Large Bone Defects

Autogenous Graft Techniques Limitations and Outcomes

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AO Masters Course
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Large Bone Defects

- **High energy trauma**
  - Open fractures with soft tissue damage
  - Radical debridement of open fractures
- **Excision of pathologic tissues**
  - Septic or aseptic nonunions
  - Osteomyelitis
  - Bone tumors
  - Congenital pseudoarthrosis

Treatment Alternatives

- Nonvascularized cancellous autografts
- Nonvascularized cortical strut autografts
- Vascularized bone grafts
- Acute shortening
- Bone transport procedures
- Bone allografts
- Endoprosthesis implantation

Cancellous Autografts

- **Osteoinductive**
- **Osteoconductive**
- **Osteogenic**

Cancellous Autografts

- **Limited source**
  - 30 cc from posterior iliac crest → 4 cm tibial defect

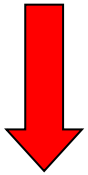
- **> 4 cm defect → graft resorption**
  - Bone atropy
  - Nonunion

Hertel R. Cancellous bone graft for skeletal reconstruction: Muscular versus periosteal bed. Preliminary report. Injury, 25(Suppl 1): A59-70, 1994.

Weiland AJ. Bone Grafts: A radiological, histological and biomechanical model comparing autografts, allografts and free vascularizedbone grafts. Plast Reconstr Surg, 74(3): 368-79, 1984

Cancellous Autografts

- **Vascular aseptic enviroment**
- **Stable fixation**

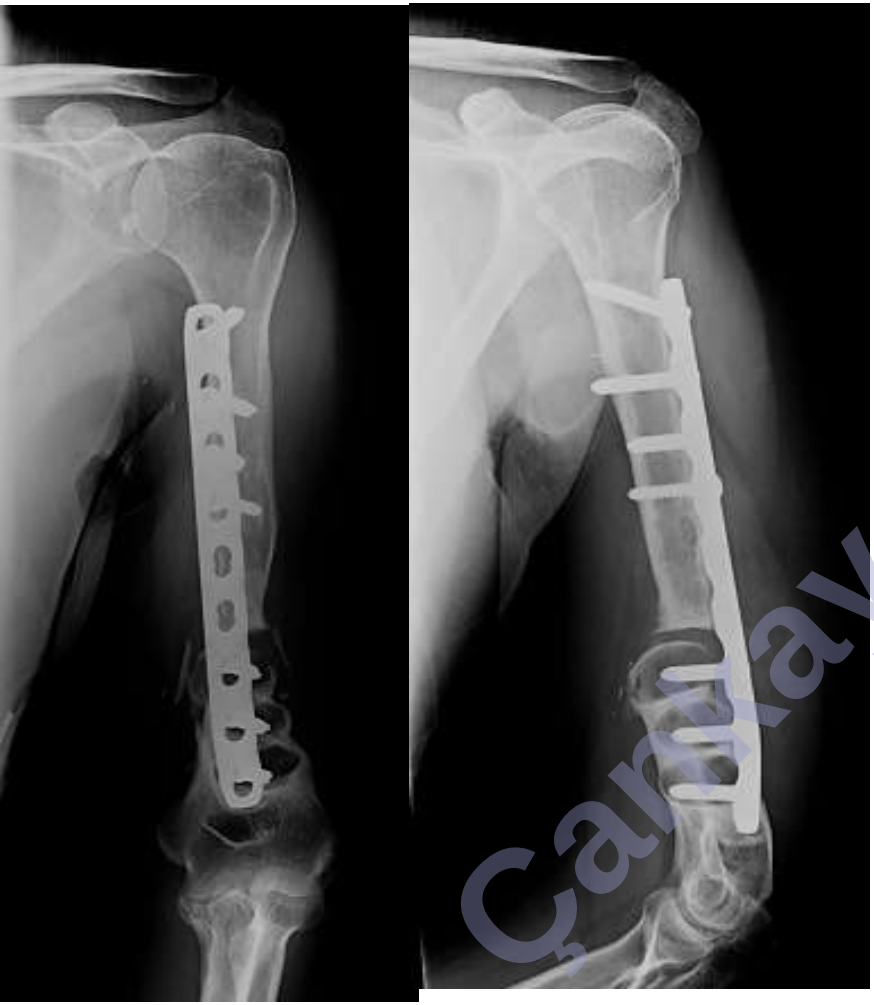


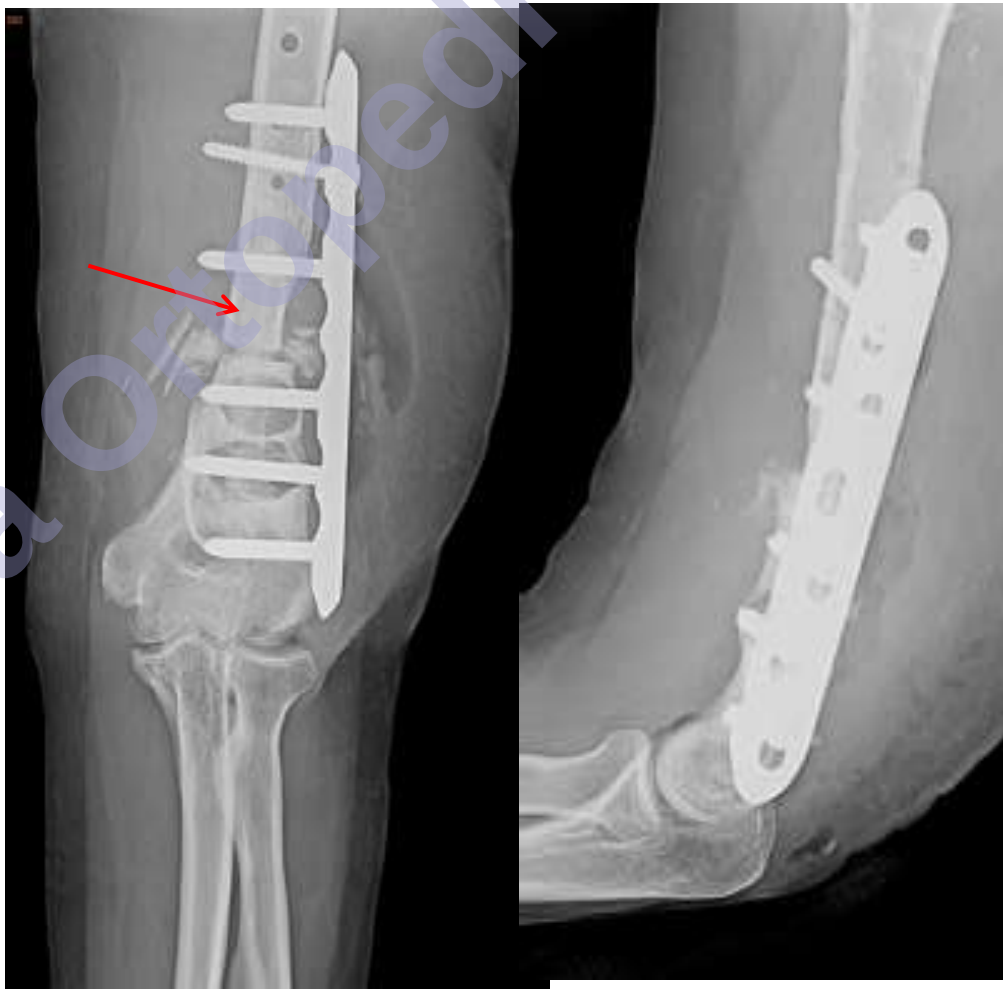
- **Staged procedure**
  - 6 weeks after soft tissue healing
  - Bone cement spacer with antibiotic

