Fractures of the Humerus

10

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In external fixation of the humerus according to the Ilizarov method wires of diameter 1.5 mm are used. The basic wires used in CEF are 1.8–2 mm in diameter, and the wires used for reduction are 1.5 mm in diameter. Half-pins of diameter 5 mm are inserted into the diaphyseal part of the humerus and 4-mm half-pins or console wires are inserted into the epicondyle. For patients with bone diameters of 28–30 mm it is permissible to use 6-mm threaded half-pins throughout the first three levels (0, I, II). The set for fixation must also include 2-mmconsolewires with a stop at the positions allowing various lengths of the wire to be inserted into the bone (5, 10, 15 or 20 mm) (Figs. 10.1, 10.2, 10.3, 10.4, 10.5, 10.6, 10.7, 10.8, 10.9, 10.10, 10.11, 10.12, 10.13, 10.14, 10.15, 10.16, 10.17, and 10.18).

The supports for the first three levels of the upper arm (levels 0, I and II) are assembled on the basis of a half-ring that is "elongated", if required, on each side by connection plates. The modern basic Ilizarov device set includes special half-rings with the ends bent up and elongated. At level III of the upper arm, two-thirds or three-quarter ring supports are used to allow movement of the limb.

As a rule, in external fixation of the upper arm the reductionally fixing and distal basic supports have one standard size and the proximal basic support, if located at the first three levels (levels 0, I and II), is one or two standard sizes larger. Therefore, to connect the proximal basic support to the others, connection plates are used.

The supports used at the three distal levels of the upper arm (levels VII, VIII and IX) are two-thirds or three-quarter rings to allow bending of the elbow. In fixation of juxtaarticular and intraarticular fractures (11- and 13-), radiotransparent external supports should preferably be used.

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To prevent formation of adduction contracture of the shoulder joint, the transosseous elements throughout the first four levels of the upper arm (0, I, II, III) are placed in the position with the shoulder in abduction at an angle of not less than 70°. To prevent pin-induced joint stiffness of the elbow joint following insertion of the transosseous elements through the front semicircle of the upper arm and through the four distal levels of the upper arm (VI, VII, VIII, IX), the forearms placed in the position of maximum extension. During insertion of the transosseous elements through the back semicircle of the upper arm the forearm is placed bent at 90°–120°. If it is impossible to change the position in the joints at these angles, the skin is shifted manually or with a thin hook in the direction of its natural displacement relative to the bone during movement in the adjacent joint.

In using only reference positions for insertion of transosseous elements, it is not necessary to change the position of the joints. However, the skin must be displaced prior to insertion of transosseous elements in elongation of the segment, correction of deformities, bilocal fixation and other situations when it is necessary to create a "store" of soft tissue.

Prior to fixation of the wires the external support must be properly oriented relative to the anatomical axis of the bone fragment and soft tissue (Fig. 10.1). The external supports must be located perpendicular to the anatomical (middle diaphyseal) axis of the bone fragment to which they are fixed. An exception is when the supports are placed preliminarily in a position of hypercorrection; this is considered below.

The intermediate reductionally fixing supports on the upper arm are oriented relative to the soft tissue depending on the method to be used to reduce the bone fragments. If the modules fixing the bone fragments are to be mutually displaced, the distance between the inner edge of the ring and lateral aspect of the upper arm (from the inside and outside) must be equal, and at the back it must be 10–15 cm more than at the front.

If the position of the bone fragments is to be changed by means of transosseous elements inserted near the bone wound, the ring should be displaced during mounting by the necessary amount in the direction the bone fragment needs to

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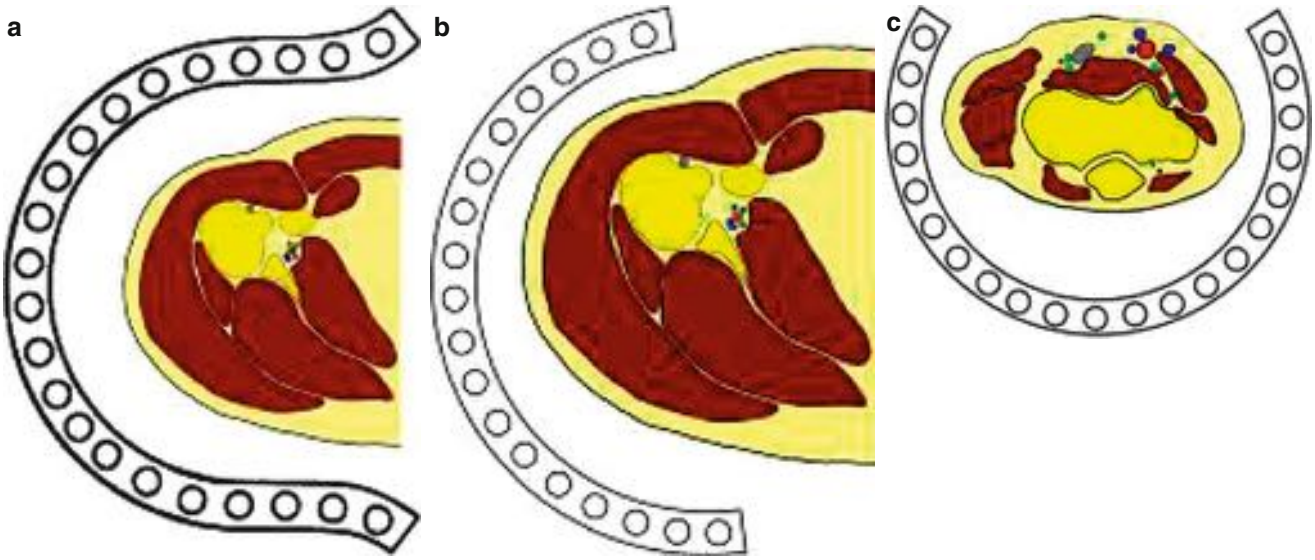


Fig. 10.1 (**a**–**c**) Supports orientation on the upper arm. (**a**, **b**) The proximal basic support on the upper arm is oriented relative to the soft tissue so that the distance between the inner edge of the ring and the skin at the front and outside are within in the range 25–35 cm. The distance from the skin to the ring along the posterior aspect must be 10–15 cm more (**a** – "wire" support; "wire – half-pin support"). (**c**) The distal basic support of the upper arm is generally oriented when it is connected to the distal reductionally fixing support. Remember that the thickness of the soft tissue on the posterior aspect of the upper arm in the top third of the segment is much greater than in the epicondylar area. Therefore, during mounting of the device, the humerus appears to be displaced forward relative to the centre of the distal basic support

move. It is possible to estimate the residual displacement from comparison radiographs.

