Textbook of
ILIZAROV SURGICAL TECHNIQUES
Bone Correction and Lengthening

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To the memory of
Professor Gavriil Abramovich Ilizarov

Portrait of Dr Ilizarov (Right) with the author
Dr Vladimir Golyakhovsky, 1988, New York

Sant Yago, Chily
Seventeen years passed since publication, in 1993, the “Operative Manual of Ilizarov Techniques”, a richly illustrated first American book about the Ilizarov techniques and methods. Utilizing the techniques developed by him, a circular external fixator, a Russian Doctor Gavriil Ilizarov, in 1950-1960s introduced principally new techniques for treatment bone fractures and deformities. With this innovation, he opened a new chapter in the subject of the whole orthopedic surgery—the minimally invasive methods of bone deformities correction. For many years, his name and work were not known in the Western countries because the communist Soviet Russia was isolated behind the so-called “Iron Curtain”. With the fall of communism, in 1990s, the great interest and enthusiasm developed toward the Ilizarov work among European and American orthopedic communities. The “Operative Manual” was written at that time with the purpose to instruct the surgeons how to assemble and apply the configurations of a circular fixator for the bone correction and lengthening. In several years there were new editions of this book translated and published in Brazil and Russia. In this way the “Operative Manual” has served thousands of orthopedic surgeons as a guide to master Ilizarov’s methods.

In the past 17 years the professional market of the books and articles on the subject of the Ilizarov methods had a plenitude of new ideas, and the “Operative Manual” was almost forgotten. In 2009, the Indian publisher company “Jaypee Brothers Medical Publishers”, based in New Delhi, came across the “Operative Manual”, which was not available any more. The Indian publisher discovered it and considered a classic book and offered to one of the authors (Vladimir Golyakhovsky) to have a new edition with revision of the recent advances happened during last several years. Indeed, there are new modifications of the Ilizarov fixator and the Ilizarov techniques developed in Italy, Germany, the US, and other countries. The author gladly agreed to have a new Indian edition, and to include the recent developments, together with the new illustrations, in the book. Authors also offered to the Publisher to write new chapters:

- Gavriil Abramovich Ilizarov—The Man, The Creator, The Teacher
- Biomechanics of the Ilizarov external fixator
- Ilizarov frame assemblage
- Biomechanics of the Ilizarov method
- Biomechanic considerations for the fracture treatment
- Basics of the method of distraction osteogenesis
- Basics of the method of compression osteogenesis
- Criteria of bone healing and fixator removal.

These chapters, composed together, have a purpose to serve as an introduction for the description of the Ilizarov techniques and methods. Some of these materials were scattered in the chapters of “Operative manual” but the author considers expedient for the reader to get to know these particular subjects before learning how to assemble and use the fixator.

The last chapter of the book “The New Modifications of the Ilizarov Technique” reflects the development of new innovations which were developed since circulation of the original Ilizarov’s ideas in orthopedic community around the
world. The apparent simplicity and clarity of the Ilizarov technique provoked many orthopedic surgeons to offer their own modifications, as it always happened to the great inventions. Some of the new modifications are based on advanced technology of new materials for fixator parts, there are introductions of aluminum rings, and carbon rings, and titanium rods. Some modifications consist of small technical innovations. All these modifications are governed by the principles discovered and technique developed by Dr Ilizarov.

The most essential innovation of the Ilizarov treatment is an addition of the computer programming to the calculation of bone deformity correction. The computer assisting control helps doctors and the patients to produce precalculated bone reduction, correction, compression and lengthening. Several special software programs including Internet-based programs are available in the US, Germany and other countries. But, as Professor Ilizarov was fond of saying; “To perform the treatment properly and successfully, one must know the method as well as the apparatus.”

