THE ILIZAROV TECHNIQUE

BY AMY M CROFT, CST/CFA, BGS

The human body has an amazing ability to heal itself and, given the right environment, to correct itself. The Ilizarov technique provides a way to heal broken bone—not through immobilization, or artificial screws, metals or compounds—but the body's own process of osteogenesis.

Developed more than 50 years ago in Russia, the Ilizarov technique has only been used in the United States for the past 20 years. It may be used for complicated fractures, fracture nonunion or to address congenital birth defects that require bone lengthening. It is cost effective and leaves minimal scarring.

Configuration

The apparatus designed by Gavriil Ilizarov consists of a fixator frame and implements for attachment to the affected limb. Two external rings, placed proximal and distal to the fracture line, surround the limb and are connected via telescoping rods. These rods allow the osseous surfaces to be either distracted or compressed. Various connectors are also applied to the frame for attachment of pins and wires. Transosseous wires secure the rings to the limb, and half pins joined to the rings may be used for additional stabilization of bony fragments.[1,3,4,7]

The Ilizarov fixator has found multiple applications since its initial development five decades ago as an alternative to amputation. Complicated fractures and nonunion of fractures have been successfully treated with this system. The fixator has found further use to lengthen limbs, especially in cases of congenital birth defects or diseases that affect the bone. The development of hybrid systems allows the use of the fixator on virtually any bone that can be fractured. The patients suited for this method range from young children to 70-year-old adults.[1,3,4,7]

The versatility of this system allows the procedure to be done on a minimally invasive level. The application of the frame onto the limb is achieved with minimal scarring. The dynamics of the frame allow for early weight bearing and joint movement, which are key to the success of the procedure. Several days after application, the patient begins gradual corrections involving both distraction and compression techniques to accelerate osteogenesis.[1,3,4,7]

Osteogenesis

The basis of the Ilizarov method is osteogenesis—the generation of both bony and soft tissues. Knowledge of basic bone structure and remodeling is important to understanding this approach. Essentially, tissue generation occurs between two separated osseous surfaces under gradual distraction. The surrounding muscle, nerve, and vessels regenerate in the direction of the distraction, a process known as distraction osteogenesis.[1,4]

Bone structure

The macroscopic anatomy of a long bone is critical to understanding osteogenesis (Figure 1). The periosteum, which covers the diaphysis of a long bone, can be distinguished into two layers. The outer, fibrous layer contains the blood vessels, lymphatics, and nerves. The inner osteogenic layer of the periosteum contains structures such as blood vessels, elastic fibers, and osteoprogenitor cells. The periosteum is necessary for bone growth, repair, and nutrition. The endosteum lines the medullary canal and contains many bone forming cells, osteoblasts, and osteoclasts (cells that function in bone reabsorption).[5]

Histologically, bone consists of two different types of tissues, cortical and cancellous. The first, cortical tissue, is the outer portion of the bone. This hard and compact connective tissue provides support and protection. Microscopically, compact tissue appears to have hollow cylinders, known as Haversian canals, that run the axial length of a long bone. Surrounding the canals are concentric lamellae, which contain small spaces called lacunae that contain osteocytes. The canaliculi are able to provide a route for osteocyte nourishment by radiating out from the lacunae. The nourishment passes from the blood vessels in the periosteum through the Haversian canals. The blood vessels then connect with similar structures passing through the Volkmann's canals, which run transverse. This pattern repeats from the outer diameter of the bone to the inner, eventually meeting the red marrow in the medullary canal.[5]

The second osseous tissue type is cancellous or spongy bone. This tissue is surrounded by cortical bone. At the ends of long bones, the cancellous tissue is continuous. In the diaphysis of a long bone, it contains an abundance of red bone marrow. Microscopically, the tissue appears to resemble a honeycomb or scaffold. This type of structure is known as trabeculae. The blood and nerve supply for the spongy bone is derived from the vessels in the periosteum.[5]

