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Anatomic factors in the femoral implantation of the Ilizarov external fixator

R Louis, JL Jouve and F Borrione

Service de Chirurgie Orthopédique et Traumatologique, Hôpital Hôtel-Dieu, 6, place Daviel, 13001 Marseille, France

Summary. Ilizarov's method of external fixation with compression or distraction for lesions of the limbs demonstrates new possibilities in osteogenesis. Its performance with double horizontal pinning on several external rings calls for precautions to avoid lesions of the vessels, nerves and joints. This study, based on anatomic sections radiographed after opacification of the arterial system, makes it possible to propose rules for insertion of the pins. Insertion of the anteromedial pins of the thigh should be made 2 cm in front of the line of projection of the femoral artery, between the middle of the inguinal ligament and the posterior margin of the medial condyle. Insertion of the posterolateral thigh pins should be made 2 cm lateral to the line of projection of the sciatic nerve, between the center of the ischio-trochanteric interval, the apex of the popliteal fossa and the posterior aspect of the head of the fibula.

Bases anatomiques pour l'implantation fémorale du fixateur externe d'Ilizarov

Résumé. La méthode d'Ilizarov de fixation externe des lésions des membres avec compression ou détraction met en évidence des possibilités nouvelles d'ostéogenèse. Sa réalisation avec double embrochage horizontal sur plusieurs anneaux extérieurs nécessite des précautions pour éviter des lésions vasculo-nerveuses et articulaires. Le travail, basé sur des coupes anatomiques radiographiées après opacification du système artériel, permet de proposer des règles d'implantation des broches. La pénétration des broches antéro-internes de la cuisse doit se faire à 2 cm en avant de la ligne de projection de l'artère fémorale, entre le milieu de l'arcade crurale et le bord postérieur du condyle interne. La pénétration des broches postéro-externes de la cuisse doit se faire à 2 cm en dehors de la ligne de projection du nerf sciatique, entre le milieu de la distance trochantéro-ischiatique, le sommet du creux poplité et la face postérieure de la tête péronière.

Key words : Ilizarov – External fixator

Although Ilizarov has been practising his method for some 30 years at Kurgan, in Russia, his work has only become known in Europe in recent years, thanks only to Italian orthopedic surgeons. It does not concern just one more external fixator among so many others, but a method of treatment that has disclosed new possibilities of controlling osteogenesis.

The apparatus itself is rather rudimentary, using half-rings assembled in complete circles around segments of the limb and fixed to the axial skeleton by crossed pins at right angles to each other and to the axis of the limb. The rings, to the number of 2 to 4 for each segment of the limb, are connected together by vertical rods, creating the framework of what amounts to a cylinder outside the limb. The rods connecting the rings are capable of creating, as required, very gradual compression or distraction forces that can be regulated several times a day (Fig. 1ab).

The phenomena induced by this method make it possible to treat certain conditions in a remarkable manner, in particular infected pseudarthroses without