The ends of the wires and half-pins that are at a distance from the support after it is given the necessary spatial orientation are fixed using posts and/or gasket washers. The half-pins, unless they are basic or reductionally fixing transosseous elements, are stabilized by external supports only after the necessary spatial orientation of the bone fragments has been achieved. If the half-pin is inserted into the bone not parallel to the external support it is fixed to it by two posts, one with a threaded hole (female) and the other with a threaded end (male). It is possible to fix the half-pin to the sup port or post with L-shaped clips in a manner analogous to fixation of wires by wire-fixation bolts with a lateral slot (Figs. 1.11.27 and 1.11.28).

The following sections describing particular methods of fixation contain phrases similar to: "When the device module is properly installed its connection rods are located parallel to the anatomical axis of the bone fragment." However, it must be born in mind that when the basic support is fixed only with wire(s), its position is likely to change due to bending of the wires from the weight of the basic ring and the reductionally fixing ring connected to it. In such cases to control orientation of the module, it should be supported and the bending of the wires eliminated by hand.

It is important to note that in all the fixation diagrams provided, the direction of insertion of reduction transosseous elements (wires, half-pins), and the locations of the stops on the wires are given conventionally as examples. In practice, one should be guided by the actual residual displacement of the bone fragments. To avoid damage to great vessels and nerves, the safe positions identified in the atlas of the levels recommended for insertion of reductionally fixing transosseous elements should be used. The size of the external supports in the diagrams provided is also shown conventionally.

For reduction using wires the desired displacement of the bone fragments is achieved with the help of stops, at the expense of the accurate bending of the wire (Figs. 1.6.11 and 1.6.12). For reduction using half-pins, displacement is achieved by "pulling" or "pushing", and for posts with a stop only by "pushing" (Fig. 1.6.10). It is also possible to use any technique for reduction that involves mutual displacement of external supports (Figs. 1.6.4–1.6.9). Large splinters are reduced and fixed by means of wires with stops or with the help of console wires with stops (Fig. 1.6.13). If there are

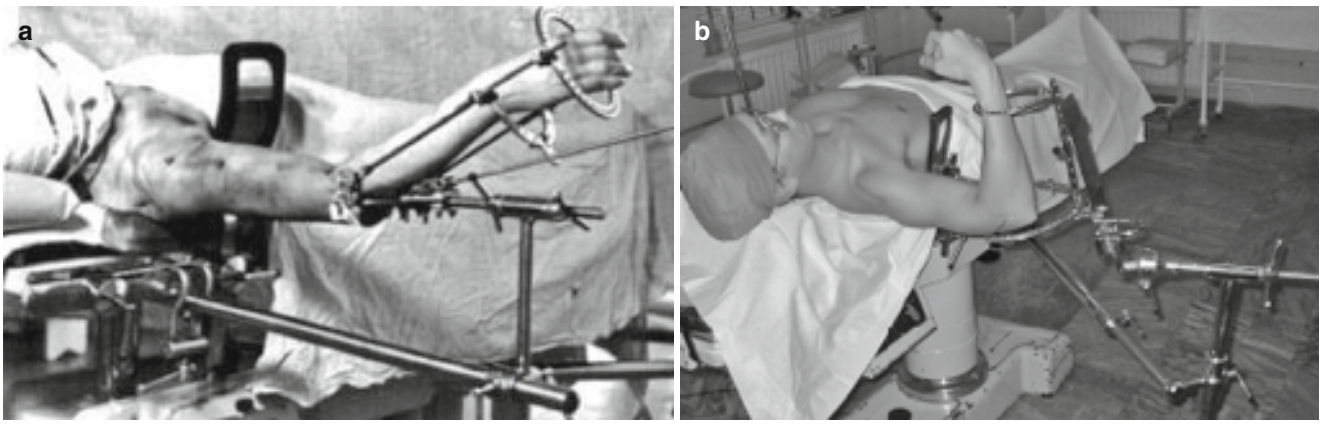


Fig. 10.2 (**a**, **b**) External fixation of the humerus involves preliminary elimination of the rough displacement of the bone fragments by skeletal traction. The equipment generally available on an orthopaedic traction table can be used. If a reductionally fixing post is unavailable it must be specially produced. (**a**) Device developed at the Ilizarov Russian Research Center [9]. (**b**) Structure based on minimum modification of an orthopaedic traction table

great vessels and nerves in the plane of a splinter, it is reduced and fixed using a fork-shaped rod (Fig. 1.6.17).

Regional anaesthesia is generally used for external fixation of the humerus. Transport immobilization is removed on the surgical table after induction of anaesthesia. A pillow 12–15 cm high is placed under the patient's head and between the scapulas, and the patient is laid so that the shoulder joint projects beyond the edge of the surgical table (Fig. 10.2).

In cases of skeletal traction, a wire is inserted through the olecranon (olecr., 3–9). It is strained and fixed to the reductionally fixing post (Fig. 10.3). The recommended position of the shoulder during skeletal traction in fractures of the proximal part of the humerus is abduction 90°, front deviation 20–30°, and external rotation 20°. In dislocation fractures (injury 11-B3), abduction of the shoulder should not exceed 50°. In fractures of the diaphysis (injuries 12-) and the distal humerus (injuries 13-), the shoulder is placed at an angle of 90° with a frontal deviation of 15–20°.

Instead of skeletal traction on the operation table a special distraction device can be used (Fig. 10.3).

Axial traction and manual manipulation improve the location of the bone fragments. To facilitate reduction, measures are taken to achieve "hyperextension" of the damaged segment to 5 mm controlling distraction at the post by comparison with the contralateral shoulder. X-ray contrast markers are placed on the skin (injection needles, fragments of wires) and radiographs in two standard planes are acquired for comparison, or fluoroscopy is used. Lines are drawn on the skin of the front and outer aspects of the segment corresponding to the plane of the anatomical axis of each bone fragment. Using the special device shown in Fig. 1.8.2, the levels for insertion of the transosseous elements are marked. As clinical experience increases, comparison radiographs during skeletal traction are obtained only in cases of juxtaarticular and intraarticular fractures (11- and 13-). The operative field is treated and covered with drapes.

Radiographic confirmation of an accurate reduction on the surgical table is a rule of external fixation of closed fractures. The practice of hastily assembling an external fixation device in the operating room and performing the reduction after the patient has been transferred to the outpatient department with daily step-wise radiographic monitoring of the manipulations is an unsatisfactory and discredited method of external fixation. An exception to this rule is when a fixation device is applied as described below.

