metaphyseal defect (pilon/plateau)
  - Good bone marrow access
  - Good blood supply
  - Adequate soft tissue protection
  - A purely osteoconductive agent (Calcium phosphate) will suffice.
  - An osteoinductive component added in a poor host (smoker/diabetic/steriods)

Autogenic Bone Graft

- 'Gold Standard'
- Iliac crest (limited vol. – > at PSIS)
- Graft replaced by 'creeping substitution'
- Osteogenic: (diff and undiff cells)
- Osteoconductive (ideal scaffold)
- Osteoinductive (small amounts of BMP)
- Advantages: porous / rapid ingrowth of vessels / no graft reaction
- Disadvantages: Limited volume / donor site morbidity
- RIA: Reamer Irrigation Aspiration system – Synthes (IM femoral reamimg – 4 x volume of ABG)

Platelet Derived Growth Factor

- Platelets rich in PDGF
- ? Help bone formation (osteoinductive)
- Popular with spinal fusion augmentation
- Limited and conflicting evidence: No clear evidence that it improves fusion rates compared to ABG alone.

Allograft

- Good available vol. / no donor site probs.
- Porous / good osteoconduction – good bone graft extender
- No osteoinductive properties
- Impaction grafting (THR) and spinal fusion
- Structural allograft – femoral shaft / allows weight bearing
- Screening of cadaveric donors for exposure to specific diseases such as HIV with appropriate blood tests.
- Processing ensures sterility but reduces the graft's biological and mechanical properties

Calcium Based Cements

- Commonly used bone graft extender
- Osteoconductive
- Little inflam. / no disease transmission
- Low fracture resistance + tensile strength
- JOT 2005 (Leighton): Cancellous bone versus alpha BSM / cadaveric paired study on split depression tibial plateau fractures / bone substitute exhibited > stiffness and < fracture collapse
- JBJS (A) 2008: Multi centre RCT. Bioresorbable CaPO4 showed less subsidence compared to ABG in unstable tibial plateau fractures.

Products

- Moldable putty / Injectable paste / Pellets
  - MIIG X3 (Wright Medical) ($CaSO4$)
  - Norian SRS Fast Set Putty (Synthes)
  - Alpha BSM (DePuy)
  - OsteoSet / OsteoSet T (Wright Medical)
  - HydroSet (Stryker)

Demineralised Bone matrix

- Decalcification of cortical bone
- Removes Ca and PO4 – no structural support
- Leaves extracellular matrix: Type 1 collagen + non-collagenous proteins (BMPs)
- Little prospective clinical evidence

Bone Morphogenic Proteins

- LMW non collagenous glycoproteins
- Promote normal healing after fracture
- Bind to specific receptors on MSCs, osteoblasts and osteoclasts
- Low concentration: Promote differentiation of MSCs to chondrocytes = matrix
- High concentration: Induce direct (intramembranous) bone healing

BMP - 2

- Clinical efficacy supported but over last 5-10 years use has reduced as surgical techniques have improved

- ‘Infuse’ – used in spinal arthrodesis

- Prospective RCT in **<u>open</u>** (3A & 3B) tibia fractures (Swiontkowski JBJS (A) 2006). BMP-2 introduced at time of definitive wound closure: lower infection rates; less grafting and secondary procedures

BMP - 7

- BMP – 7 (OP – 1)

- Friedlander (2001) – JBJS (A) – *suppl*
  - OP-1 versus ABG in tibia non-unions
  - 75% versus 84% union rates
  - No significant difference

- Available for trauma, but limited good evidence

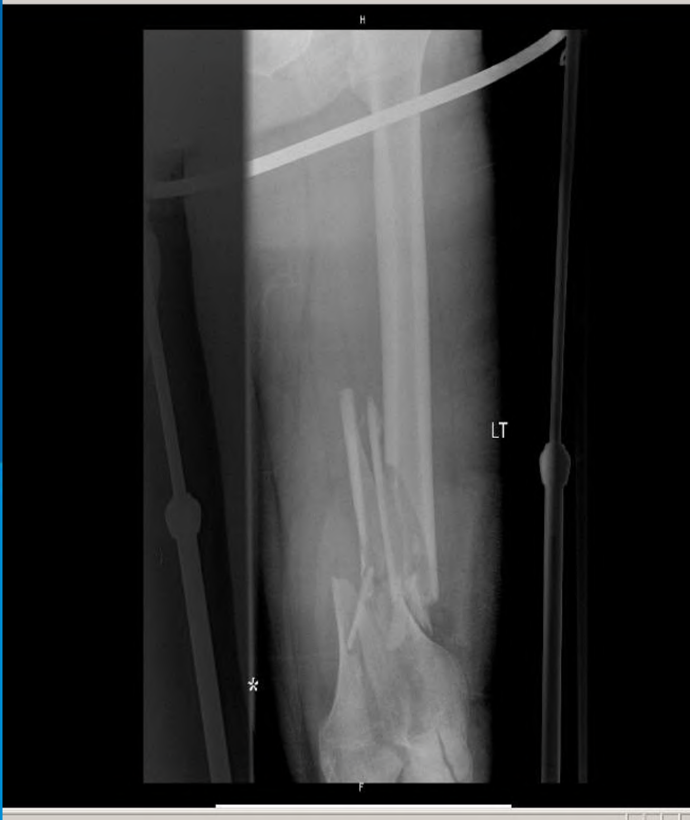
When to use BMPs?