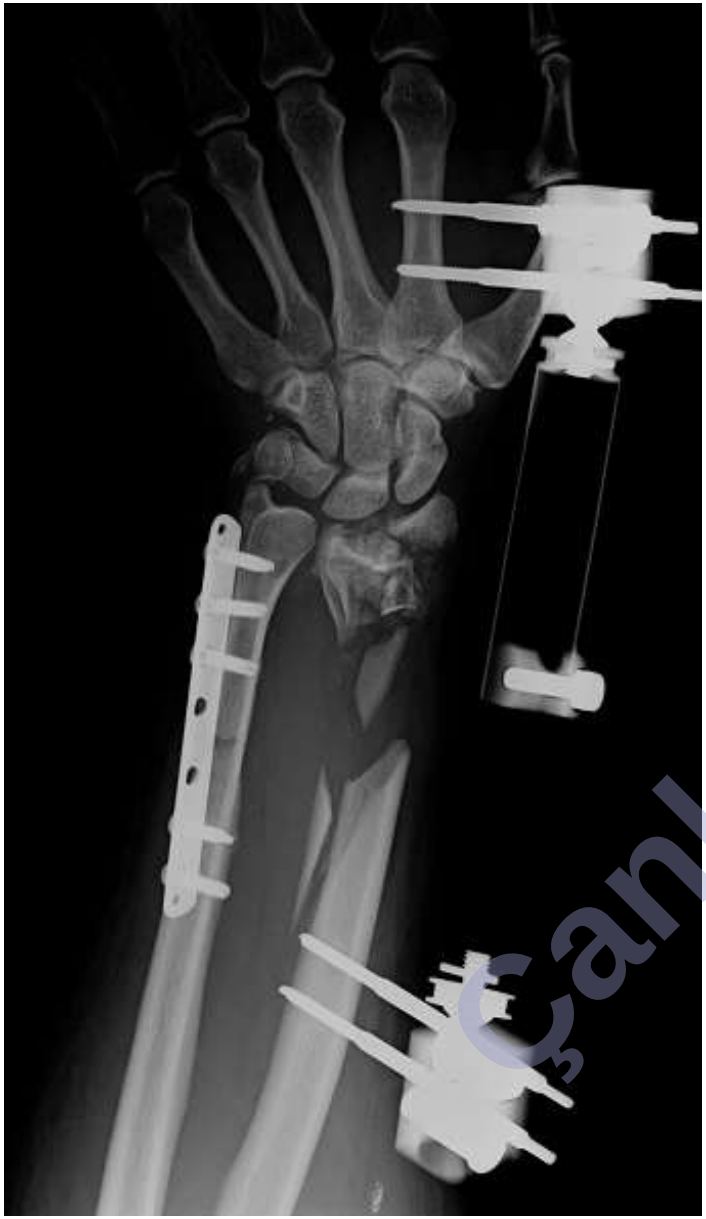
Type III A Open

Cortical Strut Autografts

- Mechanically strong
- ↓ risk of resorption
- Can be used larger defects
- Size limit ?
- Mostly fibula is used








Çankaya Ortoped
Post-op 2 months

International Orthopaedics (SICOT) (2002) 26:377–380
DOI 10.1007/s00264-002-0378-9

ORIGINAL PAPER

Elsayed Morsi

Tibial reconstruction using a non-vascularised fibular transfer

- 8 tibia nonunions with contralateral fibula
- Average defect size 4.7 cm (3-8 cm)
- 7 / 8 unions within 6 months
- Simple surgical technique

Annals of African Medicine Vol. 10, No. 1; 2011:25-8

Original Article

Use of non-vascularized autologous fibula strut graft in the treatment of segmental bone loss

