Continuing Medical Education

Use of Mini-External Fixation in Forefoot Surgery

These lightweight devices have revolutionized forefoot surgery.

Goals and Objectives

After reading this article, the podiatric physician should be able to:

1) Appreciate the advantages and disadvantages for the use of external fixation in foot and ankle surgery.

2) Appreciate the various forefoot applications for mini external fixators in podiatric surgery.

3) Understand the relative indications and contraindications for as well as the limitations to the use of external fixation in the forefoot.

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*Following this article, an answer sheet and full set of instructions are provided (p. 196).—**Editor***

By Charles Zelen, DPM, Glenn Weinraub, DPM, Stephanie Wu, DPM

Since the inception of external skeletal fixation in the mid-nineteenth century, there have been a number of potentially revolutionary advances in both the design and application of external fixation. In addition to its utilization in the management of traumatic fractures, external fixation is also a critical technology in the treatment algorithm of Charcot deformity, limb lengthening, symptomatic non-union, mal-alignment correction, as well as other congenital and musculoskeletal conditions[1-10]. The modernization of the external fixation apparatus and the configuration of small, lightweight, bone fixation or bone—lengthening devices have potentiated a myriad of utilizations in the forefoot. This article will examine some of the different usages of the mini-external fixators, including their role in hallux limitus, arthrodesis, non-union, osteomyelitis, and brachymetatarsia.

Superficial pin tract infections are an accepted complication of callus distraction.

Ligamentotaxis

Hallux limitus is a common disorder affecting the first metatarsal phalangeal joint (MTPJ) and is defined as a restriction in dorsiflexion of the hallux at the first MTPJ. This progressive degenerative joint disorder has long captured the interests of

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many. Several theories that postulate the etiopathogenesis of hallux limitus have been suggested. These theories include met primus elevatus, hypermobility associated with abnormal pronation, length aberrations of the first metatarsal or the first proximal phalanx, direct macrotrauma to the first metatarsal phalangeal joint, septic arthritis, muscle imbalance, and metabolic/autoimmune disorders.

The symptoms of hallux limitus vary depending on the degree of joint degeneration, and staging of the progression. Proposed treatments span the spectrum from conservative care to surgical intervention. The treatment algorithm is often tailored to the progressive state of the disease. Treatment goals are primarily aimed at pain reduction, and increased range of motion via joint decompression. While numerous osteotomies have been proposed to achieve joint decompression and improve range of motion, it is imperative to maintain both the metatarsal parabola and joint stability about the first MTPJ.

Ligamentotaxis, or distraction of the first metatarsal phalangeal joint with a mini external fixator, is a relatively new approach for the treatment of hallux limitus.[11] Joint distraction was first proposed in the ankle joint as a disease modifying treatment of osteoarthritisis. Ligamentotaxis is an extrapolation of the same principles onto the first MTPJ for the treatment of hallux limitus. Ligamentotaxis is based on the hypothesis that arthrodiastasis will release mechanical stress on the osteoarthritic cartilage while maintaining intermittent intra-articular fluid pressure to help stimulate the cartilage's intrinsic reparative mechanism. In an in vitro study, low physiological levels of intermittent fluid pressure, in the absence of mechanical stress, were found to stimulate cartilage matrix synthesis in osteoarthritic cartilage, with no appreciable effect on normal cartilage.[12]

This cartilage stimulation was accompanied by a decrease in the production of the catabolic cytokines interleukin 1 and tumor necrosis factor alpha; it had no detectable effect on the release of proteoglycans[12]. Proteoglycan aggregate is the major extra-cellular matrix component in cartilage. It comprises about 18% of the dry weight of hyaline cartilage and plays a major role in hyaline cartilage's ability to resist compression forces. Intermittent fluid pressure was also noted to reduce the inhibition of proteoglycan synthesis that was induced by mononuclear cells isolated from the synovial fluid of patients with osteoarthritis[12].