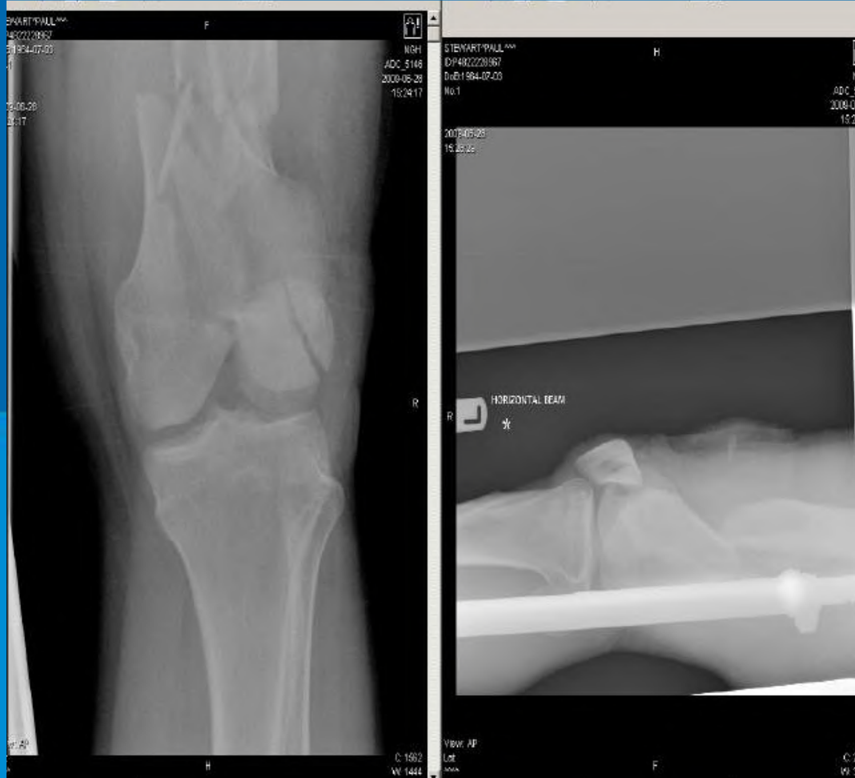
- Expensive
- No definite rules
- 2nd revision of a treated non-union - 2008

Future Developments

- Gene therapy to deliver BMP gene so that protein can be synthesised on site
- ID gene that coordinates the expression of multiple BMPs

