Nonunion with Bone Loss

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Original Authors; March 2004; Revised June 2006 and 2010
Etiology

- Open fracture
  - segmental
  - post debridement
  - blast injury
- Infection
- Tumor resection
- Osteonecrosis
## Classification

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<th>Defect</th>
<th>Size</th>
<th>Articular</th>
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Salai et al. Arch Orthop Trauma Surg 119
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Evaluation

- Soft tissue envelope
- Infection
- Joint contracture and range of motion
- Nerve function: sensation, motor
- Vasculature: perfusion, angiogram?
- Location and size of defect
- Hardware
- General health of the host
- Psychosocial resources
Is it Salvageable?

- Vascularity - warm ischemia time
- Intact sensation or tibial nerve transection
- other injuries
- Host health
- magnitude of reconstructive effort vs patient’s tolerance
- ultimate functional outcome
Priorities

- Resuscitate
- Restore blood supply
- Remove dead or infected tissue (Adequate debridement)
- Restore soft tissue envelope integrity
- Restore skeletal stability
- Rehabilitation
Bone Loss - Initial Treatment

- Irrigation and Debridement
Bone Loss - Initial Treatment

- Irrigation and Debridement
- External fixation
Bone Loss - Initial Treatment

- Irrigation and Debridement
- External fixation
- Antibiotic bead spacers
Bone Loss - Initial Treatment

- ANTIBIOTIC BEAD POUCH
  - ANTIBIOTIC IMPREGNATED METHYL METHACRALATE BEADS
  - SEALED WITH IOBAN
Bone Loss - Initial Treatment

- Irrigation and Debridement
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- Irrigation and Debridement
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- Soft tissue coverage
Bone Loss - Initial Treatment

- Irrigation and Debridement
- External fixation
- Antibiotic bead spacers
- Soft tissue coverage
- Sterilization and Re-implantation?
Potential Segment Re-implantation

- Young, healthy patient
- well vascularized soft tissue bed (femur, not tibia)
- single cleanable fragment
- early, aggressive, meticulous wound care
- adequate sterilization of the fragment
- Antibiotics, local and systemic

Mazurek et al J. Ortho Trauma 2003
Skeletal Stability: Treatment Options

- Significant loss of joint surface
  - osteochondral allograft
  - total joint or hemi-arthroplasty
  - arthrodesis
Skeletal Stability: Treatment Options for Diaphyseal Defects

- Autogenous bone graft
  - cancellous
  - cortical
  - vascularized
- Allogeneic bone graft
  - cancellous
  - cortical
  - DBM
- Distraction osteogenesis
  - multifocal shortening/lengthening
  - bone transport
- Salvage procedures
  - shortening
  - one bone forearm
Bone Grafting

- Osteogenesis - bone formation
  - Survival and proliferation of graft cells
- Osteoinduction - recruitment and stimulation of bone-forming cells
- Osteoconduction - micro scaffold
- Structural Support
Graft Incorporation

- Hemorrhage
- Inflammation
- Vascular invasion
- Osteoclastic resorption/ Osteoblastic apposition
- Remodelling and reorientation
Autogenous Cancellous Bone Grafting

- Quickest, highest success rate
- Little structural support
- Best in well vascularized bed
- Donor site morbidity
- Quantity limited - short defects?
Papineau Technique

- Direct open cancellous grafting of granulation bed
- Typically large metaphyseal defect
• 22 year old man
• RHD
• MCA
• open segmental humerus fracture with bone loss and radial nerve out
Irrigation and Debridement
Application of external fixator
Wound care
Antibiotics
Posterior plate fixation

Iliac crest bone grafting
+ antibiotic CaSo₄ beads

Implantable bone stimulator
2 months
3 months
5 months
Essentially full function at 5 months
40 year old female

10 years after cancellous grafting of distal tibial defect
Reamer-Irrigator-Aspirator

- Irrigation ports
- Aspiration ports
- Filter to catch the bone graft
Reamer-Irrigator-Aspirator

- Irrigation ports
- Aspiration ports
- Filter to catch the bone graft
45 year old female
Motorcycle accident
Open distal femur
Initially treated with irrigation and debridment and plate stabilization with ABX block spacer
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Motorcycle accident
Open distal femur
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RIA bone graft at 6 weeks
RIA bone graft at 6 weeks
Full WB at 4 mo HWR at 15 mo
Allograft

- Incorporates like autograft, but slower
- No cells survive
- May include joint
- No size or quantity limitation
- Risk of disease transmission
- Infection rate ~ 5-12%
- Intercalary grafts for tumor resection >80% success (Ortiz-Cruz, et al.)
- Can be combined with autograft
Cortical Strut Grafting

