TREATMENT OF BONE FRACTURES AND JOINT INJURIES
EXTERNAL FIXATION

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Posttraumatic deformities of the extremity joints resulting from various injuries of the locomotor system are rather common.

Treatment of joint injuries is accompanied by the contrary activity of a physician. On the one hand, the injured tissues require a prolonged rest for healing, but on the other early movements are necessary to restore normal function of the joint. Movements in the joint maintain physiological muscle tension; they prevent muscle atrophy, formation of adhesions, obliteration of the joint slit, ossification of the joint tissues, and normal blood circulation in tissues. Movements prevent contracture of the joint and mutual pressure of the articular ends.

Traditional methods of surgical treatment of joints do not allow for restoring their shape and functions simultaneously. To provide the restoration of both the shape and function of the injured joints at the same time, we jointly with M. Volkov developed an original method of treatment by means of hinged distraction apparatuses for external transosseous fixation of the elbow, knee, wrist, metacarpophalangeal, interphalangeal and ankle joints. These apparatuses are intended for complete static and dynamic unloading of joints and restoration of their function during formation of new articular ends, for elimination of contractures of joints with subsequent restoration of their function, for fixation of periarticular fractures and pseudarthroses with mutual compression of the fragments and simultaneous restoration of movements in the adjacent joint, for fixation of the articular ends at joint grafting with simultaneous restoration of function, for reduction of complicated or old dislocations with subsequent development of movements, and for correction of abnormal position of the extremity and subsequent arthrodesis at any functionally favorable angle of fixation of the articular ends. The requisite condition for successful consolidation of bone fragments is a tight and stable contact of the correctly reposed fragments. To carry this out, a method of treating bones by means of apparatuses for external transosseous fixation came into use, among other methods, during the past decades.

Observations reveal a great potentiality of compression-distraction osteosynthesis for the treatment of fractures and pseudoarthroses of tubular bones as well as for lengthening of the extremities.

This monograph presents the data on patients treated with hinged distraction apparatuses. The devices were used for mobilization of ankylosed joints, fixation of periarticular fractures or pseudarthroses with simultaneous unloading and development of movements in the joint, elimination of contractures, reduction of old dislocations. The author personally and jointly with M. Volkov has designed 9 models of reposition-fixation apparatuses for the treatment of fractures and lenghtening of the extremities. This volume includes the data on patients who were treated with these devices.
The greatest experience was accumulated when using various techniques of compression-distraction osteosynthesis in patients with fractures, pseudarthroses as well as for the correction of bone deformities and lengthening of the extremities. Patients were treated at the Russian Scientific Center “Reconstructive Traumatology and Orthopaedics”, the Central Institute of Traumatology and Orthopaedics, the Russian Scientific-Research Institute of Traumatology and Orthopaedics named after R.R. Vreden and clinics of Samara State Medical Institute, Chair of Traumatology, Orthopaedics and Experimental Surgery. The majority of patients in whom the injured joint shape and function were restored using the hinged distraction devices have been observed at the Central Institute of Traumatology and Orthopaedics named after N.N. Priorov and Moscow Regional Scientific-Research Institute named after M.F. Vladimirskiy.

The author jointly with S. Mironov, V. Zilov, E. Novikova and S. Ivannikov for the first time in the academic medicine has advanced and experimentally substantiated the concept of the role of biologically active zones (BAZ) as one of the functional systems of the organism adaptive regulation. Phenomenon of energo-informative exchange between the organism and the environment has been determined and studied.

The results of treatment of ununited fractures and tubular bones pseudarthroses after intramedullary nailing osteosynthesis using apparatuses for external transosseous fixation are presented in the book.

The author hopes that this monograph will be helpful to trauma and orthopedic surgeons in their practical work, and will stimulate new scientific research.

All criticism will be accepted with sincere gratitude.
For over 40 years Professor Oganesyan O., one of the leading trauma and orthopedic surgeons of Russia, the head of the CITO Clinic of Orthopedic Surgery for Adults, Academician of RAMS continues to develop successfully and improve the techniques and apparatuses for external transosseous fixation. The present monograph was written owing to his large personal experience in surgical treatment of several thousand patients in our country and abroad.

Unfortunately the problem of locomotor system injuries is still urgent, that is explained in many respects by continuous growth of traumatism both in Russia and all over the world. The problem of the bone and joint pathology treatment remain equally urgent, in spite of certain achieved success the rate of unsatisfactory treatment outcomes and complications is still quite high. This makes it necessary to perfect the existent and search for new, more effective treatment techniques.

Restoration of the shape and function of the injured extremity joints using hinged apparatuses of his own as well as the apparatuses designed together with Volkov M. is of priority in the scientific research of Prof. Oganesyan.

Another direction of his scientific work is the perfection of the apparatuses with the purpose of precise reposition and rigid fixation of bone fragments.