Bone remodeling

Bone remodeling is essentially the replacement of old bone tissue with new bone tissue. The increase in the diameter of a long bone and the creation of compact bone from cancellous bone are two good examples of bone remodeling. This process requires the use of two specialized osteocytes. Osteoblasts are responsible for the formation of bone tissue. They are derived from fibroblasts and form a matrix of bone. They are eventually encircled by this matrix and become osteocytes. Osteoclasts are believed to break down osseous tissue. The release of proteolytic enzymes and different types of acids digest and dissolve the osseous tissues. The activities of the osteoblasts and osteoclasts are kept in a state of homeostasis by the body.[5]

Fracture repair

When osseous tissue is damaged, the tissue has the ability to mend itself. This process can take several months to achieve. Fracture repair can be divided into three steps: formation of a fracture hematoma, formation of a callus, and remodeling (Figure 2a-d).[5]

The process begins when the blood vessels associated with the fracture are severed. The released blood forms a clot, called a fracture hematoma, at the site of the fracture. The hematoma forms within eight hours of the initial injury. The blood flow to the injured cells ceases, killing the cells along the fracture line.[5]

The next step involves the formation of a callus. A callus consists of the new osseous tissue along the fracture, which connects the severed ends of the bone. The callus can be divided into two regions, internal and external. The internal callus contains the osteoprogenitor cells from the endosteum. The external callus simply surrounds the internal callus. About two days after the initial injury, the osteoprogenitor cells from the osteogenic portion of the periosteum, endosteum, and bone marrow begin to divide. These cells then start to grow toward the fracture line. The osteoblasts initially form trabeculae. The outer trabeculae are part of the external callus.[5]

Callus remodeling marks the final stage of fracture repair. In this stage, the osteoclasts remove the dead cells from the fractured area. Cancellous bone is replaced with compact bone in the external callus. The final product of fracture repair can vary from undetectable to the presence of a thickened area of bone along the fracture line. At this point, the bone at the fracture site is able to accept mineral deposits once again.[5]

