CHAPTER 51

Principles Of Callus Distraction

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HISTORY

At the beginning of this century, surgeons were in search of new techniques to lengthen congenitally or traumatically shortened lower extremities. This search began in 1904 with Codivilla's multiple surgical techniques and progressed to the current external fixators used today, primarily the Ilizarov and the Orthofix devices.

In 1951 Ilizarov developed his circular external fixator device and later discovered that new bone formed in the distraction spaces at the open ends of long bones. Over the next 40 years, Ilizarov and his staff of orthopedic surgeons used this discovery to develop the principle of Tension-Stress. This principle governs the response of tissue to elongation. Ilizarov, at his facility in Kargan, Russia, has produced over 2,000 publications concerning the principles of distraction osteogenesis. Initial experiments were performed with the use of canine tibias. Ilizarov used these experiments to show that with the appropriate conditions, an area of growth similar to a growth plate could be produced in any bone.

Recently, De Bastiani et. al applied Ilizarov's Tension-Stress principle to develop the technique of callus distraction or callotasis. Callus distraction involves the slow elongation of a bone callus which forms at the distraction gap during osseous repair. De Bastiani used a dynamic axial fixation system which allowed for a gradual telescopic movement of the fixation device. The stability and telescopic ability of the device allows dynamic distraction without the need for removal of the device.

PHYSIOLOGY OF DISTRACTION

It is evident that with the ability to repair fractures, bone has a regenerative potential. Bone is composed of cells and an organic extracellular matrix containing a glycoprotein ground substance, collagenous fibers, and inorganic salts. Three cell types are found in bone, consisting of osteoblasts, osteocytes, and osteoclasts. Osteoblasts and osteocytes are osteoprogenitor cells which secrete an extracellular matrix called osteoid. It is this osteoid matrix which mineralizes to form bone. Osteoclasts resorb calcium and remodel the forming bone. It must not be forgotten that osseous tissue is composed of a vascular canalicular system which allows for the continual resorption and reformation of bone. After a fracture or ostectomy, the hemorrhage from vascular insult forms a clot. This clot is rapidly invaded by proliferating fibroblasts and capillaries to form a procallus. As the granulation tissue progresses, a temporary callus is formed to unite the bone ends. The osteoprogenitor cells in the periosteum and endosteum lay down spongy bone to replace the temporary callus. If the bone ends are stabilized, bony union is completed.

In callus distraction, the temporary callus is distracted at a constant rate to delay bony union. It has been shown by Ilizarov and De Bastiani et. al that under appropriate conditions of stable fixation and distraction, the temporary callus can be lengthened considerably. At the desired length, the distraction can be discontinued and the bony union allowed to form under rigid fixation. The principle of Tension-Stress is based on the fact that living tissue, when subjected to slow, steady distraction can become metabolically activated in both the biosynthetic and proliferative pathways. More recent studies confirm the principles of Tension Stress and Callus distraction.

LOCATION OF DISTRACTION

Once the decision for callus distraction has been made, it is time to prepare the bone for distraction. One question that arises is where to distract the bone; at the growth plate, or epiphysis, in metaphyseal bone, or in diaphyseal bone. If the procedure does not involve a long bone lengthening, the point

of distraction is not as optional. However, if a long bone such as a metatarsal is being lengthened, the area of distraction can be variable.

The physis has been used as a site for distraction. Obviously, the patient must be young enough for the growth plate to still be open, and secondarily, the surgeon must be technically able to place adequate fixation between the physeal plate and the joint.

Another concern involved in distraction at the physis is the integrity of the growth plate after desired length is reached and distraction is halted. De Pablos, et. al determined that the ability of the physis to return to a normal state after distraction is directly dependant on the rate of distraction. He found that when the physis was distracted too rapidly, early closure of the growth plate occurred, and when distracted too slowly, nonunion occurred. "Distraction epiphysiolysis" is a term which refers to early physeal closure secondary to distraction. Chondrodiatasis is a term used to describe an adequate rate of distraction which does not lead to early closure.

The exact histological mechanism of this process is not totally agreed upon by all, however the end result is that osteogenesis occurs through enchondral ossification, and viability of the physis is maintained. The future growth pattern of the physis is, unfortunately, difficult to predict. This fact combined with the difficulties of pin placement, is a drawback to the use of physeal distraction, and therefore it is not commonly used in the United States.