Case 1



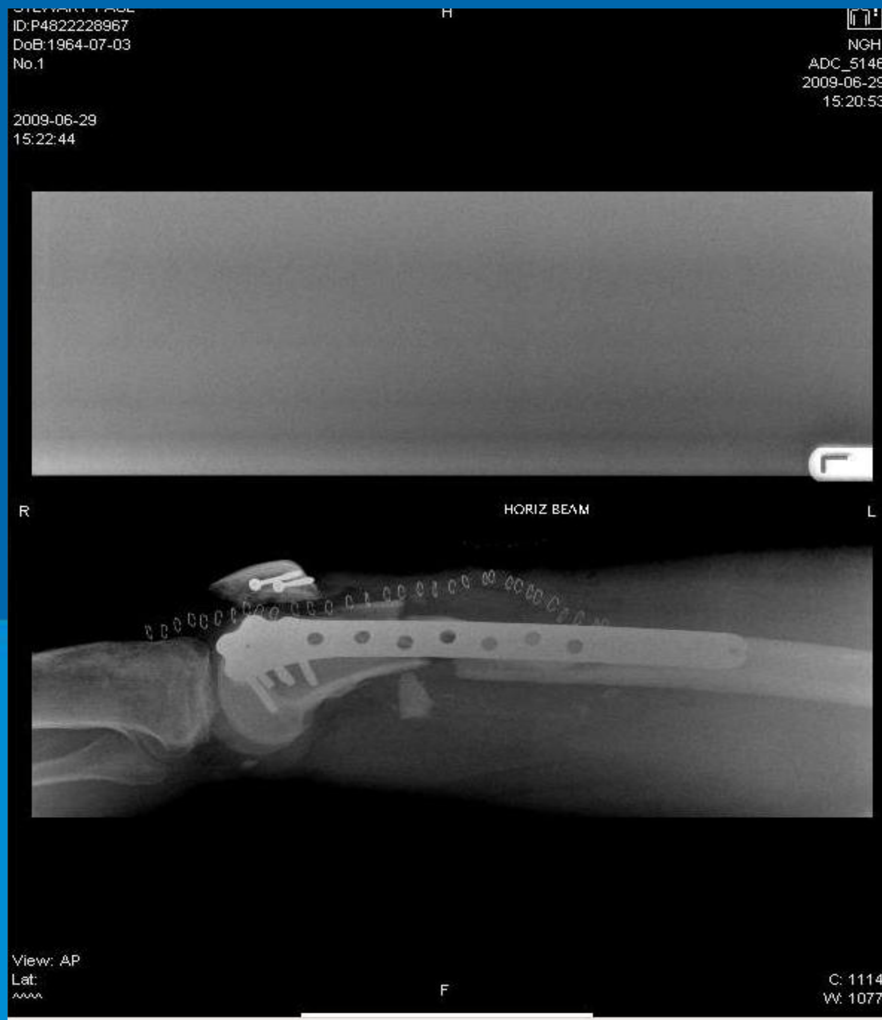


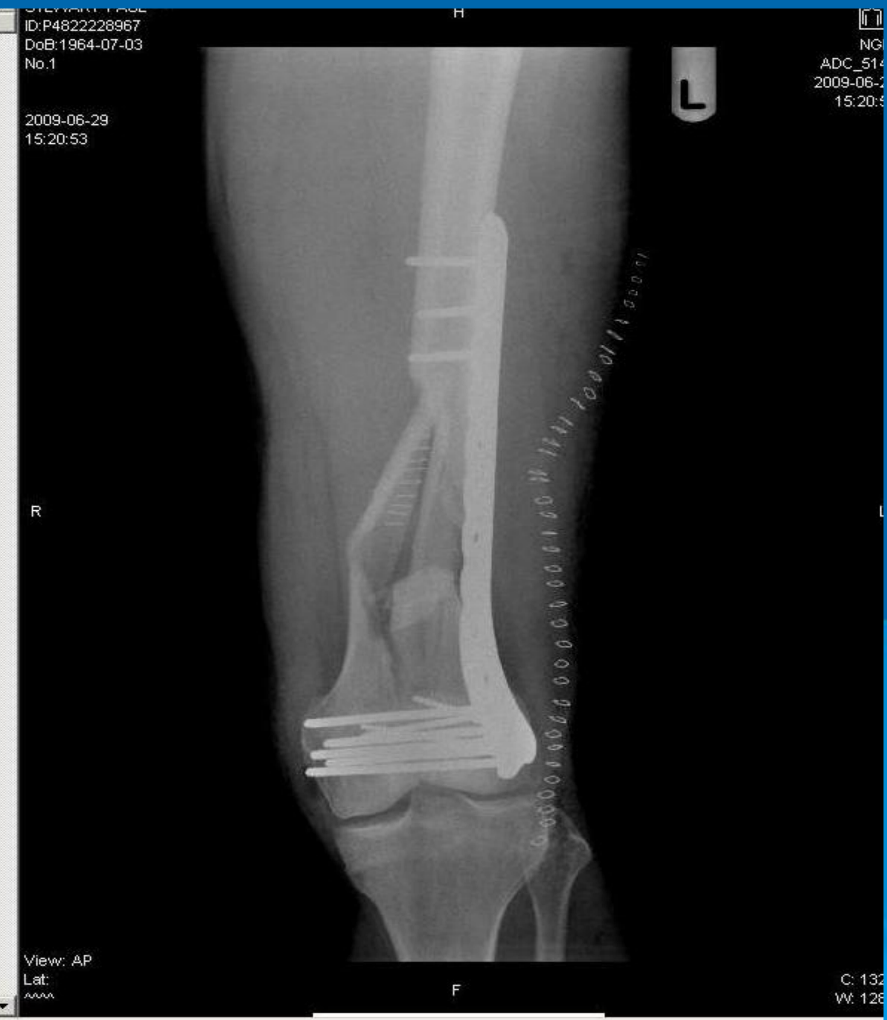
Management

Open / Periarticular fracture

- Wound debridement and irrigation
- Consider spanning ex fix (soft tissues?)
- Restore joint surface
- Attach to metaphysis / diaphysis
- Span Bone defect
- Indirect bone healing
- Graft bone defect 6-8 weeks after fixation

