

## HISTORICAL NOTES

**ILIZAROV APPARATUS – A BREAKTHROUGH IN ORTHOPEDIC SURGERY****Ana-Maria Gheorghe<sup>1</sup>, A. Florea<sup>1</sup>, O. Andronic<sup>1</sup>, M. Stănescu<sup>1,2</sup>**<sup>1</sup>The University of Medicine and Pharmacy “Carol Davila”, Bucharest, Romania<sup>2</sup>Department of Clinic “Gh. Niculescu”- The Central Emergency Military University Hospital “Carol Davila” Bucharest, Romania

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**Abstract**

*Dr. Gavriil Ilizarov is one of the most significant names in the orthopedic field, his innovations in bone deformities treatment, fracture management and limb lengthening being successfully used up until now. Although at first his principles were hardly accepted by his colleagues, his work was confirmed with many studies worldwide and his technique became the basis of modern practices. Ilizarov external fixator evolved from being a last resort solution to a method used to treat a great number of bone disorders. One of the most famous principle is “distraction osteogenesis” also called “callotasis” or “callus distraction”, a technique involving slow distraction of the callus in response to a corticotomy. It has the benefit of increasing both bone length and surrounding tissues. The purpose of this article is to present an overview of the history of Ilizarov apparatus, the mechanical laws that underlie it, the current clinical use, the most important complications and future research.*

**Keywords:** *Ilizarov, external fixator, leg lengthening*

**Introduction**

Professor Gavriil Abramovich Ilizarov (1921-1992) started his medical work in Kurgan, southwest Siberia, treating various orthopedic disorders, including World War II soldiers' sequelae. In the 1950s, after travelling with a carriage pulled by a horse wearing a harness with a shaft-bow [1], he started thinking about designing an external apparatus for slow healing fracture and non-unions.

In 1954 he treated his first patient using his new external fixation device. Being presented to the medical society of the Soviet Union, Ilizarov's discovery faced skepticism. [2] In spite of this, his fame grew locally, Ilizarov being called “the magician from Kurgan”. [3]

His technique gained recognition in 1968 when he successfully treated Valery Brumel, an Olympic champion, who suffered a motorcycle accident. They developed a great friendship and the athlete wrote an autobiographically novel (even a movie was made about it). He discovered “distraction osteogenesis” when he observed a cloudy density (bone formation) on a radiograph in a patient who, accidentally, suffered distraction instead of compression during usage of an Ilizarov apparatus. He started experimenting bone lengthening and he discovered that other tissues (skin, arteries, veins, nerves) also have the ability to regenerate during this process. Ilizarov named it “tension-stress effect”. [1,4]



Figure 1 - Gavrill Ilizarov with a patient (Image source: [http://en.wikipedia.org/wiki/Gavrill\\_Ilizarov](http://en.wikipedia.org/wiki/Gavrill_Ilizarov))



Figure 2 - Horse in harness with a shaft bow

His successes became acknowledged in Western Europe in the 1980s after treating Carlo Mauri, an Italian journalist whose leg wound from an accident reopened [1,2]. In 1987 Ilizarov was invited to give a lecture in United States and his technique started to be used and studied worldwide [1].

## Mechanics

Ilizarov apparatus has several pieces, essentially rings connected by rods. Osseous stability is one of the most important elements for osteogenesis. This is dependent on the frame. The rings impact on the frame stability as follows: rings of smaller diameter are more stable than larger ones. So, theoretically, there

should be used the smallest rings that fit the extremity [5,6]. To conform to the limb line it can be used different diameter rings in the same frame (for example knee fusion frame) [7].

In definition the bone should have a central position in the ring but studies showed that this appear not to affect stability [7,8]. Between the skin and the ring there should be a 2 cm space circumferentially for possible swelling of the soft tissue. Another element that affects bone stability is the distance between the rings: rings that are far apart from each other are relatively unstable. Using a “dummy” ring (an empty ring with no bony attachment) secured in the mid portion of the long rods will increase the stability of the frame [7].

A “ring block” is the frame attached to a bone segment. Its stability is increased by using two rings instead of one. Therefore both near and far ends of each bone segment are well controlled. In general, a minimum of four connections between the rings and two or three points of fixation per ring are needed. But this depends on the bone segment - short or long - and the type of nonunion- atrophic (mobile) ones require double ring blocks whereas hypertrophic (stiff) nonunions need only one ring block per bone segment. Lengthening frames also need one ring for each segment due to the distraction forces which give additional stability [1,2].