- Provide structural support
- weakly osteogenic
- revascularize slowly
- initially become weaker
- frequently needs supplementary cancellous graft for union
  (Enneking, JBJS 62-A, 1980)
35 yo Γ
MVC
Open femur with segmental bone loss
I&D
ExFix
Beads
ORIF with bladeplate
fibular strut allograft
cancellous autograft
CaSO₄ pellets
Bone stimulator
8 months
FWB without pain
return to work
Cancellous Allograft

• May be similar to cancellous AUTOgraft when combined with recombinant human bone morphogenic protein (rhBMP) or other growth factors
  – Volgas and Stannard, A Randomized Controlled Prospective Trial of Autologous Bone Graft versus Iliac Crest Bone Graft for Nonunions and Delayed Unions, OTA annual meeting 2004 http://www.hwbf.org/ota/am/ota04/otapa/OTA041165.htm
Vascularized Graft

• Pedicled ipsilateral fibula
• Free bone flap
  – fibula
  – iliac crest
  – rib
• Structural support, rapid healing, independent of host bed
• will hypertrophy, but maybe best utilized in upper extremity
The Free Fibula

- Taylor 1975
- branch of the peroneal and periosteal vessels
- Can be transferred with skin or with skin and muscle to reconstruct several tissues at once (Jupiter et al., Heitmann et al.)
- donor site morbidity
  - mod. Gait changes up to 18 months
  - sl. ↓ calf strength, ↓ eversion
  - FHL contracture
  - peroneal paresthesias
29 yo RHD female

GSW L arm

Pulses intact

Hand neuro exam intact
Irrigation
Debridement
ExFix
wound care
5 months

Free fibula graft fixation with long T plate
24 months post injury
revision fixation proximally with bone graft
3 years post-injury
healed
uses hand for ADLs
40 year old female

10 years after free fibula graft for femoral defect

Hypertrophy and consolidation
Distraction Osteogenesis

- Ilizarov 1951 “tension-stress effect”
- mechanical induction of new bone formation
- neovascularization
- stimulation of biosynthetic activity
- activation and recruitment of osteoprogenitor cells
- intramembranous ossification
Ilizarov Technique

- Rings and Tensioned wires
- corticotomy
- latency period
- gradual distraction, .25 mm q6°
- parallel fibrovascular interface
- columns of ossification
Ilizarov Technique

- Acute shortening and compression at fracture site, followed by lengthening at a separate site
  - reduces soft tissue defect
  - protects vascular/nerve repair
- Bone Transport - internal lengthening of one or both segments to fill gap
  - allows normal length and alignment during treatment
Bone Transport

- High rate of ultimate success, good restoration of length and alignment
- No donor site morbidity
- May be functional during treatment

But...

- Requires prolonged time in the frame ~ 2 mon/cm
- Frequent docking site problems requiring bone grafting
- Frequent complications

Transport over an IM nail (Monorail technique) or under a MIPO plate
25 yo ♀
AK-47 GSW

This case and images courtesy of Kevin Pugh, MD
Ohio State University
Application of circular frame with half-pins for transport

This case and images courtesy of Kevin Pugh, MD Ohio State University
Retrograde transport of a 14 cm segment required 2 years in the frame.

This case and images courtesy of Kevin Pugh, MD Ohio State University.
Patients can bear weight in the frame while the segment is consolidating and healing at the docking site.
Final Union Achieved

This case and images courtesy of Kevin Pugh, MD
Ohio State University
Comparisons - Ilizarov to Conventional Techniques

• 3 studies: Green, Cierny, Marsh
• CORR 301, 1994
• different outcome measures
• 2 retrospective, 1 “prospective” with historical controls
• None with concurrent treatment or randomization
• All Ilizarov advocates to variable degree
Comparisons - Ilizarov to Conventional Techniques

- Number of patients: “conventional” (C)=53, Ilizarov (I)=48
- Avg defect: C=5.7 cm, I=5.5 cm
- “Success”: C=77%, I=81%
- 2^0 procedures: C=112, I=35
- Complications: C=48, I=37
Other Modalities

- Bone Graft Extenders
- Bone Graft Substitutes
- Titanium Mesh Cages
  - Attias and Lindsay, CORR 2006
- Bone Morphogenic Proteins
- Electrical Stimulation
Future directions

• Stem cells
• Gene transfer
• Bioabsorbable structural carriers
References - General and Basic Science


- Goldstrohm GL, Mears DC, Swartz WM. The results of 39 fractures complicatied by major segmental bone loss and/or leg length discrepancy. J. Trauma 24(1):50-8, 1984
References – Induced Membrane

References - Autogenous Bone grafting

References - Autogenous Bone grafting

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References - Fragment re-implantation

References - vascularized bone transplant

References - vascularized bone transplant

References - Lengthening or Bone Transport

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References - Lengthening or Bone Transport


References - Comparisons

References - Allograft

References - Miscellaneous


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References - Experimental

References - Experimental


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