Joint distraction with an external fixator has considerable clinical appeal as it is minimally invasive and does not burn any bridges to future treatments. Even if this pro-

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Case Study

This case study illustrates usage of mini fixators as part of the comprehensive management of a patient with multiple pathologies requiring treatment for a Charcot fracture dislocation, soft tissue ulceraction, cellulitis and osteomyletis. The patient is a fifty year old diabetic with an acute infected Charcot fracture dislocation. Patient underwent initial incision and drainage, followed by appropriate antibiotic therapy and negative pressure wound management. A return to the OR for open reduction and septic fusion with usage of external fixation was performed. External fixators were removed at 12 weeks followed by a split-thickness skin graft of the residual wound site. Follow-up is seen at intervals over a period of nearly two years.

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Figure 1—Represents the initial clinical presentation with large plantar ulceration, extensive erythema, edema and purulent drainage.

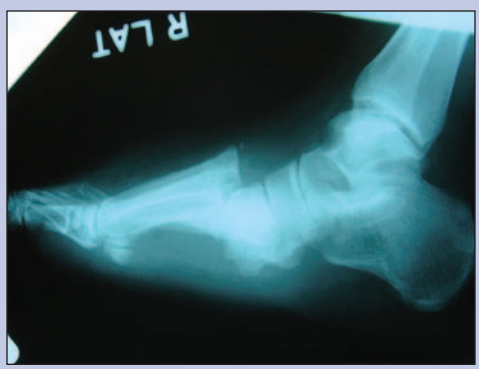

Figure 2—The AP and lateral x-ray films of the severe Charcot fracture dislocation.

cedure provides only temporary relief and clinical results slowly deteriorate over time, it offers a minimally invasive option to forestall more definitive and committed procedures. Joint distraction utilizing external fixation has demonstrated efficacy in the treatment of ankle osteoarthritis in preliminary studies. In one open prospective study with a 1+ year follow-up, significant decrease in pain and improvement in function were noted in 75% of the 57 patients with severe ankle osteoarthritis who were treated with joint distraction[13].

Full weight-bearing and ambulation were permitted during the distraction period. These patients showed radiographic evidence of diminished subchondral sclerosis secondary to the peri-articular osteopenia during the distraction period, and progressive widening of the joint space on follow-up[13]. Although the results look promising, the follow-up period is relatively short and effects of this procedure over time remain unpredictable[14]. At present, there is no published data pertaining to the application of this technique in the treatment of hallux limitus or rigidus. This treatment protocol is still considered experimental and further research and analysis are necessary to understand, validate and refine this novel approach to first MTPJ osteoarthritis.

Brachymetatarsia

Brachymetatarsia is a common anomaly in which one or more of the metatarsal bones is abnormally short, resulting in a short toe. Brachymetatarsia most commonly involves the fourth metatarsal and is believed to be secondary to premature closure of the ephiphyseal plate. It is normally idiopathic, but may be associated with Down's syndrome, pseudo-hypoparathyroidism, Turner's syndrome, or Albright's hereditary osteodystrophy. Although brachymetatarsia is often considered a cosmetic problem, in many instances there is painful pathology associated with the shortened metatarsal. Palliative treatments, including the use of orthotic or accommodative devices, may alleviate the symptoms but do not solve the underlying structural deformity and its associated psychological problems. Through the years, there have been a number of soft tissue and osseous procedures proposed for the correction of brachymetatarsia.

Post-operatively, external fixation as compared to a plaster cast allows for better care of skin and soft tissues.

Traditionally, brachymetatarsia has been surgically corrected using one stage or two stage lengthening procedures with an interpositional bone graft, or synthetic implant. The amount of lengthening, however, was often limited by vascular structures. Elongation of the metatarsal using an external fixator was first reported by Skirving and Newman[15]. With evolution of the external fixator apparatus, gradual metatarsal lengthening by callus distraction or callotasis has gained popularity over the past two decades. Both the latency period and the rate of lengthening vary slightly in current literature. The recommended latency period ranges between 5-10 days, and the rate of lengthening ranges between 0.5 mm to 1.0 mm/day[14-20]. The consolidation period is usually 6-8 weeks.

