Secondary intramedullary nailing after callus distraction

Clinical and experimental experience

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Distraction osteogenesis

- progressive bone distraction
- symmetrical distribution of distraction by a stable ring external fixator
- maintenance of periosteal and intramedullary vessels through a corticotomy
Distraction osteogenesis

Progressive distraction → Biological reaction

- Increase of leg vascularization
- 'Growth plate' phenomenon
- Development of membranous ossification
.. studies ...emphasized the importance of protecting the bone marrow during operation and have recommended a carefully limited limited corticotomy (Kawamura et al. 1968; Ilizarov et al. 1969; De Bastiani et al. 1987; Dal Monte and Donzelli 1987).

..endosteum and bone marrow are not indispensable for adequate callus formation and that the periosteum is of particular importance

Konjimoto et all, JBJS 70B:543-549;1988
DISTRACTION PHASE

limb-lengthening occurs

CONSOLIDATION PHASE

the distraction gap is sufficiently healed to permit removal of the external fixator without fracture or deformation
The consolidation phase is usually twice as long as the distraction phase in children and three to four times longer in adults.
Problems and Complications

- pain
- neurologic – vascular injury
- premature consolidation
- joint subluxation or dislocation
- axial deviation
- pin-tract problems
- joint stiffness
- refracture after removal of the apparatus
- delayed consolidation - nonunion
Distraction osteogenesis

Bone transport - docking site

delayed consolidation - nonunion

- poor vascularization
- soft tissue interfering
- not good bone contact
Distraction osteogenesis

PROLONGED USE OF THE EXTERNAL FIXATOR
Distraction osteogenesis

The prolonged use of the external fixator is the most difficult aspect of lengthening for the patient to tolerate (Paley et al, JBJS, 1997)

- fracture (9.4% Simpson and Kenwright, JBJS 2000)
- deformity
- shortening
- non-union (Paley et al, JBJS, 1997)
Lengthening over nail
| Experience with lengthening of the femur over an intramedullary rod | Bost, F. C et al, JBJS 1956 |
| Treatment of defects of the long bones using distraction osteogenesis (Ilizarov) and intramedullary nailing. Theoretic principles, animal experiment, clinical relevance. | Brunner U et al: Unfallchirurg 1990 |
| Intramedullary nailing in callus distraction | Baumgart R et al: Orthopade 1996 |
Femoral lengthening: callotasis with Ilizarov external fixator alone and with intramedullary locking nail
Lee and Huang, J Formos Med Assoc 1997

Femoral Lengthening over an Intramedullary Nail. A Matched-Case Comparison with Ilizarov Femoral Lengthening

Leg lengthening over an intramedullary nail
Simpson et al, JBJS Br 1999

Lengthening of the tibia over an intramedullary nail, using Ilizarov external fixator. Major complications and slow consolidations in 9 lengthenings.

Ilizarov bone transport over a primary tibial nail and free flap: a new technique for treating Gustilo grade 3B fractures with large segmental defects

Progressive limp lengthening with a centromedullary nail versus external fixator: experimental study in sheep
Caton et al, 2001
Femoral Lengthening over an Intramedullary Nail. A Matched-Case Comparison with Ilizarov Femoral Lengthening


Group I
29 pts ext. fix. + IN
1 proximal screw failed
1 nail failed
Complication rate: 1.4%

Group II
31 Ilizarov
6 refractures
Complication rate: 1.9%

No differences in final clinical and radiographic results

Group I: - reduced the average duration of lengthening by almost one-half
- reduced significantly (p<0.001) the radiographic consolidation index.
- the range of motion of the knee returned to normal a mean of 2.2 times faster.
... any slowing of new-bone formation due to damage to the medullary circulation may be compensated for by the effect of revascularization after reaming, the better stability provided by the nail fixation and earlier functional loading.
# Femoral Lengthening: Callotasis with Ilizarov external fixator alone and with intramedullary locking nail.


<table>
<thead>
<tr>
<th>Group I</th>
<th>Group II</th>
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<tbody>
<tr>
<td>14 Ilizarov</td>
<td>7 pts ext. fix. + IN</td>
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</tbody>
</table>

- **Medial gain in length:** 4 cm.  
- **Medial time in ext fix:** 218 days  
- **Medial time index:** 50 days/cm  

- **Medial gain in length:** 4.8 cm.  
- **Medial time in ext fix:** 70 days  
- **Medial time index:** 14 days/cm
Lengthening over nail

Problems

- pin-track infection leading to deep intramedullary infection during lengthening
  
  Simpson et al. 1999, Kristiansen and Steen 1999

- technical difficulties

- angular deformities?
Secondary intramedullary nailing

intramedullary nail application during the \textit{consolidation phase} after bone lengthening or bone transport for further \textit{stabilization} of the lengthened callus, and \textit{enhancement} of callus maturation and docking site union.
12 skeletally mature female sheep

- General Anaesthesia – chemioprophylaxis
  (3 dose of cephalosporine 2nd generation)

- Ilizarov external fixator in right tibia
  [2 rings, 6 pins (2+1, 2+1), distraction rods]

- Tibial shaft osteotomy
  (anteromedial approach)
TWO GROUPS

- 10 days latency
- Callus distraction 2cm in 20 days (0.50mm/12h)
GROUP A  Day 30

- Removing of Ilizarov fixator
- Insertion of static unreamed intramedullary nail under x-ray guidance
material-methods

