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Principles of NonUnion Management(Article Review)

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Abstract

A “non-union” is a fracture of a bone induced either by trauma or surgery which fails to progress to union within a reasonable time span. Defining healing times is difficult. A diaphyseal tibial fracture, for example, may heal in 10 weeks or twelve months depending on endogenous and exogenous factors which in turn are modulated by the effects of surgery

Introduction

Bone Healing

For bone healing to happen, the bone needs adequate stability and blood supply. Good nutrition also plays a role in bone healing.

- Stability. All treatment of broken bones follows one basic rule: the broken pieces must be put back into position and prevented from moving out of place until they heal. Some fractures can be held in position with a cast. Some fractures require surgical fixation with devices like screws, plates, rods and frames.
- Blood supply. Blood delivers the components required for healing to the fracture site. These include oxygen, healing cells, and the body's own chemicals necessary for healing (growth factors). The blood supply to the injured bone usually comes back on its own during the healing period.

- Nutrition. A broken bone also needs adequate nutrition to heal. Eating a healthy and well-balanced diet that includes protein, calcium, vitamin C, and vitamin D is the best way to ensure adequate nutrition; dietary supplements that go beyond the daily requirements are not effective. (The rare exception is the severely malnourished patient with many injured organs. In this case, the doctor will discuss dietary guidelines and make recommendations for adding dietary supplements.)

Blood Supply

.Nonunions are more likely to happen if the injured bone has a limited blood supply be

.expected to heal with minimal treatment expected to heal with minimal treatment Some

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bones, such as the upper thighbone (femoral head and neck) and small wrist bone (scaphoid), have a limited blood supply. The blood supply can be destroyed when .these bones are broken

Some bones, such as the shinbone (tibia), have a moderate blood supply, however, an injury can disrupt it. For example, a high-energy injury can damage the skin and muscle over the bone and destroy the external blood supply. In addition, the injury .can destroy the internal blood supply found in the marrow at the center of the bone

Epidemiology

In the U.S., 100000 fractures go onto nonunion .The rate of all fracture nonunion is between 1.9% to 10%. Variable rates of nonunion exist depending on the anatomic region. Femoral shaft nonunions are estimated to be 8% overall with the use of intramedullary nailing Tibial shaft nonunions occur at a rate of 4.6% after intramedullary nailing. However, there are several discrepancies, as some studies have shown tibia nonunion to be as high as 10% to 12% overall. Also, soft tissue damage impacts the ability to heal. Studies of open fractures with extensive soft compromise showed nonunions to be much higher at 16%. Sex is a predictor of nonunion, showing male gender increases the risk of nonunion, and this was proposed to be because of gender-specific activity types and injury patterns. However, this needs to be taken with caution because l replicated in larger studies could not replicate these findings. Brown and colleagues showed nonunion rates to be similar between males and females (12% vs. *12*%).

Pathophysiology

There are several physiologic processes responsible for the nonunion of the bone.

One, dysfunctional blood supply decreases the ability for the fracture to heal, which in response decreases osteogenic cells.

Second, damage to the osteoconductive scaffold causes reduced new bone formation due to the distance needed to heal bone.

Third, pathological biologic processes listed above will not only decrease blood flow but also decrease new bone formation by decrease the biologic growth factors needed to heal bone.

Fourth, poor mechanical stability at the fracture site can lower the ability of the fracture to heal .If any of these processes are altered negatively, the probability of developing nonunion increases dramatically, and patients should be counseled as such.

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• Biomechanics of Nonunions

• Important factors for consideration

-Biologic and Mechanical environment -

1- Presence or absence of infection-

2- Septic vs Aseptic-

3- Vascularity of fracture site – Stability – mechanical environment-

4-Deformity-

5-Bone involved and surrounding soft tissues-5

Smoking

Decreases peripheral oxygen tension •

Dampens peripheral blood flow •

Well documented difficulties in wound healing in patients who smokes.

Diabetes

(Neuropathic Fractures)

:Best studied in ankle and pilon fractures •

– Complicated diabetics – those with end organ disease •

neuropathy, PVD, renal dysfunction

Increased rates of infection and soft tissue complications –

Increased rates of nonunion, time to union significantly longer –

Prolonged NWB required –

Inability to control response to trauma can result in •

hyperemia, osteopenia, and osteoclastic bone resorption

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Charcot arthropathy –

Malnutrition

Adequate protein and energy is required for •

wound healing

Majority of organic phase of bone is protein •

:Screening test •

serum albumin –

total lymphocyte count –

Albumin less than 3.5 and lymphocytes less •

than 1,500 cells/ml is significant

Causes

Nonunions happen when the bone lacks adequate stability, blood flow, or both. They also are more likely if the bone breaks from a high-energy injury, such as from a car wreck, because severe injuries often impair blood supply to the broken bone.

