General Principles of Patient Management in the Postoperative Period

32

Leonid Nikolaevich Solomin

Postoperatively, it is necessary to check the peripheral pulse and the skin color (Fig. 32.1). After the patient's recovery from anesthesia, nerve function is tested (Fig. 32.2).

32.1 Position in Bed

The bed for patients who have undergone external fixation should be equipped with a Balkan frame for subsequent exercise therapy (Fig. 32.3). After external fixation of the humerus, a wedge-shaped pillow is placed between the side of the body and the device so that the arm is abducted by 35–45° (Fig. 32.2b). After external fixation of the forearm, the arm is elevated by placing it on a roll or pillow. Two rods are fixed to the distal support of the forearm between which a gauze sling is attached to support the hand in the mid-physiological position (Fig. 32.4).

Patients who have undergone external fixation of the femur should stay in bed for 7–10 days with the knee flexed at 90–100° (Fig. 32.5). A convenient method is to attach the distal support with an elastic fixator to the Balkan frame. It is also possible to use a stand made from the components of the Ilizarov apparatus; one end of the stand is fixed to the distal support and the other rests against the bed. The first night after the operation is particularly important. After the patient has regained consciousness the knee joint is flexed. The time spent in bed with the knee joint flexed can gradually be reduced.

Following external fixation of the bones of the lower leg, the extremity is kept elevated for 2–4 days. A foot support that limits plantar flexion (Fig. 32.6) is used. In fractures, this support is maintained until the active range of motion in the ankle joint is not less than 30/0/5. In deformity corrections, especially lengthening of the lower leg, the foot support should not be removed, including (preferably) overnight, for the entire period of distraction.

32.2 Anesthesia

Narcotic and non-narcotic analgesics are used for the first 2–3 days after the operation. The need for their further administration and that of other drugs is determined individually. After external fixation for acute trauma, pain in the fracture region should last no more than 3–4 days. Remaining, stable pain generally indicates a technical problem with the external fixation. First, it is necessary to remove pressure from the transosseous elements on the soft tissue by releasing the skin and fascia, if necessary, and by moving the element in the tunnel formed in the soft tissue. The skin is then sutured (Fig. 7.35). Additional information regarding the treatment and prophylaxis of pain can be found in Chap. 26. Pain is a symptoms of most of the complications discussed. Continued psychological lability of the patient despite a reduction in the pain threshold suggests that a consultation with a psychotherapist would likely be beneficial to the patient.

32.3 Dressings

The first dressings are generally applied the day after the operation. All gauze dressings are removed. The skin and device components are carefully cleaned of blood and wound exudate using a hydrogen peroxide solution. The exit sites of the transosseous elements are treated with iodine solution, the traces of which are removed using an alcohol solution to prevent skin burn. The next step is to cover the exit sites of the transosseous elements with gauze dressings impregnated with 70% ethyl alcohol. The dressing should not be wrapped on the wire because this leads to pressure on the skin. The dressing is cut in the middle, placed over the wire, and

L.N. Solomin, M.D., Ph.D.
R.R. Vreden Russian Research Institute of Traumatology and Orthopedics, 8 Baykova Str., St. Petersburg 195427, Russia
e-mail: solomin.leonid@gmail.com

L.N. Solomin (ed.), *The Basic Principles of External Skeletal Fixation Using the Ilizarov and Other Devices*,
DOI 10.1007/978-88-470-2619-3_32, © Springer-Verlag Italia 2008, 2012

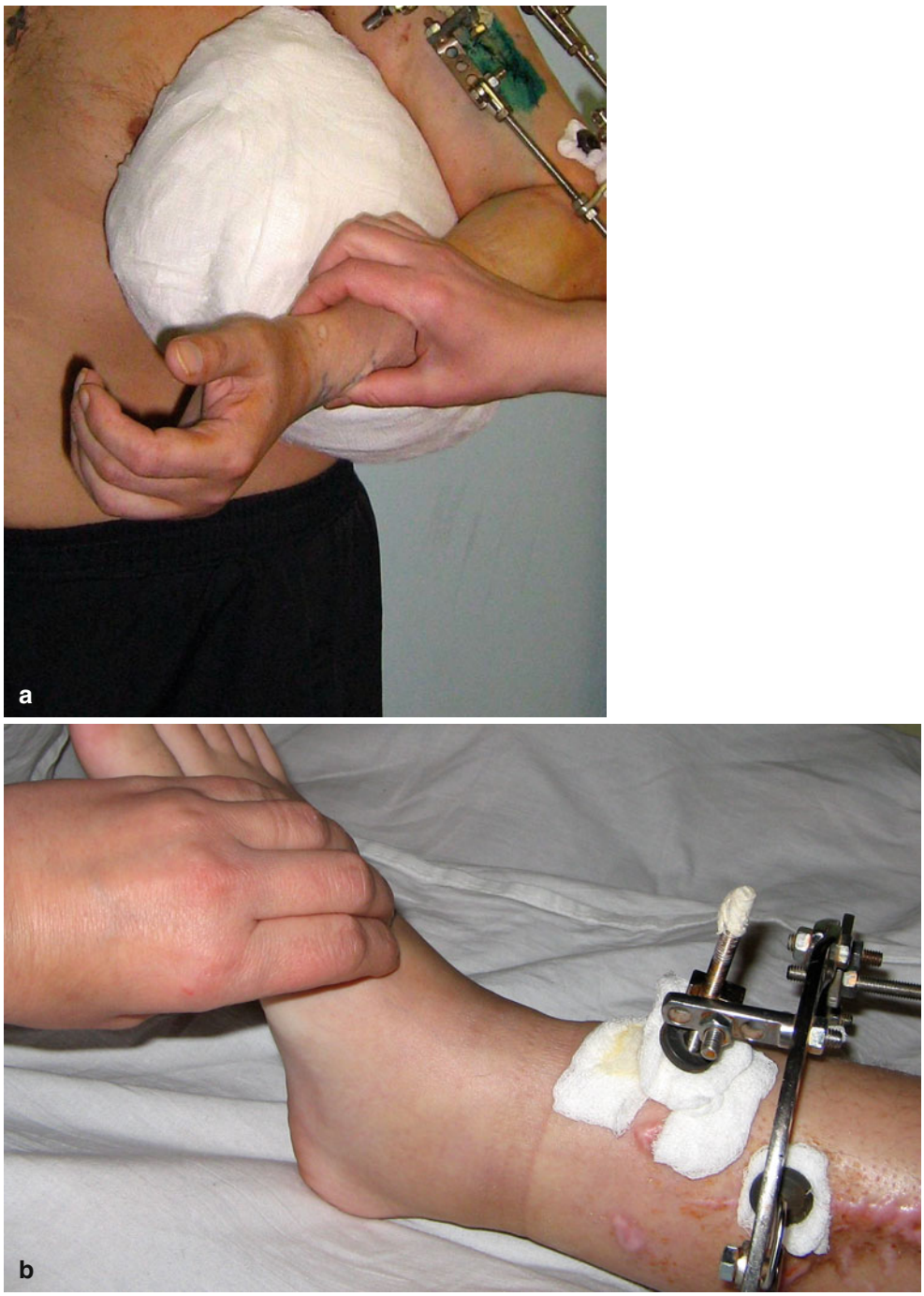

Fig. 32.1 (**a**, **b**) In the immediate postoperative phase, the surgeon should check the patient's peripheral pulse

pressed to the skin with a holder. For the first 2–3 days the dressings are changed every day, or as necessary, and thereafter as they become soiled, but at least once every 7–10 days. The cotton frame cover is changed together with the dressings (Fig. 3.22).

Crusts that form around the transosseous elements are an endogenous biological barrier and have a positive role, reducing the danger of pin-tract infection [696]. However, these "crust-covers" should not be confused with dried exudate, which is a consequence of inflammation in the region of the transosseous elements. Dried exudates should be regularly removed as they complicate outflow of the wound effluent.

During each dressing change, the skin tension at the transosseous elements is estimated and changes in edema are determined by measuring the circumference of the extremity at the level of the bone wound, as well as above and below it.

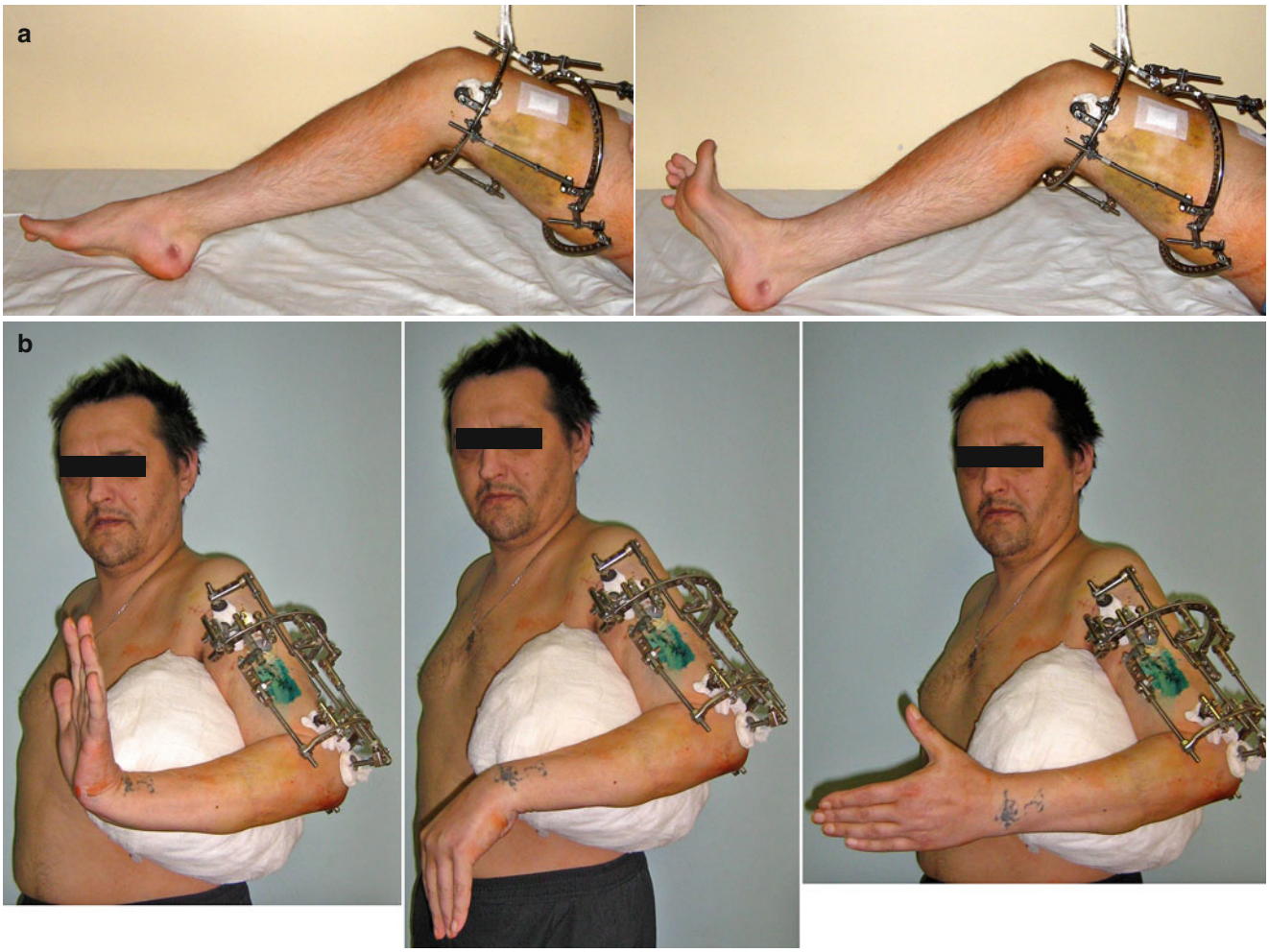

Fig. 32.2 (**a**, **b**) After the patient recovers from anesthesia, nerve function is tested

In contrast to the above-described, "Russian" method of pin-tract care, there is an alternative, "open" ("British," "Western") method: The day after the procedure, the skin and the device are washed with bactericidal soap and areas around the transosseous elements are moistened with an alcoholic solution. Similar manipulations are carried out weekly. Gauze pads and frame covers are not used. The patient can shower and even swim in pools containing sea or chlorinated water (Fig. 32.7). Taking baths is forbidden! After showering, the skin and the frame are dried using a hairdryer.