Dr Gavriil Ilizarov was in India, in 1983, with lectures and demonstrations. One of the authors (Vladimir Golyakhovsky) also was in India, in 1994, and gave lectures and performed surgeries at the hospitals in Mumbai and New Delhi. He was impressed by the great interest developed by the Indian orthopedic surgeons toward the Ilizarov’s methods. He also traveled the country and became a fan of India and Indian people. We present the new edition of the book with a hope that this will make contribution to the practice of Ilizarov techniques.

Vladimir Golyakhovsky
Victor H Frankel
The authors, with Professor Ilizarov, at the Hospital for Joint Diseases in New York City, December 1991
Acknowledgments

The authors wish to thank Dr Svetlana Ilizarov (a daughter of Professor Ilizarov) for a help with the recommendation in writing the chapters of her father biography and of New Modifications of the Ilizarov Technique. Svetlana worked for several years in the beginning of her professional life as a doctor and researcher at the Kurgan Medical Center and Institute, in Russia, under the guidance of her father and is very much familiar with the main subject of this book. She is now working in New York City and is familiar with some of the new modifications of the Ilizarov technique. We also offer our gratitude to Mrs Irina Golyakhovsky, the wife of Dr Vladimir Golyakhovsky, who word-processed the introductory chapters with the patience and dedication. And we want to express our thanks to Shri Jitendar P Vij (Chairman and Managing Director) of Jaypee Brothers Medical Publishers (P) Ltd., for his high appraisal of the original book of “Operative Manual of Ilizarov Techniques”, for offering us a new publication of the book, and his kind attention and support during our work of preparation of the manuscript.
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Gavriil Abramovich Ilizarov—
The Man, The Creator, The Teacher

The progress of science almost always is created by two types of geniuses: the first type brings about the conception of a new idea, this is the genius-discoverer; and the second type develops the existing idea, this is the genius of completion. Only in a very rare occasion the same scientist can become both the originator and developer of an idea. This rare type of genius creates a revolution in science.

Two names those of John Charnley (1911-1982) and Gavriil Ilizarov (1921-1992) are especially prominent in the history of Orthopedics of the 20th century. The success of Charnley’s innovation of low friction arthroplasty revolutionized replacement of total joint in all of the major joints. The success of Ilizarov’s circular fixator with multiplanar transfixation revolutionized the fracture, bone deformities, nonunion and other bone pathology treatment, leading to use of tissue generation for the lengthening and correction of all tubular bones.

Dr Charnley belongs to the second type of geniuses—he developed and completed the existed idea of joint replacement. Professor Ilizarov belongs to the rare type of geniuses who brought about the concept of a new idea and completed it by himself, developing the new chapter in orthopedic science. He was the first one to introduce a new type of the circular external fixator, in 1950s, and the first one to develop the Tension Stress concept for the direction and control over the tissue growth, and on the way he developed a new doctrine of tissue generation under the influence of bone distraction. The most surprising fact of his achievements is that he accomplished them under very poor and primitive conditions in a small and remote Siberian corner of Russia. In his creative work he encountered many people who did not believe the evidence of their own eyes. He had a very interesting life story full of numerous obstacles and heroic achievements.

Gavriil Abramovich Ilizarov was born in the small town of Beloveghsk in the Western Part of Whist Russia (“Gavriil” is the Russian interpretation of the biblical name Gabriel, “Abramovich” is the Russian patronymic name after Abraham). His father belonged to the little known Jewish community called Tats, “the Mountain Jewish” of the Caucasus Mountains. The family was extremely poor and to survive they moved to the father’s native place the Caucasian village of Kussary, in the southern Republic of Russia Dagestan, Young Gavriil, the oldest of six children, had to help his mother to take care of his siblings, and he could not attend the school until he was eleven. Very early, however, he displayed great intellectual curiosity toward natural phenomena and science. The hard life of his boyhood gave him strong character, a desire to explore the possible, and an ability of great persistence. All these qualities would help him in the future. Moving forward through the ordeals, he took the school course just in five years, and then the three-year Rabfack course (Russian equality of the American College) in two years.