The reasons for nonunion are; •

1-avascular necrosis (the blood supply was interrupted by the fracture

2-the two ends are not apposed (that is, they are not next to each other •

3-infection (particularly osteomyelitis •

4-the fracture is not fixed (that is, the two ends are still mobile •

5- soft-tissue imposition (there is muscle or ligament covering the broken ends and preventing them from touching each other

Risk Factors

- **A- Related to the person:**
- 1. Age: Common in old age
- 2. Nutritional status : poor
- 3. Habits : Nicotine and alcohol consumption

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- 4. Metabolic disturbance : Hyperparathyroidism
- 5. can be found in those with NF1
- 6. Genetic predisposition[3]
- **B- Causes related to fracture**:
- 1. Related to the fracture site
- 2. Soft tissue interposition
- 3. Bone loss at the fracture
- 4. Infection
- 5. Loss of blood supply
- 6. Damage of surrounding muscles
- **C- Related to treatment**1.
- I-nadequate reduction
- 2. Insufficient immobilization

3. Improperly applied fixation devices

Classification of Nonunion of Bone Into Four Categories[7]:

- **1-Hypertrophic Nonunion**[7]
- • Shown by radiographically abundant callus formation
- • Importantly, there is no bridging bone, and the ends are not united
- • This finding implies there is adequate blood supply and biology (with the formation of callus), but inadequate stability
- **2-Atrophic Nonunion**
- • Evidenced by radiographically absent callus, which indicates poor biology (from one or several of causes above) and a lack of blood supply (see above).
- • Inadequate fixation
- **3-Oligotrophic**
- • Is a balance and combination of atrophic and hypertrophic in that there is incomplete callus formation
- • Inadequate reduction
- **4-Septic Nonunion**
- • Reduces blood flow from organisms consuming the nutrition to healthy bone
- • Decreases the new bone formation

Symptoms

Patients with nonunions usually feel pain at the site of the break long after the initial pain of the fracture disappears. This pain may last months, or even years. It may be constant, or it may occur only when the broken arm or leg is used.

Patient Evaluation – Medical

History

• Diabetes, endocrinopathies, vit D, etc

• Physiologic age – co-morbidities

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– Heart disease, COPD, kidney/liver disease

• Nutrition

• Smoking

• Medications

• Ambulatory/functional status now and prior to original injury

Patient Evaluation – Physical Exam

• Appearance of limb

– Color, skin quality, prior incisions, skin grafts

– Erythema or drainage

• Range of motion of all joints

• Pain – location and contributing factors

• Strength, ability to bear weight

• Vascular status and sensation

• Deformity

– Clinically = Length, alignment, AND rotation

Patient Evaluation – Imaging

1-Tomography

• CT and MRI have replace linear tomography

• Consider Digital Tomography if available

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2-Radionuclide Scanning – Infected Nonunion?

• Technetium - 99 diphosphonate

– Detects repairable process in bone (not specific)

• Gallium - 67 citrate

– Accumulates at site of inflammation (not specific)

• Sequential technetium or gallium scintigraphy

– Only 50-60% accuracy in subclinical ostoemyelitis

Nonunion?

3-Labeled Leukocyte Scan – Infected Nonunion?

• Good with acute osteomyelitis, but less effective in diagnosing chronic or subacute bone infections

• Sensitivity 83-86%, specificity 84-86%

• Technique is superior to technetium and gallium to identify infection

4-MRI – Infected Nonunion?

• Abnormal marrow with increased signal on T2 and low signal on T1

• Can identify and follow sinus tacts and sequestrum

• Mason study- diagnostic sensitivity of

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100%, specificity 63%, accuracy 93%

Treatment

Nonsurgical and surgical treatments for nonunions have advantages and disadvantages. .More than one alternative may be appropriate.

Nonsurgical Treatment

Some nonunions can be treated nonsurgically. The most common nonsurgical treatment is a bone stimulator. This small device delivers ultrasonic or pulsed electromagnetic waves that stimulate healing The patient places the stimulator on the skin over the nonunion from 20 minutes to several hours daily. This treatment must be used every day to be effective.