Offprint requests : R Louis

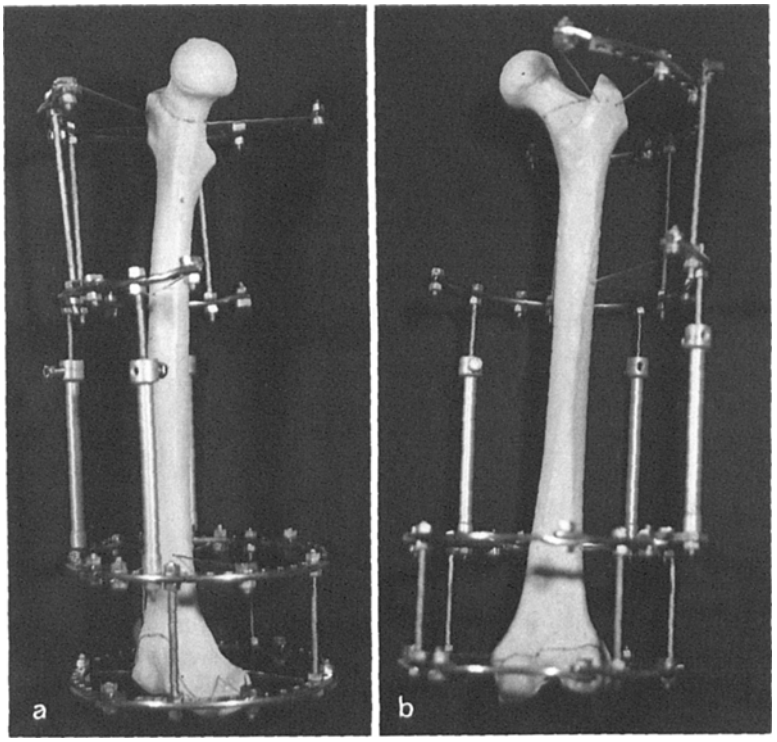


Fig. 1ab
Arrangement of the Ilizarov apparatus on two femurs, with 4 rings to each of which are fixed two crossed transfemoral pins *a* medial aspect of right femur *b* anterior aspect of left femur

Montage de l'appareil d'Ilizarov sur deux fémurs avec 4 anneaux sur chacun desquels sont fixées deux broches entrecroisées transfémorales *a* vue médiate droite *b* vue antérieure gauche

directly approaching the lesion, to repair even extensive loss of substance in the shaft without the use of bone-grafts, and to lengthen several limb segments in the same patient (dwarfism) to an extent previously unequalled and without the aid of supplementary bone-grafting.

Ilizarov's discoveries constitute the major development in orthopedics in recent decades, but the transfixion of the limbs by so many pins carries some risk of neurovascular damage. This work was undertaken to add some supplementary data to the classical anatomic features and to recent studies dealing with sections of the limbs, either anatomic or obtained with a scanner.

Materials and methods

Our experience with Ilizarov's method is both clinical and anatomic. From the clinical aspect, we have used the method for two years and have thus been able to demonstrate the difficulties of positioning the pins at the various levels, despite a good acquaintance with the neurovascular axes of the limbs. Given that it is important for the two pins of the same ring to cross as perpendicularly as possible, the levels of placement often make it very difficult to satisfy this condition while avoiding risks to the nerves and vessels.

From the anatomic aspect, we carried out the injection of the entire arterial system of two cadavers, one male and one female, using a mass with a radio-opaque red lead base. The cadavers were frozen and then sections were made and radiographed. Each thigh was divided into 10 slices of equal height between the tip of the great trochanter and the interspace of the knee. Each section was also photographed. Penetration of the pins, avoiding neurovascular axes and joint cavities, was studied in each of the sections by means of photography and radiography (Fig. 2a-e).

Results

It was easy enough in each of the 10 thigh sections to determine the best possible track for the pins so that they should be sufficiently separate from each other and from structures at risk. It is very difficult to find a methodology as simple for use in practice. We have decided to state the rules of implantation of the pins in relation to their direction of penetration. The pins thus fall into two main categories : those inserted from an anteromedial site and those inserted from a posterolateral site.

Anteromedial penetration (Fig. 3A)

At the anteromedial region of the thigh the actual risk is to the femoral vascular bundle. Given that it is easier, during the insertion of a pin (caliber 1.8 mm), to control its direction near the skin passage than beyond its