Complications

Compared to the interpositional bone graft or synthetic implant techniques, callus distraction preserves the periosteal structures[21] and is a safer and less traumatic option for the treatment of brachymetatarsia.

Callotasis is, however, not void of limitations and complications. As with any lengthening procedure, callus distraction of the metatarsal requires careful monitoring of the progress throughout both the distraction and the consolidation phase. Many authors advocate setting a ceiling on the maximum amount of lengthening, suggesting that lengthening not exceed 40% of the original length of the metatarsal[15,16]. In cases where metatarsal lengthening exceeded 40% of the pre-operative length, significant metatarsal

Continued on page 190

Case Study *(Continued)*

Figure 3—Represents the patient status-post incision and drainage, with exposure of dislocated medial cuneiform.

Figure 4—Represents open reduction and septic fusion of Charcot fracture dislocation.

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angulation was noted, along with large increases in joint stiffness[15,16]. Recent studies advocate combining shortening osteotomies of adjacent metatarsals and phalanges with metatarsal lengthening to help avoid the associated complications of over—lengthening, yet still establish an acceptable metatarsal parabola[17,18].

Other possible complications associated with callus distraction include subluxation or axial deviation of the associated metatarsal phalangeal joint, decreased range of motion about the corresponding MTPJ, narrowing of the joint space, and of course, pin tract infections[15-20].

Subluxation or axial deviation of the corresponding metatarsal phalangeal joint is believed to be secondary to tension from tendons and surrounding soft tissue structures. Concomitant soft tissue releases, such as tendon lengthening and stabilization of the metatarsal phalangeal joint with a K-wire, have been suggested[19,20]. These adjunctive soft tissue releases are recommended even in cases where minor degrees of lengthening are required to prophylactically prevent symptomatic subluxation or axial deviation of the joint.

Decreased range of motion about the corresponding metatarsal phalangeal joint is a common complication following metatarsal lengthening[15,16,19]. While normal joint range of motion was never achieved at follow-up in many patients, most patients who are pleased with their improved cosmetic appearance are not bothered by the lesser metatarsal joint limitus[19].

Superficial pin tract infections are an accepted complication of callus distraction and are considered by some authors to be a natural sequela of using external fixation[22]. Complete resolution can usually be achieved with local pin care and the administration of oral antibiotics.

The use of callus distraction, via mini external fixation to help restore the metatarsal parabola, requires both exact control of the amount of distraction and scrupulous attention to local factors. Although there are complications, they may be minimized by adjuvant soft tissue procedures, and careful monitoring of the progress throughout distraction and consolidation. As always, patient selection is extremely important as compliance is a critical factor in the success of this procedure and not every patient is a candidate for external fixation.

Osteomyelitic Bone Resection

Extrapolating on the basic principles of external fixation, mini fixators are often adapted for utilization in a variety of forefoot scenarios. One such principle is the maintenance of length,

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Case Study *(Continued)*

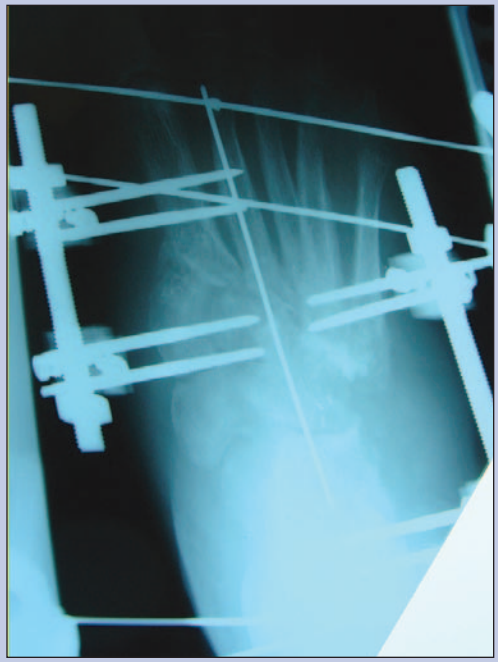

Figure 5—Represents the immediate post-operative x-rays status post surgical reduction and fusion.

Figure 6—Represents the dorsal and lateral wound two weeks after open reduction and septic fusion.