In 1939, he was accepted to the Simpheropol Medical School in Russian region of Crimea. In two years, in 1941, the War between fascist’s Germany and communist’s Russia erupted, and his Medical School was evacuated to the small town of Kzyl-Orda in the Soviet Middle East (Kazakhstan). The conditions of life and education there were extremely poor; most of the teaching staff went to the war, there was no clinical training at all. Nevertheless, the doctors were in great need in the country, and young Dr Ilizarov graduated from the school in 1944. Without any practical training, he was sent to work in the village of Dolgovka in the Kurgan district of Western Siberia. One has to imagine all
difficulties at that war time in Russia. The working conditions for a doctor there were very primitive; he lacked much necessary medicine and essential equipment. During the five years of his sole practice there, Dr Ilizarov had no alternative but to overcome all the difficulties, and to become a self-trained internist, surgeon, obstetrician, pediatrician, and so on. There he developed some skill in conservative treatment of fractures.

In 1950, he was promoted to the position of a staff physician in the Hospital for the War Invalids in the small Siberian city of Kurgan, over 2000 km east of Moscow. At that time, there were thousands of wounded World War II veterans with bone nonunion, deformities and osteomyelitis. The small provincial Hospital had the shortage of vital equipment for such patients; the treatment was usually performed either by plaster casts application or by skeletal traction, and the results were unsatisfactory. Dr Ilizarov was determined to overcome that routine ways and to break through stagnation of the old conservative principles of treatment. The necessity is the mother of his first invention, and necessity combined with extraordinary talent helped him to make something from nothing: in 1951, he developed the ring and device for stable transosseus fixation. The Ilizarov's ring was first in the World with two K-wires in crossing directions.\(^1\)

He himself told us the story how once he woke up during the night inspired by this idea. He had to immediately check up the idea. The only piece of wood to imitate the bone within easy reach was the handle of a spade. He used it as the model of a bone, introduced the two wires crosswise and fixed them to the improvised ring. This made the position of ring very stable. The idea behind was to use two rings connected to the bone above and below the fracture or nonunion, and then to connect to each other by the metal rods alongside the bone. In this way he developed a frame for a circular external fixator capable to bring about compression, distraction and correction of the bone fragments.

Dr Ilizarov did not have any training in engineering and did not have anybody to help him perfecting the model of a two-ring frame. Adding the dozens of new parts to the original construction, he overcame many difficulties by himself. Initially, for the purpose of support and stable position of the rings, he combined circular frame with the Böhler splint for skeletal traction (a popular 20th century tool for fracture treatment), then gradually he perfected the frame utilizing it for multiple purposes. Despite all his efforts, he did not get any respect and help from the bureaucratic organizations and manufacturing companies. All the frame parts were made by his grateful patients at the small local factory for repairing bus parts, and smuggled out a part at a time. Ironically, the officials in the Ministry of Health ignored the very existence of Dr Ilizarov, they called his innovations “a locksmith's approach to the surgery”.

With enormous efforts, he was able to achieve good results from the treatment and, in 1958, he brought his fixator to Moscow, the capital of Russia, to present his invention to the attention of the leading orthopedists. He was allowed to demonstrate his fixator in action just in one experimental surgery at the Botkin General Hospital. At that time, the fixator still was the circular frame supported by the Böhler splint. The application of frame was combined with simultaneous regimen of skeletal traction, and to assist him was assigned a young resident, Dr Vladimir Golyakhovsky. Surgery was a success and provoked the impression of astonishment and great interest. But none of the leading professors paid much attention to the ideas of the unknown provincial physician from a remote Siberian town. He left Moscow very disappointed.

Fortunately, Ilizarov had a great amount of energy and determination. He continued perfecting the fixator and the technique of different methods of treatment, expanding the indications for fixator use. Over the years, his fame had spread and people throughout Russia learned of his existence only from the “grapevine”, swapped stories about the miracles he performed in treating the hopeless invalids. His reputation for successful treatment slowly spread, and the patients from over the country traveled to the city of Kurgan, seeking relief from their misery. They started to call him “The Magician from Kurgan”.