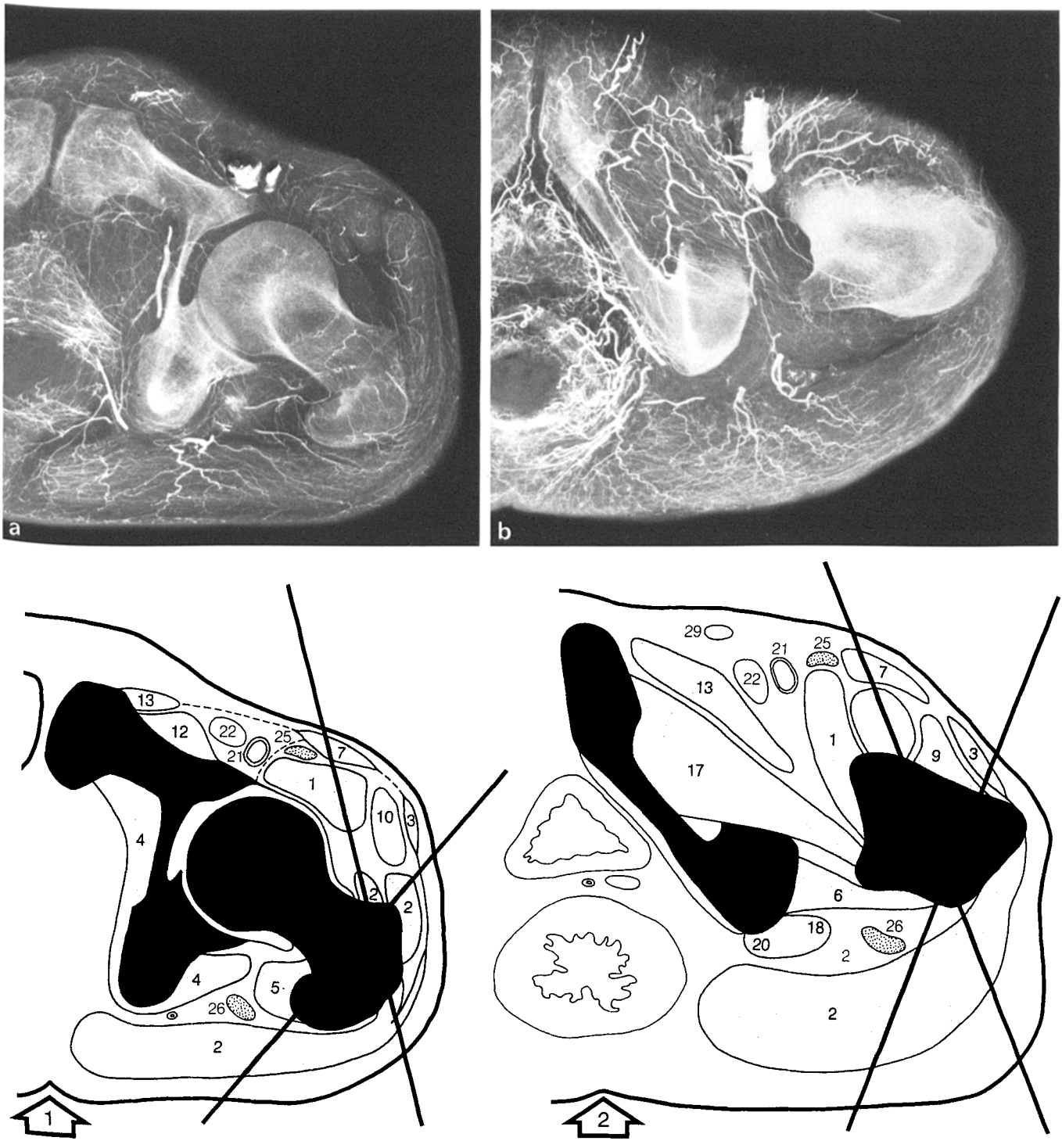
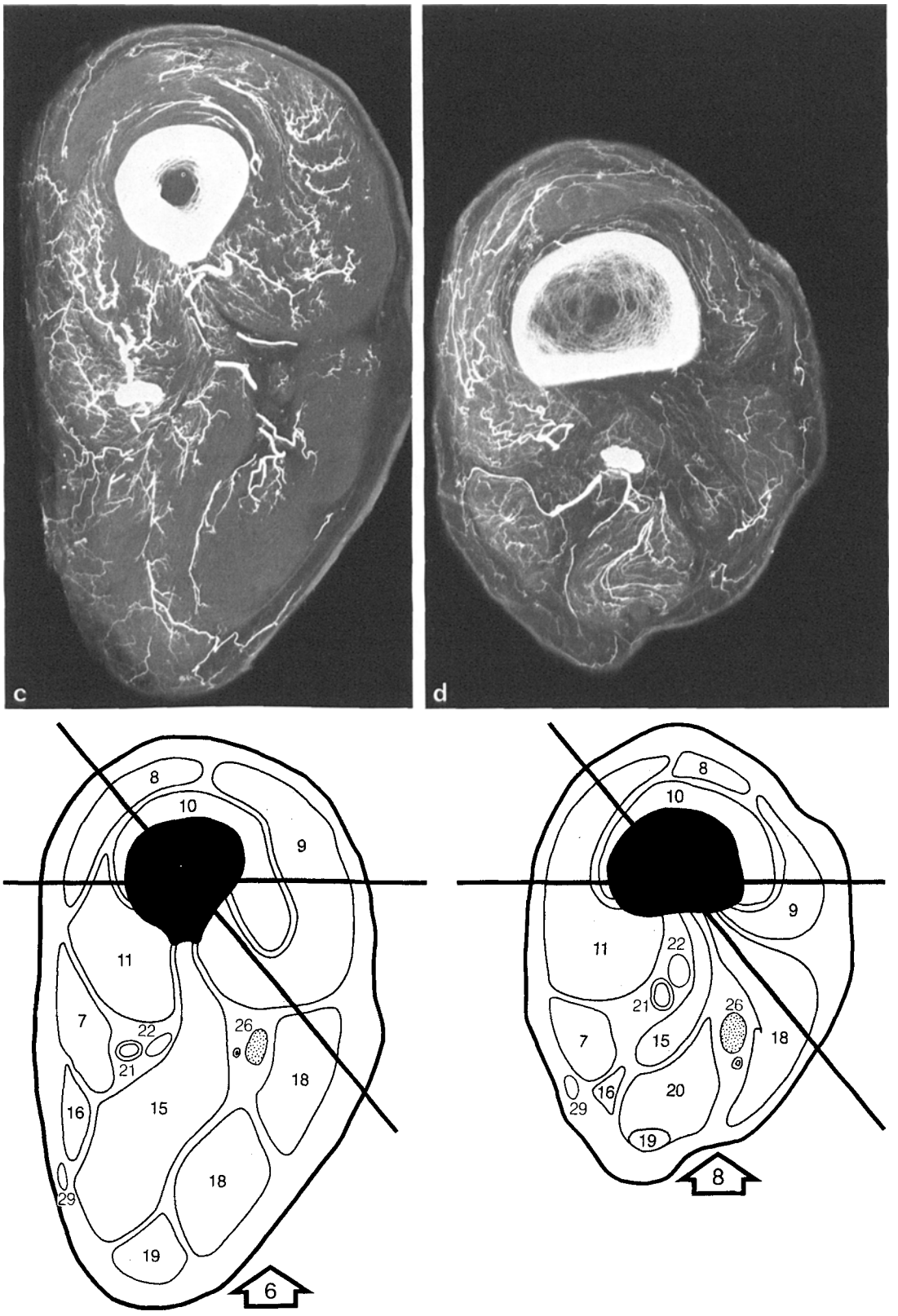


