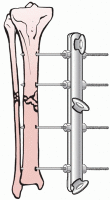
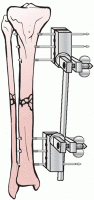
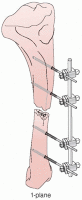
**EXTERNAL FIXATOR**

**Historical Review**

400 B.C Hippocrates described external fixation, large shackles were used  
1843 Malgaigne's description of an ingenious mechanism consisting of a   
 clamp

1902 Lambotte: a simple unilateral frame allowed for frame adjustments to   
 occur, including compression and distraction at the fracture site.   
1938 Hoffman: incorporated a universal ball joint connecting the **external** ball of the **fixator** to strong pin griping clamps. This universal joint   
 permitted fracture reduction to occur in three plane.  
1950 Ilizarov developed a circular **fixator**

Lambotte Hoffman’s Anderson AO monolateral   
  
   

Anderson's early concept called for application of through and through transfixion pins. This permitted multiplanar adjustment of the fracture fragments and allowed

compression at the fracture site.

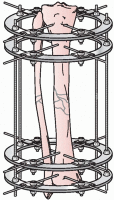
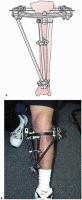
**Circular External Fixation**Russia following World War II.

In the early

1950s, Ilizarov developed a circular **fixator**, which permitted surgeons to stabilize bone fragments but also made three-dimensional reconstructions possible.

By attaching these wires to separate rings, the rings could be individually manipulated to provide for three planes of correction.

Ilizarov's circular **fixator Hybrid Frame**

A few select North American surgeons, notably Victor Frankel, James Aronson, Dror Paley, and Stewart Green, were exposed to Ilizarov's work and determined that the methodology applied to difficult contemporary orthopedic problems had vast potential and began clinical applications in the mid 1980s.

This technique today has become widely accepted for complex problems in traumatology, reconstructive surgery, and limb lengthening. In an effort to simplify and apply these techniques to traumatology, the tensioned ring concept was married to the unilateral **fixator** and the hybrid **external fixator** was developed to address

periarticular injuries with all the advantages of tensioned wires, while limiting the disadvantages of tethering large musculotendinous units with through and through transfixion wire constructs.

Taylor and others to correct complex deformities through have developed recent advancements in deformity correction and precise fracture reductions

the use of simple ring constructs using half-pin fixation. These “hexapod” fixators are ring fixators with the rings interconnected and manipulated by a system of adjustable struts, which allow for six-axis correction of bone fragments.

**FRAME BIOMECHANICS**

**Principles**

1. These frames would promote axial loading with full weight bearing and would   
 accentuate micromotion and dynamization at the fracture site to enhance healing.

2. A/O Manual showed a new tubular monolateral **external** fixation system. The tubular system of the ASIF gained wide acceptance very rapidly, because of improved pin design and frame biomechanics, as well as precise indications for their use.

**3. Large Pin Fixation**

The half pins ranges from 2-6 mm  
The actual biomechanical function that a monolateral frame will perform is dependent on the placement of the pins and orientation of the connecting bars applied. These factors, as well the inherent skeletal pathology treated, combine to impart a specific biomechanical function to the fixation construct. The ability to neutralize deforming forces is the most common mechanical principle exploited with **external** fixation.

4. The use of monolateral fixation for the stabilization of fresh fractures is used emergently as a way of dealing with soft tissue compromise in the immediate

posttrauma/postoperative period.  
5. The primary function of fixators used in this way is to provide relative stability to maintain the temporary fracture reduction at length to avoid collapse of the fracture construct.

**Components**

1. Frame type  
2. The strength and competency of the pin-bone interface.   
3. Pin geometry and thread design

Pin biomaterials and biocompatibility

Pin insertion techniques

Pin bone stresses

**Pin Design**

The bending stiffness of the screw increases as a function of the pin's radius raised to the fourth power (S = r4). Calculations have determined that in adult bone, a pin diameter of 6 mm is the maximum that can be used to achieve a stable implant

without suffering the consequences of stress fracture through the pinhole itself

A small pitch height and low pitch angle, are usually applied to cortical bone,;  
The pitch vertex angle increases and the curvature and the diameter of the thread increase, the area captured by each individual thread is broader and more likely to be applied in cancellous bone.

Conical pins have been designed so that the threads taper and increase in diameter from the tip of the pin to the shaft. This allows the pins to increase their purchase, theoretically by cutting a new larger path in the bone with each advance of the pin. This conical taper also produces a gradual increase in radial preload and thus the screw-bone contact is optimized.

Micromotion typical of a straight cylindrical screw is avoided.

**Pin Biomaterials**

Stainless steel offering substantial stiffness.