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1The ring fixators were not widely known at that time although Dr Bittner, an American, introduced similar ring in 1934. But his invention had no farther practical development and is virtually unknown by the clinicians even now. In no way could Dr Ilizarov know about it in Russian Siberia.
Most of his brilliant findings came to him empirically. A particular anecdotal case illustrates this well: one of his patients, the World War II invalid, had a very short stump of the leg below the knee, and he suffered from inability to wear prosthesis. This man begged Dr Ilizarov to do something for him just because he considered be a surgeon-magician. But the bone was too weak and even this “magician” did not know how to help him. At that time, he did not yet develop his well-balanced concept of the distraction osteogenesis. Yielding to that insisting patient, he reluctantly introduced through a short stamp of tibia two K-wires connected to the rings for gradual distraction. He made a careful cut through the bone, preserving medullar blood supply. His idea was to create a gap for filling it with a bone transplant. In three months, he ordered X-ray to calculate the size of a transplant for implantation. To his great astonishment, the traction gap was replaced by the newly formed bone. Dr Ilizarov realized that the new bone was grown in result of a slow gradual traction. Any doctor could be surprised by such observation and then forget it. But Ilizarov immediately recognized the great potentials of this observation: the distraction can produce osteogenesis.

He continued clinical experiments of the use of a careful bone cut with slow gradual traction, and almost always there was a new bone formation. This single empirical observation brought about the discovery of tension-stress phenomena and development of a new technique, the corticotomy or compactotomy. At that time, he put together a tiny experimental laboratory in which he performed solo research. Through his experimental work, he was the first to show that distraction rather than compression causes the healing of non-unions and pseudoarthrosis. This was the beginning of a new concept of conservation and exploitation of the bone's natural unlimited plasticity. In result, he introduced the concept of tension-stress effect of gradual tissue distraction.

Early in the 1960s, Dr Ilizarov reported the first successful lengthening of up to 25 cm of the shortened lower extremities. Nobody in the world could achieve such results. Undeterred, he continued to pester the professors and bureaucrats of various institutions in the attempt to gain recognition for his fixator and technique he had developed. The essence of his research and clinical findings—that the distraction but not compression is a mode of treatment—was disparaged as representing a contradiction of the fundamental principles of orthopedics. Dr Ilizarov seems to be upsetting those concerned with maintaining conventional levels of orderliness and humbleness. The envy also played an important part in this wrong attitude. As a result, his accomplishments were never reproduced in any of the major medical centers.

For 20 years, Dr Ilizarov continued to work in the same tiny hospital in Kurgan, Siberia, without support and understanding from the bureaucrats of science. He was not a communist party member in the society dominated by the communist doctrine. In 1965, at last his perseverance bore fruit: a decision was made by Moscow orthopedic bosses to send someone to Kurgan to see what that insistent Dr Ilizarov was doing and check his results. The trip to Kurgan fell on Dr Vladimir Golyakhovsky, the senior attending at the Central Institute of Traumatology and Orthopaedics, and also not a communist. At that time, the Moscow orthopedic community had known practically nothing of the Ilizarov improvements in his methods. Nevertheless, the Golyakhovsky's bosses gave him this parting briefing: “Don't trust the Ilizarov stories one bit: he's a crook. Go to the Hospital and personally examine every patient, writing down notes of each case. Back to Moscow you'll present an annihilating report. It's high time that the con artist was exposed”.