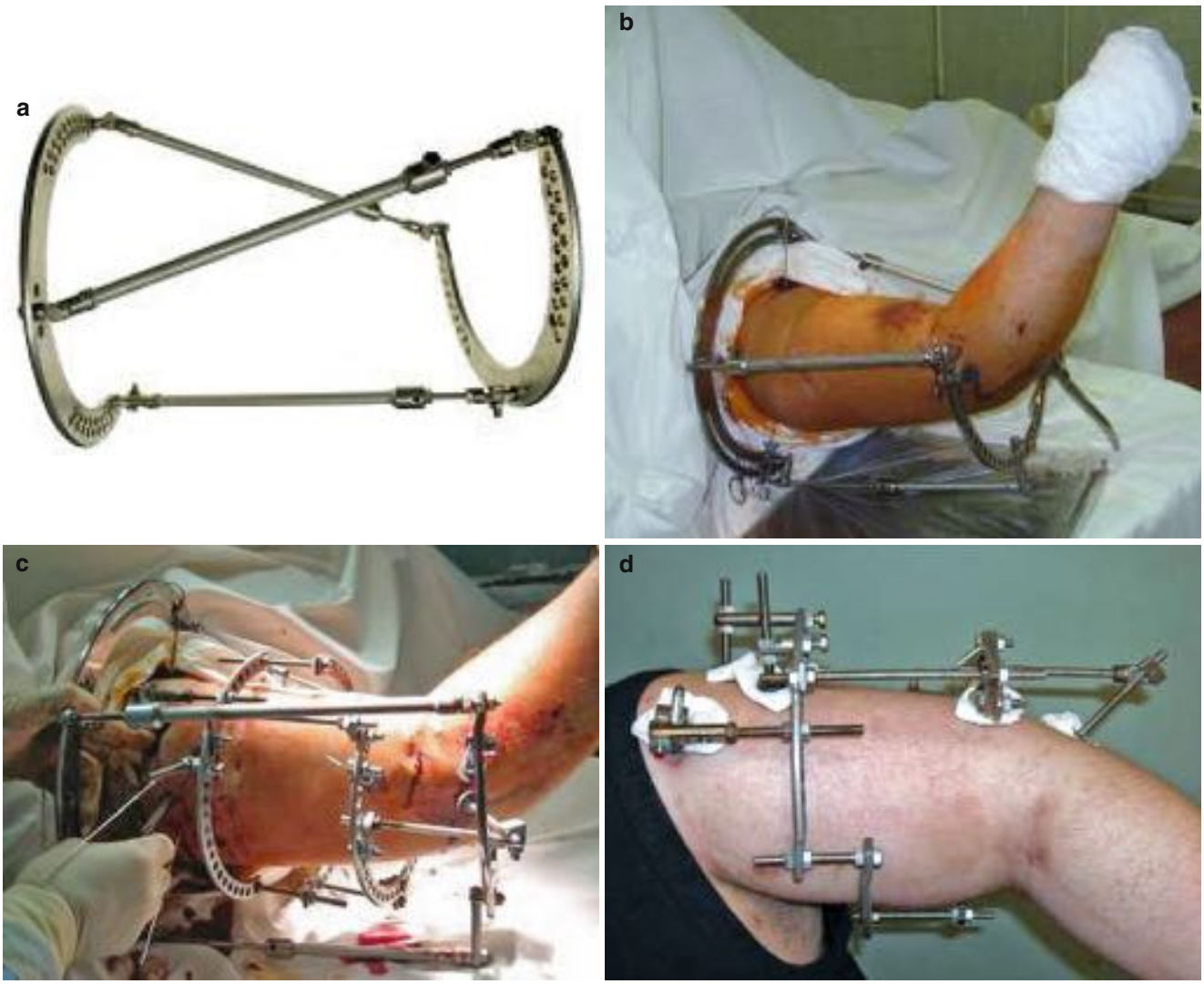


Fig. 10.3 (**a**–**c**) Using the distraction device. (**a**) Distraction device consists of two arches or the half rings connected by telescopic rods, (**b**) inserting wires. One of them or both can be basic ones. Wires are tensioned and fixed in the distraction device. Distraction is implemented, (**c**) the frame is assembled inside distraction devices, (**d**) after bone fragment reduction and fixation the distraction device is removed

10.1 Proximal Humerus (11-)

Ilizarov external fixation of fractures of the proximal humerus (11-) starts with the insertion of two wires through the supracondylar area, one in the frontal plane and the other at an angle of 30° to it: VII,9-3 and VII,10-4. The markers on the radiograph acquired under conditions of skeletal traction facilitate insertion of the wire perpendicular to the anatomic axis of the distal bone fragment.

An intermediate reductionally fixing ring support is installed at level IV of the upper arm, oriented relative to the bone and soft tissue and connected by three threaded rods with a three-quarter ring as the distal basic support. The connection rods must be parallel to the axis of the distal bone fragment. In this position, wires VII,9-3 and VII,10-4 are fixed in the distal support after tensioning.

In fractures 11-A2, 11-A3, 11-B1, and 11-B2 as well as in case of a slipped epiphysis or osteoepiphysis, the method of Ilizarov et al. [206] is used to eliminate rotational displacement. This is achieved by inserting a wire with a stop through the proximal metaphysis in a plane close to the sagittal plane, i.e., I,**5**-11. The wire is fixed in a half-ring whose standard size is larger than that of the proximal basic support. With the help of this support, the proximal fragment is placed in the position of maximum external rotation. The bone fragment is then rotated inside through an angle of 45–50°. The second wire is inserted in the sagittal plane, i.e., I,12-6. As soon as the wire is inserted in the soft tissues of the posterior

semicircle of the upper arm, the proximal fragment is placed in the position of maximum external rotation. After insertion of wire I,12-6, the proximal bone fragment is placed again in the position of internal rotation at 45–50°. Wires I,5-11 and I,12-6 are fixed to the basic half-ring so that the axis is properly oriented relative to the soft tissue and is located strictly perpendicular to the axis of the proximal fragment. The larger half-ring is then removed.

When the fracture line spreads to level I, the epimetaphyseal area of the bone can also be used for wire insertion (level 0).

The distal fragment is placed in the medio-physiological position when the first finger is inserted in the line of the deltoid-thoracic sulcus. All three supports are connected. Distraction is applied to create an interfragmentary diastasis of 4–5 mm if this was not possible by skeletal traction. Radiographs are obtained in two standard planes or an image intensifier (fluoroscopy) is used.

A wire is inserted for final reduction of the distal fragment at the level of the intermediate ring. The direction of its insertion and the location of the stop depend on the displacement of the proximal end of the distal fragment. To avoid injury to the great vessels and nerves, only safe positions as specified in the atlas for level IV of the upper arm are used. As an example, Fig. 10.4 shows wire IV,**4**-10.