Nonetheless, comparative studies have shown that application of the "Russian" method reduces the danger of infectious complications [697]. In our opinion, use of the "open" method can be justified in countries with a dry, sunny climate and high-quality water, and by patients who are able to carefully follow all of the doctor's instructions. While we do not exclude the expediency of a combination of elements from the "Russian" and "Western" methods of pin-tract care, purposeful studies in this field have not been conducted yet.

32.4 Exercise Therapy

The protocol for restoring weight-bearing and movement is established on an individual basis, with due regard to the purposes of the external fixation, the type of pathology treated, the segment, the patient's age, the specifics of the patient's somatic and local status, and the biomechanical characteristics of the fixation device used.

Usually, on the first day after the external fixation, isometric exercises and active–passive movements of the fingers or toes and the wrist or ankle are recommended. In order to prevent the development of pin-induced joint stiffness, providing the rigidity of the bone fragment fixation allows, exercise therapy is started as early as possible, generally 2–3 days postoperatively. However, if concomitant muscle injury is present exercises with minimum loading are recommended, with emphasis placed on passive movements. Exercise therapy is combined with breathing exercises and general health-improvement measures, both of which are very important for elderly and senile patients.

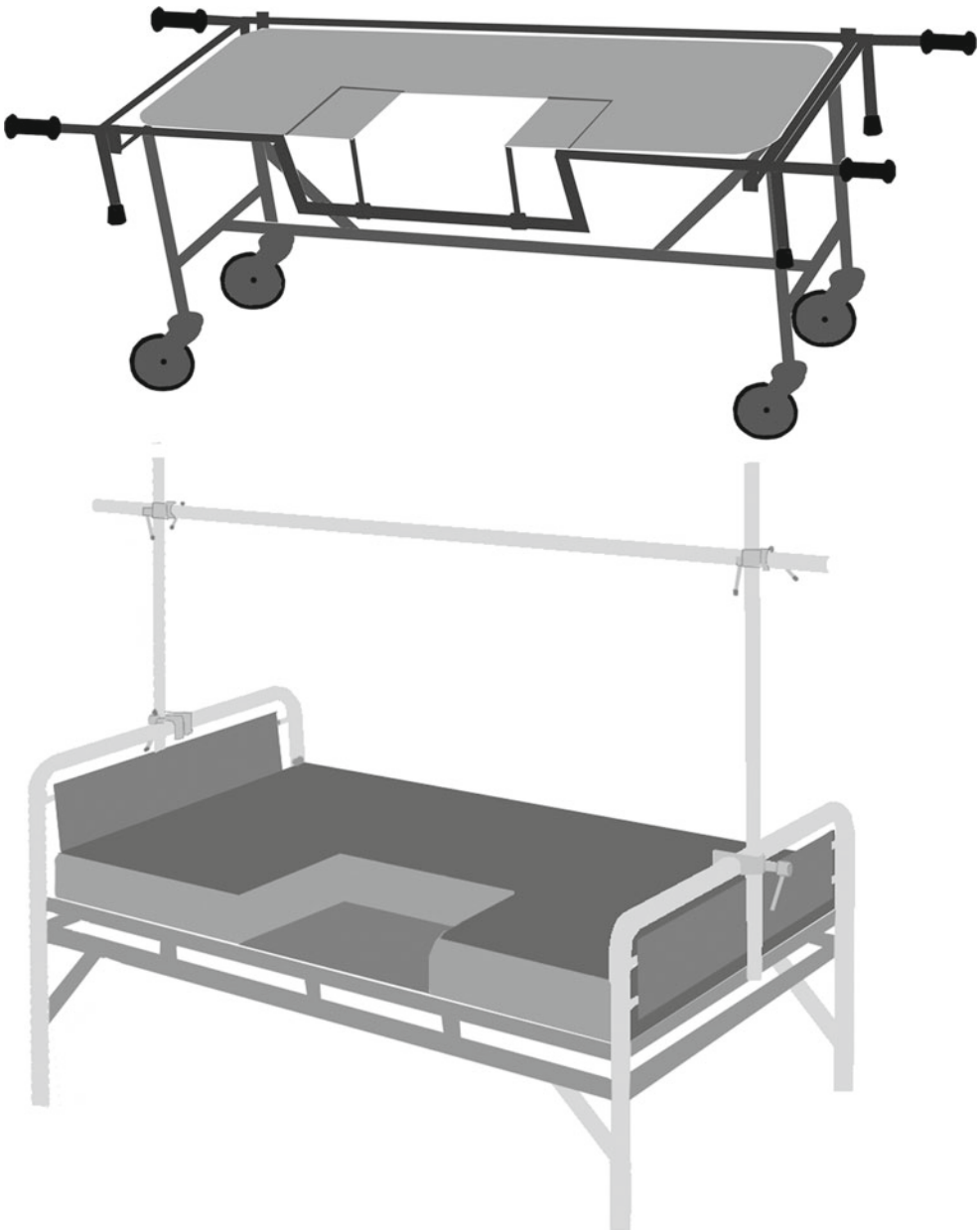

Fig. 32.3 A special trolley and bed (with a recess for the frame) are required after Ilizarov external fixation of the femur. The niche is not necessary when using hybrid devices

For the first 3–4 days, the exercises can be carried out on the ward, under the guidance of an exercise therapist. Each exercise session lasts 20–30 min with one or two sessions per day. Exercises should include passive and active movements in adjacent joints. On the third or fourth day, the exercises are performed in the gym and the duration is increased to 45–60 min. As the acute postoperative events ameliorate, mechanotherapy is started using special equipment. Light massage is also beneficial. At the same time, the patient must understand that exercise therapy under the supervision of a specialist cannot by itself restore the extremity's function, and that such therapy is not the end of the rehabilitation process. Rather, the exercises mastered should form the basis for independent efforts aimed at restoring the lost potential for self-support and working skills. An exemplary complex of exercises is illustrated in Chap. 34.

After external fixation of a leg, weight-bearing is recommended soon after the operation. The procedure for selecting the individual load is as follows: The patient is asked to balance on the treated leg while standing on the floor, and the load is gradually increased until discomfort is felt (pain,

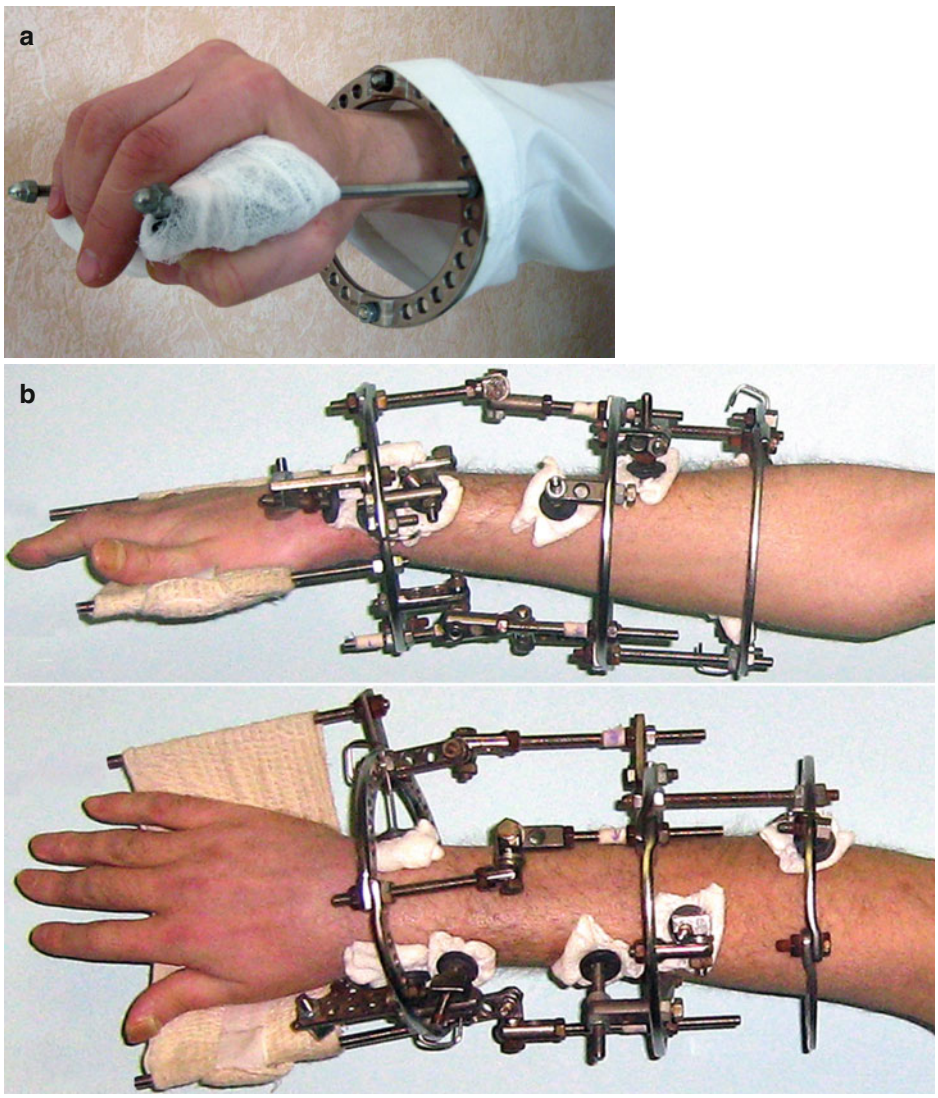

Fig. 32.4 (**a**, **b**) Two rods are fixed to the distal support of the forearm between which a gauze sling is attached to support the hand in the mid-physiological position