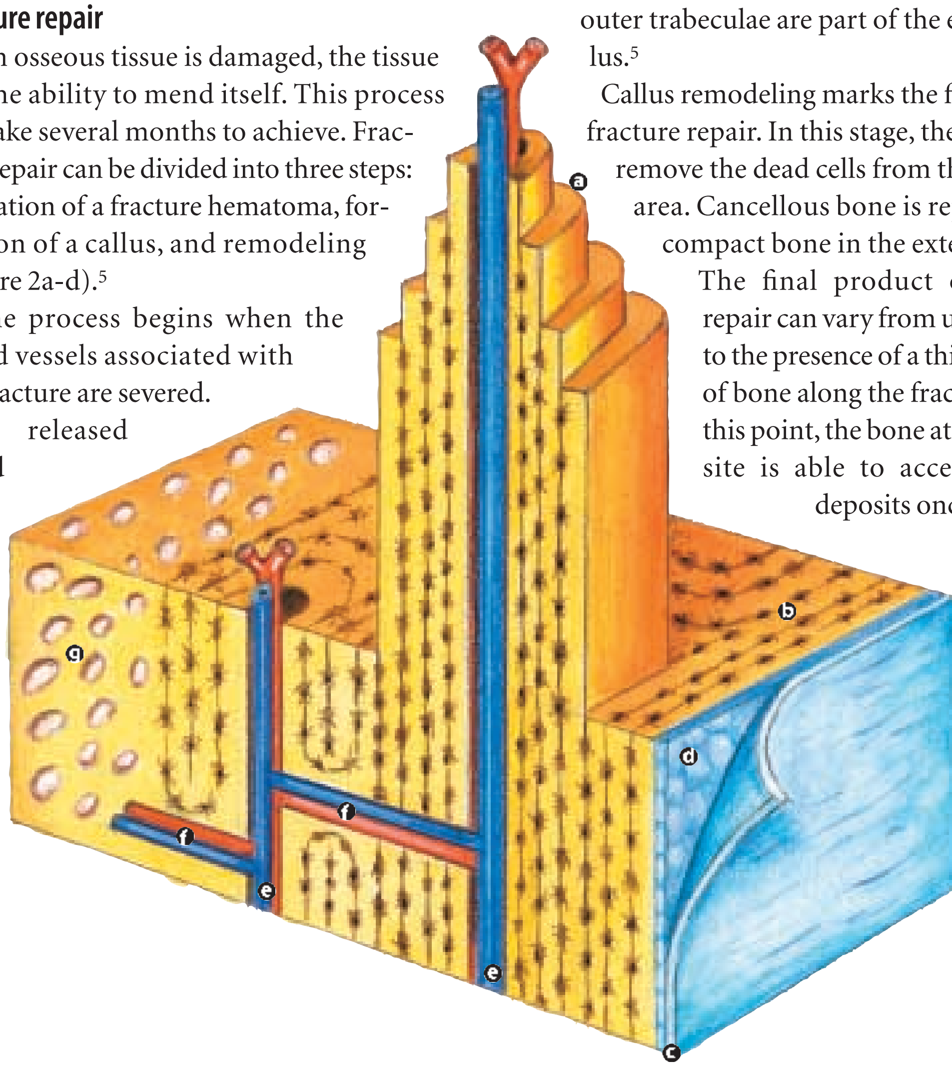


FIGURE 1

Histology of bone

- a concentric lamellae
- b cortical bone
- c periosteum
- d osteoprogenitor cells and osteoblasts
- e Haversian canals
- f Volkmann's canals
- g cancellous bone

Preoperative frame assembly

This method of fracture fixation begins with in-depth preoperative planning. The patient should have orthostatic films taken. The frame can then be templated from the X-ray. After the patient has been assessed, each frame is assembled specifically for that patient in a non-sterile fashion. The preoperative assembly reduces operating room time and increases efficiency. If possible, the completely assembled frame should be placed over the affected limb to ensure a proper fit. The frame is typically 2 to 3 cm larger in circumference than the limb. The frame can be placed off center to allow room for range of motion and swelling. Operating room personnel should sterilize the frame according to hospital and manufacturer's policies. Proper identification of the sterilized frame would include the patient's name, surgery date, and surgeon.[3,7]

Technical insights

1. When a bilateral limb lengthening is scheduled, ensure that enough supplies are available.
2. If the procedure is scheduled to correct a primary fracture, the surgical technologist should have supplies ready for a fasciotomy.
3. Sterile supports can be premade from tightly rolled sheets secured with sterile tape.
4. Small washers can be used to prevent the olive wires from passing through the bone.

The frame consists of a minimum of two rings, but four rings are more commonly used. The rings are manufactured as half circles and connected via nuts and bolts to form a full circle. Some frame styles may require the use of half rings for adequate range of motion. A variety of ring circumferences and curves have been developed to accommodate patient size and the intended application. Substances such as carbon fiber provide a lightweight yet strong material for ring composition.[3,7]

Once the rings have been assembled properly, they are connected with rods. The rods can be telescoping rods or simple threaded rods. The use of the rod depends on the ring placement. For a four-ring assembly, two rings are placed proximal to the fracture line and two rings distal to the fracture line. The rings farthest from the fracture line are called outer rings; the ones closest to the fracture line are termed inner rings. The inner rings would be connected with the telescoping rods to allow for distraction and compression techniques. The outer rings can be connected to the assembly through the threaded rods.[3,7]

Operative preparation for lower limb fracture management

The patient is placed under general anesthesia, but regional anesthesia can be used as an alternative. Patient positioning depends on the fracture site. For tibial fractures, the patient is supine on a radiolucent bed. A rolled sheet can be placed under the hip of the affected leg for adequate positioning. Pressure points should be padded, and the safety strap applied appropriately.[3,6,7]

Skin preparation should follow a typical extremity prep. The prep should extend as far proximally on the extremity as possible. Fractured limbs may necessitate special steps in addition to the routine prep. As always, emphasis is given to carefully handle fractured limbs, and to ask for assistance, if necessary, to safely support the fracture site. Use appropriate solutions for open fractures.