Nonoperative

• Electrical stimulation
• Ultrasound
• Extracorporeal shock wave therapy

1-Electrical Stimulation

• Applied mechanical stress on bone generates electrical potentials
– Compression = electronegative potentials = bone formation
– Tension = electropositive potentials = bone resorption
• Basic science suggests e-stim upregulates TGF-β and BMP's suggesting osteoinduction

2-Ultrasound

• Piezoelectric transducer generates an acoustic pressure wave
• Some evidence to show faster healing in fresh fractures
• Evidence is moderate to poor in quality with conflicting results
• SR/MA suggests there may be improvement in healing but not function

3-Extracorporeal Shock Wave Therapy

• Single impulse acoustic wave with a high amplitude and short wavelength.
• Microtrauma induced in bone thought to stimulate neovascularization and cell differentiation

Surgical Treatment

Surgery is needed when nonsurgical methods fail. You may also need a second surgery if the first surgery failed. Surgical options include bone graft or bone graft substitute, internal fixation, and/or external fixation.

• **Bone Graft.** During this procedure, bone from another part of the body at the fracture site to "jump start" the healing process. A bone graft provides a scaffold on which

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new bone may grow. Bone grafts also provide fresh bone cells and the naturally occurring .chemicals the body needs for bone healing

During the procedure, a surgeon makes an incision and removes (harvests) pieces of bone from different areas on the patient. These are then transplanted to the nonunion site. The rim of the pelvis or "iliac crest" is most often used for harvesting bone. Although harvesting the bone may be painful, the amount of bone removed usually does not cause functional, structural, or cosmetic problem

Allograft (cadaver bone graft). An allograft (cadaver) bone graft avoids harvesting o bone from the patient, and therefore, decreases the pain involved with treating the nonunion. Like a traditional bone graft, it provides scaffolding for the patient's bone to heal across the area of the nonunion. As time goes on, the patient's bone replaces the cadaver bone. Although there is a theoretical risk of infection, the cadaver bone graft is .processed and sterilized to minimize this risk

Bone graft substitutes and/or osteobiologics. As with allografts, bone graft o substitutes avoid the bone harvesting procedure and related pain. Although bone graft substitutes do not provide the fresh bone cells needed for normal healing, they do provide .a scaffold chemicals needed for growth

Depending on the type of nonunion, any of the above materials, or a combination of .materials, may be used to fix the nonunion

Bone grafts (or bone graft substitutes) alone provide no stability to the fracture site. Unless the nonunion is inherently stable, you may also need more surgical procedures (internal or .external fixation) to improve stabililty

Internal Fixation. Internal fixation stabilizes a nonunion. The surgeon attaches • metal plates and screws to the outside of the bone or places a nail (rod) in the inside canal .of the bone

If a nonunion occurs after internal fixation surgery, another internal fixation surgery may be needed to increase stability. The surgeon may use a more rigid device, such as a larger rod (nail) or a longer plate. Removing a previously inserted nail and inserting a larger one (exchange nailing) increases stability and stimulates healing within the bone. Internal .fixation can be combined with bone grafting to help stability and stimulate healing

External fixation. External fixation stabilizes the injured bone, as well. The surgeon attaches a rigid frame to the outside of the injured arm or leg. The frame is attached to the bone with wires or pins. External fixation may be used to increase the stability of the fracture site if instability helped cause the nonunion. External fixation can treat nonunions in a patient who also has bone loss and/or infection.

Currently, there are different strategies to augment the bone-regeneration process, however, there is no standardised clinical treatment guideline yet .

Surgical treatment options include:

1-Debridement: radical surgical removal of necrotic or infected soft tissue and bone • [tissue is deemed essential for the healing process

2-Immobilization of the fracture with internal or external fixation. Metal plates, • pins, screws, and rods, that are screwed or driven into a bone, are used to stabilize the .broken bone fragments

3-Bone grafting. Filling of the bone defect resulting from debridement must be •

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performed. Autologus bone graft is the "gold standard" treatment and possesses osteogenic, osteoinductive, and osteoconductive properties, although only a limited sample [can be taken and there is a high risk of side effects.[6