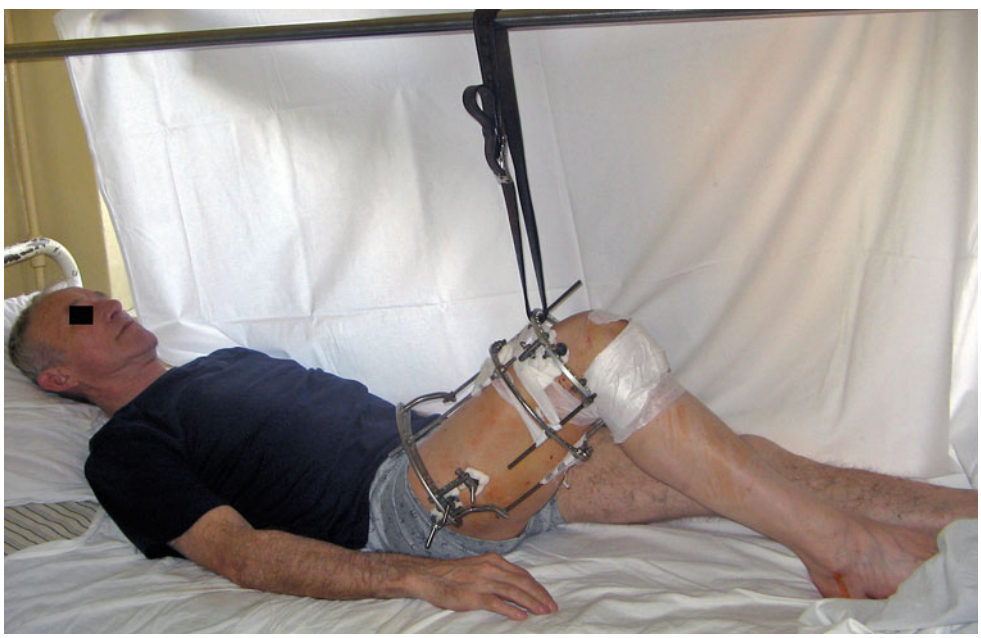

Fig. 32.5 After external fixation of the femur the patient should stay in bed for 7–10 days with the knee flexed at 90–100°

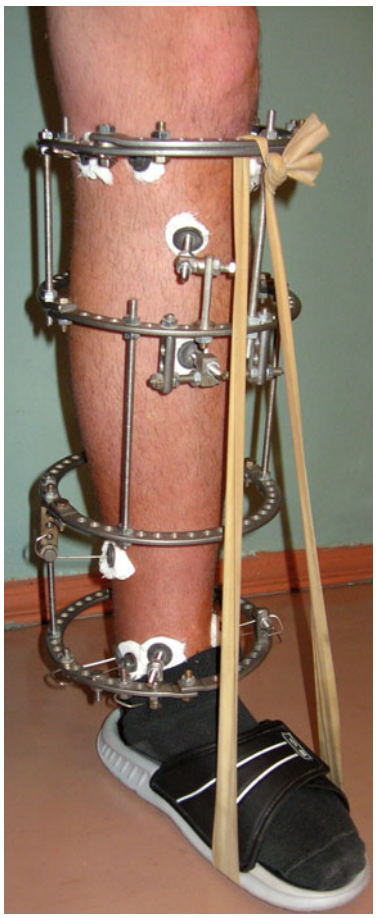

Fig. 32.6 After external fixation of the bones of the lower leg, a foot support that limits plantar flexion is used

sensation of tissue tension at the wires, etc.). That load is taken as the initial load and is recorded in the patient's medical record. Thereafter, increments in weight-bearing are monitored weekly (Fig. 3.16).

Restoration of correct gait is also an important consideration. To allow the patient to take a step with the treated leg and then bring the other leg against it is a gross methodological error. Instead, the patient should be encouraged to take steps of equal length—that is, when taking the next step, to set the heel at the level of the toe—beginning in the first postoperative days. The step length will gradually increase to the length it was before the trauma (Fig. 3.20).

An important element in the biomechanics of gait is the phase of rolling over the ankle joint. Therefore, avoidance of pes equinus and early restoration of rear flexion of the foot, accomplished using a foot-support (Fig. 32.6), are necessary. It is a mistake to use a rigid sole-shaped foot-support because it impedes rolling over of the foot.

32.5 Physio- and Pharmacotherapy

Participation of a physiotherapist and clinical pharmacologist in working out the different components of the rehabilitation protocol is essential. This protocol will be fairly complex when the patient shows pronounced edema of the soft tissues of the injured extremity (increase in circumference at any level by >40–60 mm), tension in the soft tissues, a change in skin color, asymmetry in the rheological indices of the two extremities by >40%, and/or a shift in hemostasis values towards hypercoagulation. Pharmacotherapy involves drugs that improve the rheological properties of the blood and microcirculation, tissue oxygenation, and vasoconstriction. Types of treatment include laser, ultra-high-frequency, magneto-, light, and reflex therapies. The protocol is used for 7–10 days, with dynamic monitoring of efficiency and instituting the required correction(s). Decisions as to whether treatment should be stopped, continued, or modified are based on dynamic clinical data (pain, edema, skin color, function of the extremity), functional test indices, and biochemical tests.

32.6 Biomechanical Device State

The main discussion of the different biomechanical devices is presented in the sections on the treatment of fractures, malunions, non-unions, deformities, and long-bones defects. In this section, we expand on those discussions.

At least once every 3 weeks, *tensioning of the wires* should be checked by using a wire tensioner or traction clips, or tightening the wire-fixing nuts (Figs. 7.29, 7.30, 7.31, and 7.32). In the latter case, bone fragments may become displaced if the wire fixation point on the support is displaced. Wires with a stop should be simultaneously tensioned with two wire tensioners. Maintenance of wire tension in the Ilizarov apparatus is particularly important, and even more so than in combined wire–pin assemblies.

Of great significance is maintenance of the biomechanical state (distraction, compression, and neutral forces) required at that particular moment of the postoperative stage—both between the supports of the device and between the modules—for fixing the bone fragments. During manipulations involving displacement of the external supports, it is necessary to place control marks on the connecting rods, e.g., narrow strips of adhesive tape (Fig. 1.14). Similar marks are also placed on the traction wire clips with arrows showing the direction of nut rotation. The Ortho-SUV Frame and Taylor Spatial Frame (Fig. 1.2p, q and Chap. 17) already have millimetric

Fig. 32.7 (**a, b**) "Russian" and (**c**) "Western" (observation by W. Terrell) methods of pin-tract site care

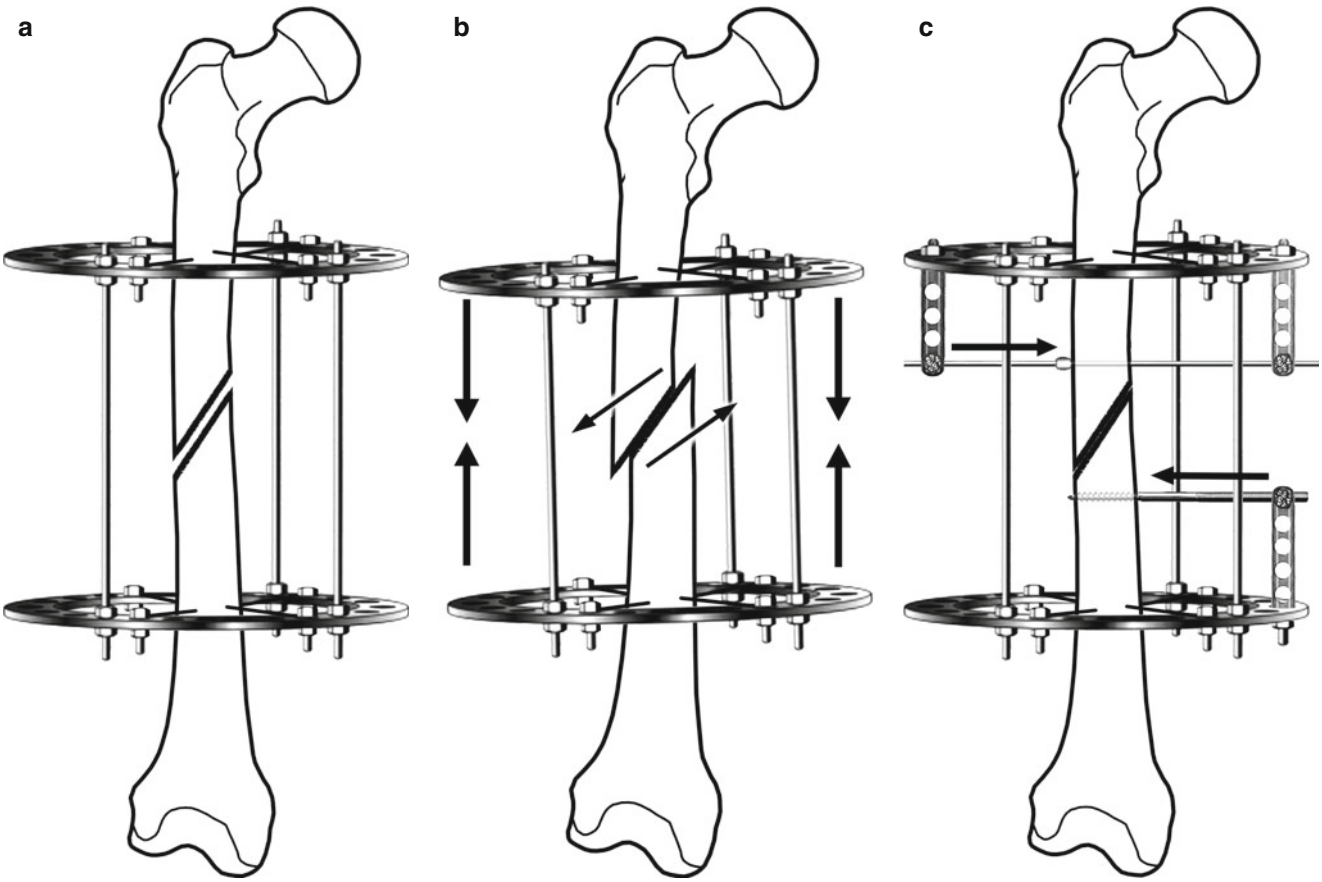

Fig. 32.8 Axial approximation of the supports in an oblique fracture (**a**) will not result in "compression," but will instead lead to the displacement of one fragment relative to another (**b**). In this case, the compression should be side-to-side rather than axial, for example, as achieved with the help of transosseous elements (**c**)

divisions on the struts such that no further labeling is needed. The patient should also receive a diagram of the external device indicating the rods that are used to carry out the distraction or compression, the necessary manipulations, and their magnitude (Chap. 34).

It is a grave error to carry out longitudinal compression of bone fragments with oblique or helical ends. In such cases, it is more appropriate to bring the external supports together, leading to the bone fragments' "sliding off" one another rather than to use compression. In such cases, contralateral compression by means of transosseous elements (Figs. 2.10, 2.11, and 2.12), or the mutual displacement of the modules fixing the bone fragments (Figs. 2.5 and 2.6) is required. The average compression rate in fractures is 1 mm/day over 10–14 days (Fig. 32.8).

In the external fixation of metaphyseal fractures or in compression arthrodesis of the large joints, the fragment ends are brought into close contact for 3–5 days. Primary vascular lacunae need to form at the site of contact. Thereafter, compression is carried out at a rate of 0.25 mm two or three times a day for 7–10 days. After a pause of 5–7 days, a radiograph is obtained. Arthrodesis is followed by continued compression at a rate of 0.5 mm a day for 4–7 days, and then supporting compression of 1 mm/day over 7–10 days [317].

In neutral external fixation (e.g., fragmented fractures), it is advisable to apply tension in the modules fixing the bone fragments. For this purpose, the supports that fix one bone fragment are approximated by 1 mm once every 3 weeks, and the external supports that fix the other bone fragment are moved apart by the same distance (Fig. 32.9).

The rate and magnitude of distraction can vary not only with the different pathologies but also over time during treatment of the same patient. A magnitude of 1 mm a day in four stages (0.25 mm four times a day) is accepted as the gold standard in external fixation. Rotation of an M6 nut by 90° corresponds to a movement of 0.25 mm. Better conditions for the formation of distraction regenerate will be obtained using automatic high-rate distracters [698, 27] (Fig. 32.10).

The first 2–3 days are taken up with bending the transosseous elements, especially in wire-based devices. Later, the increase in distance between the bone fragments should correspond to the rate of distraction, which is estimated from the marks on the connection rods.