After draping the patient, a sterile pneumatic tourniquet may be placed.[6] To allow for circumferential access to the limb, sterile supports, such as stacked towels, should be placed under the thigh and ankle. The fluoroscopy unit should be draped as well.

The sterile frame should be prepared for placement around the affected extremity. The frame should be opened (similar to a clamshell) by removing the nuts and bolts connecting the half rings on one side. The frame can now be safely placed around the extremity and the half rings reconnected.[7]

The frame is attached to the limb by transosseous wires. These wires range in diameter from 1.5 mm to 1.8 mm. Patient size and location of the frame determine the wire diameter. As a rule, the larger the wire's diameter, the stronger and more stiff the frame. Frame stiffness reduces fragment shifting and pain. Wires also appear in a variety of styles: plain or olive. Olive wires have an olive-shaped stop placed approximately one-third from an end. These wires hold fragments in place and increase stabilization.[3,7]

Several factors determine placement. Wires are placed perpendicular to the proximal and distal segments in relation to the fracture line. A 45- to 90-degree angle between each set of wires increases the frame's stability. Placement should avoid neurovascular structures, and the range of motion should not be impaired. The frame also determines wire placement. Ideally, two wires should be placed proximal and distal to the fracture line. Each set of wires should attach to the ring with one wire above and one wire below. Wires that do not touch the frame without bending should be repositioned.[3,4,7]

For reference, the goniometric system is used to indicate wire and pin placement. The range is from 0 to 360 degrees. In a caudal view of the extremity, the numbering begins directly anterior and increases clockwise for the left limb. It is mirrored for the right limb.[7]

The technique for wire insertion is simple. After determining the proper wire placement through fluoroscopy, a small skin incision is made with a number 15 blade. The wire is then gently pushed through the soft tissue from the more vulnerable side of the extremity. A mallet may be used to tap the wire slightly into the cortex. A pneumatic drill is then used to place the wire through the bone. A small skin incision should also be made as the wire exits the soft tissue. These wires do not require pre-drilling and can be placed with virtually any type of power drill. Room temperature irrigation can be used to avoid overheating of the drill and wire. The wires are then loosely attached to the frame with cannulated or slotted fixation bolts.[7]

Setup for Ilizarov frame placement

Equipment

Radiolucent operating room table

Rolled sheet for hip

Suction set up

Electrosurgical unit and appropriate grounding pad

Fluoroscopy unit and protective attire

Power source for powered instruments

Pneumatic tourniquet

Instrumentation

Major orthopedic set

Pneumatic wire tensioner and drill

Osteotomes

2.0 mm pin cutter

Berry needle holders

Ilizarov instrumentation

Supplies

Extremity drape pack

Basin set

Extra towels for lower limb support

Gowns

Gloves

Blades: 15

Electrocautery pencil

Suction tubing and tip

Asepto

C-arm drape

Irrigation

Dressing: according to surgeon's preference

Suture: according to surgeon's preference

Drains: according to surgeon's preference

Pharmaceuticals: according to surgeon's preference

Half pins can be used to incorporate larger fragments into the fixation and should be placed with the same consideration as wires. The half pins range in diameters of 4.0, 5.0, and 6.0 mm. Insertion of the half pins begins after the proper placement has been determined. A small skin incision is made, and a trocar with drill sleeve is placed through the small tissue. A mallet can be used to gently tap the trocar into the cortex of the bone. The trocar is then removed, and the appropriate size of drill is used for the desired pin diameter. The length of the half pin is determined by passing the depth gauge through the drill sleeve. The half pin of proper length and diameter is placed through the sleeve and inserted using the driver/extractor. Finally, the half pins are attached to the ring with Rancho Cubes.[7]

This process of inserting the wires and half pins is repeated until the frame is securely attached to the affected limb. Once this is accomplished, range of motion should be checked. Joint movement, flexion, and extension should not be affected by the placement of the frame. A final check of the fracture fixation should be accomplished using fluoroscopy.