Y. Z. Lawal, E. S. Garba[1], M. O. Ogirima, I. L. Dahiru, M. I. Maitama, K. Abubakar[2], F. S. Ejagwulu

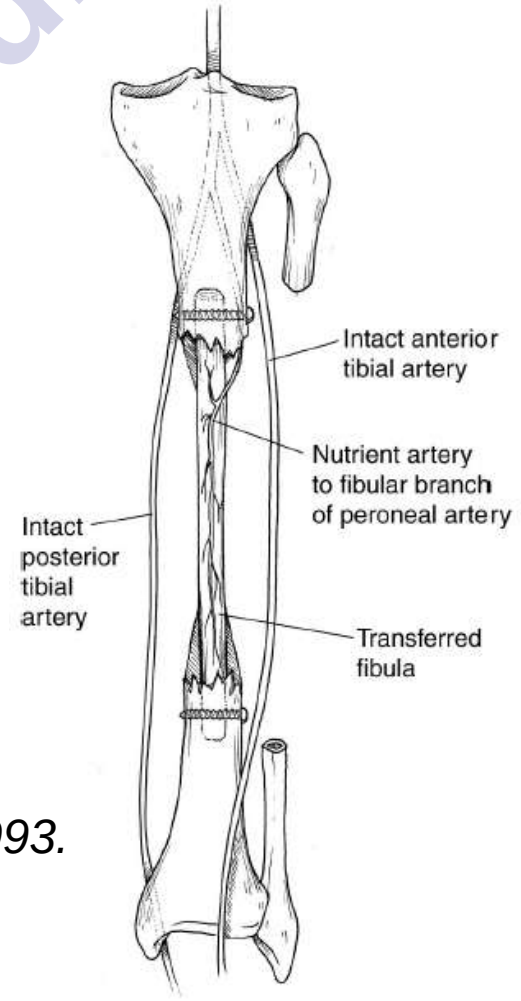
Departments of Trauma and Orthopaedics, and [1]Surgery, Ahmadu Bello University Zaria, Nigeria, [2]National Orthopedic Hospital Dala Kano, Nigeria

- **10 patients**
  - 5 Type III open tibia, 2 femur fracture, 1 tibia nonunion, 2 tumor
- **Average defect size 6.5 cm**
- **80% graft incorporation**
- **2 infection**
- **No stress fracture**

Ipsilateral Fibula Transposition (*fibula pro tibia*)

- **Described by Huntington in 1905**
- **Vascularized fibula transfer**
- **Requires intact fibula**
- **Centralised or synostosis**
- **Similar healing rates as vascularized fibula graft**

Al-Zahrani et al. Injury, 24: 551-4, 1993.



Post-op 5 years

ELSEVIER

Injury, Int. J. Care Injured 34 (2003) 770–775

INJURY
INTERNATIONAL JOURNAL OF THE CARE OF THE INJURED

www.elsevier.com/locate/injury

Ipsilateral fibular transposition in tibial nonunion using Huntington procedure: a 12-year follow-up study

M. Kassab, C. Samaha, G. Saillant*

Groupe Hospitalier Pitié-Salpétrière, Service de Chirurgie Orthopédique et Traumatologique, 83 Boulevard de l'Hôpital, 75013 Paris, France

- **11 patients**
  - 9 nonunions, 1 osteomyelitis, 1 tumor
- **Defect size 4-22 cm**
- **Mean follow-up 12 years (2-21 years)**
- **8/11 unions within 10.5 months**
- **2 infection**
- **No stress fracture**

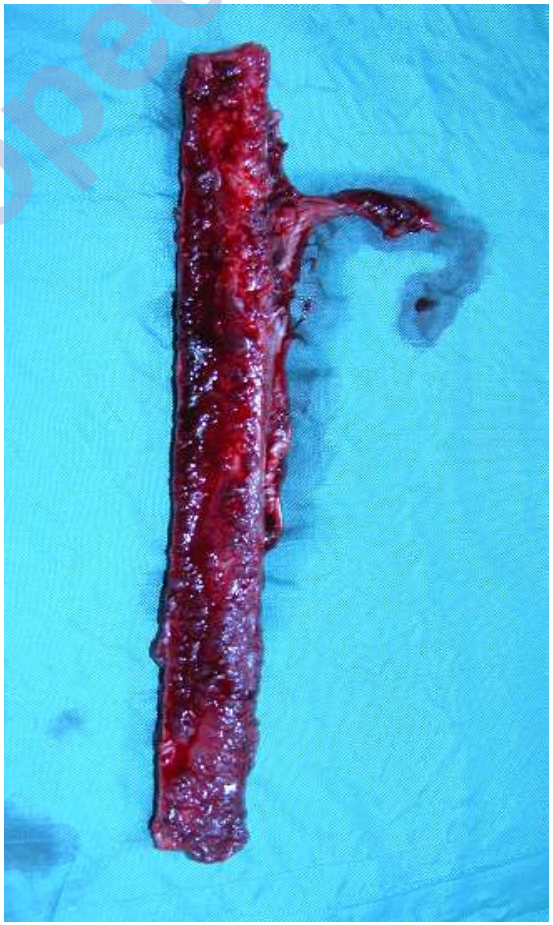
Vascularized Bone Grafts

- By pass creeping substitution
- Mechanically stronger
- Healing by bony union
- Hypertrophy potential
- Supplies vascularity to enviroment

Vascularized Bone Grafts

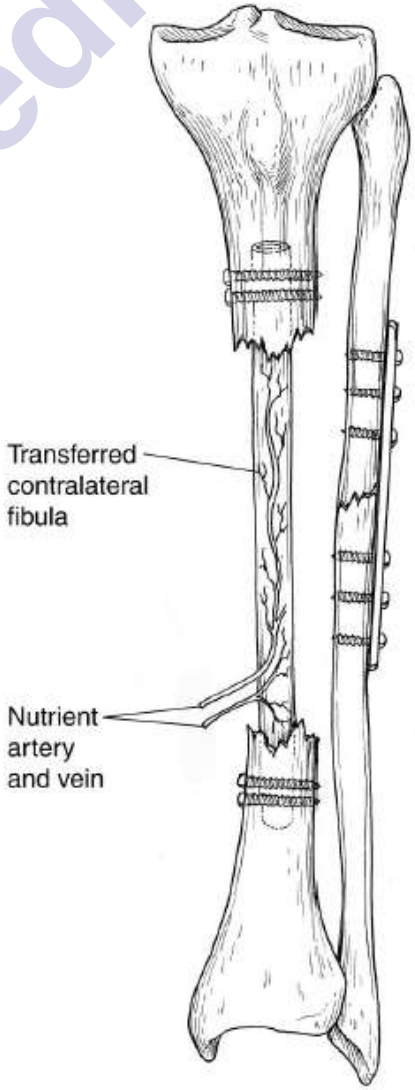
- **Fibula**
- **Iliac crest**
- **Rib**
- **Lateral scapula border**