Figure 7—Represents negative pressure wound management and electrical bone stimulation as part of the comprehensive management of this patient.

Figure 8—Represents the open dorsal wound with exposed anterior tibial tendon, six weeks status post surgical reconstruction.

Continued on page 191

especially about the first ray. Staged debridement-arthrodesis has been proposed as a first ray salvage procedure in the treatment of osteomyelitis and sepsis about the first MTPJ[23-26]. The initial salvage treatment includes debridement of all infected/necrotic osseous/soft tissue structures, followed by placement of an antibiotic impregnated bone cement spacer[23]. Soft tissue contracture is a common occurrence following the excision of bone. Before the advent of mini external fixators, K-wires were most often used to help maintain length while scar tissue fills up the void. The second stage of the procedure, which usually occurs 3-4 weeks later with clinical evidence of infection control, consists of bone cement and fixation removal and arthrodesis for the first MTPJ with a bone graft[23].

External fixators are efficacious at maintaining length and are often used for this purpose, especially when bone infections are involved. Several authors have demonstrated successful use of external fixation as part of the forefoot salvage procedure.

A mini external fixator was utilized as part of a staged treatment algorithm in a recently published case report of first ray salvage in a diabetic patient with osteomyelitis[24]. The patient presented with a septic first metatarsal phalangeal joint and associated osteomyelitis of adjacent osseous structures. A mini external fixator was used following aggressive debridement and placement of antibiotic impregnated polymethyl methacrylate bone cement. The mini external fixator helped maintain the full length of the first ray segment until the infection was well-controlled and a delayed interpositional autogeneous graft arthrodesis was performed four weeks later[24].

Another case study demonstrated similar success in preservation of the first ray in a vascular insufficient diabetic patient with a penetrating ulcer and osteomyelitis of the first metatarsophalangeal joint[25]. External fixation provided stability to the resected joint and was left intact for four weeks. This helped result in permanent control of infection and preservation of the hallux without recurrence of osteomyelitis or ulceration[25].

Similar success has been shown in fingers and hands. In a retrospective study, the finger joints of ten patients with acute bacterial arthritis were surgically debrided and stabilized, using a mini external fixation device for about three weeks, with subsequent fixation. Eight of the ten patients showed good final results without symptoms[26].

Since preservation and correct alignment of the first ray is essential for foot stability, mini external fixation may play an important role in the limb salvage about the first ray. First metatarsal-medial cuneiform fusions and first metatarsal phalangeal joint arthrodesis

First metatarsal-medial cuneiform fusion or lapidus arthrodesis is a powerful procedure indicated for the treatment of hallux valgus with a high intermetatarsal angle and associated hypermobility of the first ray. The metatarsocuneiform arthrodesis corrects metatarsal primus adductus, and allows realignment of the first metatarsal at the apex of the deformity, along with stabilization of the first ray and medial column.

Arthrodesis of the first metatarsophalangeal joint has been proposed as a definitive procedure for severe hallux valgus, hallux rigidus, and rheumatoid arthritis. It was first described by Clutton in 1894, and since then has had several modifications by numerous authors.

Mini external fixators may serve as alternate modes of fixation for both metatarsal phalangeal joint fusions[27-29] and first metatarsal-medial cuneiform

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Case Study *(Continued)*


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Figure 9—Represents the patient now 12 weeks status post-surgical reconstruction, prior to removal of mini-fixators.

Figure 10—Represents clinical photos of the patient post operative two weeks status post removal of the external fixator and placement of a split thickness skin graft.

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fusions[29]. This is especially true in patients who are not able to maintain the long non-weight-bearing, post-operative recovery. Mini external fixators, however, often play critical roles in the treatment of post-operative complications such as non-unions and bone infections.

Delayed union or non-union is a well-known complication associated with Lapidus. The incidence of non unions has been quoted as high as 12 percent. Mini external fixators are often employed in the surgical treatment of symptomatic non-unions to apply compression forces across the arthrodesis site. Mono-lateral external fixation has been noted to provide stable fixation for the treatment of established non-unions with the additional ability to simultaneously control angulation and length.