It should be noted that the magnitude of distraction (compression) is the same as the change in the distance between the bone fragments. Thus, in cases in which a triangular regenerate is formed, monolateral distraction of the external supports by 1 mm does not lead to lengthening of the regenerate base by the same value (Figs. 16.18 and 16.20). Similarly, when traction-guiding wires inserted at an angle to the displaced bone fragment (oblique-wire bone transport) are used, displacement of the traction clip by 1 mm leads to lengthening of the regenerate by a smaller amount. To ensure a preset rate of distraction, skiagrams are used to carry out the special calculations given in the sections discussing open injuries and deformity correction, and in the specialist literature [9, 236, 317, 102].

In malunited fractures, distraction to reduce the bone fragments is started after 3–5 days at a rate of 0.75–2 mm a day depending on the fracture location (metaphysis, diaphysis) and the time elapsed since the trauma. Distraction of a tight non-union with the aim of forming a distraction regenerate is carried out at a lower rate of 0.25 mm one to three times a day and is monitored by biochemical testing [322].

To form a distraction regenerate, displacement of the bone fragments after corticotomy is started 5–7 days postoperatively. Following open osteotomy, distraction is started after 10–14 days [699]. In children, the distraction rate can be increased to 1.25–1.5 mm/day and in elderly patients decreased to 0.5 mm/day. In the replacement of a bone defect by lengthening both fragments (polylocal distraction-

Fig. 32.9 Dynamic stabilization of the device in neutral osteosynthesis

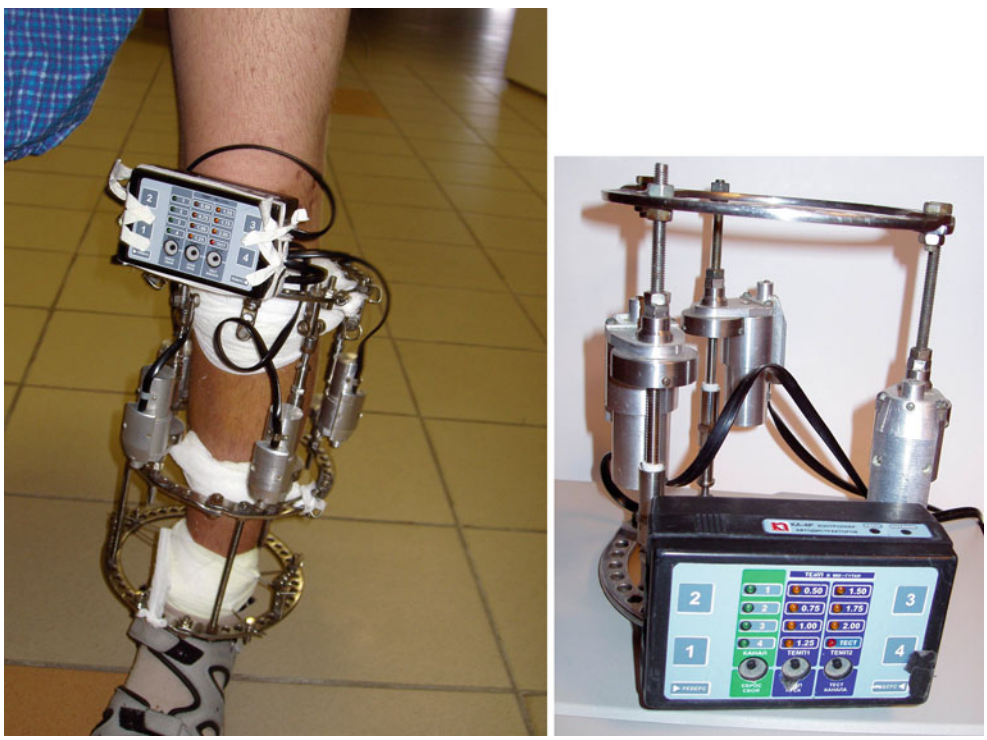

Fig. 32.10 Automatic distractors

compression external fixation, or bilocal bone transport), the rate of distraction at the distal regenerate is, as a rule, 0.25–0.5 mm less than at the proximal bone fragment. After V- and Y-shaped foot osteotomy, distraction is started after 3 days at a rate of 0.25 mm four to eight times a day [361].

Both the absence of pain and neurotrophic disturbances and the satisfactory functioning of adjacent joints are indicators of a favorable reparative course of osteogenesis, including tension and lengthening of the soft tissues. The amount and rate of distraction are monitored using radiography, densitometry, and ultrasonography, with biochemical testing carried out monthly [227, 322, 473, 700–702, 466].

The period subsequent to formation of the distraction regenerate is termed the "fixation period." To maintain the rigidity of the osteosynthesis support, distraction of 1.5 mm is performed in one stage over 7–10 days. It is recommended that the distraction regenerate is increased in thickness by an amount equal to its "growth zone" (5–10 mm). The supports are then brought together in a single step by the amount of that additional lengthening. This method, developed at the Russian Ilizarov Scientific Center "Restorative Traumatology and Orthopedics," leads to a significant reduction of the time needed for distraction regenerate reconstruction [466].

Distraction used to reduce old dislocations or to remove joint contractures is started after 3–5 days at a rate of 1.5–2 mm a day in six to eight steps. The magnitude of distraction should be reduced and the number of manipulations increased when pain or symptoms of tension in the vessels and nerves occur [396].

Exercise therapy, physiotherapy, and monitoring of the device's biomechanical status are the most important components of the restorative treatment in patients after external fixation. Generally, failure to monitor the biomechanical status of the device and the dynamics of extremity function restoration should be considered a treatment error.

32.7 Outpatient Treatment

After external fixation of closed fractures, the ambulant regimen can begin after 3–5 days (and sometimes earlier). In patients with prolonged correction of fragment position (removal of deformity, replacement of a bone defect, segment lengthening, etc.) and continuing presence of the wound, the timing of the transfer to an outpatient treatment regimen is determined individually. Thus, in patients who have undergone segment lengthening or replacement of a segment defect, a radiographic examination should be performed after 7–10 days of distraction. Correspondence between the distraction rate and the regenerate length and coaxial separation of the fragments are important factors in allowing a patient's discharge from the hospital. When correcting complex (multi-planar, multi-component) deformities according to the Ilizarov method, the patient should remain hospitalized throughout the deformity correction period or be prepared at any time to transfer to the outpatient department to change the reduction unit and to undergo radiological control of the treated limb.

After discharge, a nurse should examine the patient every 7–10 days and change the dressings. At least once a month, the patient should consult the doctor charged with controlling the postoperative regimen. During outpatient treatment, the involvement of the surgeon who performed the operation is also essential.

At home, the patient follows, in accordance with the doctor's instructions, a course of rehabilitation to ensure self-support, restore work ability, and carry out domestic tasks (cooking, cleaning, ironing), and to enable re-engagement in hobbies (playing musical instruments, etc.). Students can return to their studies, and those in non-manual employment can return to work. Elderly patients after external fixation of the arm, forearm, or lower leg, as a rule, can fully attend to themselves and do not require the continued support of caregivers. The rehabilitation regimen after external fixation of the femur is somewhat more limited.

Later, in accordance with the clinical and radiographic findings, loading of the extremity is increased so that by the end of the fixation period weight-bearing is 70–100% of the normal functional level (Figs. 25.2, 25.3, and 25.4) (Figs. 32.11, 32.12, and 32.13).

Partial reassembly of the frame is considered as a technological component in external fixation. For example, when during bone transport soft tissues are cut by wires, fixed in the support ("cross-wire bone transport"), they should be changed for traction-guiding wires ("oblique-wire bone transport") (Figs. 18.5 and 18.6). After deformity correction, reduction units (Ilizarov hinges or struts) may be replaced by connection rods and additional transosseous elements may be inserted. Furthermore, non-systematic and disorganized manipulations, a lack of care in the initial planning, and arrangement of a device based on the assumption that errors can be corrected later are unacceptable practices. The order of all manipulations should be planned in advance and documented in the medical records. Exceptions to this planned approach are when a wire needs to be reinserted because of a pin-tract infection, or a defective component of a device needs to be replaced, and similar situations requiring urgent attention. Most of the above-mentioned manipulations can be managed in the out-patient department.

Another example of changing the arrangement of a device during the fixation period is modular transformation, which is an integral component of combined external fixation. As discussed in Chap. 3 (Fig. 3.5), modular transformation of an external device is planned in accordance with the weight-bearing capacity of the bone regen-

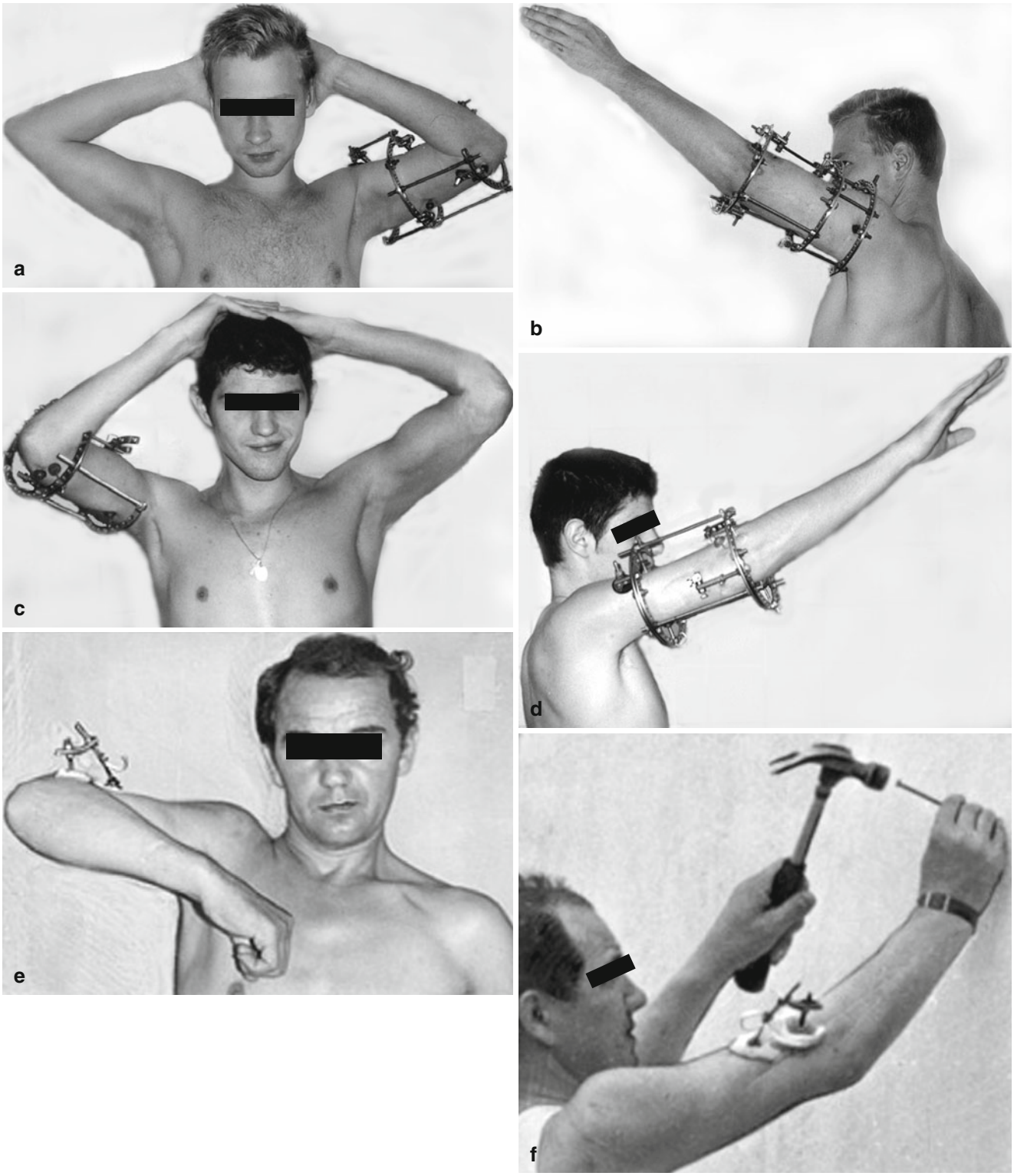

Fig. 32.11 Function of the arm after external fixation of a diaphyseal fracture (**a**, **b**) and non-union of the humerus (**c**, **d**) and after combined strained fixation of a non-union of the humerus (**e**, **f**)

erate, with the potential to gradually reduce the number of transosseous elements, connection rods, and supports without the insertion of additional transosseous elements and with the minimal amount of change in the external support's geometry following removal of a part of the support. The aims of modular transformation are to optimize the

conditions for bone wound healing (according to Ilizarov's "training the regenerate" and "dynamization" of the frame), reduce the risk of pin-induced joint stiffness and pin-tract infection, and increase patient comfort by making the device less bulky.

