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Step by Step®
Management of Cubitus Varus by Ilizarov Technique

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CHAPTER

7 Ilizarov Instrumentation

INTRODUCTION

The Ilizarov apparatus, as an external fixator, distinguishes itself from other monoaxial fixators, because, before it is applied, it must be assembled by the surgeon. In doing so, the surgeon must consider not only the dimensions of the segment being treated, but must also account for numerous other variables.

Many surgeons consider the Ilizarov fixator to be the only elastic and dynamic fixator. But elasticity and dynamics are an intrinsic characteristic of all fixators which reflect the character of the connection between the bone and the fixator. For example, every fixator in which the bone–apparatus connection lies in a straight line, such as monoaxial fixators, allows for dynamic and elastic movement. According to the configuration of the connection, the bone moves in compression but may also move in angulation. This movement, angulation, according to many studies, is defined as "parasitic" and, therefore, can negatively influence the healing of bone.

The real advantage of the Ilizarov apparatus, as an external fixator, is that it uses transosseous wires which minimize this "parasitic" movement (angulation and rotation) without eliminating the elasticity. This, as many biomechanical studies have shown, appears favorable for bone healing.

Elasticity of the fixator does not equate to weakness of the fixator, therefore, it must be constructed "monolith like" as Ilizarov said. And, dynamic does not mean it has to have fewer connection between the bone and frame. Ilizarov, in his work and lectures, always spoke of stability of the apparatus, referring to the bone-fixator connections.

In evaluating Ilizarov apparatus, that is the stability of the fixator, one needs to take into consideration the following variables:

- Rigidity of the assembly
- Connection between the apparatus and the bone
- Intrinsic (or internal) stability of the treated segment

We will now look, step by step, at the various elements that have to be considered when we set out to build our apparatus.

RIGIDITY OF THE ASSEMBLY

The material from which the half rings are made must be extremely solid and allow minimal bending when subjected to the stress of loading and tensioning of the wires.

The steel which is currently used, with a thickness of 6 mm, is considered the best with respect to weight-rigidity-cost. The carbon fiber rings of the same diameter allow for adequate rigidity to loading, but have a tendency to twist if subjected to the stress of wire tensioning; however, with an augmented thickness to 7–8 mm, this problem is resolved.

The diameter of the ring is inversely proportional to the rigidity of the construct. So, the surgeon, who has a choice, should favor the smallest diameter. However, it is recommended that a minimum distance of 2 cm between the soft tissues and the frame be maintained and that this distance be increased to 3 cm where the formation of significant swelling may occur.

The number of rings is directly proportional to the stability of the system. Therefore, when possible, try to construct frames that have two rings per segment. For example, use four rings for a lengthening.

The connection between the half rings is important. With oblique coplanar connections, there is a tendency to twist in the plane of the ring during wire tensioning. Therefore, for a frame in which there is fixation of one segment with only one ring, it is mandatory to use rings with a standard off-set connection. In this configuration, there are fewer number of holes, and therefore much more resistance to stress.

The rings with oblique coplanar connections have to be reserved for that assembly in which one utilizes a block (two rings connected with rods or sockets).

The number of connections between the various rings is directly proportional to the stability of the assembly.

The drawback here is that the more connections that are applied, the fewer the holes that are available for the application of other parts. The correct number of connections for minimal stability is at least four.

Another factor that influences the stability of the assembly depends upon the type of connection between the various rings; for example, a block of two rings connected with a hexagonal socket is much more stable than a block that uses a threaded rod or a threaded rod with conical washers. This allows for "parasitic" angular or rotational motion between the rings.

The stability of the apparatus is inversely proportional to the distance between the rings. So, in a frame constructed for lengthening, where, by necessary, the osteotomy must be performed in the metaphyseal region, it is advantageous to move the intermediate rings closer together.

CONNECTION OF THE APPARATUS TO THE BONE

The diameter of the wire is directly proportional to the stability of the assembly, that is, a larger diameter wire provides more stability.

Normally, in an adult, 1.8-mm diameter wires are used, while in a child or an adult forearm, a 1.5-mm diameter wire is used.

Also, the number of wires used per ring is directly proportional to the stability of the apparatus. The minimum number, in a wire configuration, is two wires per ring. The tension of the wire is also directly proportional to the stability. Normally, a 1.8-mm diameter wire is tensioned to approximately 110 kg, while a 1.5-mm diameter wire is tensioned to about 90 kg. Less tension must be applied to a wire used on a half ring or a five–eight ring (maximum 50 kg) to prevent ring deformation.