Figure 10.5 shows the scheme for the combined external fixation of fracture 11-.

In intra-articular fractures (11-C), the wires are inserted through the acromion process of the scapula: acr.,**7**-1 and acr.,**11**-5. After tensioning, they are fixed to the half-ring. The device is assembled from three supports, with the intermediate ring located at level IV. After distraction, comparison radiographs in two planes are obtained.

Large splinters are reduced and fixed using either Kirschner wires with stops or console wires with stops. In turn, these wires are fixed to the proximal support of the device using posts.

Distal bone fragments are reduced in a manner similar to that described for fractures 11-A2, 11-A3, 11-B1, and 11-B2. The scheme for Ilizarov fixation of fracture 11-C1 is shown in Fig. 10.6.

In dislocation fractures (11-B3), the wires are inserted through the acromial process of the scapula: acr.,**7**-1 and acr.,**11**-5. After tensioning, they are fixed to the half-ring. When manual techniques fail to reset the humeral head, a wire with a bayonet-shaped stop is inserted after moderate distraction, on the side of the axillary crease and bypassing the great vessels and nerves. By means of gradual traction of the wire, the humeral head is re-set [207].

Alternatively, a dislocated humeral head can be re-set as follows: A wire is inserted through the humeral head in the sagittal plane: I,**6**-12 (in posterior dislocations) or I,**12**-6 (in anterior dislocations). This wire is strained in the half-ring and the humeral head is re-set by traction behind it. In another variant, the wire is arched outwards and fixed to the support using distraction clips. During tensioning, the wire straightens such that the humeral head is brought out of the dislocation condition. Displacement of the head is accompanied by tension on the soft tissues along their dorsal aspect. Therefore, after the manipulation is completed, the soft tissues must be cut as much as necessary, or (more often) wire I,6-12 must be substituted for another transosseous element, for example, half-pin I,9,120.

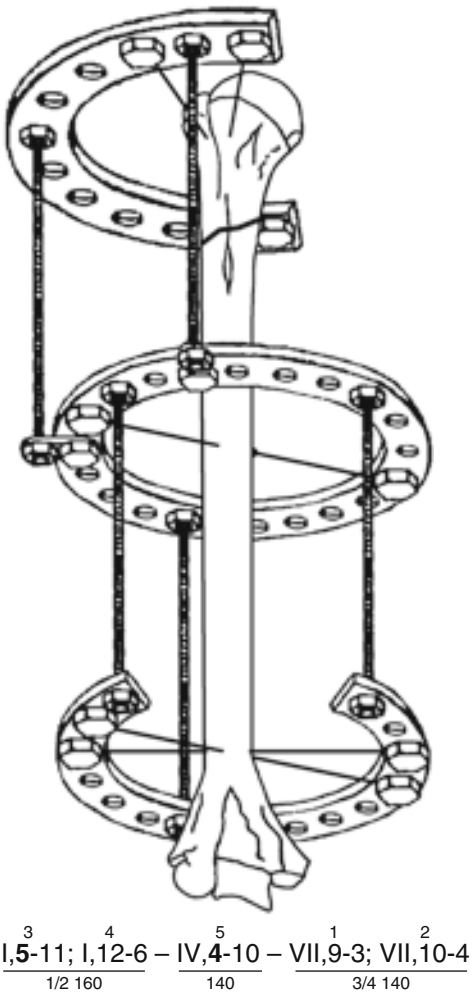


Fig. 10.4 Ilizarov external fixation device for the fixation of fracture 11-A3.2

After reduction and fixation of the humeral head, external fixation is performed using a technique similar to that described for injuries 11-A2, 11- A3, 11-B1, 11-B2.

When full-volume external fixation is impossible, for example, in the event of multiple and massive trauma in a severely injured patient, the "fixed" variant of external fixation can be carried out. A wire with a stop is inserted at levels I and VII. The proximal wire is strained and fixed to the half-ring and the distal wire is fixed to a three-quarter

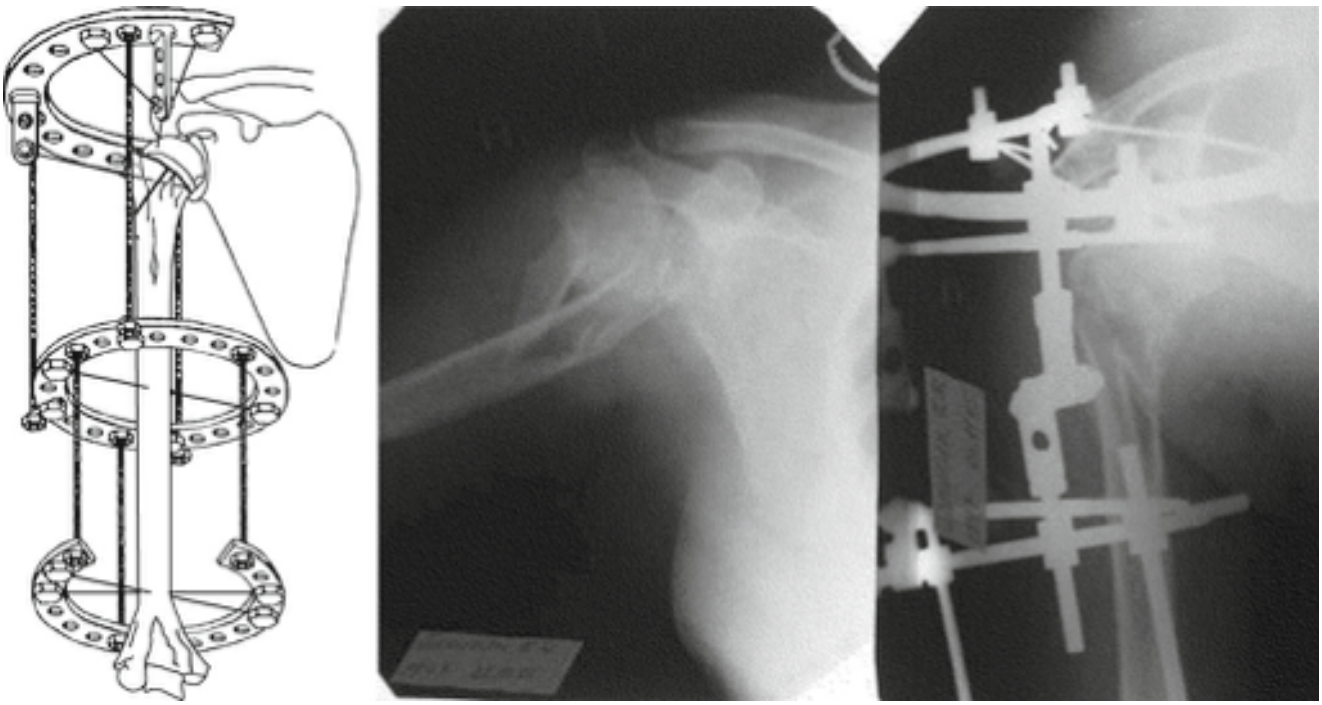
Fig. 10.5 (**a–k**) Combined external fixation device for the fixation of fracture 11- (**a**) The traction device is applied on the basis of wires acr., 6-12 and VII,**3**-9; rough displacement of the bone fragments is eliminated (below the attachment; not shown). (**b**) An alternative to the traction device is skeletal traction using wire VII,**3**-9. At this stage, Two-plane roentgenography is performed using X-ray-positive markers. (**c**) Insertion of proximal basic half-pins I,8,120 and I,11,120. (**d**) Particular attention must be paid to the orientation of the proximal basic support: it should be placed perpendicular to the anatomic axes of the proximal bone fragment in two planes