Usually at fracture fixation, weight bearing in 5–8 weeks corresponds to 50–70% of body weight, i.e., the patient can walk with the aid of one crutch. There is generally no soft-tissue edema but if there is then it does not exceed 1–2 cm above and below the level of the fracture. The range of motion in the adjacent joints is progressively restored. Radiographs obtained during this period show a fine periosteal regenerate over the surface of the fragment ends, with a density exceeding that of the soft tissues. There is pronounced endosteal regenerate rarefaction of the cortical plate (fibrosis of the cortical layer). The presence of these clinical and radiographic signs indicates that the basic supports of the device can be removed.

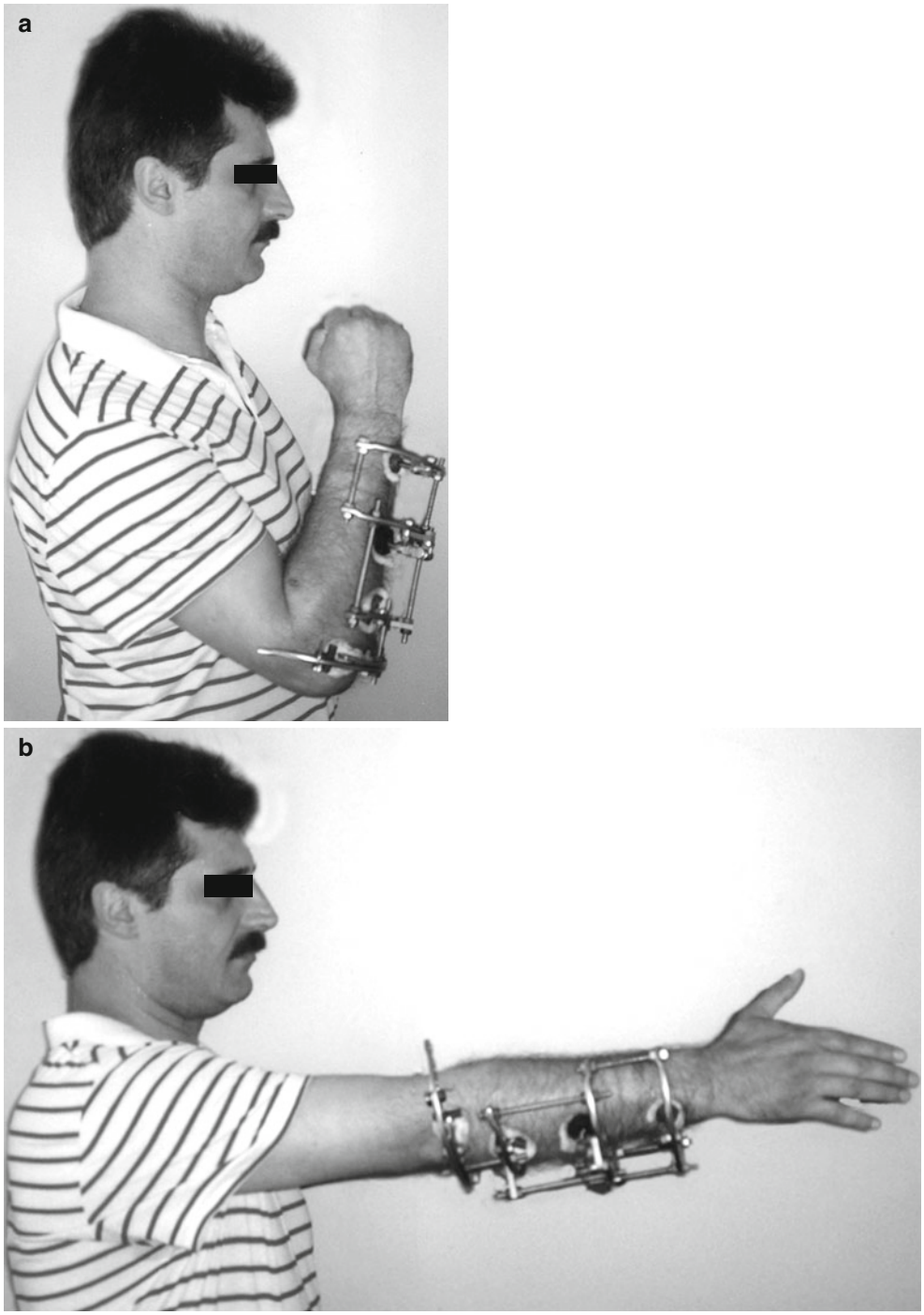

Fig. 32.12 Function of the arm after combined external fixation of a Monteggia fracture (**a**–**d**), a non-union of the ulna (**e**–**h**), and a deformity of both forearm bones (**i**, **j**). (**k**–**t**) Function of the arm after combined strained fixation of an ulnar fracture (**k**–**n**), a malunited fracture of both forearm bones (**o**–**r**), and a defect involving the soft tissue and the ulna (**s**, **t**)

Fig. 32.12 (continued)

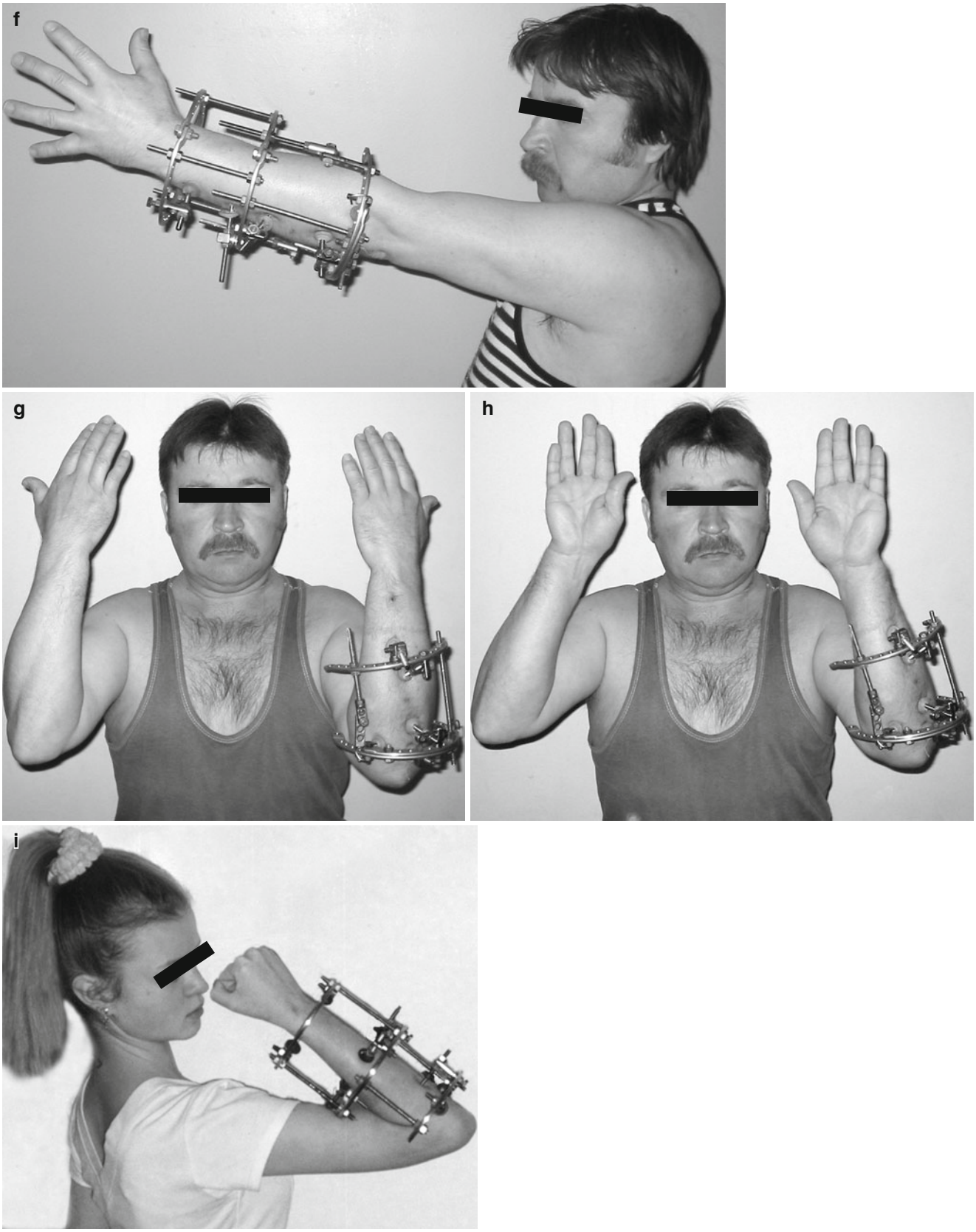

Fig. 32.12 (continued)

