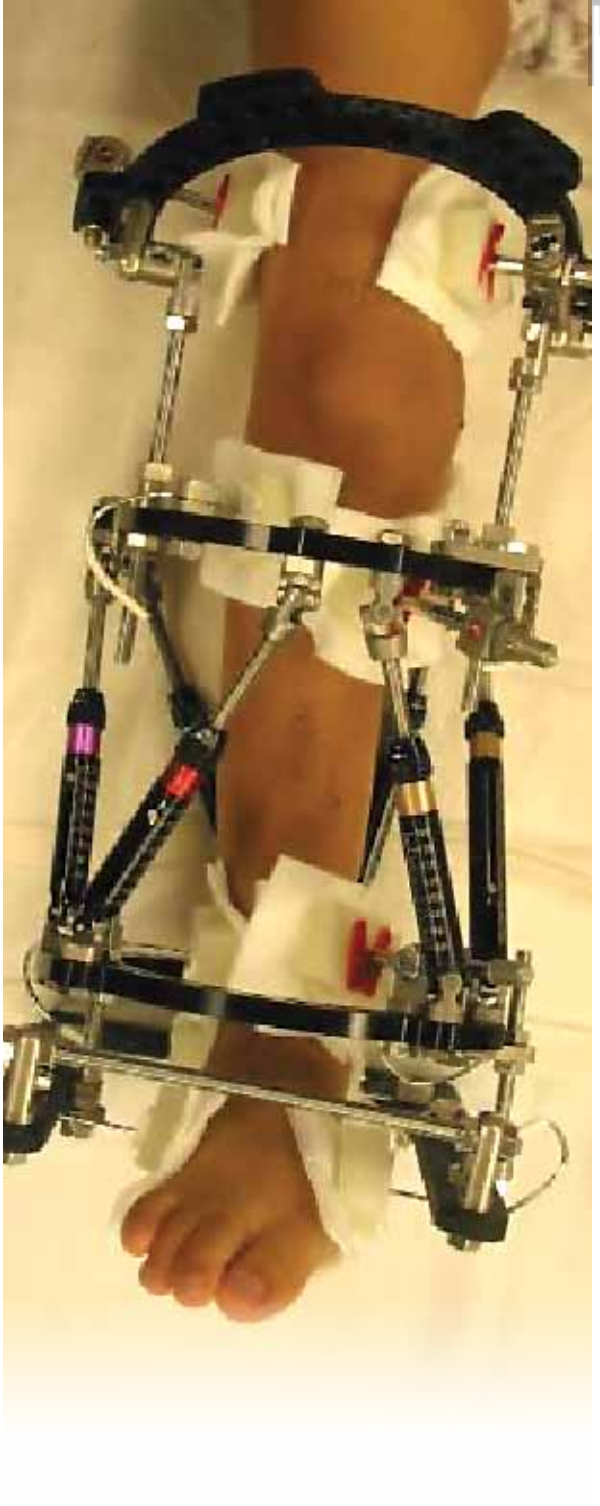

By Mark T. Dahl, MD

LIMB Lengthening

Advances improve treatments, outcomes

Differences between the lengths of the arms and/or legs are called limb-length discrepancies. Except in extreme cases, arm length differences cause little or no problem in how the arm functions; therefore, this article focuses on length differences in the legs, specifically those severe enough to require surgical lengthening.

Mild limb-length differences are common, usually just a mild variation between the two sides of the body. It is estimated that up to one-third of "normal" individuals may have a .2-inch to .6-inch difference between the lengths of their legs. Greater differences may need treatment because a significant difference can affect a patient's well-being and quality of life by virtue of placing extra pressure on joints of the lower back, hips, knees, and feet.

The many causes of limb-length discrepancy include previous fracture, bone infection (especially in infants), and bone diseases (dysplasias). Hemi-hypertrophy (one side too big) and hemiatrophy (one side too small) are limb-length discrepancy conditions in which the arm and leg on one side of the body are either longer or shorter than the arm and leg on the other side of the body.

Symptoms and diagnosis

The effects of limb-length discrepancy vary, depending on the cause and size of the difference. Differences of about 4 centimeters (~1.67 inches) in an average adult may cause a noticeable limp. Gillette Children's Gait Motion Laboratory studies have shown that energy expenditure is increased proportional to the amount of limb-length discrepancy when the discrepancy exceeds 4–5 centimeters.

The long-term effects of limb-length discrepancy on back pain are difficult to determine. Some studies show that people with a limb-length discrepancy have a greater incidence of low back pain and an increased susceptibility to degenerative arthritis of the spine and degenerative disc disease. Premature degenerative arthritis of the hip or knee is commonly observed in adults who have had longstanding discrepancies.