The proposed monograph is dedicated to one of the progressive directions in traumatology and orthopedics—restoration of the shape and function of joints and extremity as a whole by means of hinged distraction and reposition-fixation apparatuses for external transosseous fixation. On the basis of thorough study of joint biomechanics and the processes of the supportive tissues reparative regeneration the author has elaborated a number of apparatuses of various design as well as the techniques for their application based on the single principle—unity of the joint (extremity) shape and function restoration. The proposed physiologic methods of treatment showed their high efficacy in various lesions of the extremity joints and bones—ankyloses, old dislocations, contractures, extremity shortening, compound fractures, pseudarthroses.

The work is based upon large clinical material, notable for profundity of studies; original illustrations confirm convincingly the theses proposed by the author.

The monograph will certainly be of great benefit to trauma and orthopedic surgeons, as well as to surgeons involved in the treatment of loco-motor system injuries. It also offers large promise for future scientific research.

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Academician of RAS and RAMS
1.1. ANKYLOSES

Ankyloses of joints disturb the extremity function, decrease the working ability and may be the cause of invalidism.

Historically, the development of methods to restore joint mobility after ankylosis was a long and complicated one: from forced flexing and extending of the affected joint, its resection, mobilization and osteotomy near the ankylosed joint to arthroplasty with the use of various auto-, allo- and xenoplastic materials. As far back as 1823 Bush wrote in his Textbook for Teaching Surgery (in Russian) about forced elimination of fibrous ankyloses by means of his mechanical device. However, this device did not come into wide use because of the ankylosis relapse.

During subsequent years, resection of the articular ends was performed to prevent their fusion after mobilization. In order to reduce friction between the articular ends and prevent ankylosis, Groves (1923), Vel'yaminov N. (1924), Sitkovskiy P. (1929), Fridland M. (1936), and Frelov S. (1937) and others recommended resection of the articular ends up to 5 cm. However, too vast resection of the articular ends resulted in joint laxity. Therefore Eletskiy A. (1926), Vreden R. (1929), Payr E. (1934), Level (1946) advised to perform the articular ends resection up to not more than 1.5 to 2 cm.

To restore joint functions, many surgeons [Fridland M., 1928; Vreden R., 1929; Schanz A., 1933] performed joint arthrolysis, which consisted of arthrotomy, dissection of cicatrices, and mobilization of the joint. Both passive and active movements were to be carried out in the joint after arthrolysis to retain the range of mobility achieved at operation. According to Chaklin (1960), arthrolysis provides only slight range of joint motion.

Later, interposition pads were inserted to restore mobility of ankylosed joints. Vreden R. (1909) applied silver or gold plates; Foderel (1895) used celluloid plates; Sitenko M. (1927), Kiptenko N. (1930), and Hass I. (1930) inserted flaps of fatty tissue. In the opinion of the surgeons who used fatty tissue interposition pads, fat resolves slowly and prevents an ankylosis relapse. Basing on the results of 183 operations performed on various joints, Sitenko M. (1927) made a conclusion that fatty tissue inserted into the joint for its interposition often suppurates and produces fistulae. Vreden R. (1929) and Boer W. (1927) applied specially treated mucous membrane of the urinary bladder. The prepatellar capsule material was used by Campbell W. (1922), a muscular spacer by Sabaneev N. (1902) and Vreden R. (1928), beeswax by Samarin N. (1928), Oppel V. (1929), Fazagash I. and German K. (1959), the broad fascia by Kornev P. (1913), Eletsikiy A. (1926), Kiptenko N. (1935), Matzen B. (1958), Balakina V. (1961), Chaklin V. (1960), Kazakevich M. (1968), and Mikhelman M. (1968) and many others. The broad fascia is still frequently used because it gives satisfactory results as an elastic and strong material.
A frozen fetal cranium was used as a pad by Fishkin V. (1955); plexiglass was used by Dykhno A. (1948), polymethylmethacrylate by Vishnevetskaya R. (1947), and fibrinous film by Novikov N. (1956) and Tyshchuk E. (1959). A skin flap was applied by Loeffler F. (1956), Kalio K. (1956), Yusevich Ya. (1961), Balakina V. (1962), Lubegina Z. and Fishkin V. (1962), Demidov A. (1963), Serebryakov V. (1964). According to the data of these surgeons, skin is very strong; it suppresses bone proliferation and blocks fusion of the articular ends. To prevent epithelial cysts, Lubegina Z. and Fishkin V. (1962) and Demidov F. (1963) used for arthroplasty split-thickness skin flaps rather than full-thickness skin flaps. Osteocartilaginous graft was used by Levenets V. (1963), lavsan tissue by Mikhelman M. (1964), periosteum by Kuznetsov N. (1952) and Timofeevich A. (1957), hernial sacs were used by Bondarchuk (1928), tendon sheaths by Payr E. (1934), the serous membrane of the scrotum by Wilmoth C. (1936), and amniotic membrane of the human placenta by Volkov M. and Podkolzin V. (1967).