GROUP A

Day 30
material-methods

GROUP A  Day 0-70
(No 9)
GROUP B  
(No 5)  

- Ilizarov frame remained during consolidation phase. (according to the usual technique)
Callus in both groups was studied, in specific time intervals, with:

- Plain x-rays
- Ultrasonograms
- Triplex
- Digital subscription angiograms
All animals were sacrificed 70 days after osteotomy and bone specimens including callus, were evaluated with:

- MRI
- DEXA
- Histopathologic examination.
GROUP A

- All animals successfully tolerated intramedullary nailing – no infection
- In all animals limb alignment was kept
- In all but one mature callus was formed and callus length was retained
- One had a delayed formation of the callus and 0.5cm loss of callus length, because of failed insertion of distal locking screw.
GROUP B

- All formed mature callus
- 2 had axis deviation
- 3 superficial pin-track infections
- 1 deep infection
Day 70

clinical

group A

group B
Day 70

group A
group A

BMD: 130% +/- 15%

group B

BMD: 131% +/- 10%
group A

group B

Day 70
MRI

Day 70

group A

AP 54 post

AP 5A post

group B

2g 10
2E 11
Blood flow
ml/min

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<th>Time</th>
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<th>Group B</th>
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<td>70</td>
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<td>150</td>
<td>120</td>
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<tr>
<td>30 after IN</td>
<td>180</td>
<td>170</td>
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<tr>
<td>70</td>
<td>200</td>
<td>190</td>
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Digital Subscription Angiograms

Day 70

group A

group B
histologic evaluation

group A

group B
Replacement of Ilizarov device by static unreamed intramedullary nail during callus consolidation phase:

- decreases the total duration of external fixation
- limits joint stiffness
- reduces pin-track infections
- avoids axial deformities
- provides protection against refracture
- applicable in axial deformities
Our results suggest that there is no considerable difference between callus formations in the two groups
Possible disadvantages:

- 2 operations
- Increased blood loss
- Lung embolism
- Intramedullary infection
- Epiphyseal plate trauma
BONE LENGTHENING OR BONE TRANSPORT
WITH EXTERNAL SYSTEM

intolerance of the external device
angular deformity or fracture
docking site nonunion
delayed callus maturation

INTRAMEDULLARY NAILING
Secondary intramedullary nailing

**essential conditions**

- completion of bone lengthening
- reestablishment of soft tissues
- absence of clinical and laboratorial signs of infection

*normal WBC and ESR*
*free of clinical signs of infection (even pin track infections)*
Secondary intramedullary nailing

Material methods

1991 – 2001: 30p (14,29%)
M/F: 27/3
Age: 10-68 (30,4)
Femur 13, Tibia 20

- Post-traumatic bone defect (PBD)
- Septic nonunion (SN)
- Aseptic nonunion (AN)
- Chronic osteomyelitis (CO)
- Anisoscelia (A)
- Peronial hemimelia (PH)
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<th>Sex/ Age (years)</th>
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<th>Distraction type</th>
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Secondary intramedullary nailing

Stage conversion

- In 25 cases, the nail insertion was performed **immediately** after the Ilizarov frame removal.

- In 5 cases with unilateral lengthening system the nailing was **delayed for approximately 2 weeks** after the external device removal.

- In 3 patients nailing was performed because of fracture at the callus area **some days or weeks after** the removal of the external device.
Secondary intramedullary nailing

Results (follow up 2-12 years)

- Docking site healing (average 5.9 months)
  - Delayed radiologic ossification in 6 cases (35.3%)
  - Obvious radiologic healing within six months in 10 cases (58.8%)
  - Non healing in 1 case (5.8%)
Secondary intramedullary nailing

Results (follow up 2-12 years)

- **Alignment**

  satisfactory alignment in 27 cases

  1-2 cm shortening of the callus in 5 cases
Secondary intramedullary nailing

Results (follow up 2-12 years)

- Infection
  - Intramedullary infection: 30
  - Superficial infection: 2
    - Number of cases: 2
    - Number of cases: 1
Case 2
Case 5
Case 6
Case 8
Intramedullary nailing

- Approach far from neo-osteogenesis area
- Non-rigid fixation on the new bone site
- Preservation of periosteal vascularization
Intramedullary nailing

- reaming

- mechanic destruction of intramedullary vessels
- embolism of the cortical vessels

extensive cortical ischemia and necrosis
Intramedullary nailing

- intact vessels of periosteum
- intact metaphyseal vessels
- vessels of the surrounding soft tissues
intramedullary nailing

inversion of centripetal vascular flow in centrifugal

(Reichert et al. 1995)
intramedullary vascularization is restored very rapidly in a time interval of 2 weeks after the nail placement (Grundnes et al. 1994)

Finally, the total vascular cortical flow is considerably increased (Nakamura et al. 1999)
Intramedullary nailing

The extensive proliferation of periosteal vessels after a reamed intramedullary nailing in combination with the products of the reaming that acting as bone-inductive agents for bone growth, have been shown to improve the growth of subperiosteal callus via the process of membranous ossification.
Conclusions

Secondary intramedullary nailing...

...releases the patient earlier from the bulky system of external osteosynthesis

...protects the immature lengthened callus from deformities

...promotes the process of ossification at the callus area and/or the docking site
Conclusions

in these specific cases intramedullary nailing completes the treatment by stimulating the biology basis of distraction osteogenesis
We thank AO research for support

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VIENE DANK / EΥΧΑΡΙΣΤΩ