At the arrival to Kurgan, Golyakhovsky was astonished to discover that the city looked as Mecca for the crippled invalids, everywhere there were limping people with the crutches who came to seek healing by Ilizarov. The line of waiting Ilizarov surgery was more than 1000 patients. For two cold winter months, Golyakhovsky worked side-by-side with Ilizarov at rather primitive operating room, learning the techniques from that outstanding surgeon. He found that the fixator and the methods were perfected very much comparing to what he had seen 7 years before in Moscow. The conditions at the old small hospital were extremely difficult even by the Russian backward medicine: the dark rooms were crowded with a dozen or more cramped patients with the Ilizarov frames on their legs or arms, it was almost impossible to walk between the beds, the air was stuffy and stinking. But the results of the treatment were as incredible as the Ilizarov's surgical brilliance. He could gradually stretch the bone as much as twenty-five cm. Golyakhovsky was
full of admiration for “Magician from Kurgan”, and eventually they established a warm friendship. He wrote back to his Moscow bosses that Ilizarov methods are the new progressive development. There he made his first sketches of the techniques which made the framework of the illustration for this book, and he brought the sketches back to Moscow. He also brought with him an Ilizarov present—the two sets of his fixator to start to use them in Moscow.

Dr Golyakhovsky delivered a report which was exactly opposite to the one expected from him. Presenting his impressions and findings, he tried to persuade his superiors that the Kurgan surgeon deserved all the support possible for development of his ideas and for spreading his methods. He described them as the original Russian discovery deserved to be widespread abroad, and he even predicted that Dr Ilizarov deserves the world fame. But all was in vain, for his “tactical mistake” Golyakhovsky was punished by a demotion and prohibited to do the Ilizarov surgery.

In 1967, the No. 1 athlete of the world, an Olympic champion, high-jumper, Valery Brumel sustained a compound leg fracture subsequently plagued with persistent nonunion and osteomyelitis. Millions of his fans followed his condition with great attention. Moscow professors recommended amputation of the leg. Dr Golyakhovsky referred Mr Brumel to Dr Ilizarov, and the Ilizarov’s procedure saved his leg and his ability to jump came back again. The recovery of this prominent patient brought an excellent publicity to Ilizarov and this helped him to overcome the resistance of bureaucrats. After 20 years of persistent efforts, he was fully recognized in his country Russia, became a member of the Academy of Science and a member of Russian Parliament. He was granted permission and given sufficient state funds to build the new Institute of Experimental and Clinical Orthopedic Surgery in the city of Kurgan. There he established the largest medical center for the treatment of bone pathology by his own methods: 800 beds, huge rehabilitation clinic and large research department with dozens of laboratories. In Moscow, Dr Golyakhovsky was finally given permission to start using Ilizarov fixator for surgeries and the methods became popular all over Russia. Later on, Golyakhovsky visited his old friend Ilizarov now the Director of the Kurgan Institute and a professor. They published together several scientific papers. Dr Golyakhovsky became a professor in Moscow and soon after, in 1978, he immigrated to the United States. There he had to overcome all the immigrant’s difficulties, and to start from the scratch a new surgical career. In New York City, he unsuccessfully tried to excite the curiosity of American doctors telling them of the Ilizarov techniques. But even though Ilizarov’s work became highly recognized in Russia, the rest of the world knew very little about him and neither the method nor the Ilizarov name were known to the American orthopedic surgeons until the 1980s.

Meanwhile, in 1980, internationally-known Italian author and explorer, Mr Carlo Mauri, from the city Lecco, the member of the famous Kon-Tiki and Ra expeditions, went to Kurgan seeking Prof Ilizarov’s help. Mr Mauri had a severe persistent nonunion and osteomyelitis of the leg. All prominent European orthopedic surgeons tried to help him but without success, and he was recommended to have an amputation. Ilizarov performed on him one of his trademark procedures of distraction for development of local osteogenesis, the bone healed and the leg was saved. Mr Mauri called Ilizarov “the Michelangelo of Orthopaedics”. Impressed by the miracle of his recovery, the team of Italian orthopedic surgeons from the city of Lecco went to Kurgan to learn the technique. They invited Ilizarov to conduct a symposium in Italy, and they secured a license to manufacture his fixator. This catapulted Ilizarov to international fame, he was invited to visit many countries including India, in 1983. In 1985, Dr Victor Frankel, the President of the New York Hospital for Joint Diseases, has seen the Ilizarov procedure in Spain and Italy and developed a great interest in this pioneering technique. He brought the fixator to New York and performed the first Ilizarov surgery in America, in December 1986. At the same time, another American surgeon, Dr Stuart Green, of California, was also bringing the Ilizarov technique to America. In 1987, Drs Frankel and Green went to Kurgan and invited Professor Ilizarov to New York. At the same time, Dr Dror Paley, from Canada, also went to Kurgan, he learned the technique there and performed the first Ilizarov surgery in Canada, in 1987.