Fig. 10.5 (continued) (**e**) Orientation of the distal module perpendicular to the axis of the distal bone fragment and its fixation on wire VII,**3**-9. (**f**) Connection of the proximal and distal modules. Distraction for a diastasis of 3–5 mm. Two-plane X-ray examination

Fig. 10.5 (continued) (**g**) Insertion of reductionally fixing half-pin III,9,90 and reduction of the distal bone fragment. Two-plane X-ray examination. (**h**) Insertion of stabilizing half-pins I,10,120 and V,10,70

Fig. 10.5 (continued) (**i**) Fixation of stabilizing half-pins, elimination of the diastasis, removal of skeletal traction. (**j**) First stage of module transformation (MT): removal of the distal basic support

Fig. 10.5 (continued) (**k**) Second stage of MT: removal of the medial half ring of the reductionally fixing support. (**l**) The patient after the second stage of MT (M) The patient after the second stage of MT



3 4 5 6 7 1 2
acr.,**7**-1; acr.,**11**-5; 0,**6**-12; I,9,80 – IV,**4**-10 – VII,9-3; VII,10-4
1/2 160 140 3/4 140

Fig. 10.6 External fixation for the fixation of fracture 11-C1

ring support. A moderate distraction force is applied between the supports: I,**6**-12 ↔ VII,**3**-9. In cases of an intra-articular fracture (11-C), the device applied is: acr.,**7**-1 ↔ VII,**3**-9.

The "fixed" variant is used as a "lesser of all evils" solution and in cases in which the closed reduction of complicated intra-articular fractures (11-C3) is unattainable and open reduction is contraindicated. The following device is applied: acr.,**7**-1; acr.,**11**-5 ↔ IV,**4**-10 – VII,9-3; VII,10-4.

After final comparison radiographs are obtained, the arm is placed in abduction at an angle of 45–60° by means of a wedge-shaped pillow. Exceptions are cases in which the wires were inserted through the acromial process of the scapula.

10.2 Diaphyseal Fractures (12-)

10.2.1 Proximal Third

Ilizarov external fixation of fractures of the proximal third of the humeral diaphysis (injuries 12-A1.1, 12-A2.1, 12-A3.1, 12-B1.1, 12-B2.1, 12-B3.1) starts with the insertion of crossing proximal basic wires through the proximal metaphysis of the humerus. One such wire is inserted in the sagittal plane and the other at an angle of 30° to the first: VII,**6**-12 and I,**11**-5. This is followed by insertion of the distal basic wires: one in the frontal plane and the other at an angle of 30º to it: VII,9-3 and VII,10-4. The proximal support based on an extended half-ring is oriented relative to the bone and soft tissue and the wires are fixed to it after tensioning.

The intermediate reductionally fixing ring support is then installed at level IV of the upper arm and is connected by three rods with the three-quarter ring distal support. The intermediate support is oriented relative to the bone and soft tissue. The connection rods must be parallel to the longitudinal axis of the distal bone fragment. After tensioning, wires VII,9-3 and VII,10-4 are fixed to the distal support, which if properly installed is perpendicular to the anatomic axis of the distal bone fragment.

The proximal basic support is connected by three rods to the reductionally fixing support. Distraction is applied to create an interfragmentary diastasis of 5–7 mm if this was not done by skeletal traction. Radiographs are obtained in two standard planes or an image intensifier is used.

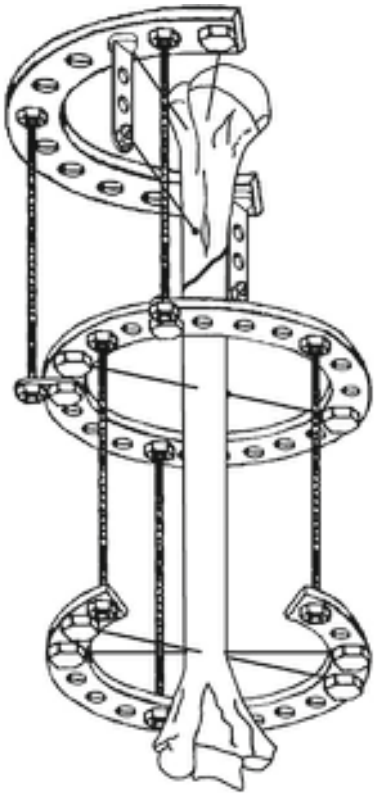


Fig. 10.7 The Ilizarov external fixation device for the fixation of fracture 12-A2.1

To eliminate residual displacement of the proximal bone fragment at level II, a reductionally fixing wire is inserted. If the residual displacement is at level IV, a second reductionally fixing wire is inserted. The direction of insertion of these wires and the location of the stop on both of them depend on the residual displacement of the bone fragments. To avoid injury to the great vessels and nerves, only safe positions as specified in the atlas for levels II and IV of the upper arm are used. Figure 10.7 shows an example for wires II,**11**-5 and IV,**4**-10.

Figure 10.8 shows the scheme for the combined external fixation of fractures of the proximal third of the humerus.

10.2.2 Middle Third

Ilizarov external fixation of fractures of the middle third of the humeral diaphysis (injuries 12-A1.2, 12-A10, 12-A3.2, 12-B1.2, 12-B10, 12-B3.2) starts with insertion of the crossing wires II,**6**-12 and II,11-5. If the fracture is located closer to the proximal third of the diaphysis, proximal basic wires are placed at level I: I,6-12 and I,11-5. The distal basic wires VII,9-3 and VII,10-4 are then inserted. If the fracture is located at the border of the middle and distal thirds of the diaphysis, distal basic wires are placed at level VIII: VIII,3-9 andVIII,2-8.