Preserved membranes of bovine testes were used as spacers in arthroplasty by Peterson B. (1959), Emeliyanov D. (1962), Sklyarenko E. (1966) and Yurchenko A. (1970); Nesterov N. (1969) applied homocartilage that was preserved by deep freezing. Belousova I. (1953) and Boltanova D. (1959) showed in their experimental studies that a fascial pad used in arthroplasty necrotizes completely and is replaced by the connective tissue. Oppel V. (1929) and MacAusland W. (1929) had determined that whatever biological tissue was used for arthroplasty, it degenerated in 3 to 4 weeks and was replaced by a connective cicatrix. These authors have experimentally proved that two months after arthroplasty no one could describe the origin of the pad. Also, fibrous tissue may develop without a pad if a diastasis is kept between the sawn articular ends. In none of these studies those authors observed the formation of a new cartilage.

According to the data of experiments performed by Zimcher J. (1931) and Loffler F. (1956), who applied skin flaps as pads, the latter transformed into dense connective tissue, separate islets of which revealed fibrocartilaginous structures. Pensky Yu. (1893), Vorobiyov N. and Emets G. (1964), and Uleshchenko V. (1965) used homografts of articular cartilage. These writers observed disintegration of the articular cartilage and its replacement by the connective tissue. Consequently, many surgeons gave up using any pads between the newly formed articular surfaces after arthroplasty articular surfaces [Eletskey A., 1926; Fridland M., 1936; Kaplan A., 1970; Volkov M. and Oganesyan O., 1974].

To prevent fusion of newly forming articular surfaces following arthroplasty, Novachenko N. (1948) suggested burning them with an electric coagulator. During the following years, publications appeared on the use of strong solutions of various acids for burning newly formed articular ends. Klimov A. (1948) applied nitric and sulfuric acids, neutralizing them later with sodium bicarbonate; Mezhenina E. (1950) used solutions of nitric, sulfuric and phosphoric acids of various concentrations; Leonchuk A. (1950) applied 50% solution of calcium chloride.

To maintain an articular slit between the articular surfaces formed by arthroplasty of various types, many surgeons [Fridland M., 1930; Chaklin V., 1960; Glysell J. and Ricard, 1963; Mikhelman M., 1968] used the extremity traction for the period from 15 days to 1.5 months.

To prevent fusion Kaplan A. (1970) kept up a diastasis between newly formed articular ends by means of transarticular fixation of the articular ends with two pins.

To provide a constant slit between the elbow joint articular surfaces after arthroplasty, Kuntscher G. (1950) proposed and applied a T-shaped Vitallium plates. A deep hole was
drilled along the bone marrow canal of the ulna, and the long sharpened end of the nail was hammered into it. Another hole was drilled strictly along the joint rotation axis in the trochlea of the humerus, and the shorter branch of the nail was inserted into that hole. The diastasis between the articular ends was 0.5 cm. Kuntscher nails did not come into wide practice because the technique of application was troublesome and the fixation of the articular ends was poor.

In 1963 Seppo A. proposed an application of the metal hinge to the hip joint region; it was used for the formation of neoarthrosis in the intertrochanteric region. Subsequently the author used that method for the restoration of mobility in the arthrotic hip joint.

Suggested by Seppo A. metal hinge (orthopedic endoapparatus) for the restoration of hip joint mobility enables not only to unload the hip joint and provide movements in the unloaded joint but, on the contrary, can hamper such movements for the three following reasons:

• Translational motion and circular movement of the hinge stem are possible only in free space but not within the tissues as it was suggested by the author. When the device functions, soft tissues are inevitably injured by the hinge stem translational motion. As a result inflammatory process develops that is accompanied by pain component.

• Arched slit in which the hinge moves could not stay empty because in several days it will be filled with scary tissue and will impede the hinge motion. Due to the impedance of free motions in the hinges of any endoapparatus, the strength of the device-to-bone fixation always decreases resulting in the loose of the construction as a whole.

• Our data show that for the restoration of the articular cartilage and function of the injured joint it is necessary to maintain distraction of a specified value between the articular surfaces and accurate centering of the articular ends that is possible only with external hinged distraction devices. Constructions for internal application have no such potentialities.

• Slack Seppo device with 5 mm stem cannot function as a hip joint and unload it, because it will not bear such a load; the reinforced construction will not go in the tissues in the region of the hip joint. All existing hip joint implants that are used in our country and abroad are much stronger than the device suggested by Seppo.

• Biomechanics of the hip joint is very complicated. Rotation center of the joint is a point so, any attempt to elaborate an interstitial apparatus that would unload the joint completely and at the same time would not impede joint movements in all or almost all directions, will fail.

• In the other joints the situation is much simpler because the axis, for example of the elbow joint, is a direct line and the joint is of a cylindrical shape therefore the coincidence of the joint and device rotation axes is quite possible. All that enables complete unloading of the articular surfaces and at mutual rotation the surfaces do not come into contact with each other.

The current methods of arthroplasty for the extremity joints cannot always provide for the requisite conditions of sliding in the joint, since essential friction appears between newly formed articular surfaces. In addition, it is not possible to form required geometrically correct shape of the articular ends that hampers smooth sliding of the articular surfaces. The absence of synovial fluid in the joint and increased friction of the articular surfaces create a flow of pain impulses and reflex muscle contracture; and plastic materials applied in
arthroplasty often cause the formation of fibrous adhesions resulting in unsatisfactory outcomes.