The first international Symposium of the Ilizarov technique was organized in New York, in October 1987, by the Hospital for Joint Diseases together with the Smith and Nephew Richards Medical Company. The symposium was a
real triumph of Prof Ilizarov. More than 300 American orthopedic surgeons came to listen to his lectures and to start training in the techniques. The Smith and Nephew company started to produce the Ilizarov apparatus in America. At the Symposium, the first meeting in ten years between the two old friends professors Ilizarov and Golyakhovsky occurred.

Golyakhovsky was given by Dr Frankel a position at the Hospital, and they started to work together. The result of their joint work was the first American Manual of the Ilizarov technique based on 300 first surgeries, which is also the basis of this book.

Professor Ilizarov has published more than 600 scientific papers and the monographic creation "Transosseous Osteosynthesis", and he received almost 300 patents from many countries. He became a well-known scientist and surgeon around the world and was invited to lecture to dozens of countries. Dr Golyakhovsky's early prediction proved finally to be right.

Thousands of orthopedic surgeons around the world use now the Ilizarov methods and Ilizarov fixator performing the Ilizarov procedures. Even the title of procedure “Ilizarov” became itself the common noun. In many countries the ASAMI (Association for Study of the Application of the Method of Ilizarov) chapters have been organized.

On July 24, 1992, Professor Gavriil Abramovich Ilizarov suddenly passed away from heart failure, at the age of 71. The world lost the remarkable Man, the Creator, and the Teacher.

Vladimir Golyakhovsky
Professor Gavriil A. Ilizarov
Receiving
Inspiration for His External Fixator

Caricature by Dr. Vladimir Golyakhovsky presenting Dr. Ilizarov in a pose and costume of Sir Isaac Newton at the historical moment of his Inspiration for Discovery from the falling apple. Dr. Ilizarov liked this drawing very much because there were real similarities in both discoveries.
TECHNIQUE OF BONE DISTRACTION

Distraction is used for bone lengthening (primarily), for correction of bone deformities, for bone segment transport, as a stimulus for nonunion and pseudoarthrosis healing, as a stimulus for neovascularization, and for joint contracture correction.

Motor forces of distraction are achieved by movement of the nuts fixed to the ring or by turning of the graduated telescopic rod, and are translated to the tensioned wires introduced into the bone. Three parameters of these forces produce the full effect of distraction: speed, rhythm, and distribution on the bone circumference.

The optimum speed is 1 mm/day, and the optimal rhythm is four times per day. Thus there must be four distraction adjustments daily, at intervals of 6 hours, with each adjustment being 0.25 mm, or one-fourth of the thread pitch.

The speed and rhythm of distraction are adjustable; in some cases they must be increased, in others reduced.

The chief indications for increase in distraction speed and rhythm include: (1) young age of the patient, usually children up to 12 to 14 years; (2) when the X-ray control image indicates a tendency to premature bone consolidation at the site of distraction; and (3) when the X-ray control image indicates an uncompleted bone cut at the site of corticotomy.

The chief indications for reduction of the distraction speed and rhythm include: (1) severe pain at the site of distraction, especially after creating a 3- to 4-cm gap; (2) clinical signs of peripheral vascular and/or neurologic deficiency; (3) X-ray control image indicates slow development of bone regeneration.