Case 1(distal femur)





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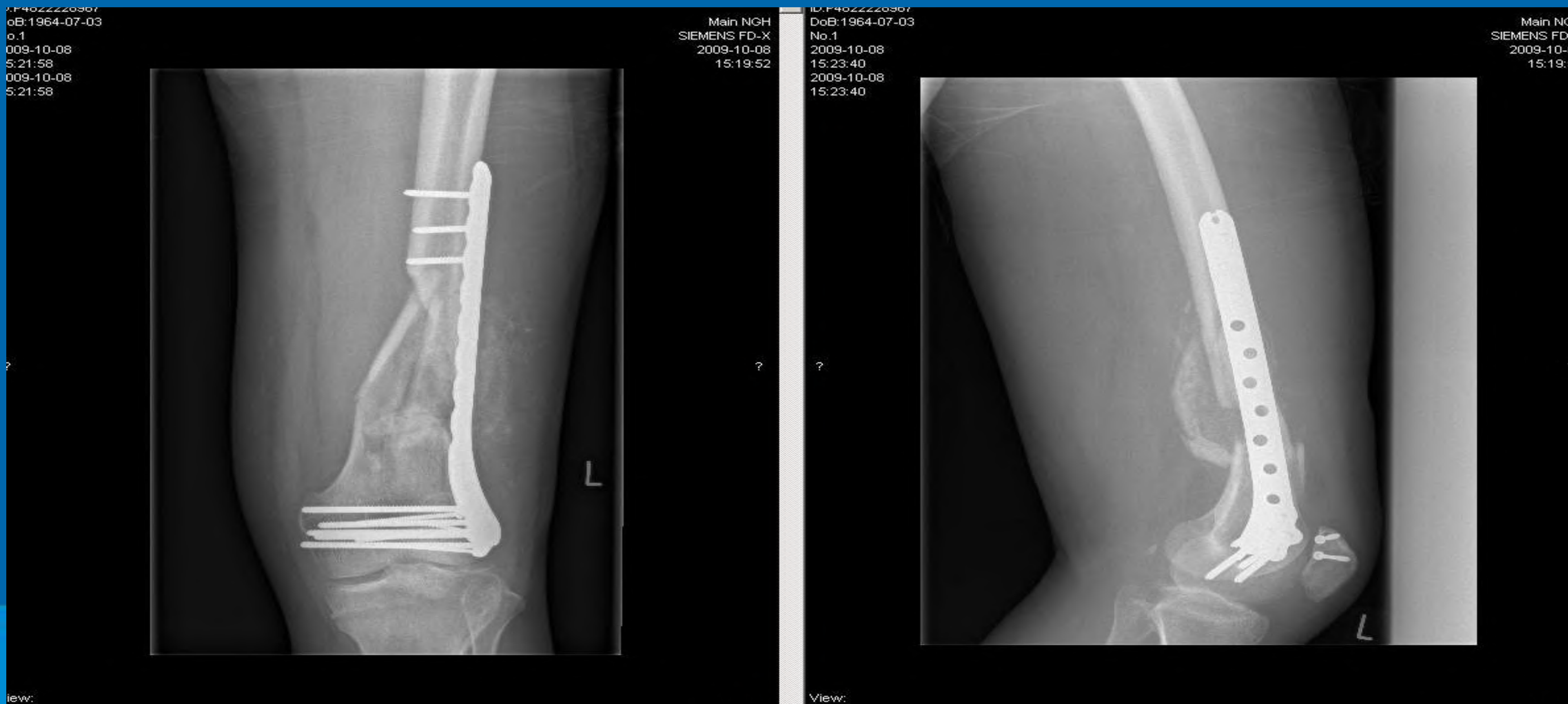

- Combination of autograft / allograft (volume the problem here)
- Added ‘IGNITE’ (Wright Medical) - injectable scaffold of demineralized bone matrix with aspirated red bone marrow
- Other optios: RIA

Case 1 (9 months after injury)