Titanium has a much a lower modulus of elasticity. Because of the better biocompatibility, this is preferred as it lowers pin-bone interface stresses and hence

a lower rate of pin sepsis. This may be due to many factors, including an actual bone ingrowth phenomenon seen at the pin-bone interface.  
The **external fixator** pins were either stainless steel or titanium alloy for radius, the rate of premature **fixator** removal because of severe pin tract infection (5% versus 0%) and the rate of pin loosening (10% versus 5%) were higher in the stainless steel pin group.   
  
Among the many different techniques to enhance the pin-bone interface fixation, coating the pins with hydroxyapatite (HA) has been shown to be one of the most effective.

**Insertion Technique and Pin-Bone Stress**

1. Preloading the implant-bone interface has an effect on pin loosening.   
 Radial preload is a concept that prestresses the pin-bone interface in a   
 circumferential fashion rather than in just one direction.

**2. Fixator** pins are placed with a slight mismatch in the greater thread diameter versus   
 the core diameter of the pilot hole. The small mismatch increases insertion and   
 removal torque, with a decrease in signs of clinical loosening. There is a point at   
 which insertion of pins with a mismatch of greater than 0.4 mm can result in

significant microscopic structural damage to the bone surrounding the pin. High   
 degrees of radial preload or large pilot hole thread diameter mismatch will exceed   
 the elastic limit of cortical bone, with subsequent stress fracture. Thus, the use of   
 oversize pins producing excessive radial preloads must be questioned  
3. Predrilled pins and self-drilling pins   
 Predrilled pins: a pilot hole prior to insertion of the pin. The pilot hole has a root   
 diameter equal to or somewhat less than the core diameter of the pin.  
4. The use of self-tapping cortical pins allows each thread to purchase bone as the pin   
 is slowly advanced by hand.

Some studies indicate a 25% reduction in bone purchase of self-drilling, self-tapping pins compared with that of predrilled pins.

Clinically, there does not appear to be any increased incidence of pin tract infection or other pin-associated complications reported with the use of self-drilling pins.

**Monolateral Frame Types**

Separate bars, attachable pin bar clamps, bar-to-bar clamps, and separate Schanz pins).

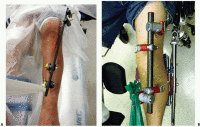
The telescoping tube will allow for axial compression or distraction of

this “monotube”-type **fixator**. “Simple monolateral fixators” have the distinct advantage of allowing individual pins to be placed at different angles and varying obliquities while still connecting to the bar. This is helpful when altering the pin position relative to areas of soft tissue compromise.   
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**“Simple” Monolateral Fixators**

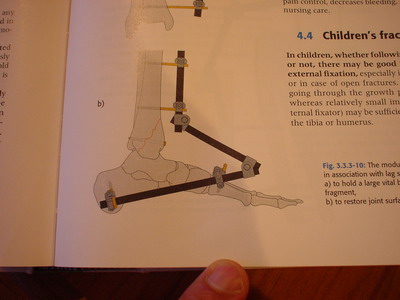
The stability of all monolateral fixators is based on the concept of a simple “four-pin frame.”

**Spanning External Fixator**

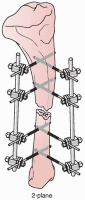


Two similar monolateral **external** fixators both used to span knee dislocations.

**Pilon fracture**

Mechanically, most effective were the “delta” plane configurations, when two simple four-pin fixators are applied at 90-degree angles to each other and connected.  
 However, single and double stacked bar anterior four-pin frames have the best combination of clinical and mechanical features (.



A delta configuration is composed of two “simple” four-pin frames

connected at 90 degrees to each other.

**Monotube Fixators**

Because the pin clusters are fixed at either end of the monotube body, the ability to

maximize pin spread in relation to the fracture site is limited by the monotype body's length.

These devices offer higher bending stiffness, as well as equal torsional stiffness

and variable axial stiffness compared with standard Hoffman-quadrilateral frames with transfixion pins



**Ilizarov Fixator**

**Wires** Thin smooth wires of 1.5, 1.8, and 2 mm   
 Wire strength and stiffness increase as the square of the diameter of the wire   
 (S = d2).   
 As these wires are tensioned, they provide increased stability. This occurs by   
 increasing wire stiffness, which simultaneously decreases the axial excursion   
 of the wires during loading.  
 The amount of tension in the wires directly affects the stiffness of the frame. Compression and bending resistance increase as a function of wire tension as   
 tension is gradually increased up to 130 kg.   
  
Beaded wires (olive wires) perform many specialized functions. During insertion, the beaded portion of the wire is juxtaposed onto the cortex. As the far side of the wire is tensioned, the bead is compressed into the near cortex. This allows olive wires to be inserted to perform interfragmentary compression, which may be useful in fracture applications.