•**4-**Bone graft substitutes. Inorganic bone substitutes may be used to complement or replace autologous bone grafting. The advantage is that there is no morbitidy on smapling and their availability is not restricted. S53P4 bioactive glass has shown good results as a promising bone graft substitute in treatment of nonunions, due to its osteostimulative, osteoconductive and antimicrobial properties

Complications

1-Nerve injury - e.g., the radial nerve in the humeral shaft fractures- •
2-Persistence of nonunion •
3-Eventual need for amputation •
4-Infection with further damage to surrounding anatomy •
•5- BMP-2 can cause osteolysis, heterotopic bone formation, retrograde ejaculation in spine surgery, and wound complications

Prognosis

Nonoperative treatments of nonunion can be quite effective. Ultrasound union rates can be as high as 70% to 93%..The usual course of nonoperative treatment with ultrasound is the placement of ultrasound therapy within three months after the last surgical procedure. [There are better union rates when ultrasound is applied less than six months from surgery The surgical treatment of nonunions has high union rates. Nail dynamization with an 83% union rate . Exchange nailing in humeral shaft fractures has shown a 95.6% union rate Infected nonunion, however, perturbs a poor prognosis with most studies showing low union rates after surgical treatment. The prognosis of nonunion if treated depends on many factors including the age and general health of the patient, the time since the original injury, the number of previous surgeries, smoking history, the patient's ability to cooperate with the treatment. In the region of 80% of nonunions heal after the first operation. The success rate with subsequent surgeries is less.[

Prevention of nonunion

.1-Controll of diabetes mellitus-
.2-using good aseptic technique to avoid infection and give prophylactic antibiotics
3-With the improvement of quality of life, the negative impact of obesity has gradually .become a hot issue of concern. Obesity can lead to vitamin D deficiency
4-The use of NSAIDs was also associated with fracture nonunion. Some experiments have - .proved that NSAIDs can temporarily inhibit the process of fracture union
.5-Stop smoking because it decreases blood supply and affects bone healing-
6-Good fracture reduction-
7-Good fracture stability-
8-Protect fracture vascularity-
9-The tools currently available to determine union including various imaging modalities, biomechanical testing methods, and laboratory and clinical assessment
10-Open reduction had a higher rate of fracture nonunion than closed reduction. In surgery, although open reduction can bring good fracture repair, but closed reduction can .better protect blood supply and soft tissue
11-Nonunion rate of conservative treatment was the highest one compared with that of surgical treatment
12-IMN(itramedullaray nail) can achieve better healing effect in the treatment of tibial

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fractures, comparing to ORIF and external fixation .MIPPO (minimialy invasive percutenous plate osteosynthesis)can maximize the protection of soft tissue and bone marrow around the fracture site.so it had the lowest nonunion rate of all fixation modes.

Conclusion

There are many possible approaches for patients who develop a non-union. One of the best .methods of treatment is prevention.
Howev,
if a non-union does occur, there are multiple conservative and surgical options available. Early diagnosis is very important to allow for the initiation of conservative treatment methods. Clinical, radiographic and advanced imaging are available to help in early diagnosis. Patient selection and preparation for surgery are very important to limit risk .factors and optimize the possibility of fusion.
Good surgical technique to provide a stable construct and maintaining immobility are keys, not only of prevention, but also of surgical treatment of a non-union. External products are often indicated to aid in the basic principles of bone healing and one can often mix these products with bone marrow to provide an even higher probability of success.

References

1-Jump up to:a b Page 542 in: Rigmor Texhammar, Christopher Colton (2013). AO/ASIF Instruments and Implants: A Technical Manual (2 ed.). Springer Science & Business .Media. ISBN 9783662030325

.**2**-Nonunions - OrthoInfo - AAOS". Retrieved 2018-09-02"

3-McCoy, Thomas H.; Fragomen, Austin T.; Hart, Kamber L.; Pellegrini, Amelia M.; Raskin, Kevin A.; Perlis, Roy H. (January 2019). "Genomewide Association Study of Fracture Nonunion Using Electronic Health Records". JBMR Plus. 3 (1): 23–28. .doi:10.1002/jbm4.10063. ISSN 2473-4039. PMC 6339539. PMID 30680360

4-Calori, Gm (2017). "Non-unions". Clinical Cases in Mineral and Bone Metabolism. 14(2): 186–188. doi:10.11138/ccmbm/2017.14.1.186. ISSN 1971-3266. PMC 5726207. PMID .29263731