Regarding the crossing of the wires, the best configuration is 90° between one wire and other. The larger the angle of intersection, the greater the stability of the basic part (ring and two wires). The stability decreases with a smaller angle, but is relatively sufficient if the final angle is 45°. Below 45°, the stability decreases rapidly in the plane of the obtuse angle of crossing, invariably motion occurs in the other planes.

Twelve years ago, the original Ilizarov apparatus (rings and wires) was modified for the femoral configuration. This was done with the introduction of arches of smaller dimension fixed to the bone with half pins. The half pins were

5–6 mm in diameter. Obviously, this innovation influenced the stability of the whole system (using more rigid materials and greater diameter half pins increased the stability of the system). Pin configuration described by Catagni–Cattaneo (the so called delta pattern) provides better stability with the pins crossing at 60–90°. This configuration is the result of observing other fixator (Hoffman, 1983) along with the clinical experience of the creator of the assembly.

Finally, with regard to the bone fixator connection, one needs to consider the centralization of the bone axis with respect to the central axis of the apparatus. The closer the longitudinal axis of the bone is to the central aspect of the frame, the more stable the apparatus will be. For anatomic reasons (soft tissues), unfortunately, this ideal configuration is difficult to achieve in the tibia while it is more easily obtained in the femur, humerus, and forearm.

INTERNAL STABILITY

Very important, to the stability of the system, is what is more easily defined as internal stability.

In evaluating a fracture or pseudoarthrosis, one needs to first evaluate the surface area of the injury site—the larger the surface area, the better the stability and, therefore, the possibility of allowing weight bearing.

In lengthening a bone, the quality of the regenerate, its diameter, and its maturation determined the intrinsic stability. The better the maturation, the larger the diameter, and the lesser the length of the regenerate, the more stable is the resulting system. One also needs to keep in mind the quality and the quantity of the soft tissues that surround the bone segment in treatment.

And lastly, do not forget the length of the segment treated: in fact, length interferes negatively with the stability of the whole system.

Summary

Variables which are directly proportional to the stability of the system:

- Rigidity of the materials of the rings
- Number of rings
- Rigidity of the connection between the rings
- Number of the connection between the rings
- Diameter of the wires
- Number of wires
- Tension of the wires
- Crossing angle of the wires
- Diameter and angle of crossing of the half pins
- Centralization of the apparatus
- Surface area of the contact between bone ends
- Diameter of the regenerate and its maturation

Variables which are inversely proportional to the stability of the system:

- Length of the connection between the rings
- Length of the regenerate
- Length of treated segment

Now we can look at what variables are controlled by the surgeon:

- Construction of a stable apparatus with enough rings (at least two levels of fixation per each bone segment)
- Enough wires and half pins per each basic part (ring or arch) (two wires per ring or one half pin or one wire and two half pins)

- In regards to the internal stability, it is necessary to have a good reduction of the fracture and adequate surface contact of a pseudoarthrosis. If necessary, use open reduction to optimize fracture reduction. In the nonunion, bone ends may need to be opened and remodeled to optimize surface contact.
- The diameter of the regenerate depends on the level of the corticotomy. The corticotomy must be performed in the metaphyseal region where the bone has a larger cross-sectional area.
- Obviously, for a good regenerate, the corticotomy needs to be accurate. One must not damage the periosteum nor traumatize the bone. Avoid the use of an oscillating saw or aggressive manipulation.
- The maturation of the regenerate can be guided by careful observation and applying a rhythm of elongation that respects the biology of the patient; if there is slow maturation, the surgeon can intervene with an accord on maneuver or in extreme cases of atrophic regenerate, he may add bone graft.

In conclusion, we again review the basics for stable construction of a circular frame:

- Select an appropriate diameter ring
- At least four connections between the level of the rings and point of bone instability
- Two levels of fixation for each injured bone segment
- Monitor the stability of the parts of the fixator frequently, changing the apparatus during treatment as indicated
- Osteotomy at low energy, subperiosteal, percutaneous in metaphyseal region
- Observe closely the regenerate bone with ultrasound and X-ray

ILIZAROV HARDWARE

The components of Ilizarov apparatus can be divided into two categories—a main and a secondary one.