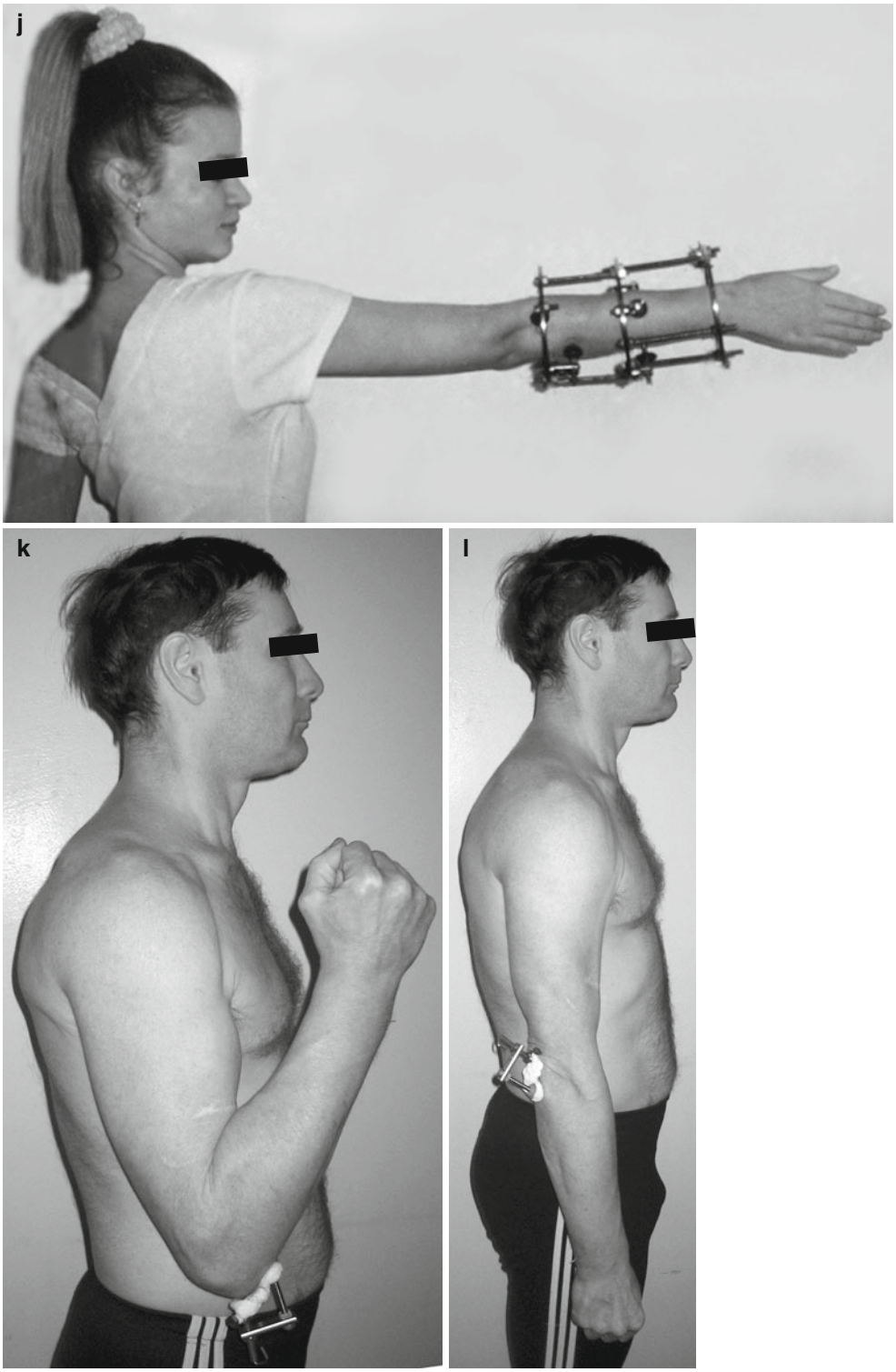

Fig. 32.12 (continued)

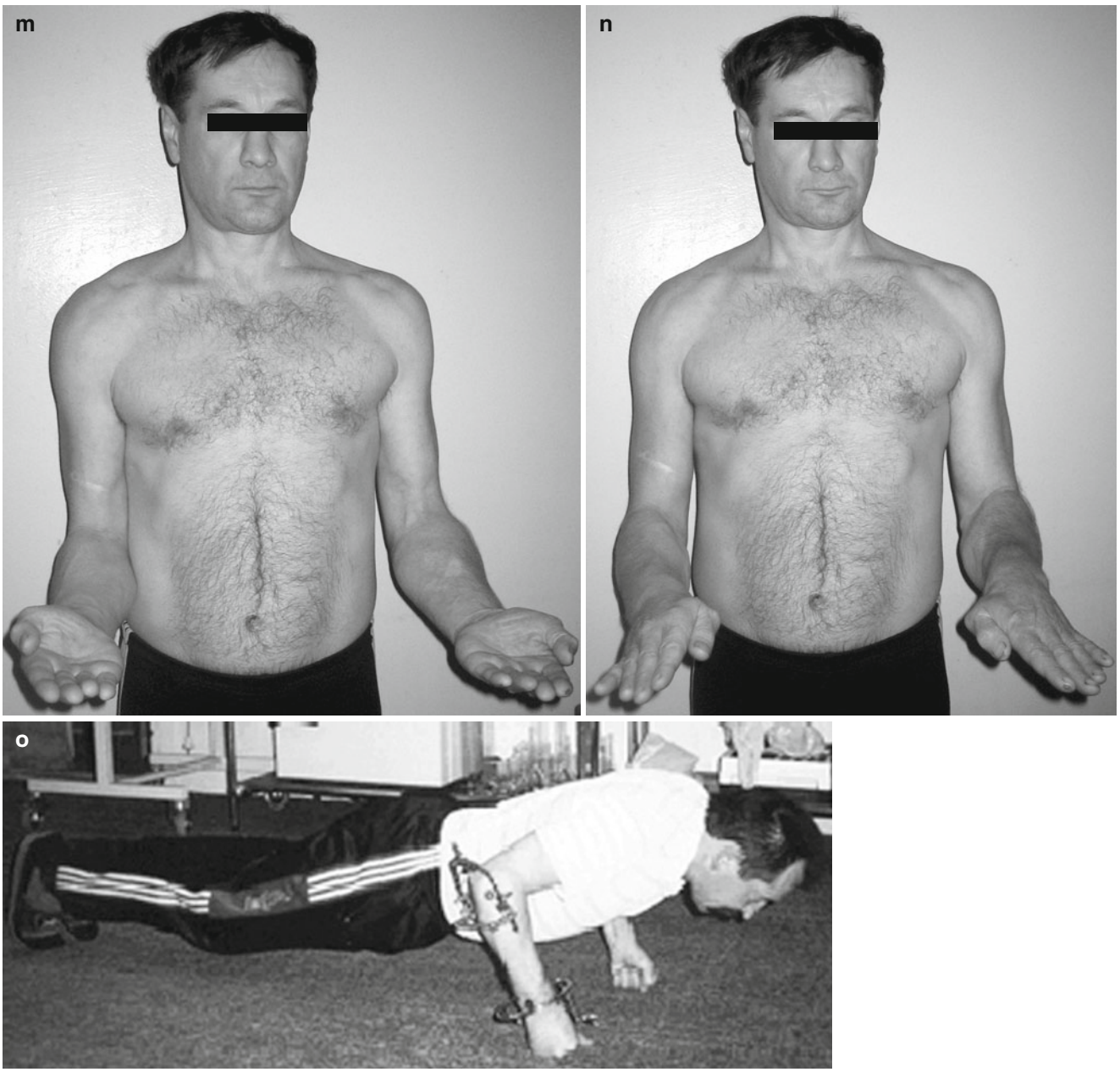

Fig. 32.12 (continued)

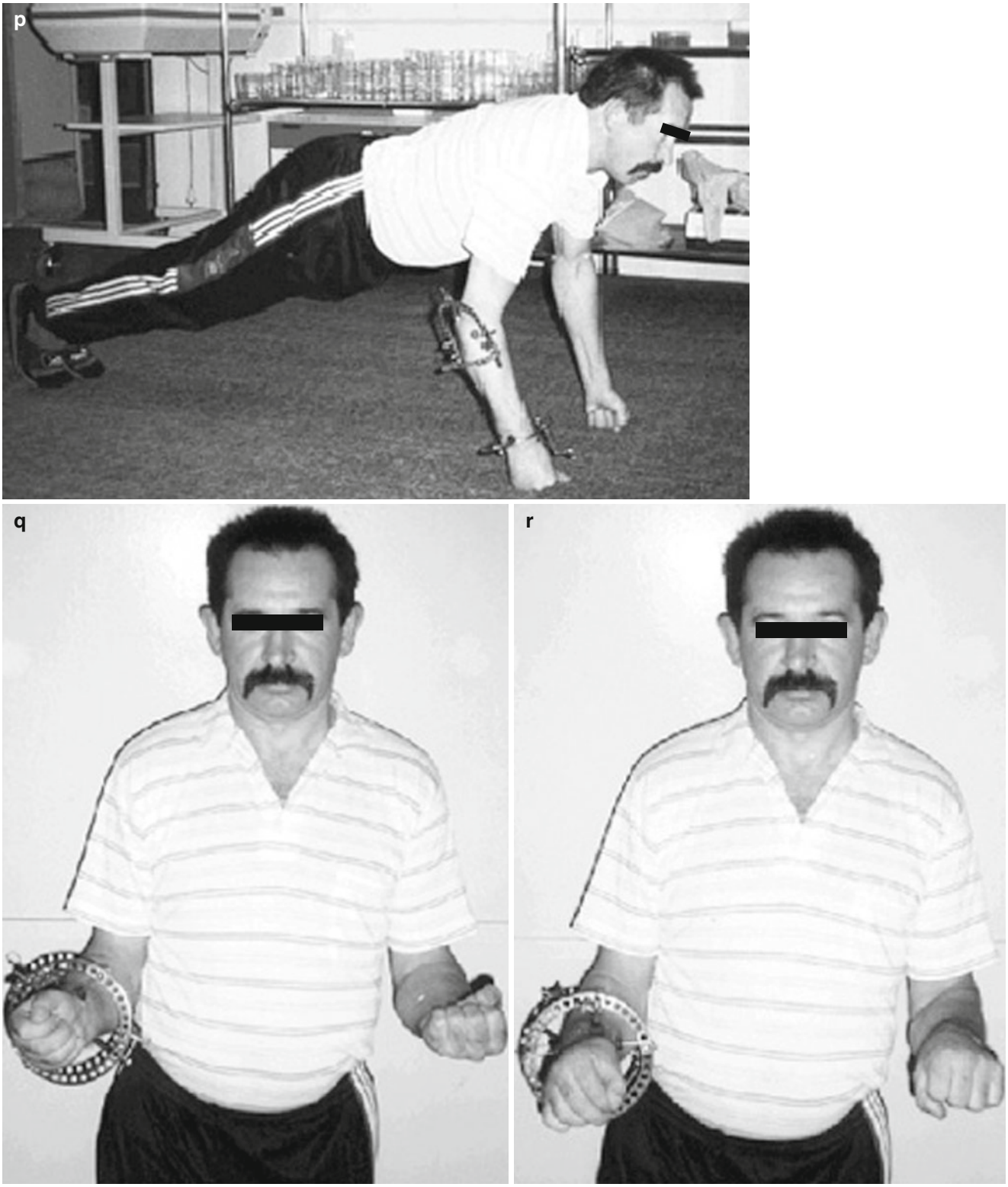

Fig. 32.12 (continued)

Fig. 32.12 (continued)

At 9–11 weeks after surgery, weight-bearing has increased to 70–100%, meaning that the patient can walk with the aid of a cane. Movements in the knee and ankle joints are not limited. Clinical testing of the union shows the presence of a tight bond. Radiography shows an increase in the density of the periosteal regenerate, with structural conversion into bone. In the interfragmentary gap, single longitudinally oriented shadows of the newly-built bone regenerate are seen, and there are initial signs of the formation of a common cortical plate. The presence of these signs indicates that sectors of the reductionally fixing supports can be removed. Similar clinical and radiological data are used to decide upon module transformation in patients with non-union or deformities of the long bones.

It is necessary to emphasize that, at least for now, the mobility of the bone fragments is determined based on clinical and radiological parameters, such as the criteria used for module transformation. Unfortunately, there is no accessible, commercially released device that determines the degree of bone fragment mobility during the fixation period. The benefits of this type of device would be that, in defining the degree of fragment mobility in a patient (in vivo) it would provide a higher degree of objectivism than the current indirect criteria. The criteria for module transformation are, as a whole, similar to those for dynamization of a locking nail. However, it is necessary to recognize that in external fixation dynamization is much more strictly controlled.