Both metaphyseal and diaphyseal bone offer advantages for the location of distraction. Metaphyseal bone, with its increased diameter and trabecular pattern, offers a greater surface area for regeneration and a more abundant blood supply. For this reason, some authors feel that metaphyseal bone is a more suitable location. De Bastiani, who pioneered the callotasis method, felt that metaphyseal osteotomies yielded a lower complication rate.

The benefit of a diaphyseal site is that it lends itself to greater ease of fixation. The effects of decreased surface area and blood flow are arguable in the overall distraction process. However, excellent clinical results have resulted from distraction at either site.

ROLE OF PERIOSTEUM

Once the site of distraction has been chosen, the periosteal covering and its surgical approach should be considered. Several studies have been undertaken to compare distraction with and without preservation of the periosteum. A 1988 study by Kojimoto, et. al compared three groups of rabbits undergoing callotasis and determined the role of periosteum and endosteum in callus formation. In one group, the periosteum was opened and reapposed following corticotomy (transcortical osteotomy with an intact endosteum). In a second group, the segment of periosteum surrounding the distraction site was removed. In the third group, the endosteum was scraped out following the osteotomy, and before reapposition of the periosteum.

Kojimoto concluded from his study that preservation of the periosteum is critical in the success of callus distraction. However, preservation of the endosteum is not as crucial due to its rapid regenerative potential.

OSTEOTOMY VERSUS CORTICOTOMY

Following adequate periosteal dissection, there are several methods to instigate callus formation. The two most common are direct osteotomy and corticotomy. Osteotomy, when performed with power instrumentation, must be done carefully with rapid cooling to prevent bone damage. Corticotomy is a technique of using sequential drill holes circumferentially around the bone with subsequent connection via osteotome or scalpel. With this technique, one is able to maintain an intact endosteum. However, the method of bone transection (osteotomy or corticotomy) appears irrelevant to the success of the procedure.

LATENCY, RATE OF DISTRACTION, OSSIFICATION PERIOD

The point at which the surgeon begins distraction is a debated, yet well-studied subject. A wide range of latency periods (the time between osteotomy and distraction) have been attempted from immediately following corticotomy, up to 3 or 4 weeks. Studies have shown that the optimal latency period varies from species to species and bone to bone. Immediate distraction is associated with increased fibrin deposition and decreased

bone formation, whereas, a latency period allows for increased vascularity and bone formation. This latency period correlates to the subsidence of the inflammatory phase of normal fracture healing, which begins 4 to 12 days following injury.

The optimal latency period appears to be from five days to two weeks, depending on when callus formation is radiographically evident. The rate of distraction has also been varied in previous studies, but according to Ilizarov, the optimal rate and rhythm in larger bones is one millimeter per day in four equal increments. This more frequent interval, versus one distraction per day, may also allow for better relaxation of the surrounding soft tissues.

Once the desired length or position of the bone is reached, distraction can be halted. Some authors recommend distracting 0.5 millimeters past the desired position, followed by a seven day waiting period, and then compress for the final fixation period. Others do not feel that this is necessary, and recommend stopping at the desired position while allowing for ossification to take place.

The period of ossification will vary according to the amount of distraction, patient's age, or other factors. The fixator is left in place until there is radiographic evidence of uniform ossification at the distraction site. There is no set time between the end of distraction and the removal of the external fixators. In general, the fixator should be removed only when the surgeon is satisfied that there is clinical and radiographic evidence of a solid union.

EXTERNAL FIXATORS

Several types of distraction fixators have been employed in the technique of callus distraction. The Ilizarov frame, named for its inventor, and the Orthofix device, pioneered by De Bastiani are two of the most common types. The Ilizarov frame is composed of multiple transfixation wires attached to circular rings. Ilizarov's frame is very versatile, but compared to others, it is more difficult to apply and has more pin tracts which are a potential source of infection. The ring system of Ilizarov offers the advantage of multi-plane correction and is less prone to shearing forces which may compromise the outcome. This frame also allows for immediate full weight bearing.

The Orthofix device, a cantilever system with a telescoping component, has less pin tracts than the Ilizarov system. Theoretically, this can decrease the chance of pin tract infections. Like the Ilizarov system, the cantilever system allows for immediate full weight bearing. Clinical experience has shown excellent bone formation and satisfactory results from both systems.

CONCLUSION

Callotasis or callus distraction is an exciting new approach to some challenging problems that confront the podiatric surgeon. Compared to more traditional techniques of bone lengthening, callus distraction has been found to be more forgiving on the surrounding soft tissue, without decreasing the time to approach the desired response.

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