1.2. CONTRACTURES

There are many various techniques for conservative and surgical elimination of contractures.

According to Lesovoi V. (1895), apparatuses of Ambroise Pare, Dehelden and Verdu were already applied to eliminate contractures of the joints in the 16th century. In the late 19th and early 20th centuries many hinged sleeve apparatuses were used for various joints: apparatuses of Eulenburg, Sayre, Hessing, Bidder, Blanes, and Oilier for the knee joint; apparatuses of Stromeyer and Lukes for the ankle joint; the Bidder apparatus for the elbow joint; apparatuses of Reibmayer and Bruns for the wrist joints; and apparatuses of Schonborn and Mathieu for interphalangeal joints. These devices are described in many textbooks [Hoffa A., 1893; Haudek M., 1908; Schanz A., 1923; Fridland M., 1928; Vreden R., 1936]. All these apparatuses consist of cuffs or splints applied to the limb both proximal and distal to the joint and are connected by various constructions by means of which correction of the abnormal extremity position is performed. The effecting force in the apparatuses is exerted by a screw, a spring, a spiral and an elastic link.

Eulenburg suggested the apparatus in which the correction of abnormal extremity position is carried out by means of worm gears that drive apart the cuffs fixing joint ends and make the limb extend.

In Sayre apparatus, limb correction is performed by a pressing spiral spring. The spring drives apart the cuffs of the apparatus and extends the joint. In Hessing apparatus (Fig. 1.1), the main element is an extending leaf spring with one of its ends rigidly attached to the bows connecting both ends of the femoral splints. The spring is supported by a bow and the knee joint hinge is placed in its branches. A belt is attached to the free end of the spring; by means of the belt the spring extends the leg, thus correcting contracture of the knee joint.

Hoffa applied and recommended the Bidder apparatus (Fig. 1.2), which eliminated the all-around bracing of the limb. Three troughs, two for the posterior surface of the leg and the thigh and one for the anterior surface of the femur (or for the forearm and upper arm, respectively, in the apparatus for the elbow joint), are the main supports. They are hinged

Fig. 1.1. Apparatus of Hessing.
Part I. LITERATURE REVIEW

on both sides of the joint at the level of the joint rotation axis. Worm gears are built in the hinges, which align the troughs to and therefore correct the contracture.

Blanes apparatus straightens the limb by means of a thick rubber ring stretched by belts; the ring is located on the anterior surface of the knee joint and is linked to two metal levers attached to the splints on both sides.

Oilier apparatus is of interest. It extends the knee joint using the elastic energy of the spring. The thigh and the leg are covered with leather sleeves. Two side steel splints are attached to each of them and are linked by hinges. Three plugs are mounted on each of the hinges, and strong clock springs are inserted into each plug, 3 to 6 on each side as needed. These springs straighten the knee joint gradually.

Among the devices for the elimination of ankle joint contracture, the Stromeyer apparatus (Fig. 1.3) attracts the interest of orthopedic surgeons. It consists of a splint with a belt applied to the posterior surface of the leg and a footboard hinged to this splint. A rope pulls the footboard. The rope is pulled by a ratchet-and-pawl gear, causing the foot gradually to flex and thus eliminating an extension contracture.

The Schenborn apparatus (Fig. 1.4) was widely applied in the early 20th century to correct finger contractures. It consists of a leather sleeve with a steel splint on its dorsal side. The splint is shaped like a trough and covers two-thirds of the first phalanx of the affected finger. Another trough splint is hinged to the first one and covers the plantar surface of the second and third phalanges. This trough is pulled by an elastic band dorsally and thus causes the finger to extend.

In 1928 Sazontov V. proposed an apparatus to correct contracture of the knee joint. The apparatus consists of two metal bands with uniaxial hinges. The hinges on both sides are

Fig. 1.2. Apparatus of Bidder.

\[a\text{—for the elimination of knee, and } b\text{—elbow contractures.}\]
aligned with the knee joint axis. The bands are mounted on two cuffs, one around the ankle joint over the malleoli, the other around the proximal third of the femur. There is a screw on the lateral surface of the apparatus. Rotation of this screw in one direction flexes the knee joint while rotation in the other direction extends the joint. Treatment requires bed rest. The technique of the apparatus application is rather complicated.

In the Abramson device two cylindrical bushings with an internal thread are mounted on two bows, one for the femur and one for the shin. A central screw controls two pairs of screws with right-hand and left-hand threads. Its rotation causes the bushings to move apart gradually and smoothly. These movements are transferred to the extremity segments to which the bows are plastered. The apparatus is simple and does not impede walking.

Subsequently many apparatuses to correct contractures of various joints were elaborated by Fridland M. (1928), Preston R. (1934), Petrov V. (1942), Il’in V. (1953), Schede F. (1953), Belyakov P. (1958), Vitenko P. (1967), however they were not too much different from the apparatuses developed earlier.

In some cases the splint-sleeve apparatuses allowed to correct fresh joint contractures. Their main disadvantages are compression of soft tissues and mutual pressure of the joint
surfaces. They also do not provide for restoration of joint functions after correction of the abnormal extremity position.