After the proximal pair of the wires are strained, they are fixed in an extended half-ring that is preliminarily oriented relative to the bone and soft tissue as specified in Sect. 10.

One reductionally fixing support is placed at level III (or level IV, depending on the fracture site) and another at level V (or level VI). The reductionally fixing rings and the distal basic support are two-thirds or three-quarter rings connected to form a single module. The reductionally fixing rings are oriented relative to the soft tissue, and the module is installed so that the connection rods are parallel to the anatomic axis of the distal fragment. Only then are the distal basic wires strained and fixed to the support. To preserve the orientation of the reductionally fixing supports relative to the soft tissue, the module comprising three distal supports is connected by three rods to the proximal basic support using, if required, connection plates (various diameters of the supports).

Distraction is then applied between the reductionally fixing supports to create an interfragmentary diastasis of 4–5 mm, if this was not previously done by skeletal traction. Radiographs are obtained in two standard planes or an image intensifier is used.

To eliminate residual displacement of the proximal bone fragment, a reduction wire is inserted at level IV (or level III, depending on the line of the fracture). To eliminate residual displacement of the distal fragment, a second reduction wire is inserted at level V (or level VI). Figure 10.9 shows, as an example, wires IV,**10**-4 and V,**4**-10.

Figure 10.10 shows the scheme for the combined external fixation of fractures of the middle third of the humerus.

10.2.3 Distal Third

Ilizarov external fixation of fractures of the distal third of the humeral diaphysis (injuries 12-A1.3, 12-A2.3, 12-A3.3,12-B1.3, 12-B2.3, 12-B3.3) starts with insertion of the intercrossing proximal basic wires III,**6**-12 and III,1-7. The distal basic wires VIII,9-3 and VIII,8-2 are then

Fig. 10.8 (**a–j**) Combined external fixation for the fixation of fractures of the proximal third of the humerus. (**a**) Application of skeletal traction using wire VIII,**3**-9. Division of the lower leg into levels. Two-plane X-ray examination with X-ray contrast markers. (**b**) Insertion of proximal basic half-pins I,10,120 and II,8,90. Particular attention must be paid to the orientation of the proximal basic support, which should be placed perpendicular to the anatomic axes of the proximal bone fragment in two planes. (**c**) Orientation of the distal module perpendicular to the axis of the distal bone fragment and its fixation on wire VII,**3**-9

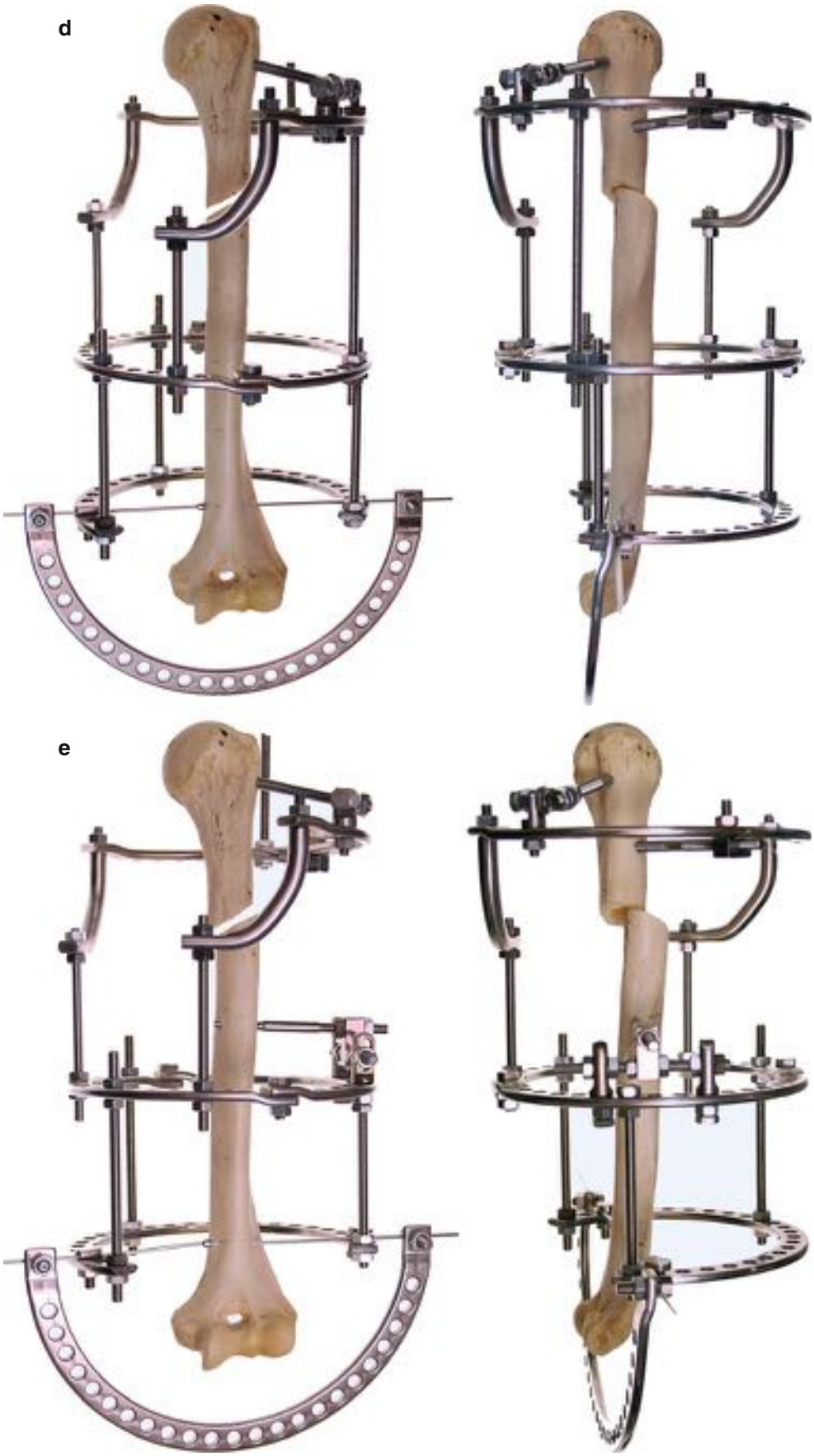


Fig. 10.8 (continued) (**d**) Connection of the proximal and distal modules, distraction for a diastasis of 3–5 mm. Two-plane X-ray examination. (**e**) Insertion of half-pin IV, 9,90 and its fixation with the help of a reduction device to a reductionally fixing support