In a study by Hashmi et al., 107 patients, with a mean age of 36 years, with fracture non-union of 23.4 months (mean duration) were treated with mono-lateral external fixation. The success rate using the initial fixator was 90% and the mean time to bony union was 12.69 months (range 2.5-64)[30].

Surgical management of an infected fusion varies depending on the clinical presentation and the presence of a solid arthrodesis. An established bone infection early in the bone healing phase may require hardware removal to eliminate the nidus for continued infection. In these situations, a small monorail external fixator may be used to stabilize and distract the arthrodesis site after adequate bone debridement. The fusion site is distracted until the infection is controlled. A bone graft may then be inserted at the fusion site and the mini external fixator utilized once again to apply compression across the arthrodesis site. Septic joint destruction presents an unfavorable situation of soft tissues and chronic osteomyelitis and is associated with high failure rates of fusions. External fixation has been shown to be a successful alternative for arthrodeses in these types of situations. In a prospective study, 15 patients with bone and soft tissue infections received ankle arthrodesis via external fixation. Solid tibiotalar fusion was achieved and maintained in 14 of the 15 patients with a full weight-bearing status at one year follow-up[31].

Case Study *(Continued)*

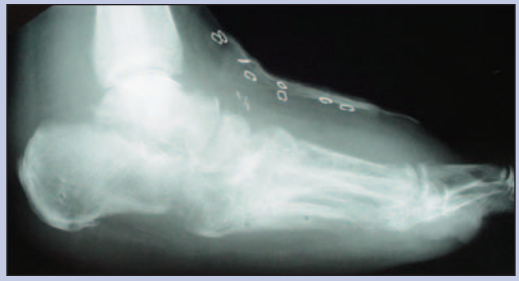

Figure 11—Represents the x-rays, of the patient two weeks status post external fixator removal.

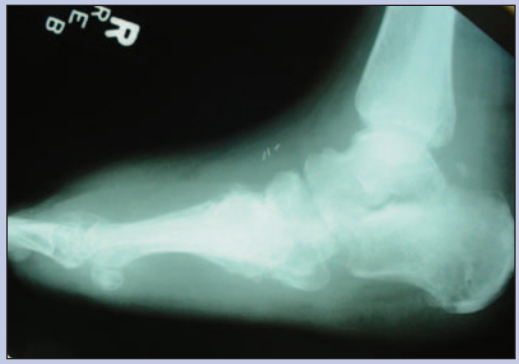

Figure 12—Represents x-rays, three months status post-op external fixator removal.

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Fracture Management

Fractures of the metatarsals and phalanges have traditionally been fixated with pins, wires, and screws. Mini external fixation offers a viable alternative to traditional fixation methods for forefoot fractures. It avoids internal dissection, yet provides fracture stability and allows early movement with mobilization of joints proximal and distal to the fracture[32]. Mini external fixators also allow an avenue of fixation for highly comminuted fractures or complex intra-articular fractures that are not amenable to internal fixation.

Intra-operatively, external fixators can also serve as a temporary traction device to help condition the soft tissues and as a temporary distraction device to aid in reduction. Post-operatively, external fixation as compared to a plaster cast allows for

Continued on page 193

better care of skin and soft tissues.

In a recently published study, ten patients with a mean age of 25.2 years underwent external fixation for acute Jones fractures. Clinical and radiography healing times were 5.7 and 6.5 weeks respectively. The mean follow-up was 46 months and all patients were pain free and were able to resume their pre-injury activity levels[33].

Summary

External skeletal fixation is unique in that it offers the flexibility of additional compression or distraction at the clinician's discretion in addition to applying stable, uniform compression of osseous fragments. External fixation also offers many advantages over traditional techniques of internal fixation, especially in patients where adequate compression is not achievable, such as those with poor bone stock, patients who for one reason or another are unable to remain non-weight-bearing, or in cases where a deformity limits access for proper, accurate fixation with appropriate anatomic reconstruction. Because of its versatility, external fixation is often selected as the alternative or remedy type of fixation.