To eliminate contractures many surgeons of the past [Bekkers L., 1860; Pirogov N., 1865; Bruns G., 1901; Aberle R., 1904; Frolov V., 1909] performed single-step redressment of the joints. However, such severe complications as subluxation, vessel rupture, embolism, or paralysis due to nerve tension compelled surgeons to give up this technique. Krupko I. (1946) wrote that the crippling method should be excluded from the arsenal of techniques for contractures treatment.

Cuff, kleol and skeletal types of traction are also applied to correct joint contractures. In 1928 Tregubov S. suggested his original technique of “drop” traction. The weight for traction was a small pail into which three drops of water fall each minute; i.e., about 250 ml per 24 hours.

According to Nikiforova E. (1945), Fridland M. (1954), and Chaklin V. (1960), kleol or cuff traction is indicated only in fresh contractures when the muscles are not shortened and there are no gross changes in the capsule.

Vegner K. (1917), Fridland M. (1928), Hass S. (1938), Bom G. (1943), and Ochkur I. (1944) started to apply skeletal traction in patients with more persistent contractures.

Compared with splint-sleeve apparatuses and staged plaster casts, traction has certain advantages, i.e. the joint capsule stretches and mutual pressure of the joint surfaces decreases. Skeletal traction allows for a small range of active movement in the joint. But traction also has its disadvantages (the patient has to stay in bed for a long time and difficulties in nursing). Fridland M. (1936) noted that maintenance of partial mobility in a separate joint during skeletal traction is often acquired at the high price—general immobilization of the patient.

Further development of the techniques for joint contractures correction was promoted by implementation of the winding technique [Momsen F., 1920] (Fig. 1.5). The technique consists of the following: Plaster tutors are applied proximal and distal to the joint, leaving the joint free. Uniaxial hinged arms are cast to the lateral surfaces of the tutors and a rod is cast to the anterior or posterior surface (depending on the joint) of one tutor. The end

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Fig. 1.5. Winding by Momsen.
of the rod should reach the distal third of the other tutor; free end of the rod is connected to a plaster tutor by a double cord. Then the cord is gradually wound up by means of a stick so as to draw together the distal part of the limb and the end of the rod, which results in the limb extension.

Momsen technique was modified. To eliminate the knee joint contracture Ermolaev G. (1927) added a curved lever in the anterior surface of the leg cast so that the direction of the effective force would coincide with the parameters of joint movements. Nikiforova E. (1945) casted the rod not directly into the anterior surface of the femur but into two Bohler stirrups, so that the external force correcting contracture would be distributed over the whole anterior surface of the femur but not focused in the region of the distal third of the femur.

The “winding” technique came into wide use in the Soviet Union. Shturm V. (1929), El’yashberg F. (1934), Pogorelskiy M. (1935), Vereshanovskiy I. (1935), Genkin I., Sukhoryobryi I., and Meerov L. (1944); Firer S. (1945), and Bruk B. (1948) and others perfected that method and put it into practice for correcting contractures of various joints. The advantage of “winding”, as well as of the splint-sleeve apparatuses, is gradual correction of contractures when bed rest in not compulsory. Sometimes “winding” enables to correct not only myogenic but more persistent contractures as well [Bulynin I., 1943; Nikiforova E., 1945; Chaklin V., 1960], however the main disadvantages of both this technique and splint-sleeve apparatuses are compression of soft tissues and mutual pressure of the articular ends.

Conservative methods of contracture treatment include staged plaster casts. Every 5–7 days the joint is extended as much as possible and tight plaster cast is applied. These manipulations are repeated until the limb is straight. Staged plaster casts are indicated in fresh contractures with small-angle of limb flexion. They exclude use of massage, therapeutic physical exercises and thermal procedures for a long period of time. They also impair muscular tonus and may cause bedsores.

In old contractures with advanced changes in the joint and soft tissues operations on the soft tissues or bones are indicated. Operations on soft tissues include various types of skin plasty for scary contractures; transfer, lengthening and grafting of the tendons; transection, mobilization and plasty of the muscles; dissection of the capsule. The most widely used techniques of surgical intervention on the bones are various types of correcting osteotomy in the zone of the articular ends metaphysic. In severe contractures with an essential deformity of the articular ends and grossly limited joint mobility, joint resection is indicated. In myoparalysis a method of choice is arthrodesis.

Despite certain disadvantages the main methods of conservative and surgical treatment of contractures are used in our country and abroad but due to strong compression of the soft tissues and mutual pressure of the articular ends the application of conservative techniques often gives unsatisfactory results. Surgical techniques are more effective but, firstly, it is not physiological since it violates the principle of gradual correction of the abnormal limb position with further restoration of the joint functions. Secondly, movement in the joint cannot be trained for a long time after operation. Thirdly, operation on the joint may be complicated by infection or may cause the formation of postoperative scars. It is essential to correct joint contractures gradually and strictly dosed avoiding the compression of soft tissues and mutual pressure of the articular ends. Early training of joint movements is required for correcting joint contractures.
1.3. OLD DISLOCATIONS

Reconstruction of joint shape and restoration of joint function in old dislocations of the extremity joints is a difficult task for the trauma surgeons.