Limb-length discrepancy can be measured by a physician during a physical examination and with X-rays. The physician measures the level of the hips when the patient is standing barefoot. A series of measured blocks are placed under the short leg until the hips are level. If a more precise measurement is needed, x-rays may be used. In growing children, the physician repeats the physical examination and x-rays every six to 12 months to see if the limb-length discrepancy has increased, decreased, or remains unchanged.

Nonsurgical treatment

For minor limb-length discrepancy in patients with no deformity, treatment is unnecessary. Because the risks may outweigh the benefits, surgical treatment to equalize leg lengths is usually not recommended if the difference is less than 1 inch. For small differences, a lift inserted in or fitted to the shoe can often improve walking and running, and can relieve back pain that may be caused by the discrepancy.

Surgical treatment

Epiphyseodesis. In growing children, legs can be made equal or nearly equal in length with a simple surgical procedure that slows down the growth of the longer leg at one or two growth sites. The procedure (epiphyseodesis, or growth plate arrest) is performed under X-ray control through very small incisions near the knee. The limb-length discrepancy will gradually decrease as the opposite extremity continues to grow and "catches up" in length. Because the procedure is useful only in growing children with differences between 1 inch and 2 inches, timing is critical.

Limb-shortening. In adults, the longer leg can be shortened, but a major shortening may weaken the muscles of the leg. In the femur, a maximum of 3 inches can be shortened.

Limb lengthening using distraction osteogenesis. Surgical lengthening of the shorter leg is another choice. Modern surgical techniques for limb lengthening are largely based on the work of Russian surgeon Gavril Ilizarov, who invented many limb-lengthening methods and techniques for repairing significant defects in bone. The Ilizarov method of limb lengthening, brought to the West in 1983, encompasses many methods and techniques.

Based on the principle of distraction osteogenesis (see sidebar), Ilizarov's limb correction process is actually a reshaping of injured or deformed limbs. Distraction osteogenesis relies on the body's ability to spontaneously regenerate tissue, eliminating the need to add bone graft (see Fig. 1).

The bone is lengthened by surgically applying an external fixation device to the leg (see Fig. 2). The external fixator, a scaffold-like frame, is connected to the bone with wires, pins or both. A small crack is made in the bone and the frame creates tension when the patient or family member turns its dial. (The adjustments can also be accomplished automatically by a programmable computer mounted to the external fixator.) This is done several times each day. The lengthening process begins three to five days after surgery.

As the bone segments separate, new bone tissue forms in the gap, ultimately assuming the strength of the original bone. The bone may lengthen 1 millimeter per day, or approximately 1 inch per month. Lengthening may be slower in a bone that was previously injured. Bones in adult patients may need to be lengthened more slowly, at perhaps half the rate.

The external fixator is worn until the bone is strong enough to support the patient safely. This usually takes about three months for each inch. Factors such as age, health, smoking, and participation in rehabilitation can affect the amount of time needed.

As versatile as the fixators are, they must be worn for many months, prolonging pain, discomfort, and difficulties with daily living. To alleviate these problems for patients, recent innovations have combined the use of external fixators with rods or plates (see Fig. 3). These newer techniques permit the surgeon to remove the fixator much earlier than before (as few as 30 days), allowing the patient to return to normal more quickly.

Other surgical options

External fixation alone. When an external fixator is used alone, it must remain in place for both the distraction and

Figure 1. Ilizarov's bone transport technique is used to fill bone defects.

Figure 2. An external fixator was used to lengthening the tibia.

Figure 3. The X-ray demonstrates recent innovations to combine the external fixator with rods or plates.