The wires may be tensioned after ensuring the placement of the frame, wires, and half pins. Two types of wire tensioners are available. The dynamometric tensioner is hand operated to the desired tension. Pneumatic tensioners come with adapters to allow for tensioning where the wire joins with the ring. After all of the wires have been tensioned to approximately 100 to 130 kg of force, they can be cut. To avoid injury from the sharp edges of the wires, the ends should be turned in toward the frame.[3,7]

Limb breakage for nonunion or limb lengthening

In the case of nonunion of a fracture or the need for limb lengthening, the affected bone must be broken. The bone can be fractured in several ways. The technique described by Ilizarov consists of a low energy osteotomy or corticotomy. This method of disrupting the continuity of the bone causes minimal damage to the blood supply, which is found in the periosteum and endosteum. Adequate nutrition at the fracture site is vital for osteogenesis, and this method indeed preserves the blood supply. Ilizarov accomplished a true corticotomy by cracking only the cortex of the bone.[1] Although ideal, surgeons have found this technique difficult to master. Other techniques for an osteotomy include the use of a Gigli saw or an oscillating saw. Also, pre-drilling several shallow holes in the cortex can be used to form an initial fracture line. The fracture would be then be extended with an osteotome and mallet.[1,3,7]

The corticotomy is achieved through a small incision at the intended site. The soft tissue is bluntly dissected to allow for insertion of a

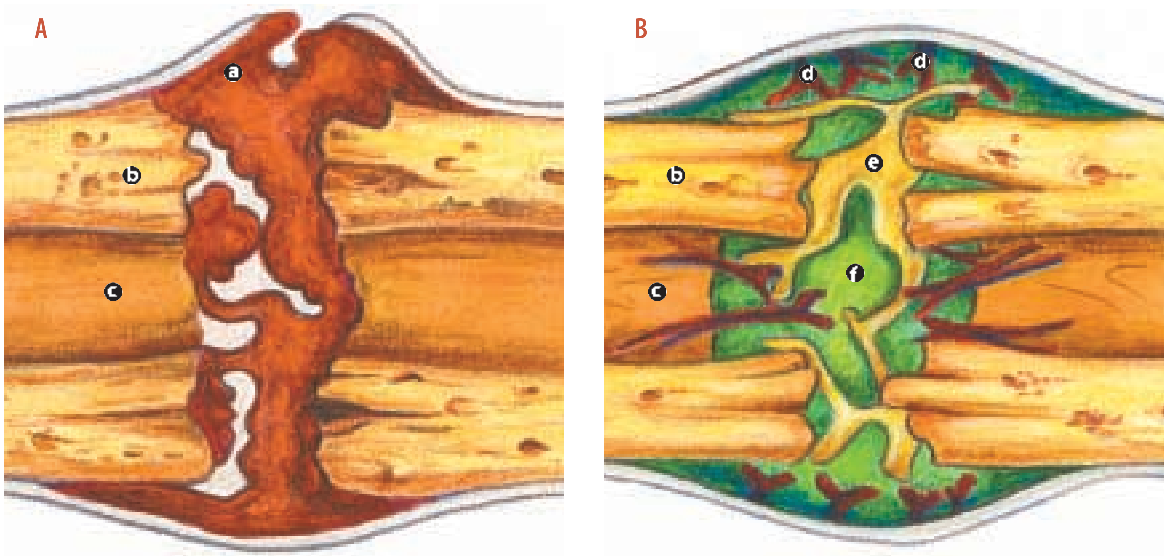


FIGURE 2

A Blood escapes from ruptured blood vessels and forms a hematoma

B Cancellous bone forms in regions close to developing blood vessels, and fiberous tissue forms in more distant regions

C Fiberous tissue is replaced by bony callus

D During remodeling, osteoclasts remove excess bony tissue, making new bone structure much like the original periosteal elevator. The periosteum is then gently elevated, and the corticotomy is performed according to the surgeon's preference. The incision is closed after the frame is securely attached to the affected limb.