Lin CH et al. Outcome comparison in traumatic lower extremity reconstrction by using various composite vascularized bone transplantation. Plast Reconstr Surg, 104: 984-92, 1999



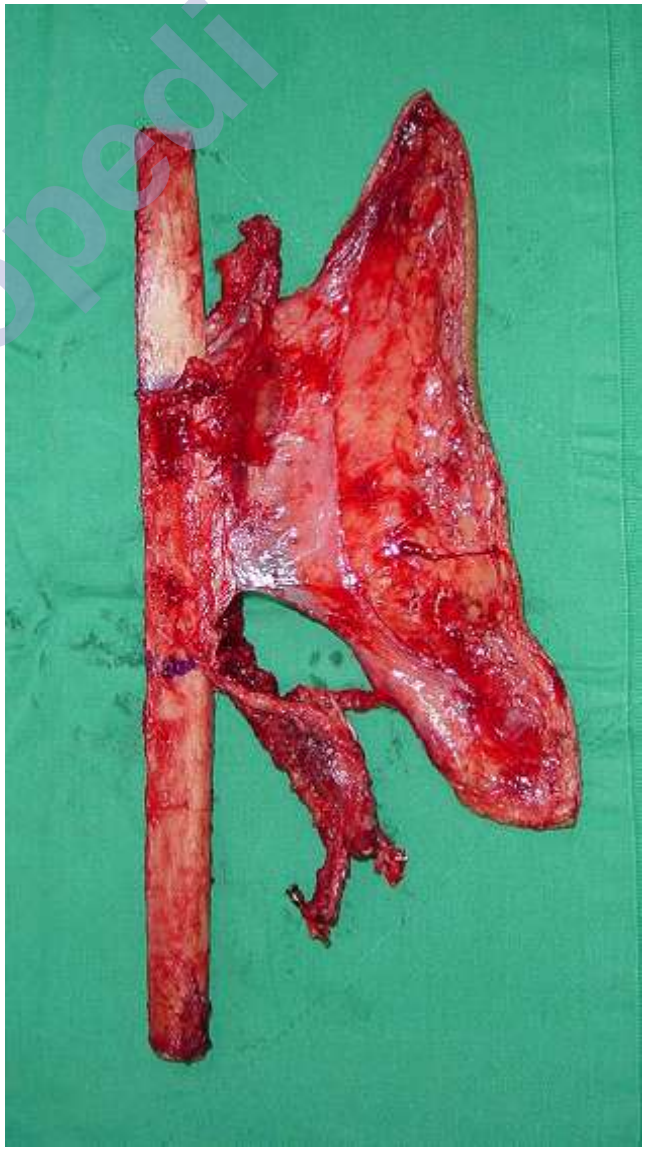
Free Vascularized Fibula Graft

- First reported by Taylor in 1975
- Strong cylindrical cortical strut
- Constant blood supply
- Recommended for defects > 6 cm
- Up to 26 cm
  - 7 cm proximal
  - 6 cm distal



FVFG

- **Dual vascularity**
  - Endosteal and periosteal
  - Improves healing
  - Allows “double barrel” technique
- **Composite skin flaps**
  - Perforating septacutaneous branches
  - For monitoring the viability
- **Composite muscle flap**
  - Soleus
  - Flexor hallusis longus



Open Fractures

- **Staged procedure**
  - Debridement of avascular bone and soft tissue
  - Soft tissue management
  - Reconstruction of bone defect after 6-8 weeks
- **One-stage procedure**
  - Combined bone and soft tissue reconstruction
  - Composite skin or muscle flap
  - ↓ soft tissue and vessel scarring
  - ↓ infection

Yazar S et al. One stage reconstruction of composite bone and soft tissue defects in traumatic lower extremities. Plast Reconstr Surg, 114: 1457-66, 2004

Nonunions

- **Have multiple previous surgeries**
- **Removal of implants**
- **Excision of avascular bone and soft tissue**
- **Infected nonunions**
  - Staged procedure
  - Bone cement spacer with antibiotic
  - External fixation
  - FVFG after 1-3 weeks of i.v. antibiotics

Osteomyelitis

- Staged procedure like infected nonunions
- Radical debridement is mandatory
- 6-8 weeks antibiotic treatment
- FVFG enhances antibiotic and immune components

International Orthopaedics (SICOT) (2010) 34:425–430
DOI 10.1007/s00264-009-0761-x

ORIGINAL PAPER

Free vascularised fibular grafting in the treatment of large skeletal defects due to osteomyelitis

Yuan Sun · Changqing Zhang · Dongxu Jin · Jiagen Sheng · Xiangguo Cheng · Xudong Liu · Shengbao Chen · Bingfang Zeng

- **10 patients**
  - 6 infected nonunions, 4 post-op osteomyelitis
- **One stage procedure**
- **Average defect size 9.5 cm (6-17 cm)**
- **All patients united within 4.5 months**
- **No recurrrent infection**