The frame supports the limb through transfixion wires and half-pins. Small bone segments can be fixed by using multiple wires (for example pediatric fractures). Frame stability increases using larger diameter wires, bigger tension across the wire, more wires per ring placed on opposite sides of the ring and in different planes. Wires are generally tensioned to 130 kg or until the ring begins to deflect. Tension beyond 155 kg will deform the wire. Increasing crossing angles of wires approaching 90° gives maximal stability. Crossing angles of less than 60° need using opposing olive wires or the addition of a half-pin [8].

Olive wires give an important buttress effect and prevent bone sliding. There are advantages of using half-pins (Shantz screws) such as rigid fixation, patient comfort, low infection rate, familiarity in application. Pins are inserted by hand. They are available in many sizes because the diameter of the half pin should be less than

one-third of the bone diameter. Otherwise it increases the risk of fracture at the pins' site. Choosing wires or half-pins is based on the clinical scenario [7].

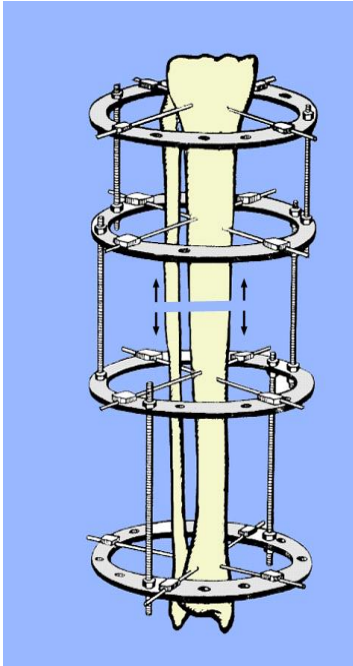


Figure 3 – Ilizarov apparatus – scheme

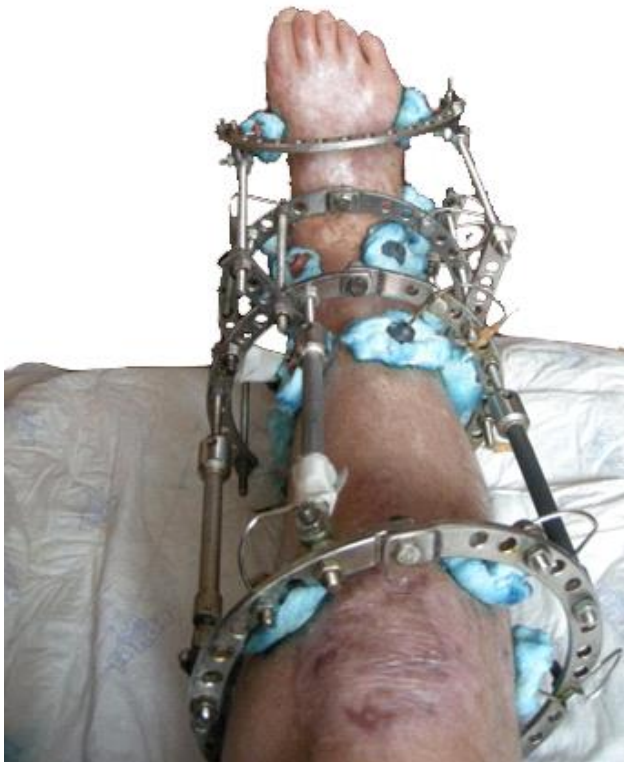


Figure 4: Double corticotomy tibiae 1/3 proximal and 1/3 distal with osteogenesis with Ilizarov apparatus for a 5cm shortness of right leg after an aviatic accident (From archive of the Central Emergency Military University Hospital "Carol Davila" Bucharest)

## Indications

Ilizarov apparatus is currently used for treatment of many conditions such as:

- Lengthening of short limbs (even after 18 years)
- Deformities of the limbs correction, congenital and acquired (including Poliomyelitis sequelae)
- Multiple fragments fractions
- Nonunion and malunion fractures
- Congenital Pseudarthrosis
- Arthrodesis
- Chronic Osteomyelitis

## Leg lengthening

About 1/3 of the population has a 0.5-1.5cm inequality between leg length, 5% more than 1.5 cm and 1‰ has a shoe lift recommended. However, leg lengthening is a hard process used only in specific cases. As a rule, only the discrepancies more than 4cm are an indication for callus distraction and the process requires considering the patient's wishes and status [9].