In any event, the increase in distraction speed and rhythm cannot exceed 1.5 mm/day, in increments of six turns of 0.25 mm. The reduction of distraction cannot be less than 0.25 to 0.50 mm/day. In some cases a situation may arise in which distraction may be halted for 2 to 3 days, and even may be reversed with a slower speed (see compression technique description, later in this chapter).

The motor forces must be distributed evenly on the moving bone fragment circumference. Even distribution requires that these forces be applied with consideration to the number and positioning of wires attached to the ring. The resistance of the surrounding soft tissue to distraction also is easier to overcome with the even distribution of forces. Undesirable bone angulation also may develop because of asymmetric distraction.

Provided that on average two wires are introduced into the bone at a 60- to 90-degree angle to one another, the optimal distribution of distraction forces is four points of application with 90-degree angles between them (Fig. 14.1).

It is not recommended that directional forces be applied to the ring fixed to the bone with half-pins. For distraction of more than 2 to 3 cm there are two reasons to avoid exertion of forces on the half-pin ring. First, the half-pins cut the skin, leaving gross scars. Second, the half-pins do not allow micromotion at the site of distraction, which is an important component of the regenerate bone stimulation.
Distraction Technique

There are three ways to perform distraction with the Ilizarov apparatus:

1. With the wrenches, by turning the nuts attached to the ring. This is done by loosening the nut at the ring wall situated farthest from the distraction site. Then the opposite nut is tightened to the ring wall, turned exactly one-fourth of the full turn. This produces 0.25 mm movement of the ring to the side opposite the corticotomy site and moves the bone. After this, the first nut must be tightened firmly to the ring wall to secure the new ring position (Fig. 14.2).

To be precise in turning the hexagonal nut for one-fourth of a turn, it is useful to compare the

Figure 14.1: Three optimum parameters for distraction forces. Segments of the frame and the bone are shown with the corticotomy site to the right and the ring to the left. Large arrow indicates direction of distraction; small solid arrows indicate sites of application and direction of distraction forces. Four evenly distributed forces are applied to the ring four times a day, each producing 0.25 mm of ring motion each time. Together they produce 1 mm of bone distraction per day

Figure 14.2: Distraction technique using the nuts. Segment of the pushing-pulling ring of a frame is shown with a threaded rod and nuts attached to the ring. Curved arrows indicate direction in which nuts are turned; straight arrow indicates direction of ring movement. A, nut at the wall opposite the distraction site is loosened. B, nut at the distraction site is tightened one-fourth turn, producing exactly 0.25-mm movement of the ring. C, first nut then is retightened to secure the new (moved) ring position
wrench position with the position of a clock hand. This simplifies the procedure, especially for non-trained patients or for parents who must perform this for their children. Imagine the wrench as if it was a clock hand against a dial; the nut must be advanced 3 hours each time (Fig. 14.3). Another way to simplify the precise turning of the nut for one-fourth of a turn is to color one of its six sides (e.g. with nail polish or correction fluid) and to advance the marked side to the 12-, 3-, 6-, and 9-o’clock positions, respectively, with each turn. There also is a special combined nut for the same purpose.

Because the threaded rods are flexible, this technique is recommended only for short rods used between the supporting and pushing-pulling movable rings. It is useful for 7- to 10-cm rods, and for the distraction device.

2. With the increased length of threaded rods up to 12 to 20 cm it is expedient to use the hollow aluminum telescopic rod technique. These rods increase frame stability by increasing the outer rod diameter, and also allow frame expansion from within.

To carry out distraction, it is necessary first to loosen the bolt tightening the head of the telescopic rod, then to turn the nut fixing this head on the threaded rod. The one-quarter turn will produce 0.25 mm of distraction. The bolt must be tightened after each nut turn (Fig. 14.4).