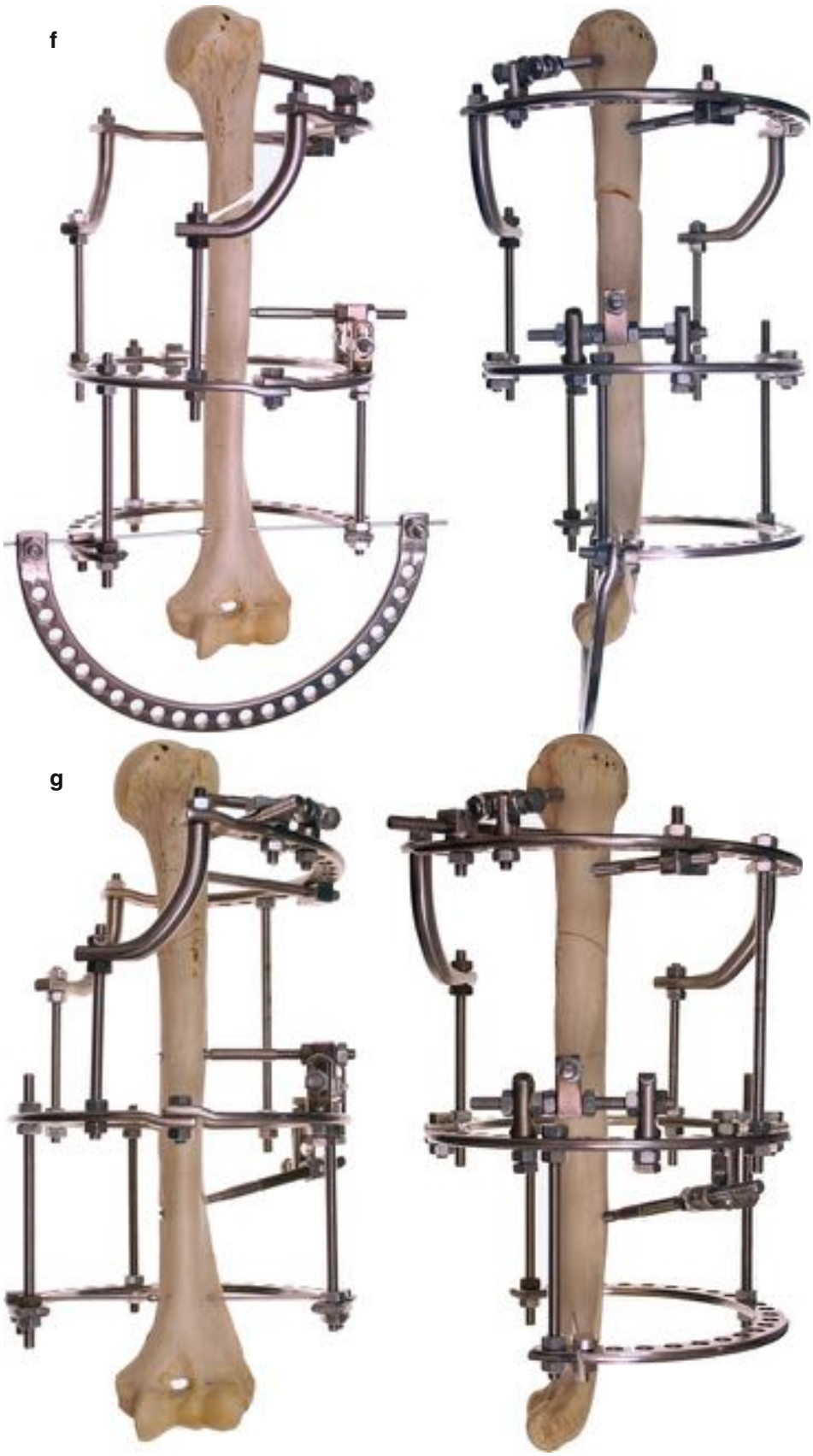


Fig. 10.8 (continued) (**f**) Distal bone fragment reduction in two planes. Two-plane X-ray examination. (**g**) Fixation of stabilizing half-pins II,11,90 and VI,8,70. Elimination of the diastasis and the removal of skeletal traction