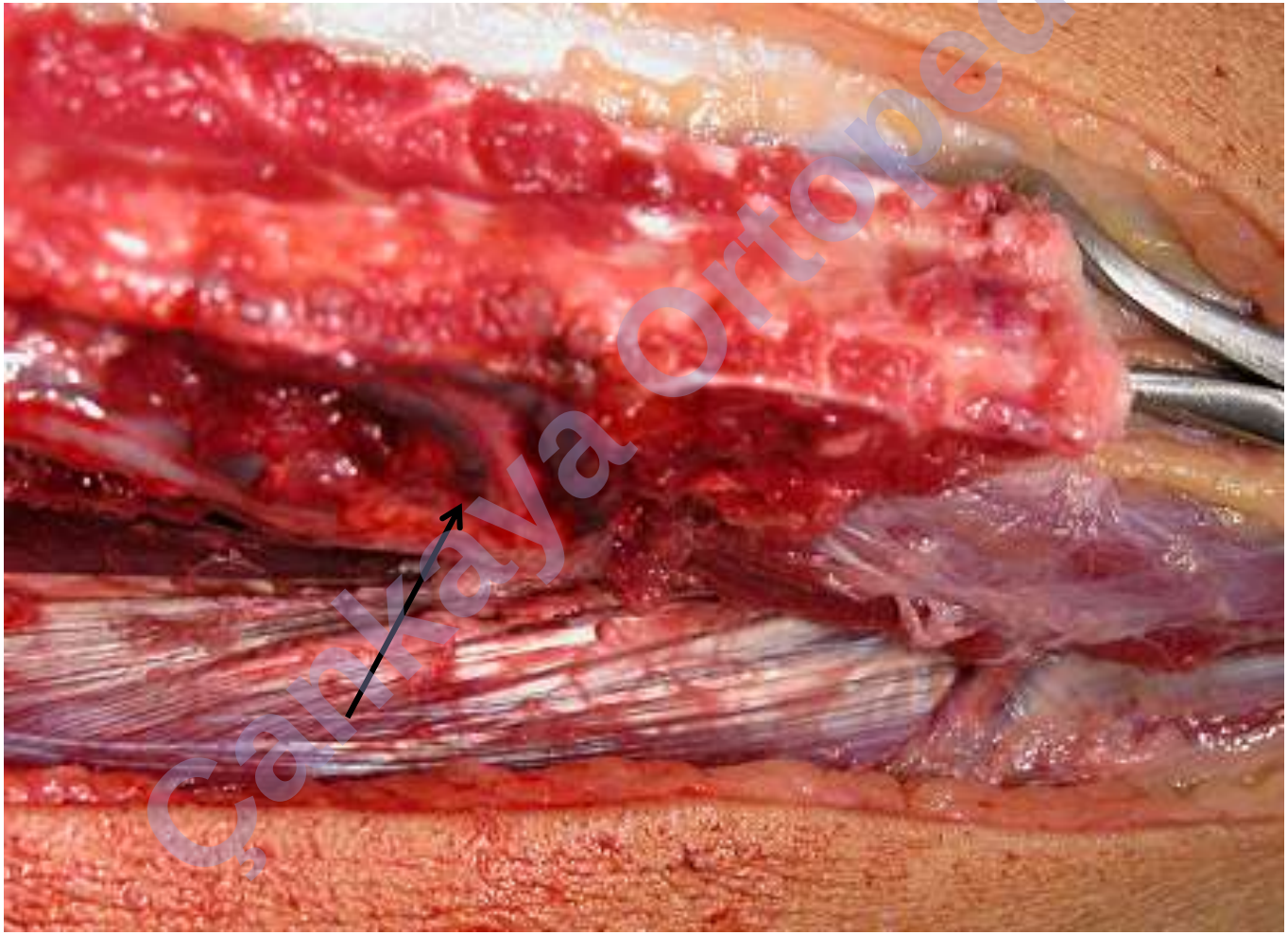
Upper Extremity

- **Forearm**
  - Excellent size match
  - No need for hypertrophy
  - Both bone defects → "Double barrel" technique
- **Humerus**
  - No weight bearing
  - Intramedullary placement

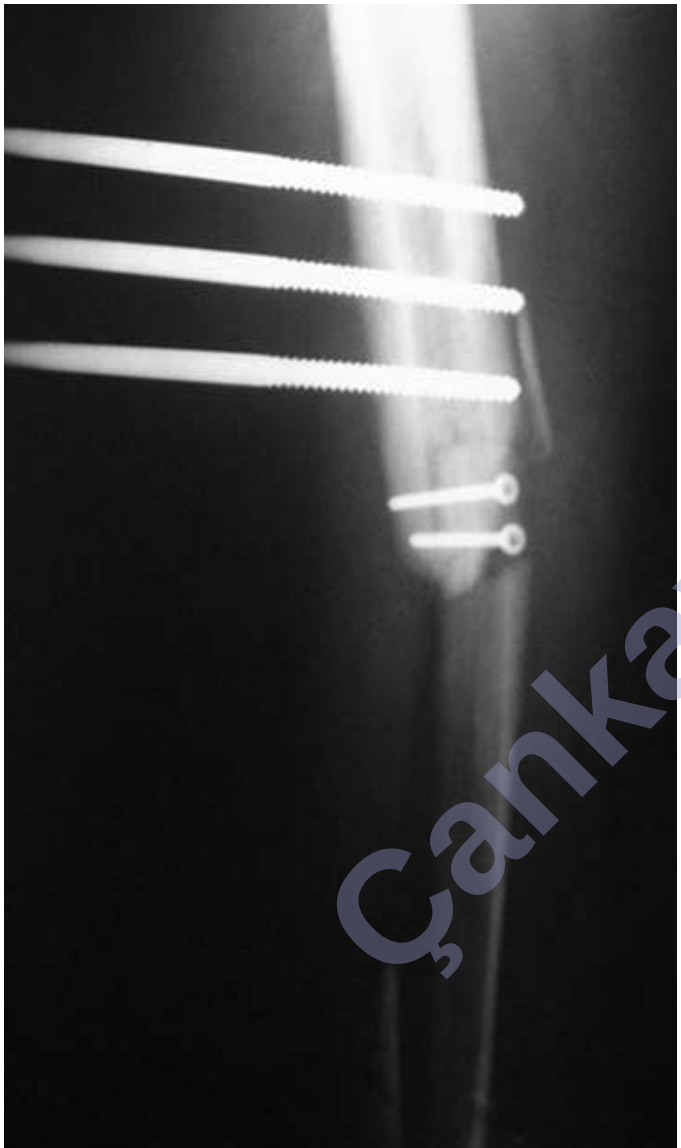
Lower Extremity

- Diameter is smaller than tibia and femur
- Weight bearing is an issue
- Graft hypertrophy is important
- Stress fractures are more common