Fresh and old dislocations of the knee and elbow joints are rather common. There is no general agreement on the treatment of leg dislocations. There are two basic trends: conservative reduction with further immobilization by a plaster cast [Dzhanelidze Yu., 1953; Fridland M., 1954; Vashchenko V. and Tikhomirov V., 1961] and surgical reduction with syndesmoplasty [Wette, 1929; Gissane, 1954; Krupko I., 1961]. In dislocation of the forearm bones, surgical reduction is indicated only when closed reduction fails [Chaklin V., 1960; Kaplan A., 1967].

According to Romanchuk (1971), closed reduction of shin dislocations is permissible only within the first 3 to 4 days. But although such reduction after the fourth day is possible, relaxation occurs frequently. Since cicatrices and ossification develop rapidly in the region of the elbow joint [Watson-Jones R., 1956] surgical reduction of forearm dislocation is recommended as soon as possible, in a matter of days if a closed reduction has failed. Surgical reduction, though possible, is very difficult. Consequently, in inveterate dislocations of the forearm and shin, some surgeons [Nikiforov M., 1930; Konik A., 1940; Griswold A., 1951; Lederer H., 1951] often perform arthroplasty or arthrodesis in a functionally favorable position.

The problem of the duration of immobilization in shin or forearm dislocations remains an issue. In the literature there is a difference of the optimum terms, from several days to 3 or even 4 months. Maiserenko A. (1961), Vainshtein V. (1963), Bartel M. and Kempter M. (1967), and Babich B. (1968) believe that success depends on prolonged fixation of the limb after reduction and advise immobilization up to 4 months in shin dislocations. These authors state that deforming arthrosis may develop when the duration of immobilization is short. Other writers [Konik A., 1940; Chaklin V., 1960; Fridland M., 1954; Korzh A., 1958; Myles, 1967] believe, on the contrary, that prolonged immobilization in leg dislocations results in muscle atrophy, deforming arthrosis, tendon ossification, and joint stiffness. They recommend a relatively short term of the injured extremity immobilization (not more than 10 to 15 days). Considering complications caused by prolonged fixation, some writers [Sommer R., 1928; Osipovsky V., 1937] recommend immobilizing the extremity for only 3 to 6 days after reduction, and then passive and active movements should be started. In forearm dislocations, Kekshin A. (1966) is in favor of short-term fixation with early development of joint functions after reduction. Babich B. (1968) considers a 2-week term of fixation reasonable. Fellus P. (1962) fixes the joints at the angle of 80° for 7 to 10 days; Caravins D. (1957) uses 3 to 4 weeks immobilization period.

According to Korzh A. (1958), Knysh I. (1966) and Shatsillo I. (1963) it is advisable to perform open reduction of old forearm dislocation within 3 weeks. If 4 to 6 weeks or more have passed, arthroplasty of the elbow joint is needed. Sadykina N. (1936) and Slusar’ Ya. (1962) revealed in their histological studies that following the one-step reduction of an old dislocation, joint cartilage resolves due to mutual pressure of the articular ends. In order to improve functional performance after arthroplasty, it is necessary to eliminate undue reciprocal compression. For this purpose, the triceps tendon of the arm is elongated. Vainshtein V. (1963) prefers surgical reduction rather than arthroplasty.
After open or closed reduction, the joint is usually fixed in a plaster cast or a splint. To avoid reluxation, Sosaar V. (1964), Kaplan A. (1967), and Romanchuk I. (1971) suggest additional transarticular fixation with two pins passed cross like through the joint ends.

The disagreements concerning open versus closed joint dislocation reduction and optimum duration of fixation after dislocation reduction are accounted for by the fact that there is no method of closed gradual and dosed reduction of fresh irreducible or old dislocations. There are no methods either that would enable to perform both passive and active joint movements while maintaining exact alignment of the articular ends at a given constant gap between the articular surfaces.

1.4. PERIARTICULAR AND INTRA-ARTICULAR FRACTURES ACCOMPANIED BY THE ADJACENT JOINT CONTRACTURE

Despite certain success achieved in treatment of periarticular and intra-articular fractures of the extremities with the contracture of the adjacent joint, the treatment results are often unsatisfactory. The difficulty of treatment is grounded by the anatomic and functional peculiarities of the joints, problems with perfect reduction of bone fragments of the articular ends and possibility of early movements in the injured joint.

Treatment of intraarticular fractures has certain peculiarities. The main purpose is perfect reduction of the articular ends fragments and restoration of their anatomical shape that results in primary healing of the bone and cartilage. When bone fragments of the articular ends are inadequately reduced and congruence of articular surface is not restored, no primary healing of the bone and cartilage takes place. Irregularity of the cartilage surface of the articular surfaces results in scars and ossifications followed by the development of traumatic synovitis and deforming arthrosis.

The sooner the bone fragment reduction is performed, the better the shape and function of the joint restore. When timely reduction of bone fragments is delayed then hematoma, synovitis, ossification, deforming arthrosis develops and anatomo-functional outcome of treatment becomes poor.