Fig. 2a-e

Serial sections of the thigh at the level of sectors 1, 2, 6, 8 and 10. Each section shows the ideal placement of the pins. *1* Iliopsoas *2* Gluteus maximus, minimus, medius *3* Tensor fasciae latae *4* Obturator internus *5* Gemelli *6* Quadratus femoris *7* Sartorius *8* Rectus femoris *9* Vastus lateralis *10* Vastus intermedius *11* Vastus medialis *12* Pectineus *13* Adductor longus *14* Adductor brevis *15* Adductor magnus *16* Gracilis *17* Obturator externus *18* Biceps femoris *19* Semitendinosus *20* Semimembranosus *21* Femoral artery *22* Femoral vein *23* Popliteal artery *24* Popliteal vein *25* Femoral nerve *26* Sciatic nerve *27* Common peroneal nerve *28* Tibial nerve *29* Great saphenous vein

Coupes étagées de la cuisse au niveau des secteurs 1, 2, 6, 8 et 10. Sur chaque coupe figure l'emplacement idéal des broches *1* miliopsoas *2* m. gluteus maximus, minimus, medius *3* m. tensor fasciae latae *4* m. obturatorius internus *5* mm. gemelli *6* m. quadratus femoris *7* m. sartorius *8* m. rectus femoris *9* m. vastus lateralis *10* m. vastus intermedius *11* m. vastus medialis *12* m. pectineus *13* m. adductor longus *14* m. adductor brevis *15* m. adductor magnus *16* m. gracilis *17* m. obturatorius externus *18* m. biceps femoris *19* m. semitendinosus *20* m. semimembranosus *21* a. femoralis *22* V. femoralis *23* a. poplitea *24* v. poplitea *25* n. femoralis *26* n. ischiadicus *27* n. peroneus communis *28* n. tibialis *29* v. spahena magna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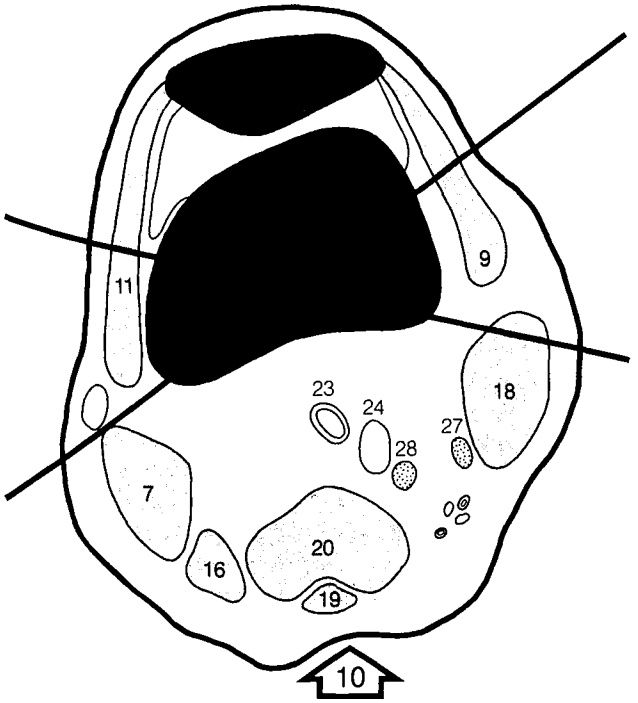