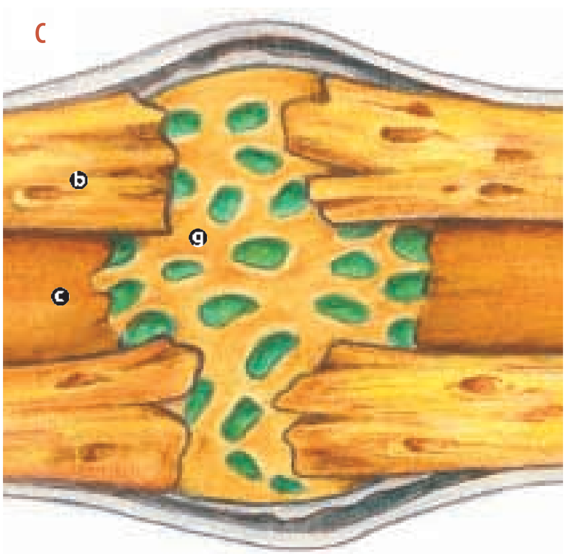
Dressing

The application of a large device, such as the Ilizarov frame, necessitates a specialized dressing. Gauze impregnated with iodine can be cut and placed around the wire and pin sites. Gauze dressing can be placed around the pins. When a fasciotomy has been performed, the frame can be filled with ABDs and wrapped with a 6-inch ACE bandage.

Postoperative exams should include an inspection of the frame. Infection along pin sites should be immediately addressed. The tension of the wires should also be checked regularly. Loosening of the frame will extend healing time and cause undue pain. Neurological exams on the affected extremity are important to indicate any injury to associated neurovascular systems. Routine orthostatic X-rays monitor osteogenesis and indicate growth of the regenerate.[3,7]

Osteogenesis and regenerate

Regenerate refers to the product of the osteogenesis. Distraction begins after a latent period of five to 10 days.[4] The patient simply turns the



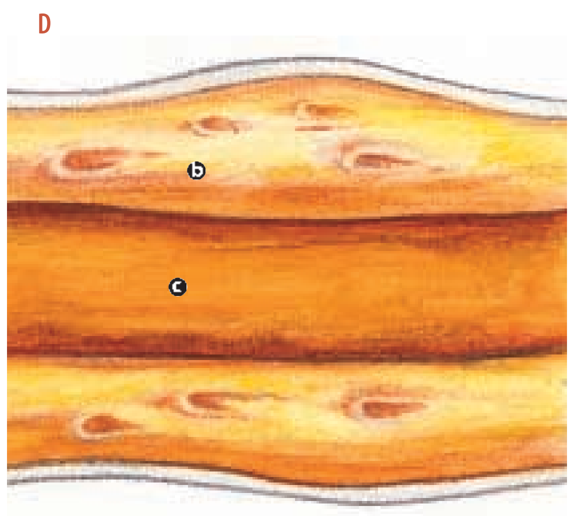


ILLUSTRATION Dave Ludwig

Postoperative procedures

A patient with an external fixator should be taught proper wound care. The most common complication with this type of device is infection of pin and wire tract sites.[1,3,7] The patient, using an antimicrobial solution, can daily cleanse the skin around the pins. The dressing around each pin should be changed daily as well.