If it is not possible to perform simultaneous complete reduction and fixation of bone fragments using extraosseous and intraosseous osteosynthesis, later it is possible to repeat the reduction of fragments because the construction is placed within the tissues.

When using interstitial constructions it is not possible to provide an adequate contact that is required for the successful fracture regeneration if diastasis between the fragments develops. Internal fixatives do not allow elimination of secondary diastasis between the fragments and to achieve their perfect reduction. Besides, internal metal constructions are to be removed after fracture consolidation and it is rather traumatic procedure.

Our hinged distraction devices for external transosseous fixation enable to achieve gradual and dosed perfect reduction and rigid fixation of bone fragments, maintain adequate contact between the fragments during consolidation period and to develop movements in the adjacent joint. Early active tactics of treatment creates optimum conditions for successful reparative regeneration of tissues as well as for the restoration of the extremity shape and function.
1.5. TREATMENT OF UNUNITED FRACTURES AND PSEUDARTHROSES OF LONG TUBULAR BONE DIAPHYSIS AFTER INTRAMEDULLARY NAIL OSTEOSYNTHESIS

The basic conditions for fracture osteosynthesis are perfect reduction and rigid fixation of bone fragments in order to improve the conditions for fracture consolidation and restoration of movements in the injured extremity. Since the 19th century, with the purpose of rigid bone fragments fixation, two techniques of surgical treatment for diaphyseal long tubular bone fractures have been used, i.e. extraosseous metal constructions and intramedullary nails. These techniques were perfected. Applications of extraosseous fixatives of various designs were suggested by Klimov A., Kaplan A., Trotsenko V., Nuzhdin V. and AO group.

At osteosynthesis of diaphyseal fractures with extraosseous metal constructions vast skeletonization of bone fragments in the zone of fracture is performed that is accompanied by massive blood loss and significant traumatization of tissues. Sometimes it happens that the injury itself is less traumatic than the fixation of bone fragments with bulky 10-screw constructions. It often happens that it is much more difficult to remove the device than to apply it [Brennward A., 1975; Krbec M., 1993].

Various intramedullary nails [Kuz'min B.I., 1890; Levitskiy A., 1893; Razumovskiy B., 1906; Spizharnyi I., 1912; Schone G., 1913; Rush Z., 1943; Kuntscher G., 1940; Cambel W., 1941; Boler Z., 1943; Venable S., 1948] were suggested and applied for the intramedullary (intramedullary) fixation of bone fragments in long tubular bone fractures. The nail is to be tightly inserted into the bone marrow canal and the head of the nail is to project the bone for 1-2 cm so that it is possible to remove it after fracture consolidation. Russian surgeons [Dubrov Ya., 1946; Bogdanov F., 1949; Fridland I., 1956; Kaplan A., 1956; Krupko I., 1956; Chernavskiy V., 1956] have suggested and widely introduced into clinical practice various modifications of intramedullary fixatives. They also have elaborated various techniques of intramedullary osteosynthesis that are used when conservative methods fail. Despite the development of the technique of bone fixation with intramedullary fixatives it was not possible to achieve stable fixation of bone fragments that is why additional external immobilization was used.

For rigid fixation of bone fragments Kunischer G. was drilling bone marrow canal with special long reamers and then inserted massive nails into the canal. The drilling of bone marrow canal resulted in better contact between the nail and inner surface of the bone and thus increased stability of osteosynthesis.

Since the 1970s intramedullary massive nail osteosynthesis with drilling of bone marrow canal has been widely used by Chernyavskiy V., Okhatskiy V. (1956); Suvalyan A. (1971); Karl Storm G. (1974); Schatzker J. (1980) and others.

The drilling of intramedullary canal causes embolization of endosteal intracortical vessels that results in the significant disturbance of cortical plate blood supply and increases the risk of fat embolism, thromboembolism and infection development.

The disadvantage of intramedullary fixatives is rotational instability of bone fragments. According to Kaplan A. (1973) the main disadvantage of bone fixation with nail are rotational movements of bone fragments and absence of mutual stable contact between them. In order to prevent rotational instability of bone fragments at intramedullary osteosynthe-
sis various authors suggested multiple modifications of such fixatives and techniques of their application.

For the stability of osteosynthesis and intramedullary fixation Kaplan A. (1977) performed artificial narrowing of the bone marrow canal lumen using bone grafts. Sivash K. (1971) suggested using compression nail in order to provide stability at intramedullary osteosynthesis. Fishkin V. has designed compression screw with paddles on the end.

In fractures intraosseous fixation of bone fragments is performed either by closed or open technique. When closed method is used after primary bone fragments reduction, which sometimes fails, metal rod is inserted into the bone marrow canal of both fragments via small incision using special devices. As a preliminary under X-ray control special guide is inserted; the rod is hafted to the guide and driven into the bone marrow canal of both fragments; then the guide is removed. At open technique the fragments are reduced in the surgical wound in the place of fracture and then are connected by the inserted rod.

The main disadvantage of bone fragments fixation with rod is the fact that the rod poorly protects bone fragments from vertical movements.