passage through the bone, we recommend that pins due to emerge in the anteromedial aspect of the thigh should be inserted with reference to the landmarks of the femoral vessels. We found that the best method of marking the skin projection of the femoral vessels was to use Faraboeuf's landmarks for tracing the line of incision for exposure of these vessels. This involves drawing on the skin a line extending from the middle of the inguinal ligament, equidistant from the anterior superior iliac spine and the pubic tubercle, where the femoral pulse can be felt, to a point situated immediately behind the medial femoral condyle.

The penetration of the pins must be made 2 cm in front of this line towards the region of the femoral shaft, which can be ascertained with the tip of the pin. The angle of penetration of the pins in relation to the median sagittal plane of the thigh varies progressively from 25° to 120° from the first (upper) segment to the tenth (lower) segment of the thigh (Fig. 3).

The first four segments of the thigh correspond to the femoral triangle. As the artery becomes deeper and deeper, the angle of penetration of the pins should deviate downwards from the sagittal plane by 25°, 30°, 50° and 70° respectively. At the middle region of the thigh, i.e., in the 4 subsequent segments, corresponding to the adductor canal, the angle of penetration should be at 90° in relation to the sagittal plane.

Finally, for the two last sections adjoining the knee region, penetration must depart still more from the sagittal plane, since the artery becomes posterior, reaching 100° at the ninth segment and 120° at the last segment. The pins inserted by the anteromedial route will emerge at the lateral surface of the thigh.

Posterolateral penetration (Fig. 3P)

Next to the femoral bundle, the second great danger for the pins placed posteriorly is the sciatic nerve and its two terminal branches, the tibial and common peroneal nerves. To avoid these nerve trunks, it is therefore important to insert the pins directly through the posterior aspect of the thigh, starting from the projection of the nerve. The nerve is projected on a vertical line which passes from the buttock, equidistant from the trochanter and the ischial tuberosity, to the middle of the popliteal fossa at the knee.

At the lower third of the thigh, the projection of the common peroneal nerve is made on a line passing from the posterior aspect of the head of the fibula to the preceding line at the apex of the lower third of the thigh. Insertion of the posteromedial pins must be made 2 cm outside these nerve landmarks.

We have found to optimal angles of insertion for each of the pins in relation to the median posterior sagittal plane of the limb, for the 10 sectors of the thigh,