Table 32.1 summarizes the clinical and radiological criteria for module transformation.

If necessary (for example, in the insertion of additional transosseous elements or partial reassembly of the device), a patient can be hospitalized again for a short time.

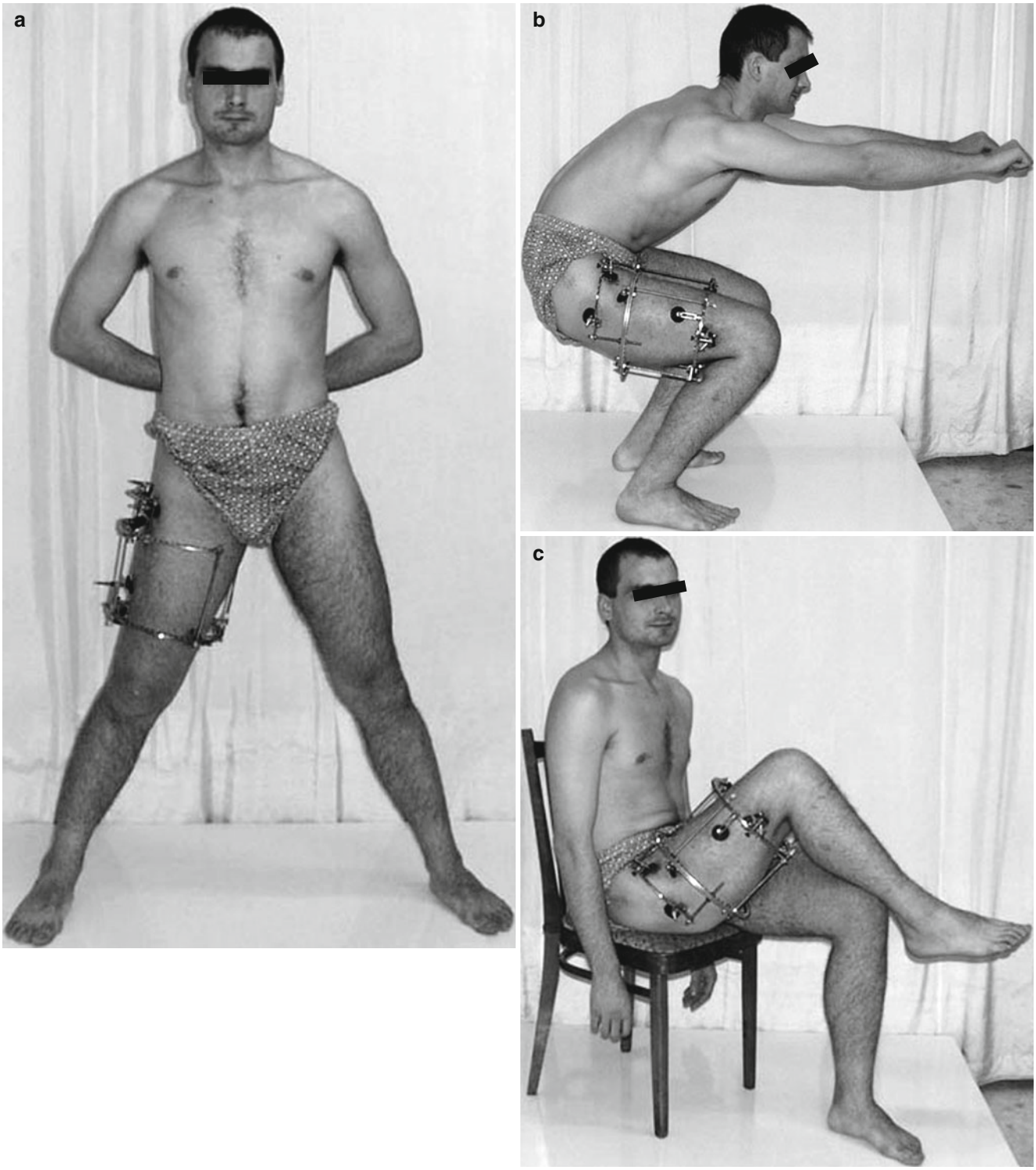

Fig. 32.13 (**a–f**) Function of the lower extremity after combined external fixation of a femoral non-union (**a–c**) and a traumatic coxa vara with the femur shortened by 11 cm (**d–f**). (**g–m**) Function of the lower extremity after combined external fixation of a tibial segment fracture (**g–l**), and splintered fractures of the femur and lower leg bones (**k–m**)

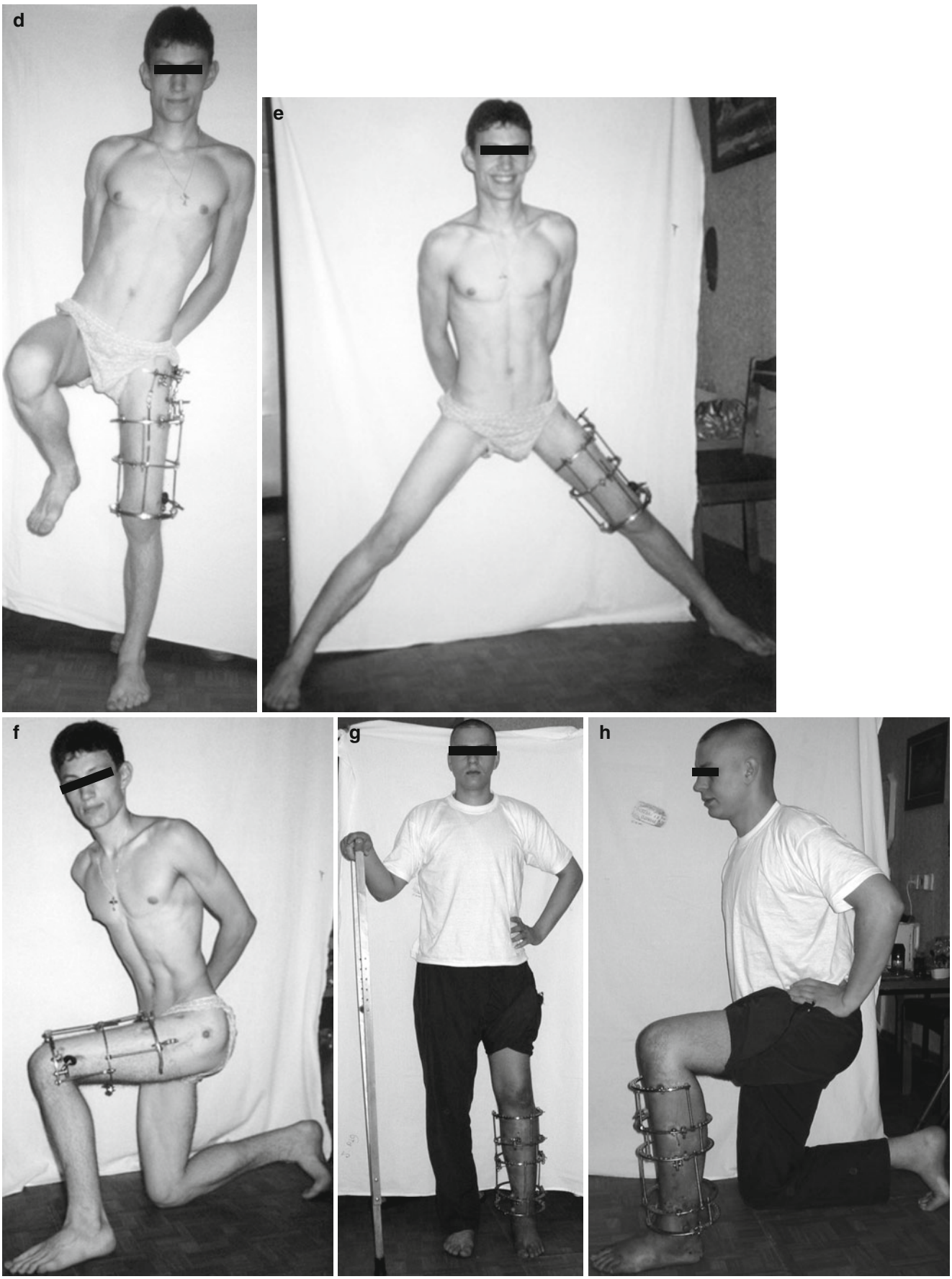

Fig. 32.13 (continued)

Fig. 32.13 (continued)

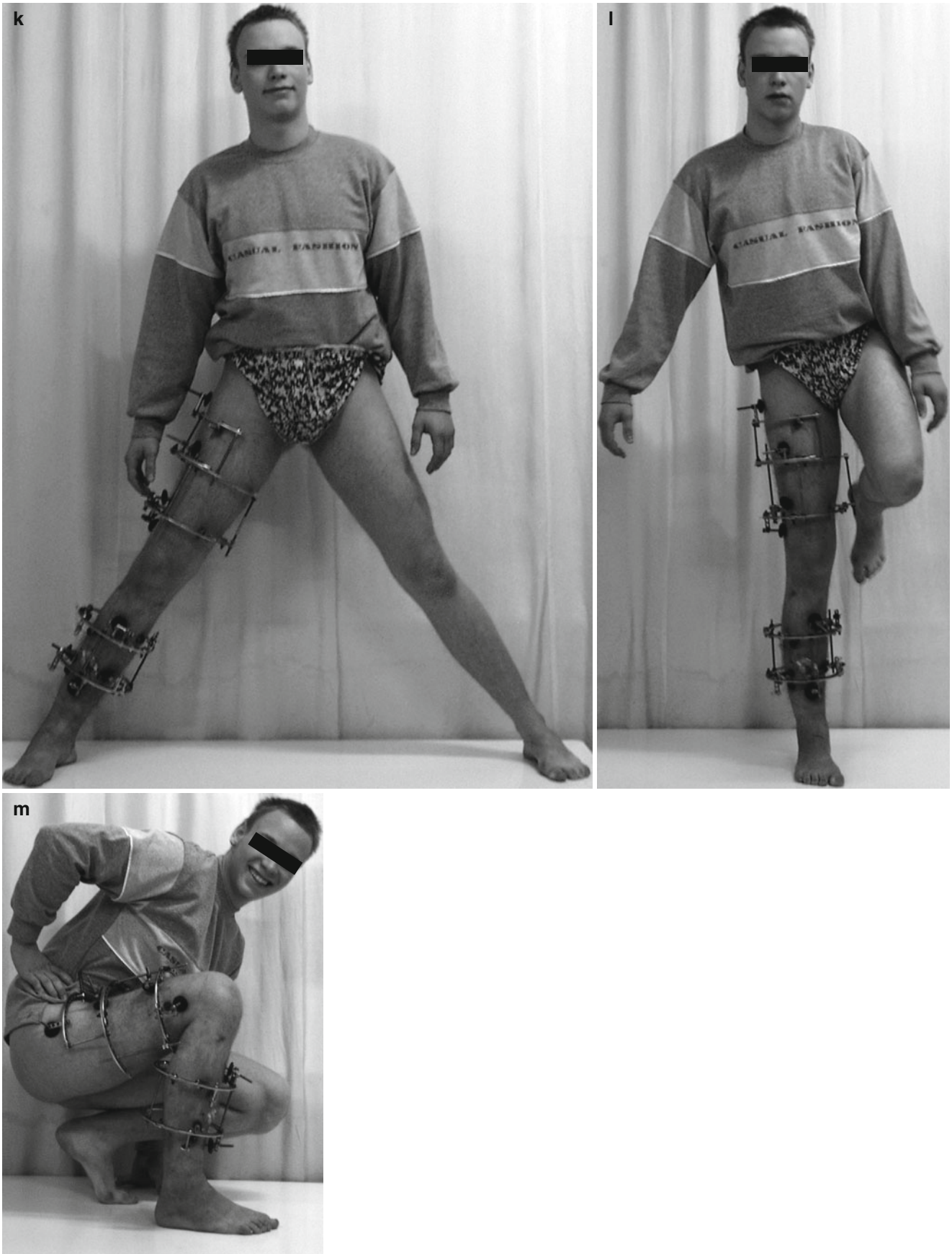

Fig. 32.13 (continued)