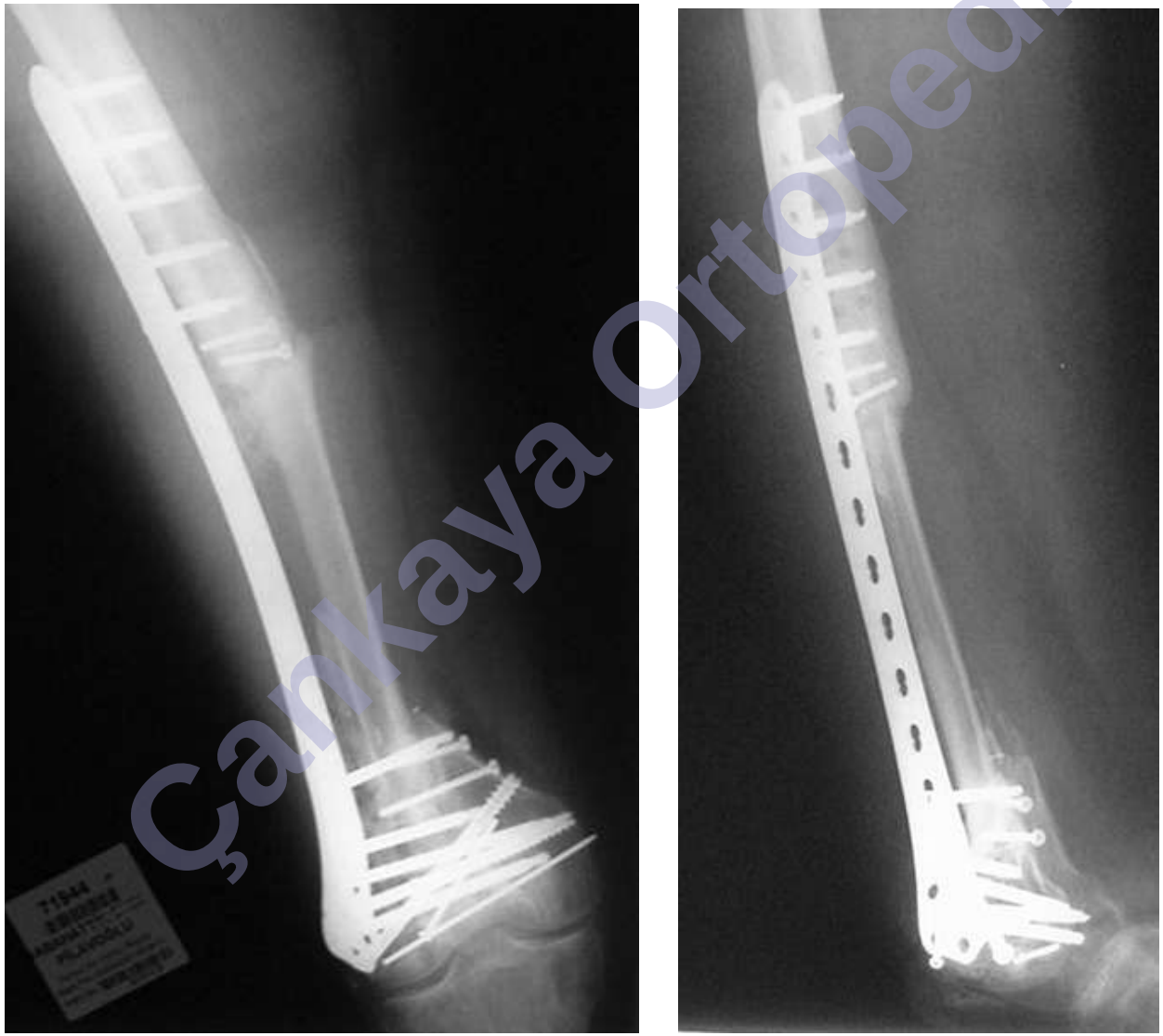
Post-op 4 weeks



Post-op 4 months



Post-op 5 months



Post-op 5 years

Graft Hypertrophy

- Slow process up to 2 years
- More in lower extremity
- More in young patients and children
- More rigid fixation → less graft hypertrophy

Graft Hypertrophy

Fixation

- **Intramedullary placement of graft**
  - 1-2 screws on each end
- **Spanning locking plate**
  - Especially in upper extremity
- **External fixation**
  - In lower extremity
  - In case of infection
- **IM nail ?**
  - In femur with onlay graft

Alternative Techniques

- **“Double barrel” technique**
- **Combination with allograft**
  - Intercalary
  - Onlay
- **Simultaneous two FVFG**

Complications

- **Thrombosis of the anastomosis**
  - Skin flap monitoring
- **Stress fracture → 20-35%**
  - Within one year
  - Less rigid fixation and controlled weight bearing
  - “Double barrel” technique
- **Nonunion → 20%**
  - Inadequate fixation
  - Compromised vascularity
  - Cancellous grafting of both ends is recommended
- **Recurrent infection**
  - Insufficient debridement
  - Bone cement spacer with antibiotic is recommended

Donor-site Morbidity

- **Muscle weakness**
- **Contracture of great toe**
- **Sensory abnormalities**
- **Ankle pain**
  - Distal 6 cm must be preserved
- **Children**
  - Valgus deformity of ankle
  - Tibiofibular stabilization is required

Clinical Results

- **75-80% primary union**
- **Increases up to 95% after secondary procedures**
- **Better results in forearm and tibia**
- **Average union time is 3-6 months**
- **Lowest union rates in case of infection**

Han et al. J Bone Joint Surg Am, 74: 1441-9, 1992

- **After 2 years**
  - 80% good function in upper extremity
  - 90% full weight bearing in lower extremity

Induced Membrane Technique

- **Described by Masquelet and coworkers in 2000**
- **Two staged procedure**
- **First stage**
  - Radical debridement
  - Insertion of block bone cement
- **Bone cement → induces a membrane formation**
- **Second stage**
  - Removal of bone cement
  - Cancelloue bones grafting into the membrane

Animal Studies

Pelissier P, Masquelet AC, Bareille R, Pelissier SM, Amedee J.

Induced membranes secrete growth factors including vascular andosteoinductive factors and could stimulate bone regeneration.

J Orthop Res. 22(1): 73-9, 2004.

Viateau V, Bensidhoum M, Guilemin G, Petite H, Hannouche D, Anagnostu F, Pelissier P.

Use of induced membrane technique for bone tissue engineering purposes: animal studies.

Orthop Clin North Am. 41: 49-56, 2010.