1. The main parts are standard elements used to correct skeletal deformities—wires (with/without stoppers or olives), half pins, full rings, half rings, arches, wire fixation bolts, (cannulated and slotted), pin clamps, and wire fixation buckles.
2. The secondary parts of the fixator consist of the standard elements necessary for the assembly of apparatus. Namely, threaded rods, telescopic rods, threaded rods with slots, connection plates, curved and twisted plates, supports and posts, hinges, washers, sockets, bushing, bolts, and nuts. To assemble the numerous pieces of equipment, various types of wrenches and wire tensioners are needed.

Half Ring

The ring is made-up of either stainless steel with a mechanical resistance greater than 90 kg/mm^2 or carbon composite ring.

It is available in 12 sizes, viz., 80, 100, 110, 120, 130, 140, 150, 160, 180, 200, 220, and 240 mm inner diameter. Hole diameter of 8 mm with clear spacing between holes of 4 mm. Half rings are ledged at the ends to accommodate the other half ring so that the assembled ring is in one plane **(Figs. 7.1 and 7.2)**.

5/8 Ring

It is available in three sizes of inner diameter 130, 150, and 160 mm. Hole diameter and spacing are same as that of

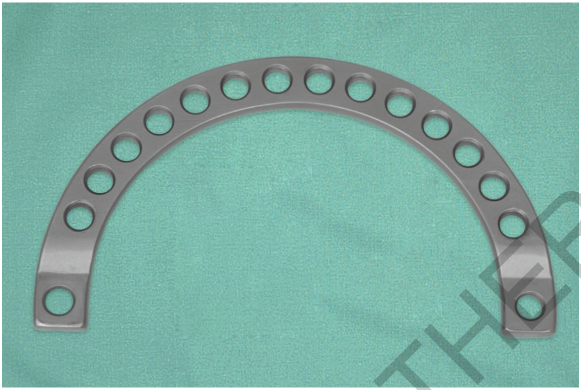


Fig. 7.1: Half ring.

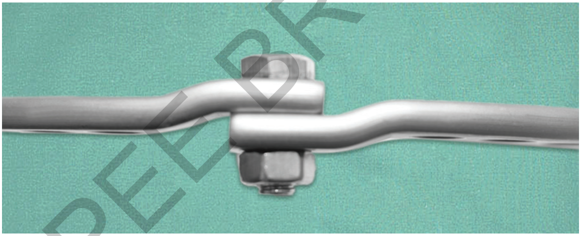


Fig. 7.2: Connected ring.

half rings. It is used near joints to facilitate movement and dressing of open wounds. It is used in combination with another full ring for reinforcement **(Fig. 7.3)**.

Threaded Rod

Threaded rod is of 6 mm diameter with a thread pitch of 1 mm. These are available in lengths of 40, 60, 80, 100, 120, 150, 200,

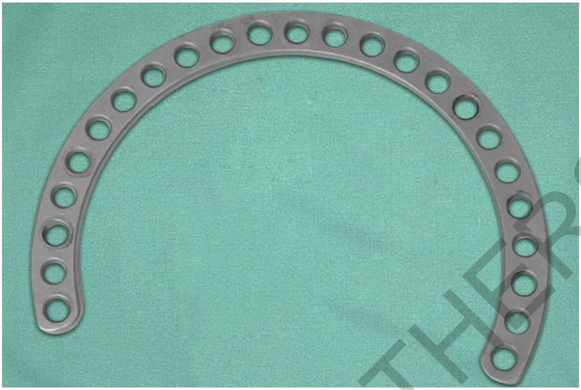


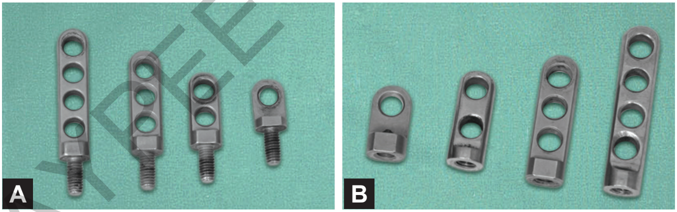
Fig. 7.3: 5/8 ring.

250, 300, 350, and 400 mm, to be used to interconnect rings/arches. Three connecting rods are sufficient to provide the desired mechanical strength when placed 120° apart. Since holes are engaged with other components, it is not possible to maintain 120° spacing and hence four connecting rods are used. Threaded rods can withstand high axial loading but with increased length their stability to resist bending reduces. It is advisable to keep the length of connecting rods not greater than that of the diameter of the rings **(Fig. 7.4)**.

Post

Post is a short plate with 2 to 4 smooth holes of 7 mm diameter and is used as an auxiliary support element for fixing wires/rods/plates at any angle to the main support. They can also be used as locked/mobile joints that can be assembled into multiplanar hinges **(Figs. 7.5A and B)**.