Mini external fixators, when applied correctly, may have numerous utilizations in the forefoot. They provide excellent stability for fixation osteotomies and arthrodesis and allow patients to participate in their own care. External fixation, however, is not the universal answer for fixation of bone. External fixation is not for everyone. Contraindications that include moderate to severe peripheral arterial disease without vascular surgical intervention, mental incompetence, and psychological intolerance to the frame, can be limiting factors for utilization of this type of fixation.

The understanding of the conditions under which bone and soft tissue can be regenerated by distraction has inspired different applications of the distraction techniques with some promising results. As the evolution of external fixation continues through research and development, new clinical possibilities of indications and usage expand. Further research and development with external fixation needs to be performed, and with time, this treatment

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Case Study *(Continued)*

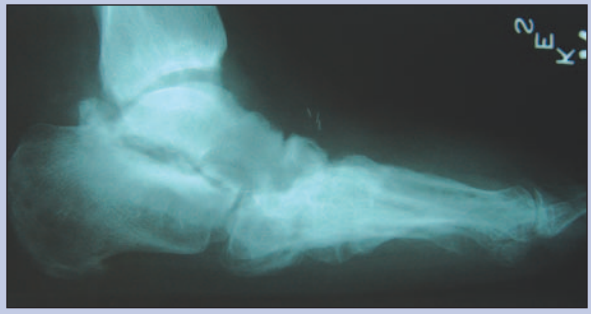

Figure 13—Represents long-term 18 month follow up x-rays and clinical photos status post-op external fixator removal, just prior to two years from the original date of presentation.

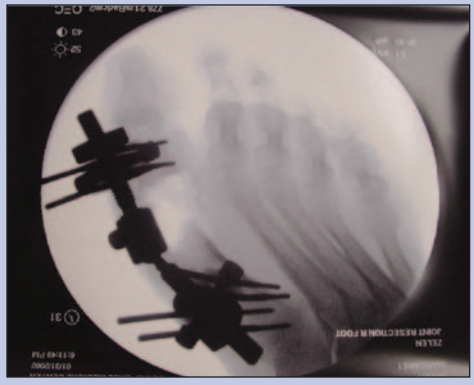

Figure 14—Osteomyelitis Joint Distraction

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Forefoot Surgery...

will more than likely become fully integrated into modern clinical practice. ■

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EXAMINATION

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See answer sheet on page 197.

1) External fixation may be utilized in the management of which of the following?
   A) congenital and musculoskeletal conditions
   B) Charcot deformity
   C) symptomatic nonunion
   D) all of the above

2) A mini external fixator may be utilized in the management of all of the following except:
   A) brachymetatarsia
   B) forefoot non unions
   C) ankle arthrodesis
   D) forefoot fractures

3) Joint distraction was first proposed as a treatment for osteoarthritis in which of the following joints?
   A) knee
   B) ankle
   C) hip
   D) first metatarsal-phalangeal joint

4) External fixation may be advantageous over traditional techniques of internal fixation in which of the following situations?
   A) patients with poor bone stock
   B) patient unable to maintain non weight bearing
   C) it offers the flexibility of additional compression or distraction at the clinician's discretion
   D) all of the above

5) All of the following are contraindications to external fixation use except
   A) severe to moderate peripheral arterial disease without vascular surgical intervention
   B) there are no contraindications, external fixation is for everyone
   C) mental incompetence
   D) psychological intolerance to the frame.

6) In treating brachymetatarsia, the amount of lengthening is most likely limited by which of the following?
   A) skin
   B) bone
   C) vascular structures
   D) patient tolerance

7) Mini external fixation may be a viable alternative to traditional fixation methods for forefoot fractures because
   A) it avoids internal dissection
   B) it allows early movement with mobilization of joints proximal and distal to the fracture
   C) it allows an avenue of fixation for highly comminuted fractures or complex intra-articular fractures that are not amenable to internal fixation.
   D) all of the above

8) When using callus distraction for the treatment of brachymetatarsia, many authors suggest that lengthening not exceed what percentage of the original length of the metatarsal?
   A) 20%
   B) 40%
   C) 60%
   D) 80%