Animal Studies

- **Macroscopic findings**
  - 1-2 mm thick and mechanically competent
  - Adherent to bone edges
- **Histologic findings**
  - Mild foreign body inflammatory response
  - Decreaes after 2nd week and disappeares by 6 month
  - Highly vascularized
  - Epithelial-like inner surface with collagenous matrix and fibroblasts

Animal Studies

- **Angiogenic properties**
  - Secretion of *vascular endothelial growth factor*
- **Osteoinductive properties**
  - Secretion of *transforming growth factor* $\beta 1$ and *BMP-2*
  - Peaks at 4 weeks
- **Osteogenic properties**
  - Secretion of *core-binding protein* $\alpha 1$
  - Critical transcription factor for osetoblast transformation
  - Membrane protein extract $\rightarrow$ MSC proliferation and differentiation

The Mechanism of Action of Induced Membranes in Bone Repair

Olli-Matti Aho, BM, Petri Lehenkari, MD, PhD, Jukka Ristiniemi, MD, PhD, Siri Lehtonen, PhD, Juha Risteli, MD, PhD, and Hannu-Ville Leskelä, MD, PhD

Investigation performed at the University of Oulu, Oulu, Finland

- **Human samples**
- **Vascularized fibrous tissue**
  - Vascularization decreased after two months
  - Type I collogen and IL-6 decreased after two months
- **VEGF decreases after <u>one month</u>**
- **Co-cultures → stem cell differentiaton**
  - ↑at one month

Induced Membrane

- Protection against graft resoption
- Maintenance of graft position
- Prevention of soft tissue interpositon
- Secretion of osteoinductive growth factors