Early weight bearing is instrumental for the success of the osteogenesis. Patients with lower limb frames should be instructed on proper limb positioning during rest and ambulation. Appropriate pain-relief medications should be supplied to aid in the healing process.[1,3,7]

telescoping rods to distract the osseous surfaces. The regenerate is procured at a distraction of 1.0 to 1.5 mm a day. Adults can attain a 15 percent increase in limb length. To further monitor the distraction between office visits, colored tape can be placed on the telescoping rods. After the desired length is achieved, the distraction continues until 7 to 10 additional millimeters of growth is seen. The regenerate is then compressed until the desired length is again achieved. This technique is referred to as "training the regenerate."[7]

Removal of the frame should be carefully considered. If in doubt, the frame should not be removed prematurely. Guidelines for frame

a hematoma
b cortical bone
c medullary canal
d new blood vessels
e cancellous bone
f fiberous tissue
g bony callus

removal include the presence of cortical ossifications and a stress test. Three of four ossifications at the regenerate site should be present on the X-ray prior to the stress test, which is performed prior to frame removal and can be used as an indicator for regenerate ossification. The test involves removing the rods connecting the rings, and the patient is asked to partially bear weight. If partial weight bearing is too painful, the rods and frame should be replaced.[7]

If the guidelines have been met, the patient can be taken to the operating room for frame removal. The removal should be carried out in a sterile fashion. The wires can be cut on one side with a heavy wire cutter. The pins are released from the Rancho Cubes and the frame is gently removed from the limb. Wire and pin removal can be quite painful. Make sure the patient remains comfortable during the procedure. Large holes left by pin removal should be closed and the sites dressed in a sterile fashion. The surgeon may opt for application of a splint according to the patient's general condition. The patient may be allowed partial weight-bearing status for several additional weeks to ensure adequate ossification at those sites.

Advantages and disadvantages

The Ilizarov method to apply ring external fixators has enhanced orthopaedic medicine. The system is extremely versatile. The minimally invasive procedure incorporates early weight bearing with both distraction and compression techniques for osteogenesis.

However, it can require long assembly time, and the surgical technique can be involved and complicated. Postoperative management requires a well-informed and compliant patient. Examinations can be quite lengthy, requiring frequent visits and X-rays. The chance of infection at wire and pin sites is always a possibility.[1,3,4,7]

Recent advances in the Ilizarov method, such as hybrid systems, have minimized the disadvantages of this important technique for fracture repair. The ongoing research into the dynamics and methodology of osteogenesis will advance the success of this system. Education of the clinician and patient in all aspects of care will ensure the continuing use of the Ilizarov method of external fixation.

About the author

Amy Croft, CST/CFA, has been working in the OR for more than 10 years. She received her certification in surgical technology from Amarillo College in Amarillo, Texas, and obtained a BS degree in biochemistry from Texas Tech University in Lubbock, Texas. Croft is now a first-year student in the Physician Assistant Program at Wake Forest University in Winston-Salem, North Carolina. In addition, she was a contributing author to the recently released textbook, *Surgical Technology for the Surgical Technologist: A Positive Care Approach.*

References

1. Aronson J. Limb-Lengthening, Skeletal Reconstruction, and Bone Transport with the Ilizarov Method. *Jounal of Bone and Joint Surgery* 1997; 79-A(8):1243-1258.
2. Einhorn TA. One of Nature's Best Kept Secrets. *Journal of Bone & Mineral Research* 1998; 13(1):10-12.
3. Bianchi-Maiocchi A, Aronson J, Pous L Barral J. *Operative principals of Ilizarov.* Baltimore: Williams & Wilkins; 1991
4. Gugenheim JJ. The Ilizarov Method: Orthopedic and Soft Tissue Applications. *Clinics in Plastic Surgery* 1998; 25(4):567-578.
5. Wheeless C. *Wheeless' Textbook of Orthopaedics.* 2000.
6. Tortora GJ, Anagnostakos NP. *Principles of Anatomy and Physiology.* Philadelphia: Harper & Row, 1987.
7. Watson JT, Coufal C. Treatment of Complex Lateral Plateau Fractures Using Ilizarov Techniques. *Clinical Orthopaedics and Related Research* 1998;(353):97-106.

Picture courtesy of Smith & Nephew.