5-Simpson, A. H. R. W.; Deakin, M.; Latham, J. M. (April 2001). "Chronic osteomyelitis: THE EFFECT OF THE EXTENT OF SURGICAL RESECTION ON INFECTION-FREE SURVIVAL". The Journal of Bone and Joint Surgery. British Volume. 83-B (3): 403–407. .doi:10.1302/0301-620X.83B3.0830403. ISSN 0301-620X

6-Sen, M.K.; Miclau, T. (March 2007). "Autologous iliac crest bone graft: Should it still be the gold standard for treating nonunions?". Injury. 38 (1): S75–S80. .doi:10.1016/j.injury.2007.02.012. PMID 17383488

7-Malat, Tarek Al; Glombitza, Martin; Dahmen, Janosch; Hax, Peter-Michael; Steinhausen, Eva (April 2018). "The Use of Bioactive Glass S53P4 as Bone Graft Substitute in the Treatment of Chronic Osteomyelitis and Infected Non-Unions – a Retrospective Study of 50 Patients". Zeitschrift für Orthopädie und Unfallchirurgie (in German). 156 (2): .152–159. doi:10.1055/s-0043-124377. ISSN 1864-6697. PMID 29665602

8-Niedzielski K, Synder M (2000). "The treatment of pseudarthrosis using the Ilizarov .method". Ortop Traumatol Rehabil. 2 (3): 46–8. PMID 18034140

9-Victoria, Galkowski; Petrisor, Brad; Drew, Brian; Dick, David (2009). "Bone stimulation for fracture healing: What's all the fuss?". Indian Journal of Orthopaedics. 43 (2): 117–20. .doi:10.4103/0019-5413.50844. ISSN 0019-5413. PMC 2762251. PMID 19838359

10-Higgins, A; Glover, M; Yang, Y; Bayliss, S; Meads, C; Lord, J (October 2014).

"EXOGEN ultrasound bone healing system for long bone fractures with non-union or delayed healing: a NICE medical technology guidance". Applied Health Economics and Health Policy. 12 (5): 477–84. doi:10.1007/s40258-014-0117-6. PMC 4175405. PMID .25060830

11-Griffin, XL; Parsons, N; Costa, ML; Metcalfe, D (23 June 2014). "Ultrasound and shockwave therapy for acute fractures in adults". The Cochrane Database of Systematic Reviews (6): CD008579. doi:10.1002/14651858.CD008579.pub3. PMC 7173732. PMID .24956457

12-Leighton, R.; Watson, J.T; Giannoudis, P.; Papakostidis, C.; Harrison, A.; Steen, R.G. . (May 2017). "Healing of fracture nonunions treated with low-intensity pulsed ultrasound (LIPUS): A systematic review and meta-analysis" (PDF). Injury. 48 (7): 1339–1347. .doi:10.1016/j.injury.2017.05.016. PMID 28532896

13-Bassett C, Mitchell B, Gastan S. 'Treatment of Ununited Tibial Diaphyseal Fractures With Pulsing Electromagnetic Field'. J Bone Joint Surg[Am] 1981, 63A: 511–23.Google Scholar

14-Nicoll E. 'Fractures of the Tibial Shaft. A Survey of 705 Cases'. J Bone Joint Surg. [Br] 1964, 46B:373–87.Google Scholar

15-Crenshaw A. 'Delayed Union and Nou-union of Fractures' Ch 7 in Campbell's Operative Orthopaedics. 6th Edition. Eds. Edmonson A, Crenshaw A, the CV Mosby Company, 1980.Google Scholar
.

16-Muller M. 'Reconstructive Bone Surgery. Supplement'. in Manual of Internal Fixation, Techniques Recommended By the AO-Group. 2nd Edition. Eds. Muller M, Allgower M, Schneider R, Willenegger H. Springer-Verlag Berlin Heidelberg New York, 1979.Google Scholar

17-Sharrard W. 'Bone and Joint'. Ch 14 in Wound Healing For Surgeons. Eds; Bucknell T, .Harold Ellis. BalliereTindel, 1984

18-Brighton C. 'Use of Constant DC In the Treatment of Non-Union'. AAOS Instructional Course Lectures 31:94–103,1982.Google Scholar

19-Weber B, Cech O. Pseudoarthrosis. Eds, Bern-Stuttgar-Wein, Huber, 1976.Google Scholar

20-Esterhai J, Brighton C, Heppenstall R et al, 'Detection of Synovial Pseudarthrosis by TC Scintigraphy - Application To Treatment of Traumatic Non-Union With Constant Direct Current' Clin Orthop 1981, 161: 15.PubMedGoogle Scholar
.