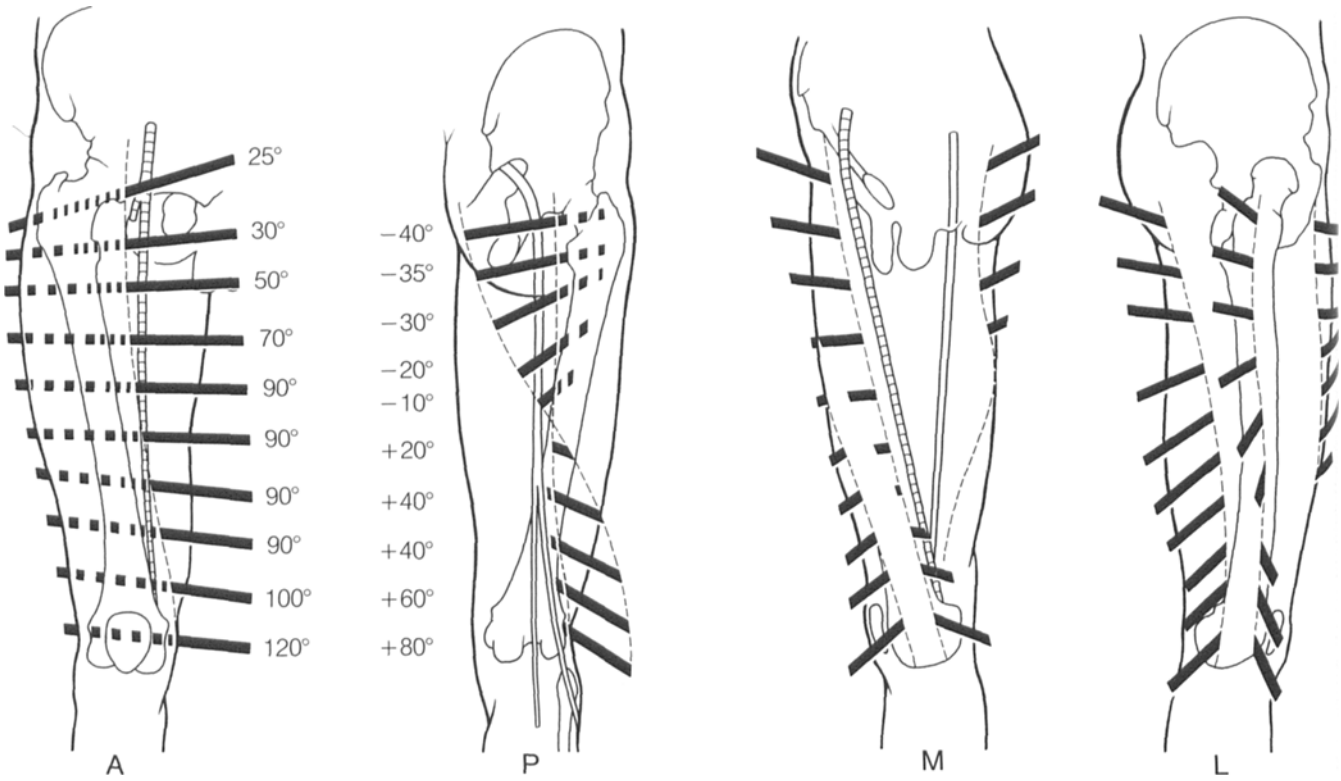

Fig. 3
4 diagrams of placement of the femoral pins *A* Anterior view of pins inserted anteromedially in front of the femoral vascular axis *P* Posterior view of placement of pins inserted posterolaterally, based on the reference projection of the sciatic nerve *M* Medial view of placement of transfemoral pins *L* Lateral view of placement of transfemoral pins

4 schémas de la mise en place des broches fémorales *A* Vue antérieure des broches à pénétration antéro-interne devant l'axe vasculaire fémoral *P* Vue postérieure de la mise en place des broches à pénétration postéro-externe à partir du repère de projection du nerf sciatique *M* Vue médiale de la mise en place des broches transfémorales *L* Vue latérale de la mise en place des broches transfémorales

to be as follows : for the upper half of the thigh, penetration is made medial to the median sagittal plane at angles of −40°, −35°, −30°, −20° and −10°; for the lower half of the thigh, the angle of penetration is made lateral to the median sagittal plane, i.e., at positive angles whose values from above downwards are 20°, 40°, 40°, 60° and 80°. These pins emerge at the anterior aspect of the thigh.

For each sector of the thigh, the pins belonging to the two series mentioned must be in the same horizontal plane, i.e., perpendicular to the axis of the limb. It is virtually impossible in the thigh to place the pins strictly perpendicular to each other because of the risk of neurovascular damage. The angle of intersection is, on average, 60° in the upper third of the thigh, 110° in the middle third and 45° in the lower third.

Discussion

We now wish to discuss the systems of landmarks, the risks to nerves and vessels, musculo-tendinous injuries, the risks to joints and the possibilities for percutaneous osteotomy.