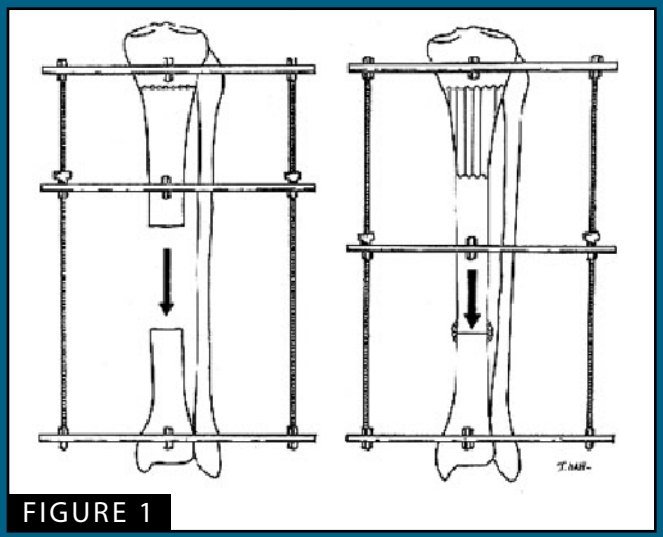
FIGURE 1

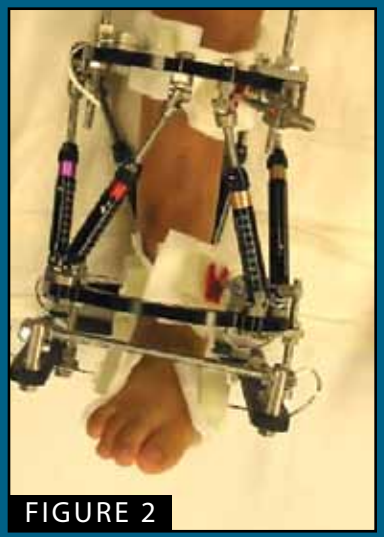
FIGURE 2


FIGURE 3

consolidation phases, until the bone is solidly healed and nearly fully remodeled. Time in the external fixator is usually approximately one month per centimeter lengthened in children and two months or longer per centimeter in adults.

Lengthening with rod and fixator. To decrease external fixator time and reduce the risk of the new bone bending or breaking, a titanium rod is inserted into the bone and the external fixator is applied around the rod, using the latter only to distract the bone osteotomy. The bone is lengthened through the corticotomy site. As soon as the length is achieved, the patient returns to the outpatient operating room where screws that lock the rod to the bone are inserted and the fixator is removed. The intramedullary rod then supports the bone during the consolidation phase. This reduces external fixator time by more than half.

Fully implantable lengthening rods. A recent development is an implantable rod that can lengthen the limb from within without the need for an external fixator. This method has several advantages: it reduces the risk of pin infection; muscle is not damaged by the pins; and the patient experiences less pain. It is limited to use in adults and nearly mature children, as implanting rods in children would injure growth plates.

Deformity correction. The spatial frame allows for correction of the most complex of deformities by constantly changing parameters and adjusting rate of correction to accommodate nerves, tendons, muscles, and joints. Severe deformities previously could not be treated or were treated with amputation and prosthetics.

Risks and complications

Risks of limb-lengthening procedures include infection at the site of wires and pins, stiffness of the adjacent joints, and slight over- or undercorrection of the bone's length.

Specifically, complications of bone lengthening and deformity correction include delay in bone healing, premature bone healing (preventing further bone separation), axial deviation during lengthening, muscle contractures (when the soft tissues cannot adjust to changes in bone length), muscle weakness, and nerve damage.

Though such complications often can be corrected, it is essential that patients be medically stable, healthy, and compliant.

Future developments

Soft-tissue adaptations, damaged cartilage due to excess lengthening pressure, and slow bone formation are receiving research attention. Synthetic grafting material (bone morphogenic proteins) for severe traumatic defects, stem cells stimulating bone and cartilage formation in congenital limb deficiencies, and fully implantable limb lengtheners will soon be realities in this exciting field.

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How Limb Lengthening Works

Ilizarov's modern technique of limb lengthening using an external frame is based on principles of distraction osteogenesis. Two phases of lengthening occur before the bone is fully healed: distraction and consolidation. During the distraction phase, many changes to the patient's limb occur, including stretching of nerves, muscle, tendon, and skin. Weekly follow-up visits are necessary to monitor progress. After the desired length is obtained, the newly formed bone is weak because of lack of calcium within it. The hardening of this new bone is called the consolidation phase.

Recent innovations present a variety of orthopedic device choices to distract the bone and soft tissues. Device selection is individualized for each patient so that the best method to achieve the desired correction can be chosen.

There are two general types of devices: external fixators and internal fixators. The external devices attach to the bone from outside the body by means of wires and threaded pins. The internal devices are inserted inside the body and lie on the bone (plates) or inside the bone marrow cavity (intramedullary rods). To shorten the time in the external fixator, we often combine the external fixator method with an intramedullary rod in adults. Alternatively, we may use a fully implantable, self-lengthening rod that has internal roller bearings, eliminating the need for an external fixator. This method is available for certain adult cases. Surgeons may combine a plate with an external fixator in children to shorten the fixator time.

Limb lengthening requires:

- Regular follow-up visits to the physician's office
- Meticulous cleaning of the area around the pins and wires
- Diligent adjustment of the frame several times daily
- Rehabilitation as prescribed by the physician