21-Tscherne H, Götzen L. (Eds) Fractures With Soft Tissue Injuries. Springer-Verlag, 1984.Google Scholar
.

22-Gustilo R, Mendoza R, Williams D. 'Problems In the Management of Type III (Severe) Open Fractures: A New Classification of Type III Open Fractures'. J Trauma1984, 24: 742–6.PubMedCrossRefGoogle Scholar
.

23-Trueta J Studies of the Development And Decay of the Human Frame. William Heinemann Ltd: London, 1968.Google Scholar
.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 792-806
Received 25 April 2021; Accepted 08 May 2021.

24-McKibbin B. 'The Biology of Fracture Healing In Long Bones'. J Bone Joint Surg. [Br] 1978, 60b: 150.Google Scholar
.
25-Friberg O. 'Clinical Symptoms and Biomechanics of Lumbar Spine and Hip Joint In Leg Length Inequality'. Spine1983, 8:643–51.PubMedCrossRefGoogle Scholar
.
26-Lavender J, Peters A, Ring D, Henderson R, 'Radionuclide Scintigraphy' Ch 8 in Infection In the Orthopaedic Patient. Eds; CoombsR, Fitzgerald R. Butterworths: London, 1989.Google Scholar
.
.**27**-Elson R. 'Revision Arthroplasty'. Ch 1516 .
28-Coombs R, Jessop J. 'Biopsy In Orthopaedic Infection'. Ch 10 in Infection In the Orthopaedic Patient. Eds; Coombs R, Fitzgerald R. Butterworths: London, 1989.Google Scholar
.
29-Ratliff A. 'Vascular And Neurological Complications'. in Complications of Total Hip Replacement. Ed, Ling R, Churchill Livingstone: Edinburgh, 1984.Google Scholar
30-Bohler L. 'The Treatment of Pseudarthrosis'. in The Treatment of Fractures. Wilhelm Maudrich: Vienna, 1929.Google Scholar
.
31-Judet R, Patel A. 'Muscle Pedicle Bone Grafting of Long Bones By Osteoperiosteal Decortication'.Clin Orthop. 1972, 87: 74–80.PubMedGoogle Scholar
32-Nicoll E. 'Closed And Open Management of Tibial Fractures'. Clin Orthop. 1974, 105: 144–53.PubMedGoogle Scholar

33-Phemister D. 'Treatment of Ununited Fractures By Onlay Bone Grafts Without Screw Or Fixation And Without Breakdown of the Fibrous Union'. J Bone Joint Surg. 1947, 29: 946–60.PubMedGoogle Scholar
. .
34-Colchero F, Orst G, Vidal J. 'La Scarification Son Interet Dans Le Traitement de LTnfection Osteo-Articulaire Chronique Fistulisee A Pyogenes'. Int Orthop 1982, 6(4): 263–71.PubMedGoogle Scholar
. .
35-Saleh M, Harriman P, Edwards D. 'A Radiological Method For Producing Precise Limb Alignment'.J Bone Joint Surg [Br] 1991, 73-B No.3: 515–6.Google Scholar
. .
36-Ilizarov G. 'Clinical Application of the Tension-Stress Effect For Limb Lengthening'. Clin Orthop. 1990, 250: 8–6.PubMedGoogle Scholar
. .
37-Hagen K, Bunkle H. 'Treatment of Congenital Pseudarthrosis of the Tibia With Free Vascularised Bone Graft'.Clin Orthop. 1982, 166: 34–44.Google Scholar
in Complications of Total Hip Replacement. Ed. Ling R, Churchill Livingstone: Edinburgh, 1984.Google Scholar
. .
38-Chao Eys, Aro H 'Biomechanics And Biology of External Fixation'. Chapter 11 in External Fixation And Functional Bracing Ed. Coombs R, Green S Sarmiento A. Orthotext: London, 1989.Google Scholar
. .
39-Muller M. 'Treatment of Non-Union In Fractures of Long Bones'. Clin Orthop. 1979,