Table 32.1 Criteria for stages of module transformation

	Stage 1	Stage 2
Parameters	5–8 weeks	8–11 weeks
Painless loading	50–70%	70–100%
Soft-tissue edema	+2–3 cm	+1–2 cm
ROM	Not limited, painless	Not limited, painless
Clinical test for fragment union	–	Tight amortization
X-ray examination	Fine periosteal regenerate over the surfaces of the fragments ends, with density exceeding that of soft tissues; pronounced endosteal regenerate with signs of rarefication (fibrosis of the cortical layer) of the cortical plates	Increase density of the periosteal regenerate with conversion of its structure into bone. In the interfragmentary gap single longitudinally oriented shadows of the newly-built bone regenerate are observed; initial signs of the formation of a common cortical plate

32.8 Device Removal

There are three levels of strength of bone fragment unions: stabilized, strong, and final [703]. In stabilized unions, the strength of the bone callus ensures the absence of pathological mobility, but slight mobility (where the fragments have become bonded) still occurs in the fracture zone. Establishment of this level of union, according to the recommendations of the Russian Ilizarov Scientific Center "Restorative Traumatology and Orthopedics", indicates that the device can be removed. Such conditions are generally found in external fixation of the humerus or the forearm bones. When a strong union has been achieved, 1–2 months after device removal, the strength of the callus is such that the patient can return to work without limitations. By the time a final union has been achieved, 1.5–2 years after the trauma in diaphyseal fractures, the coarse bundle of bone callus with low strength has been replaced by lamellar bone.

Clinical testing of the strength of the bone fragment union is carried out 10–14 days before the intended day of device removal. Prior to testing, the modules fixing the proximal and distal bone fragments are left unattached for some time. The degree of mobility of the bone fragments is then determined by testing the patient's ability to maintain the extremity in the horizontal position, and by manually applying lateral, axial and torsional loads (Fig. 32.14a). When no pathological mobility is seen, the connection rods are reattached and the device is "dynamized" by slackening the nuts of the connection rods of the intermediate support(s) by 1–2 mm (Fig. 32.14b). In combined strained fixation, dynamization is carried out by reducing the tension of the axial compression wire. Earlier dynamization of the frame (3–5 weeks before the intended day of device removal) is also known. To "train" the regenerate so as to achieve this goal, some of the transosseous elements are removed in stages, some of the external supports are removed, spring-loaded connection rods are used, etc. This type of procedure is the basis of module transformation.

In conclusion, we can say that there are two approaches to determining device removal. First, the device is removed in the presence of a stabilized union. In such cases, weight-bearing by the extremity is considerably (up to 50%) reduced. Whether a plaster support or brace is used is decided on an individual basis. Second, the device is removed when a strong union is present. In such cases, the reduction in weight-bearing by the extremity is insignificant (average up to 20%) after device removal. In both cases, loading gradually increase up to full-weight bearing within 4–6 weeks. The patient should be involved in the decision as to which approach is adopted: to continue fixation with the device (accepting some continuing inconvenience) or to remove the device earlier (with initial limits to activity) [213].

It should be noted also that the period of fixation with an external device is established individually, on the basis of dynamic clinical and radiographic monitoring. Normal skin color, absent or insignificant edema, painless movement of the joints, positive clinical testing for union, and the absence of negative dynamics after device "dynamization" are clinical criteria for device removal. The presence of a radiographically visible fracture line and the absence of pronounced periosteal regenerate in the presence of the listed signs of union are not contraindications for device removal. Computed tomography can be used to resolve uncertain cases.

Methods to quantify the restoration of the bone's mechanical strength on the basis of biomechanical, laboratory, optical, electrophysiological, radiological, and other kinds of monitoring are currently the subject of intensive development. Unfortunately, for various reasons, none of the widely known approaches and methods is in clinical use, at the time of publication of this book. Therefore, in uncertain cases we should, at least for now, be guided by the principle: "Better one month late than one day early."

Table 32.2 lists the average periods of fixation and treatment used in the external fixation of fractures according to the data of the Russian Ilizarov Scientific Center "Restorative Traumatology and Orthopedics" [704, 705].

The period for fixation of a pseudoarthrosis mainly depends on the initial type of bone formation, the shape of the bone fragment ends, and the degree of their devitalization; typically it is in the range of 3–4 to 6–8 months. Longer periods for fragment consolidation should be expected if non-union occurs after bone osteosynthesis. Union of an arthrodesis takes place in 3–5 months.

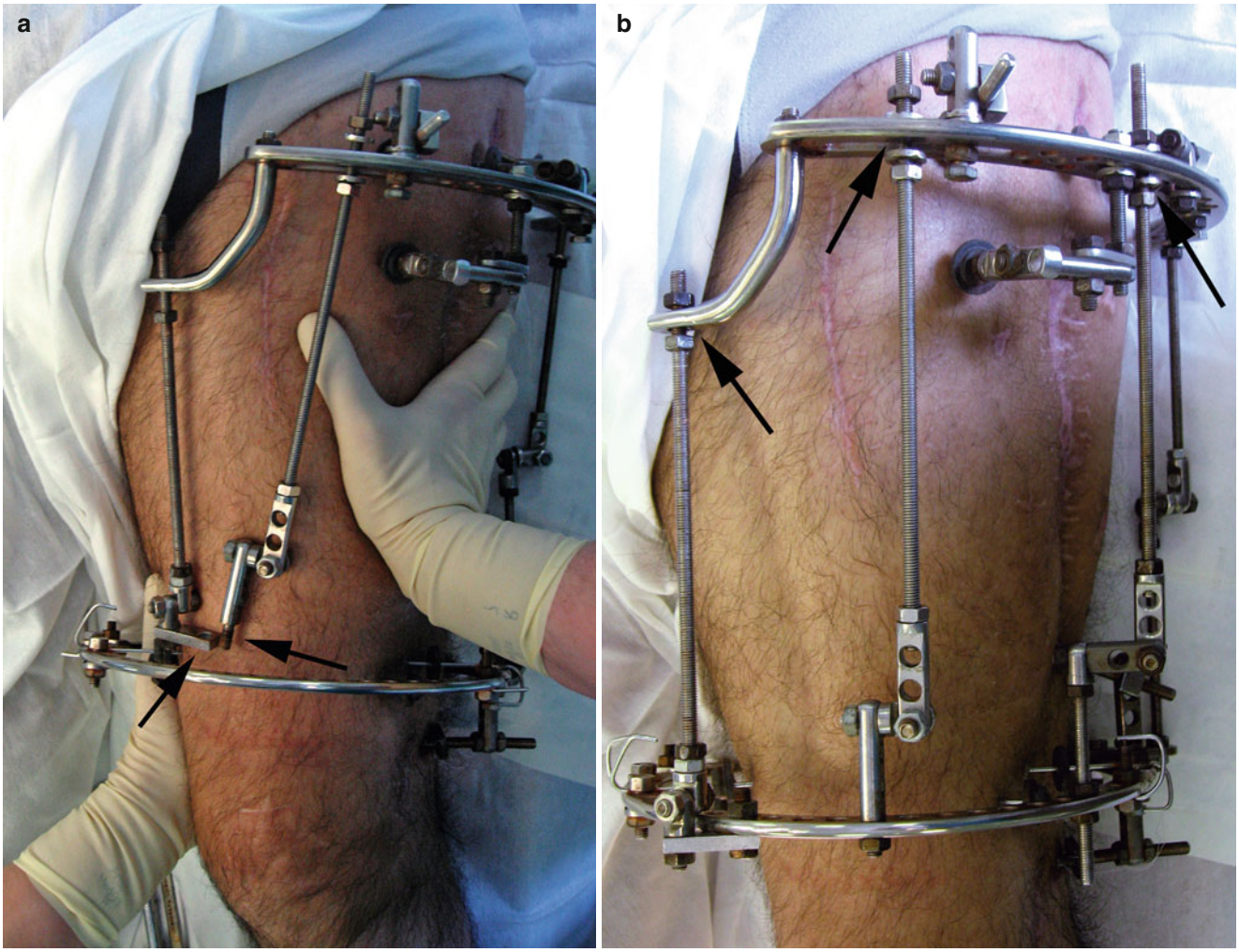

Fig. 32.14 Manipulations before frame removal: (**a**) clinical testing of the strength of the bone fragment union; (**b**) frame dynamization

During formation of the distraction regenerate, the fixation index (number of days for fixation of the formed regenerate divided by the length of the regenerate in centimeters) should not exceed 25–30.

Devices are generally removed in the out-patient department. To remove wires with stops and half-pins, local anesthesia is sometimes required. In children and psychologically unstable patients, a sedative is also needed, or perhaps the induction of brief narcosis.

First the basic transosseous elements are disconnected from the external supports. Then, the reductionally fixing wires and half-pins are disconnected. To avoid causing pain by the sudden release of tension in a wire, the tension should be eliminated before the wire is cut off at the level of the skin. After removal of the transosseous elements, the wounds are treated with antiseptics and covered with a sterile dressing. The patient can take a hygienic bath only after the skin wounds have healed but by no means earlier than 10–14 days after removal of the device.

Once again, we emphasize that after device removal weight-bearing should be decreased and then gradually increased up to the functional norm within 1–1.5 months (for an arm, within 3–5 weeks). Whether plaster bandages and braces are needed during this period is established on an individual basis. Patients with a device mounted on the ankle or foot should be advised to use an orthopedic insole for 6 months after removal of the device.

Table 32.2 Average periods of fixation and treatment (days) in Ilizarov external fixation

Location and type of fracture	Fixation period	Treatment period
Closed fractures of the proximal humerus (11-A, 11-B)	22–27	46–51
Closed/open diaphyseal fractures of the humerus (12-A, 12-B, 12-C1)	39–66/49–73	85–118/109–156
Closed fractures of the distal humerus (13-A, 13-B)	18–25	32–53
Closed fractures of the proximal forearm bones (21-A, 21-B)	25–47	39–89
Closed/open diaphyseal fractures of both forearm bones (22-A3, 22-B3)	49–67/88–117	100–115/124–152
Closed/open diaphyseal fractures of the ulna (22-A1, 22-B1)	50–67/65–82	77–94
Closed/open diaphyseal fractures of the radius (22-A2, 22-B2)	48–59/62–77	80–96
Closed fractures of the distal forearm bones (23-A, 23-B)	18–37	32–58
Closed fractures of the proximal femur (31-A, 31-B)	50–53	155–186
Closed/open diaphyseal fractures of the femur (32-A, 32-B)	62–92/77–92	109–154/189–229
Closed fractures of the distal femur (33-A, 33-B, 33-C1) and the proximal lower leg (41-A, 41-B, 41-C)	46–52	78–88
Closed/open diaphyseal fractures of the lower leg (42-A, 42-B)	60–82/101–121	97–122/151–169
Closed fractures of the ankle (44-B, 44-C)	51–57	106–116