Systems of landmarks

Bianchi-Maiocchi subdivides the thigh into 12 segments, which is not too easy to manage in practice for the thigh of every patient. Our division into 10 segments is easier for measurement, as it is enough to divide the femoral length by ten to give the height of each segment of each patient. Other authors have put forward descriptions of bands of skin where pin insertion is permissible or forbidden, but it is not easy to reserve such complicated surfaces for each of the segments of the limbs. Our reference system, based on a vascular and a nervous line with the size of the angles in regular progression from above downwards, is helpful to memorization on the one hand and to practical performance on the other.

Risks to nerves and vessels

There have been numerous clinical reports of neurovascular complications in the employment of Ilizarov's method.

It is not therefore unprofitable to insist quite firmly on precise and reliable landmarks. Other neurovascular risks may arise, either from the progressive lengthening of the limb or from relative displacement of the pins when a ring is progressively displaced to mobilize a bone segment. In fact, the slow and regular inferior elongation by 1 mm a day promotes not only elongation of the limb at the bony level but also elongation of the soft parts, including the vessels and nerves, without any deficit or ischemia. On the other hand, relative displacement of intermediate pins over a considerable distance for the repair of major losses of bone substance may theoretically bring a pin into contact wity neurovascular structures, even though the initial insertion had been made correctly. Therefore, the final direction of the intermediate pins should be envisaged to avoid their penetration into dangerous territory. Given the spiral shape of the zones of election for penetration of the pins, it may be indicated to secure, over and above the axial movement of a ring, a rotation allowing regular distancing of the pins from the neurovascular axes.

Musculo-tendinous injuries

Penetration of the pins through the musculo-tendinous layers may be a major and definitive factor in tissue damage. In fact, the method aims at transfixing the muscles in their longest position. When the pins in the first part of their course penetrate a plane of extensor muscles, the limb should be flexed; and when the pin has traversed the bone and arrived in the flexor muscle plane, the limb should be extended. This technical detail makes it possible for the muscle to retain a certain of lengthening, thus permitting adequate residual mobility for the joints above and below.

Risks to joints

In order to avoid osteoarthritis with possibly permanent residual stiffness, it is desirable that the pins should not penetrate the synovial cavities. At the hip, this danger is avoided by using pins that penetrate the trochanter only. At the knee, penetration at the medial and lateral aspects of the condyles, and at least 1.5 cm above the femoro-tibial and patello-femoral parts of the joint-line, will avoid synovial penetration.

Percutaneous osteotomy

The Ilizarov method implies the possibility of percutaneous osteotomy, either to correct axial malalignment or to compensate for loss of substance in the bone by displacement of an intermediate bone segment. Such an osteotomy must use the rules governing pin penetration, in order to avoid the neurovascular axes.

Conclusions

The classical anatomic knowledge of the neurovascular axes of the thigh does not suffice for placement, with the minimum of risks, of crossed pins at each of the horizontal planes of the thigh.

Penetration of the anteromedial pins of the thigh should be made 2 cm in front of the line of projection of the femoral artery, between the middle of the inguinal ligament and the posterior margin of the medial femoral condyle. The angle of insertion of these pins increases from 25° to 120°, in relation to the sagittal plane, between the first (upper) segment and the tenth (lower) segment of the thigh.

Penetration of the posterolateral pins of the thigh should be made 2 cm lateral to the line of projection of the sciatic nerve, between the center of the ischio-trochanteric interval, the apex of the popliteal fossa and the posterior aspect of the head of the fibula. The angles of insertion vary between −40° at the first (upper) segment and +80° at the tenth (lower) segment of the thigh.

The angle of intersection of the two types of pins varies between 45 and 110°.

Percutaneous osteotomy should utilize the same landmarks as insertion of the pins.

References

1. Bianchi-Maiocchi A (1985) Introduzione alla cononscenza delle methodiche di Ilizarov in orthopedia e traumatologia. ASAMI Editore Medi Surgical Video, Milano
2. Ilizarov GA, Soibelman A (1969) Clinical and experimental dates on bloodless lengthening of lower extremities. Exp Khir Anest 14 : 27-32
3. Ilizarov GA (1971) Basic principles of transosseous compression and distraction osteosynthesis. Orthop Traumatol Protez 32 : 7-15
4. Ilizarov GA, Trokhova VG (1973) Surgical lenghtening of the femur. Orthop Traumatol Protez 34 : 51-55