138:141–53.PubMedGoogle Scholar
.
40-Rosen H. 'Compression Treatment of Long Bone Pseudarthrosis'. Clin Orthop.1979, 138: 154–66.PubMedGoogle Scholar
. .
41-Mennen V. 'A New Bone Holding Clamp For General Use During Internal Fixation of Fractures'. S Afr Med J 1981, 60: 580.PubMedGoogle Scholar
. .
42-Hackethal K. Die Bundelnagelung. Springer: Berlin-Gottingen-Heidelberg, 1961.Google Scholar
. .
43-Barranowski D, Brug E. 'Current Indications For Intramedullary Bundle Nailing'. Unfallchirurg. 1989, 92(10): 486–94.Google Scholar
.
44-Kempf I, Grosse A, Abalo C. 'Locked Intramedullary Nailing'. Clin Orthop. 1986, 212: 165–73.PubMedGoogle Scholar

45-De Bastiani G, Aldegheri R, Brivio L. 'The Treatment of Fractures With A Dynamic Axial Fixator'. J Bone Joint Surg [Br] 1984, 66-B No.4, 538–45.Google Scholar
.
46-Borrione F, Hardy J. Le Fixateur Externe Circulaire Sequoia, Technique Applications. Springer-Verlag;Paris,1990Google Scholar
47-Sarmiento A. 'Functional Bracing of Tibial Fractures. ' Clin Orthop.1974, 105: 202.PubMedGoogle Scholar
. .
48-Woo S L-Y, Akeson W, Coutts R, et al 'A Comparison of Cortical Bone Atrophy Secondary To Fixation With Plates With Large Differences In Bending Stiffness'. J Bone Joint Surg [Am] 1976, 58-A: 190–5.Google Scholar
. .
49-Tayton K, Johnson-Nurse C, McKibbin B, et al 'The Use of Semi-Rigid Carbon-Fibre-Reinforced Plastic Plates For Fixation of Human Fractures. Results of Preliminary Trials'. J Bone Joint Surg [Br] 1982, 64-B: 105–11.Google Scholar
.
50-Schatzker J, Alho A, Sheehan J. 'Screws And Plates And their Application'. Chapter 3 in Manual of Internal Fixation, Techniques Recommended By The AO-ASIF Group. 3rd Edition. Eds. Muller M, Allgower M, Schneider R, Willenegger H. Springer-Verlag, 1991.Google Scholar
51-Rheinlander F. 'Tibial Blood Supply In Relation To Fracture Healing'. Clin Orthop. 1974, 105: 34–81.Google Scholar
52-Johnson K. 'Management of Malunion And Non-Union of the Tibia'. Orth Clin N Am 1987, Vol. 18 No. 1: 157–71.Google Scholar
.
53-Vidal J, Buscayret C, Connes H, et al 'Guidelines For Treatment of Open Fractures And Infected Pseudarthroses By External Fixation'. Clin Orthop. 1983, 180: 83–95.PubMedGoogle Scholar
54-Aro H, Kelly P, Lewallen D, et al 'Comparison of the Effects of Dynamisation And Constant Rigid Fixation On Rate And Quantity of Bone Osteotomy Union In External Fixation'. From Transactions of 34th Annual Meeting of Orthopaedic Research Society, Atlanta, Georgia. Vol 13: P 303, Feb 1988.Google Scholar

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 792-806
Received 25 April 2021; Accepted 08 May 2021.

55-Paley D, Chaudray M, Pirore A, et al 'Treatment of Malunions And Mal-Non-Unions of the Femur And Tibia By Detailed Preoperative Planning And the Ilizarov Techniques'. Orth Clin N Am 1990, Vol 21, No 4, 667–91.Google Scholar
.

56-Glowacki J, Mulliken J. 'Demineralised Bone Implants'.Clin Plast Surg 11985,12: 233.PubMedGoogle Scholar
. .

57-Cockin J. 'Autologous Bone Grafting: Complications At the Donor Site'.J Bone Joint Surg [Br] 1971, 53-B: 153.Google Scholar
. .

58-Weikal A, Habal M. 'Meralgia Paraesthetica: A Complication of Iliac Bone Procurement'. Plast Reconstr Surg 1977, 60: 572–4.CrossRefGoogle Scholar
. .

59-Summers B, Eisenstein S. 'Donor Site Pain From the Ileum'. J Bone Joint Surg [Br] 1989, 71-B: No.4, 677–80.Google Scholar
. .

60-Saleh M. 'Bone Graft Harvesting. A Percutaneous Technique'.J Bone Joint Surg [Br] 1991, 73-B: No.5, 867–8.Google Scholar
.