In 1972 the technique of blocking the nail with screws came into practice. This technique enabled to eliminate rotational mobility of the bone fragments.

In 1980 the Association of Osteosynthesis (AO) has designed original nails for the femur and tibia. In 1982 AO elaborated new universal femoral and tibial nails taking into account the peculiarities of the bone marrow canal shape.

Starting from 1986 the information on the use of monolithic block nails without preliminary drilling of bone marrow canal has been published [Zhowe D., Hansen S., (1988); Hass (1990)]. The presence of the nail in the bone marrow canal eliminates horizontal displacement of the bone fragments. Possibility of bone fragments to slide along the nail creates the compression in the zone of fracture. Insertion of blocking screws via the nail improves the contact between the nail and the bone and thus creates an antirotational effect. This method is used in Russia. Suvalyan A. (1999), Volna A. (1999), Sokolov V., Byalik E. (2000), Sergeev S., Zagorodnyi N. (2000) and Charchyan A. (2002) believe that the use of this technique for the treatment of diaphyseal bone fractures accelerates the process of bone fragments consolidation. Postoperative rehabilitation period shortens.

The main disadvantages of blocking intramedullary osteosynthesis for diaphyseal long tubular bone fractures are the following.

1. Formation of diastasis between the bone fragments. After the fracture small bone splinters are inevitably formed on the ends of fragments. Injury of multiple osseous and tissular blood vessels in the zone of fracture results in hemorrhage and formation of necrotic sites. After resorption of these formations the diastasis between the fragments develops. Blocking screws serve as a distance bar and for a long time prevent close contact of the bone fragments until the static screw is removed. Davidovskiy I. (1952), Rusakov A. (1959) considered the distance between the bone fragments to be one of the most important condition that determined the rate of fracture consolidation: the smaller is the distance, the more effective is the process of fracture regeneration.

2. Sliding of bone fragments along the nail at osteosynthesis of oblique and spiral after static nail removal and under physiologic load may result in the shortening of the injured extremity.

3. Disadvantage of blocking intramedullary osteosynthesis is repeated traumatic intervention with the purpose of construction removal.

4. Treatment of patients using the technique of blocking intramedullary osteosynthesis is more expensive as compared with the use of transosseous fixation devices. Besides, it is
necessary to be equipped with an orthopedic table, image converter (IC), set of instruments for osteosynthesis and blocking of the bone. It is often a problem for regional clinics.

The basic complications in intraosseous osteosynthesis are fat embolism, thromboembolism, infection and shock.

Advantages of external transosseous fixation using apparatuses as compared with blocking intramedullary osteosynthesis are the following:

- prevention of diastasis formation between the bone fragments because starting from the first days the apparatus maintains compression and contact between the bone fragments promoting successful fracture consolidation;
- possibility of lateral compression of bone fragments in the apparatus of transosseous fixation in oblique and spiral fractures as well as the possibility of physiologic loading that promotes the consolidation of bone fragments;
- application and removal of the apparatus for transosseous fixation, the use of which is based on the passing of thin nonstatic pins through the extremity with no incision (no need to use a scalpel). Cheap transosseous fixation devices of stainless steel and titanium are intended for external use and can be used repeatedly (only pins are to be changed);
- possibility of external fixation apparatus application at the regional clinics; all one needs are drills and pins.

The main complication of external transosseous osteosynthesis is the inflammation of soft tissues around the pin so when using this technique special attention should be paid to the infection prevention. It is not difficult to avert infection; a surgeon only should keep the requirements of aseptics and good technique. To prevent complications one should try not to pass the pins through the acupuncture points.

In patients with ununited fractures and pseudarthroses, who were admitted to our clinic after insertion of nails into the bone marrow canal, we have started to apply a lightened device, consisting of two or four bows that have been taken from the set intended for the hinged distraction apparatus. In those apparatuses the bone fragments were fixed with one pin. Application of such devices eliminates rotational mobility of bone fragments and creates compression between the fragments resulting in successful consolidation of the fracture. Since 1978 the hinged distraction apparatus for bone fragment fixation and restoration of motion in the adjacent joint [Kaplan A., 1979] has been applied in cases when ununited fracture or pseudarthroses was accompanied by the adjacent joint contracture.

At the end of the 1970s I helped Professor Lapchinskiy A. to replant the hind leg at the middle third level of the femur in dogs. When at replantation we fixed the bone fragments with either extraosseous plate or intramedullary nail, the dog felt discomfort and for several weeks could not load the leg. When we started to fix the hind leg with intramedullary nail in combination with lightened external transosseous fixation device which consisted of four bows and pins, the dog could bear weight to the operated leg in a few days after operation.

To the patients with ununited fractures, pseudarthroses and previously inserted nail in the intramedullary canal we applied either the lightened apparatus or, in case of adjacent joint contracture, hinged device to both articular ends.

In diaphyseal long tubular bone fractures fixation of bone fragments with intramedullary nail in combination with the transosseous fixation device ensures the rigid fixation of bone fragments, maintains close contact between them starting from the first days after apparatus application, eliminates lateral and rotational mobility of bone fragments.