Figure 14.3: Wrench position in technique of distraction by turning of the nuts. The wrench is positioned according to the hands of a clock, and is turned “3 hours” with each turn. This produces 0.25 mm of distraction

Figure 14.4: Distraction technique with the aluminum telescopic rod. Straight arrow indicates direction of distraction; curved arrows indicate directions in which the tightened bolt and fixing nut are turned
3. The most reliable, and the recommended method of performing distraction is by using the graduated telescopic rod. This device has a rotating head with a ratchet mechanism. This mechanism is released by depressing the lever, and it stops by itself after one-fourth revolution. With movement of the levers into locking position, a clicking sound is produced. Because of this sound the rod often is called the "clicker."

The advantage of this technique is that the clicker may be turned with the fingers or with the special 19-mm wrench for telescopic rod, applied to the square part whose sides are calibrated in increments from 1 to 4 (Fig. 14.5).

4. In the 1980s Ilizarov developed the autodistractor, a mechanism programmed to produce a 1-mm revolution of the threaded rod, in 64 micromotions per day. In essence, this is a nonstop motor. Four autodistractors are attached to the threaded rods, and are powered by batteries carried on the patient's belt.

This motor produces smooth distraction and is free of the constant need to be turned. Several companies in the United States now are trying to develop an analog of this system.

Figure 14.5: Distraction technique with the graduated telescopic rod. Curved arrow indicates direction in which the movable head is turned; straight arrow indicates the direction of distraction.

Figure 14.6: Three optimum parameters for compression forces. Segment of the frame and the bone are shown with the nonunion site on the right and the ring on the left. Large arrow indicates compression direction; small arrows indicate sites of application and direction of compression forces. Four evenly distributed forces are applied to the ring four times a day, each of them producing 0.25 mm of ring movement each time. Together they produce 1 mm of bone compression per day.
**TECHNIQUE OF BONE COMPRESSION**

**General Considerations**

Compression is used in treatment of bone nonunion (primarily), correction of bone deformities, bone segment transport, arthrodesis technique, and reversing distraction.

The motor forces of compression are produced by the threaded rods fixed to the ring and are translated to the tensioned wires introduced into the bone or to the half-pins. Use of the thick half-pins for compression can be indicated in some cases of arthrodesis and for short compression (< 2 cm), but is not recommended for a large gap (> 3 cm) nonunion treatment for the same reasons that it is not recommended in distraction.

In most situations compression is produced in the same manner as distraction, but in the opposite direction. The same three parameters of operation effect compression: speed, rhythm, and distribution of forces on the bone circumference (Fig. 14.6).

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**Figure 14.7:** Compression-distraction technique (stage 1). Femoral bone pseudoarthrosis with angulation and shortness. The frame with the pushing component and multiple hinges is applied. The main supporting element of the frame consists of two connected long plates; additional support is provided by the telescopic rod. Pushing component consists of two half-rings connected with hinged rods and connected to supporting plates by hinged pushing devices. Straight arrow indicates direction of correcting forces; curved arrows indicate movement of the hinges. Note that the distal ring is fixed by two half-pins. This decreases risk of knee flexion contracture and is acceptable for a short distraction.
The same three techniques used to produce distraction also are applicable to compression: (1) turning the nuts attached to the ring walls, (2) aluminum telescopic rod, and (3) graduated telescopic rod.

In contrast to the distraction technique, there are few indications for the increase of speed and rhythm in compression, but more indications for the reduction of compression speed and rhythm.

The chief indication for increased speed and rhythm in compression is the creation of a large bone loss after resection. In a situation in which 3 to 5 cm of bone tissue is to be resected, the speed of compression can be increased by up to 1.5 or 2 mm/day. But it is contra-indicated to produce compression with full closure of such a large gap on the operating table. This can produce neurovascular deficiency. The chief indication for reduction of the compression speed and rhythm is severe pain at the site of compression.

Clinical signs of neurovascular deficiency must be monitored, with the X-ray control image indicating completed approximation of the bone fragments. In any event, the speed of compression cannot be reduced to less