9) Possible complications associated with callus distraction for the treatment of brachymetatarsia include:
   A) subluxation or axial deviation of the associated metatarsal-phalangeal joint
   B) decreased range of motion about the corresponding MTPJ
   C) narrowing of the joint space
   D) all of the above

10) Ligamentotaxis is based on which of the following hypothesis?
   A) arthrodiastasis will release mechanical stress on the osteoarthritic cartilage while maintaining intermittent intra-articular fluid pressure to help stimulate the cartilage's intrinsic reparative mechanism
   B) arthrodiastasis will stretch the soft tissues structures surrounding the joint to allow for greater, pain free range of motion
   C) arthrodiastasis will limit motion across the joint and ensure patient compliance
   D) all of the above are correct

11) Joint distraction with an external fixator for the treatment of osteoarthritis may have considerable clinical appeal because
   A) it is minimally invasive
   B) it does not burn any bridges to future treatments
   C) it offers a way to forestall more definitive and committed procedures
   D) all of the above

12) Which of the following may be considered an accepted complication of using external fixation and is considered by some authors to be a natural sequela of using external fixation?
   A) breakage of wires and pins
   B) higher incidence of falls and injuries
   C) superficial pin tract infections
   D) all of the above

13) Successful use of callus distraction via mini external fixation in the treatment of brachymetatarsia depends on which of the following?
   A) exact control of the amount of distraction
   B) careful monitoring of the progress throughout distraction and consolidation
   C) patient selection
   D) all of the above

14) The role of mini external fixation in the treatment of forefoot osteomyelitis is to
   A) Maintain length after bone resection to prevent soft tissue contracture
   B) Provide easy access to the wound to facilitate physician monitoring
   C) To facilitate post-operative dressing changes
   D) All of the above

Continued on page 196

Continuing Medical Education

EXAMINATION

(cont'd)

15) With regard to arthrodesis of the first metatarsal-cuneiform joint or the first metatarsal-phalangeal joint, a mini external fixator may be used
- A) as an alternate mode of fixation for the arthrodesis
- B) in the treatment of non unions
- C) in the treatment of post-operative bone infections
- D) all of the above

16) When using callus distraction for the treatment of brachymetatarsia, over-lengthening of the affected metatarsal (beyond the recommended length) would most likely result in which of the following?
- A) narrowing of joint space
- B) metatarsal angulation with large increases in joint stiffness
- C) pin tract infections
- D) all of the above

17) When using callus distraction for the treatment of brachymetatarsia, the recommended latency period
- A) ranges between 1-2 days
- B) ranges between 5-10 days
- C) ranges between 1-2 months
- D) ranges between 5-10 months

18) Mini external fixators may be employed in the surgical treatment of symptomatic non-union to
- A) apply compression forces across the arthrodesis site
- B) provide stable fixation
- C) simultaneously control angulation and length
- D) all of the above

19) When using callus distraction for the treatment of brachymetatarsia, the rate of metatarsal lengthening usually ranges between
- A) 0.5 mm to 1.0 mm/day
- B) 1.0 mm to 2.0 mm/day
- C) 0.5 cm to 1.0 cm/day
- D) 1.0 cm to 2.0 cm/day

20) When using callus distraction for the treatment of brachymetatarsia, adjunctive soft tissue procedures are often recommended to help prevent which of the following?
- A) Pin tract infections
- B) Narrowing of joint space
- C) subluxation or axial deviation of the joint
- D) all of the above

See answer sheet on page 197.

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EXAM #6/05
Use of Mini-External Fixation in Forefoot Surgery
(Zelen, Weinraub, Wu)

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2.	A	B	C	D	12.	A	B	C	D
3.	A	B	C	D	13.	A	B	C	D
4.	A	B	C	D	14.	A	B	C	D
5.	A	B	C	D	15.	A	B	C	D
6.	A	B	C	D	16.	A	B	C	D
7.	A	B	C	D	17.	A	B	C	D
8.	A	B	C	D	18.	A	B	C	D
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