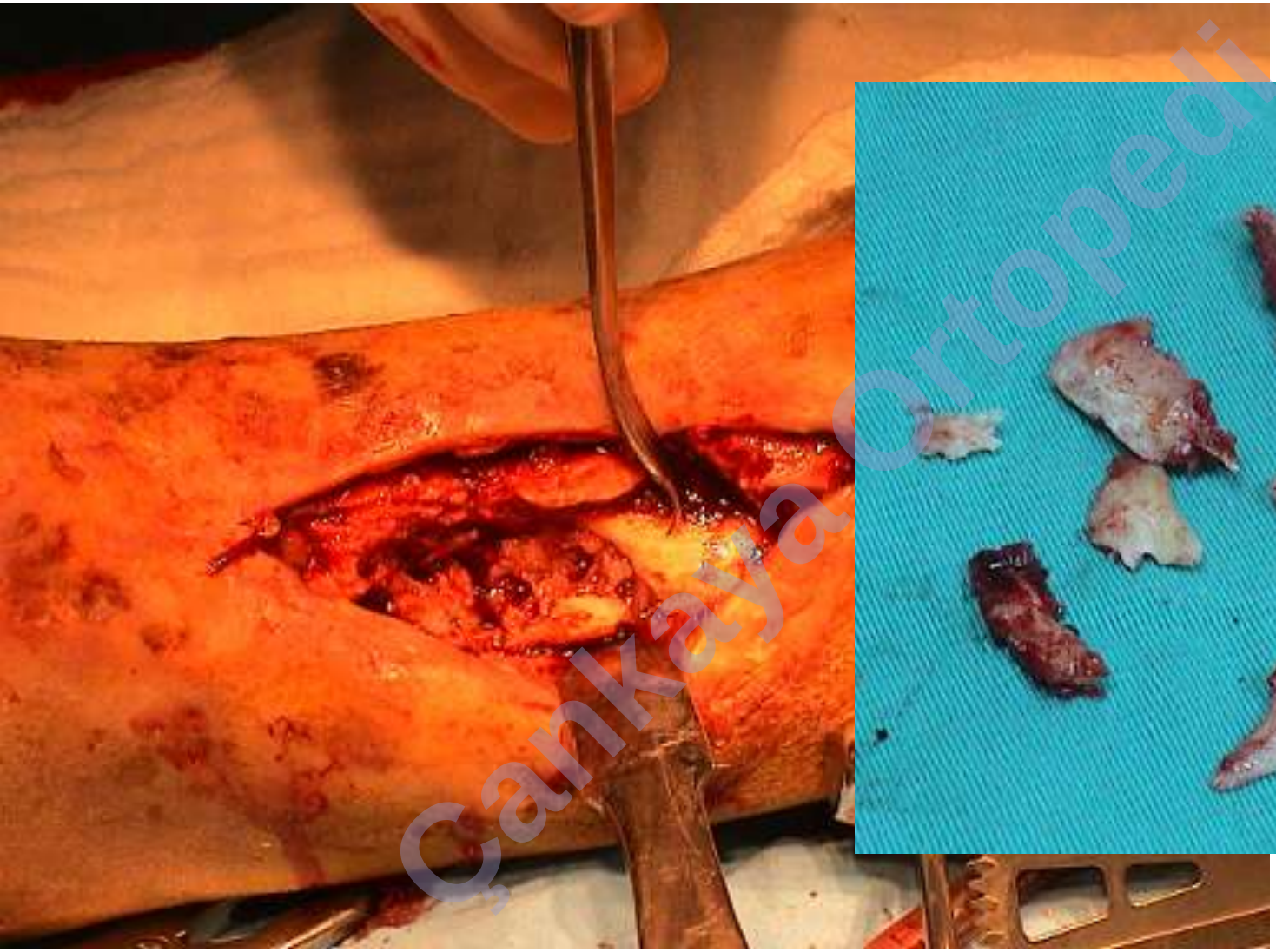
Surgical Technique

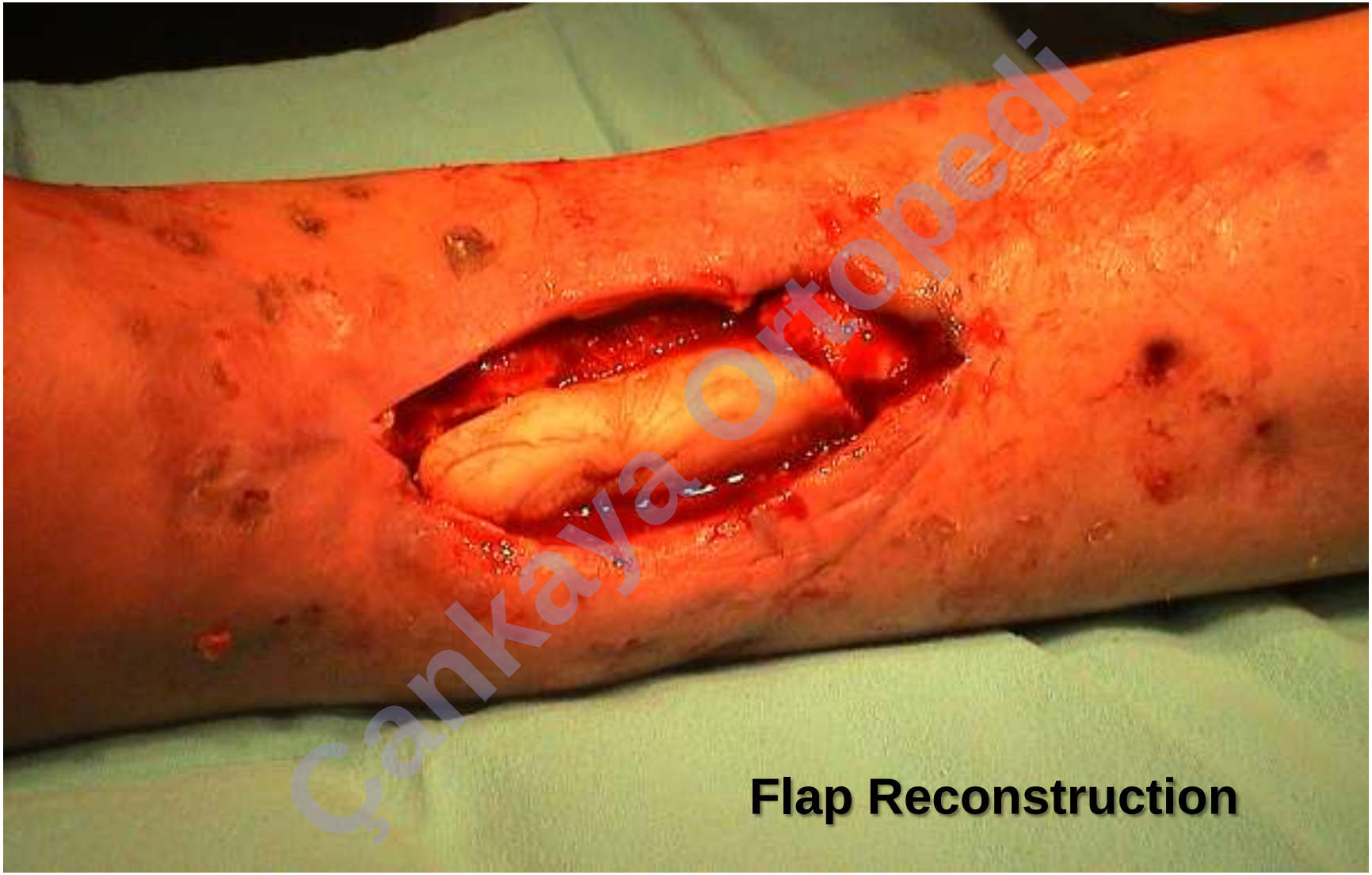
- **Radical debridement**
- **Appropriate fixation**
  - Ex-fix → in case of infection
  - Plate
  - IM nail (*Apard T et al. Orthop Traumatol Surg Res. 96(5): 549-53, 2010.)*
- **Bone cement**
  - Single block
  - Placed over the bone edges and inside IM canal
  - Tibia → as far as fibula
  - Cement with antibiotics → in case of infection
- **Soft tissue recontruction**

Surgical Technique

- **Second stage after 4-8 weeks**
- **Membrane is incised carefully**
- **Cancellous bone graft into the cavity**
- **Membrane is sutured over the graft**
- **Adequate mechanical stability**
  - Conversion to plate

Infected Nonunion

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Flap Reconstruction

Graft amount ?

- **Four iliac crests → ~ 90 cc graft**
  - 10 cm femoral defect
  - 15 cm tibial defect
  - 20 cm humeral defect
- **Bone extenders**
  - Allografts , DBM
  - With a ratio of 1:3
- **Reamer-Irrigator-Aspirator (RIA, Synthes) system**
  - 40 - 90 cc from each femur
  - Biologic content is equal to iliac crest

Clinical Results

Masquelet et al.

Ann Chir Plast Esthet. 45(3): 346-53, 2000.

- **Between 1986-1999**
- **35 patients**
- **4 – 25 cm defects with ex-fix**
- **100% healing at 4 months**
  - Independent of the defect size
- **Full weight bearing at 8.5 weeks**
- **4 stress fractures**

Clinical Results

Masquelet AC and Begue T.
Orthop Clin North Am. 41(1): 27-37, 2010

- **Prospective study**
- **Between 2000-204**
- **11 patients**
- **5 – 18 cm defects**
- **Graft mixed with BMP-7**
- **91% union**
- **Local partial resorption of graft in all cases**

Retrospective Studies

- **85-90% union**
- **Infection → ~ 8%**
- **Stress fracture is rare**

Karger C et al. Orthop Traumatol Surg Res, 98: 97-102, 2012
Stafford PR et al. Injury. 42(Suppl2): S72-5, 2010
McCall TA et al. Orthop Clin North Am. 24(1): 46-52, 2010
Apard T et al. Orthop Traumatol Surg Res, 96(5): 549-53, 2010
Flamans B et al. Chir Main. 29(5): 307-14, 2010
Huffman LK et al. Foot Ankle Int. 30(9): 895-9, 2009

Autogenous Bone Grafts

- **Radical debridement is mandatory**
  - Vascular, noninfected enviroment
- **Stable fixation**
- **Free vascularized fibula graft**
  - Defects > 6 cm
  - Allows combined soft tissue reconstruction
  - Long healing time
- **Bone cement**
  - Prevents of soft tissue interpositon
  - Combined wtih antibiotics → in case of infection
  - Forms biological membrane
- **Induced membrane technique**
  - Promising technique in large defects