**Wire Tension**

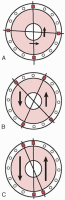
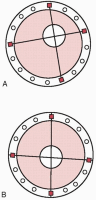
As you perform limb lengthening, tension in the wire will inherently be generated from the soft tissue forces achieved through distraction. This may generate tension in the wire up to as much as 50 kg.

If the wire was initially tensioned to 130 kg and additional tension is added through

lengthening and weight bearing, then the yield point of the wire may be approached with possible wire breakage occurring   
  
Thus, the degree of initial wire tension should take into account the pathology being treated and the treatment forces being generated.

**Wire Orientation**

Wires placed parallel to each other, and parallel to the applied forces, provide little resistance to deformation.   
In bending stresses, the frames can be much less rigid due to bowing of the transverse wires and slippage of the bone along these wires. The most stable configuration occurs when two wires intersect as close to 90 degrees as possible. The bending stiffness in the plane of the wire is decreased by a factor of 2 as the angles between the wires converge from 90 to 45 degrees.

**A.** Wire crossing angle of 90 degrees provides the most stable configuration   
**B.** A wire convergence angle of 45 to 60 degrees allows acceptable amounts of translations to occur with satisfactory frame stability.   
**C.** As the convergence angle decreases, the translation increases dramatically to the point where the bone slides along a single axis

**B.** Center/center location of bone in the ring mounting simulating a femoral or

humeral mounting.

Parallel wires produce a grossly unstable frame configuration.

Eccentric bone location in the ring, simulating a tibial mounting

**External fixation and distraction histogenesis**

.**External** fixation facilitates **external** bridging callus. **External** bridging callus is largely under the control of mechanical and other humoral factors and is highly

dependent on the integrity of the surrounding soft tissue envelope.

These early cartilaginous elements undergo remodeling through endochondral bone formation.

**Dynamization**

Dynamization converts a static **fixator**, which seeks to neutralize all forces including axial motion and allows the passage of forces across the fracture site to occur. As the elasticity of the callus decreases, bone stiffness and strength increase and larger loads can be supported. Thus, the advantages of axial dynamization are that it helps to restore cortical contact and produces a stable fracture pattern with inherent mechanical support.

**Limited Open Reduction Internal Fixation with External Fixation**

This type of methodology is very useful in metaphyseal bone and has been

demonstrated to work well in periarticular fractures, its use in diaphyseal regions must be questioned.

The rate and rhythm of distraction are crucial in achieving viable tissue following distraction histogenesis. Histologic and biochemical studies have determined that a distraction rate of 0.5 mm per day or less leads to premature consolidation of the lengthening bone, while a distraction rate of 2 mm or greater often results in undesirable changes within the distracted tissues. Faster rates of distraction will

disrupt the small vascular channels and areas of cysts can occur inhibiting mineralization. For osteogenesis to proceed more rapidly, optimum preservation of the periosteal tissues, bone marrow, and surrounding soft tissue blood supply at the time of osteotomy is mandatory.

Ilizarov recommended achieving a goal of 1-mm total distraction (rate of distraction) per day. The actual number of distractions (rhythm of distraction) should be at least four each day, achieving the total daily distraction in four divided doses. His work has also demonstrated that constant distraction over a 24-hour period produces a significant increase in the regenerate quality compared with other variables.

**CONTEMPORARY EXTERNAL FIXATOR APPLICATIONS\***

1. open fractures and closed fractures with high-grade soft tissue injury   
2. For temporary, if not definitive, stabilization of these long bone injuries.

3. Complex periarticular injuries, which include high-energy tibial plateau and distal   
 tibial pilon fractures.

4. Limb lengthening, osteotomy, fusion, and deformity correction, as well as bone   
 transport for the reconstruction of bone defects

**Damage Control External Fixation**

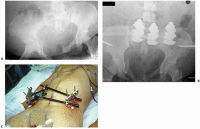
The concept of temporary spanning fixation for complex articular injuries has become widely accepted.

Manual distraction is carried out and a ligamentotaxis reduction is achieved. A simple anterior monolateral frame can be used to maintain similar reduction across the knee joint for temporizing the management knee dislocations, complex distal femoral fractures, and tibial plateau fractures

Application of these techniques in a polytraumatized patient is valuable when rapid stabilization is necessary for a patient in extremis, so-called damage control orthopaedics.

Pelvic injury with anteroposterior disruption and hemodynamic instability.

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**Wrist External Fixation**

Distraction ligamentotaxis alone

   
Fracture spanning EF  


**Advantage**

Quicker in poly-trauma patient is unstable

Less soft tissue dissection

Can be easily adjustable

Does not require expertise

**Disadvantage**

1. Placement and subsequent graft

2. Pin track infection

3. NV damage

4. Closeness to the joint: septic arthritis

5. Cumbersome

6. Nonunion and Malunion