Fig. 7.4: Threaded rods.



Figs. 7.5A and B: Male and female post.

Posts may be male or female. Male posts are 28, 38, or 48 mm long with 2, 3, and 4 holes respectively. Female posts are 30, 40, or 50 mm long with 2, 3, and 4 holes respectively.

Hinges

Hinge female standard and low profile ***(Fig. 7.6)***: These have a supporting base with two flat surfaces for matching standard 10 mm wrench. It has only one hole which is 4 mm thick at base. Low profile half hinges of 30 mm height are also used in multiple planes (hinges have flange on one side).

Construction of hinge ***(Fig. 7.7)***
Hinge male standard and low profile ***(Figs. 7.8A to C)***

Hinge—90° standard and 90° low profile ***(Fig. 7.9)***: In 90° hinges, two flanges are positioned at right angles to the long axis and can be used as a middle component of a two-axis hinge **(Fig. 7.9)**.

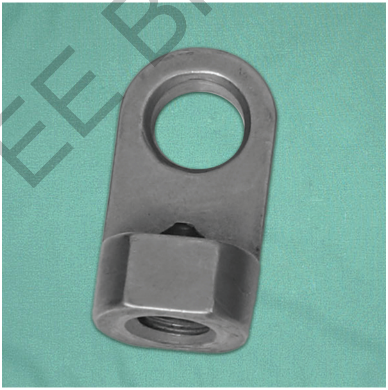


Fig. 7.6: Hinge female.

Step by Step®

Management of Cubitus Varus by Ilizarov Technique

As per our experiences, this book will provide a simplified method of correcting the cubitus varus deformity of the elbow. We have tried and practiced other recommended methods as well and have found our recommended method comparatively useful.

RA Agrawal was born in Uttar Pradesh, India, in 1948. He graduated from GSVM Medical College, Kanpur, Uttar Pradesh, in 1973 and completed his Master of Surgery in Orthopaedics in 1977. He joined government service in 1977 and was posted at Nainital and then transferred to District Hospital, Gorakhpur, Uttar Pradesh, as an Orthopedic Surgeon. He established a 60-bedded orthopaedic and trauma hospital in Gorakhpur. He worked in City Hospital, Karlsruhe, in Germany for 2 months in 1988. He got special training for Ilizarov Technique from Altai Regional Orthopaedic Center, Burnaul, Russia, in June 1994. He received National Award from the Government of India in public recognition for his outstanding performance in the field of "People with Disabilities" in December 2000. He received AO International Fellowship in May 2001 and worked in City Hospital, Feldkirch, Austria. He worked as co-supervisor in the Department of Science and Technology, Government of India, and worked in one project for carbon composite ring at the National Physical Laboratory, New Delhi. He received Gold Medal from the Indian Orthopaedic Association for best poster. He was invited as a faculty member at 13th Limb Deformity Course at Baltimore, USA. He was awarded President's Gold Medal for best paper in UPCON 2007. His previous book "Step by Step Management of Equinus Foot by Ilizarov Technique" is already a success, having sold more than 2,000 copies. He was the Editor of Journal of Foot and Ankle Surgery (India), Past President of ASAMI India, and Past President of UP Orthopaedic Association. His paper "Post-traumatic cubitus varus: Long-term follow-up of corrective osteotomy using the Ilizarov method of compression distraction osteogenesis" has been published in Journal of Pediatric Orthopaedics in 2020. He has been presenting national and international scientific papers from time to time. He has been organizing conferences and camps for the handicapped for many years. He has recently received the "Outstanding Achievement Award" in the 6th World Congress of the ASAMI-BR & ILLRS Societies.

Sureshwar Pandey has a brilliant academic career with more than 40 years of teaching experience. He has authored several books, one of which has the Japanese edition. He has published many papers in the international and national journals of repute. He has been awarded BJMF National Award for his outstanding social work volunteering services to the handicapped. He has been selected as an "International Teacher" to conduct courses in different countries. He is visiting Professor of several universities in Japan, Australia, and Indonesia.

Rajat Agrawal is one of the youngest presidents of ASAMI India from 2023 to 2025. After completing his MS, he did a fellowship in Advance Trauma at Bombay Hospital in 2008. Then, he went to Baltimore, USA, to do a 1-year fellowship in LLRS. In 2010, he joined BRD Government Medical College, Gorakhpur, as an Assistant Professor. He went to Kurgan, Russia, to do Ilizarov fellowship in 2016.

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