All current methods of limb lengthening rely on Ilizarov's "distraction osteogenesis" principle [9]. The term describes the new bone production between osseous surfaces during gradual distraction by a process similar to intramembranous ossification (there are two major processes in embryonic bone formation: intramembranous ossification and enchondral ossification. The first one involves direct transformation of mesenchymal tissue into bone, while the second one consists in cartilage conversion of mesenchymal cells before bone differentiation) [10].

Ilizarov's technique uses a percutaneous corticotomy (instead of using an osteotomy) which involves cutting only the cortex, in such a way that preserves periosteum and medullary vessels. This principle emphasizes the importance of blood supply in the process of bone lengthening [11].

This procedure has a high risk of inducing a comminuted fracture, so another method was introduced - the multiple drill osteotomy which requires a small incision more precise than the corticotomy, but the blood supply of the marrow is partially damaged (it recovers in a few days).

Through years, many other techniques were discovered, but these two methods are considered the fastest [12].

After the corticotomy the bone needs a latency period before distraction of 3 to 7 days, allowing the neovascularization process [13].

The experiments in canine tibiae evidenced the adequate rhythm of distraction: 0.25mm carried out 4 times per day (less often resulted in premature consolidation while more in poor regeneration). The results are enhanced by using an autodistractor which fragments the millimeter per day in 60 equal steps. The period of distractions is the amount of time needed to achieve the desired length [11].

“Distraction osteogenesis” is a widely used technique not only in bone lengthening, but also in deformity correction, nonunions and osteomyelitis [14].

The process involves a few indispensable steps: osteotomy, stable fixation of the bone fragments, the waiting period, distraction, consolidation (at least 2-3 days for each day of distraction), careful assessment and external frame removal [15].

At first the indications were limb inequality due to poliomyelitis, osteomyelitis, war wounds, malunited fractures. Nowadays, they have shifted to congenital disorders [9].

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## **Nonunions**

A nonunion is defined as a permanent failure of healing in a fracture.

Atrophic nonunions can be treated by removing the nonunion site, compression and bone lengthening, technique that allows deformity correction if it is present. The compression is needed first because this type of fraction has nonreactive bone ends.

Hypertrophic nonunions can be treated by primary distraction because these fractures have an important blood supply from each bone segment and a dense collagenous interface.

Infected nonunion is one of the golden indications of Ilizarov method. It requires careful resection of the infection site and it achieves both union and eradication of the infection [16].

The treatment of nonunion fractures uses another of Ilizarov's concepts - the

“transformational osteogenesis” defined by applying variations of compression and distraction forces to induce normal bony regeneration [17].

Another important method to manage large defects in the diaphysis involves moving a fragment from the metaphysis across the gap (the concept is called “internal bone transport”). The process requires both distraction and transformational osteogenesis [18]. This technique can be used to treat defects up to 30cm [19].

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## **Angular deformity**

The deformity correction starts with the mechanical axis awareness. The point of intersection between the proximal and distal mechanical axis lines is the center of rotation and angulation (CORA). An osteotomy at this site will allow angular correction. Gradual correction uses the principle of “distraction osteogenesis” [2].

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## **Complications**

Immediate complications involve potential injury to the neurologic and vascular structures. Early complications are pain, regional edema, joint stiffness, pin site infection, muscle contraction. Late complications include osteomyelitis, reflex sympathetic dystrophy, premature or delayed consolidation, nonunion, fracture after removing the apparatus [2]. Psychological problems may also appear, depression being a common issue [11]. These problems show that the success or failure of the procedure depends not on the operation and the assembling itself, but on the postoperative care.

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## **Current and future concepts**

Ilizarov's technique passed the test of time, his frame being used with great success in many fields of treatment. His method has developed considerably and its integration with new technologies has brought better results and more comfort for patients. Some of the most important methods that apply Ilizarov's

principles are: external monolateral fixators, intramedullary kinetic distractors, automated external distractors, external minifixators for the hand, the Taylor spatial frame, orthofix ring and hybrid fixators, locked intramedullary nails and plates, guided growth plate systems. Future studies should include:

- the combination of technologies of external and internal fixation (hybrid technologies) in order to use the advantages of both and minimize the inconveniences.
- application of automated distraction in order to bring the bone growth process close to natural
- avoiding infections
- stimulating effects on regeneration of various biological substances
- increasing the patients' quality life [20]

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