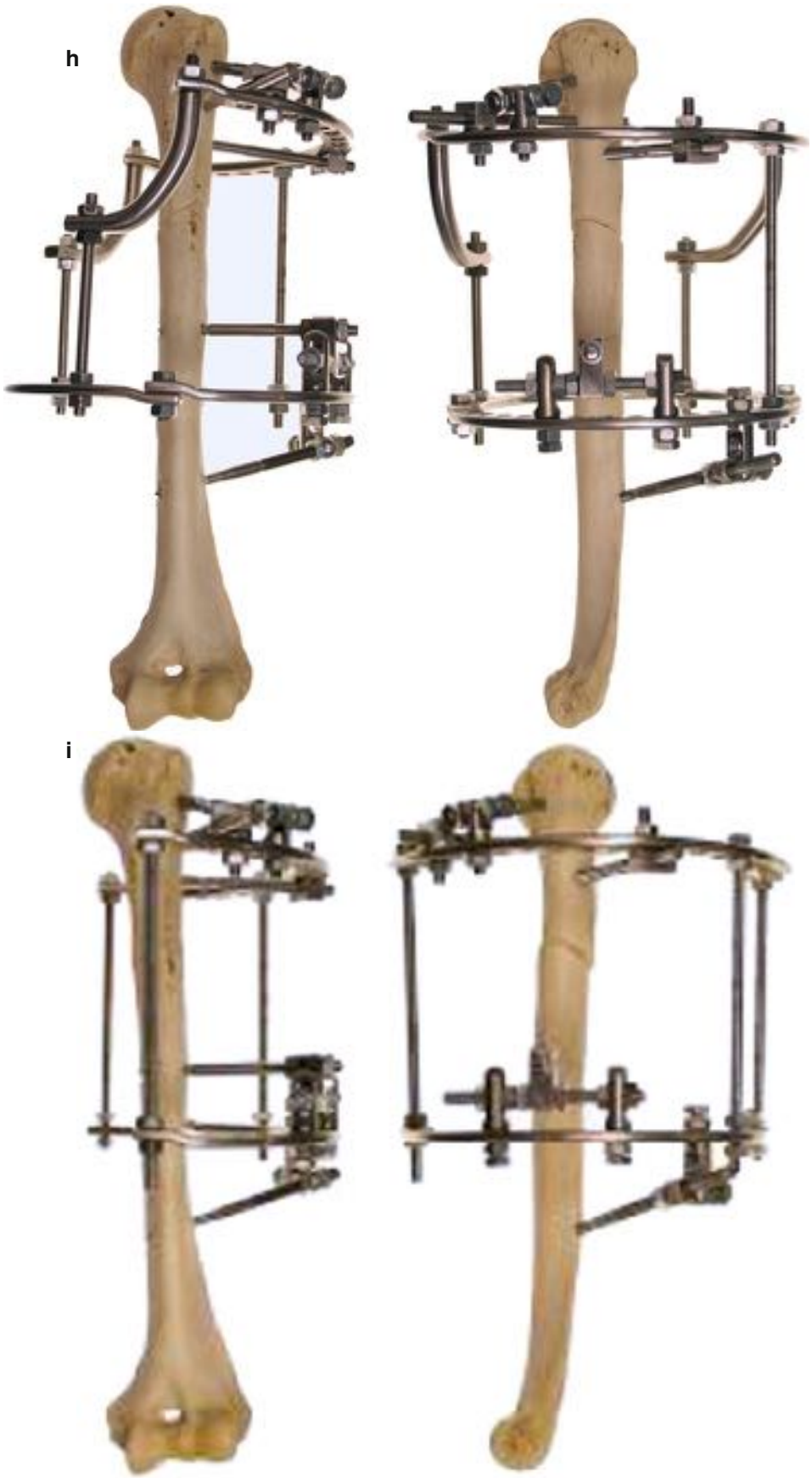


Fig. 10.8 (continued) (**h**) First stage of module transformation (MT): removal of the distal basic support. (**i**) Second stage of MT: removal of the reductionally fixing support

Fig. 10.8 (continued) (**j**) The patient after the second stage of MT

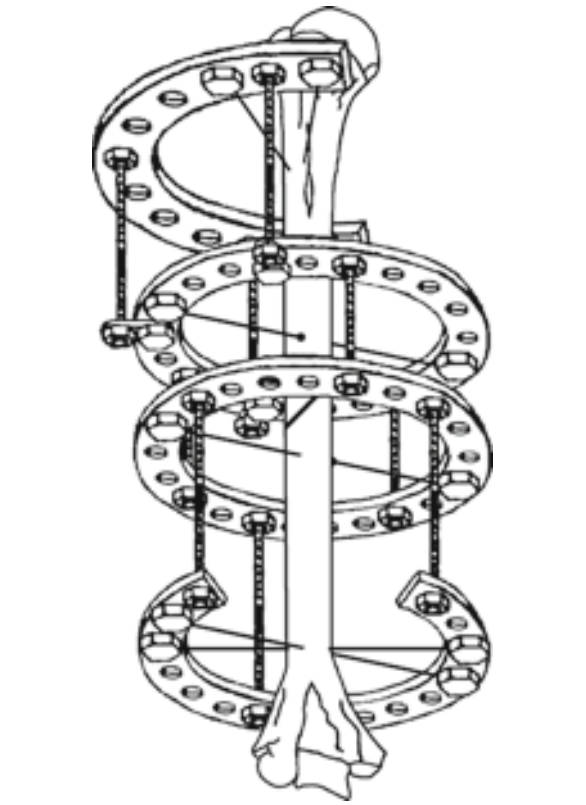


Fig. 10.9 Ilizarov external fixation device for the fixation of fracture 12-A3.2

inserted. The proximal support is a two-thirds ring placed at level III of the upper arm and oriented relative to the bone and soft tissues as described in Sect. 10. After tensioning, wires III,**6**-12 and III,1-7 are fixed to the proximal basic support.

At level V, an intermediate reductionally fixing ring is installed and oriented relative to the soft tissue. The intermediate ring is connected by three rods to the proximal basic support. To achieve proper orientation of the supports, the connection rods must be parallel to the anatomic axis of the proximal bone fragment.

The distal basic support is a three-quarter ring oriented perpendicular to the anatomic axis of the distal bone fragment; it is connected by three rods to the intermediate support. In this position, wires VIII,9-3 and VIII,8-2 are fixed to the distal supports after tensioning.

Distraction is applied to create a 4–5 mm diastasis between the fragments, if this was not done previously by skeletal traction. Radiographs are obtained in two standard planes or an image intensifier is used.

To eliminate residual displacement of the proximal bone fragment, a reduction wire is inserted at level V. If the eliminate residual displacement involves the distal fragment, at level VII, a second reduction wire is inserted. Figure 10.11 shows, as an example, wires V,**4**-10 and VII,**9**-3.

Figure 10.12 provides the scheme for the Combined external fixation device for the fixation of segmentary fractures is presented on Fig. 10.13.

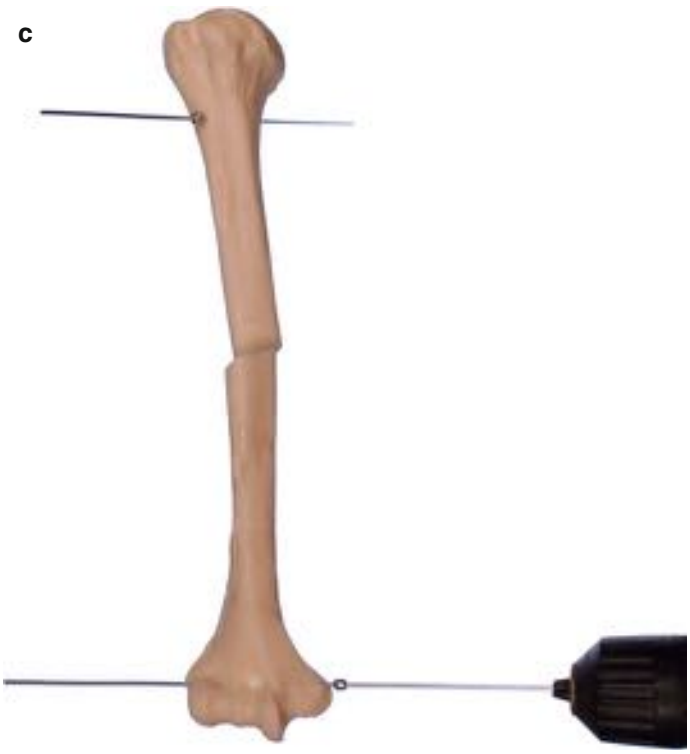


Fig. 10.10 (**a–l**) Combined external fixation device for the fixation of fractures of the middle third of the humerus. (**a**) The traction device is applied on the basis of wires II,5-11 and VIII, **3**-9. Rough displacement of the bone fragments is eliminated. These wires will be basic ones. (**b**) An alternative to the traction device is skeletal traction using wire olecr.,3-9 or VIII,3-9. Wire VIII,3-9 will be the basic one. At this stage Two-plane roentgenography with X-ray contrast markers. (**c**) Insertion of basic wires II,**5**-11 and VIII,**3**-9

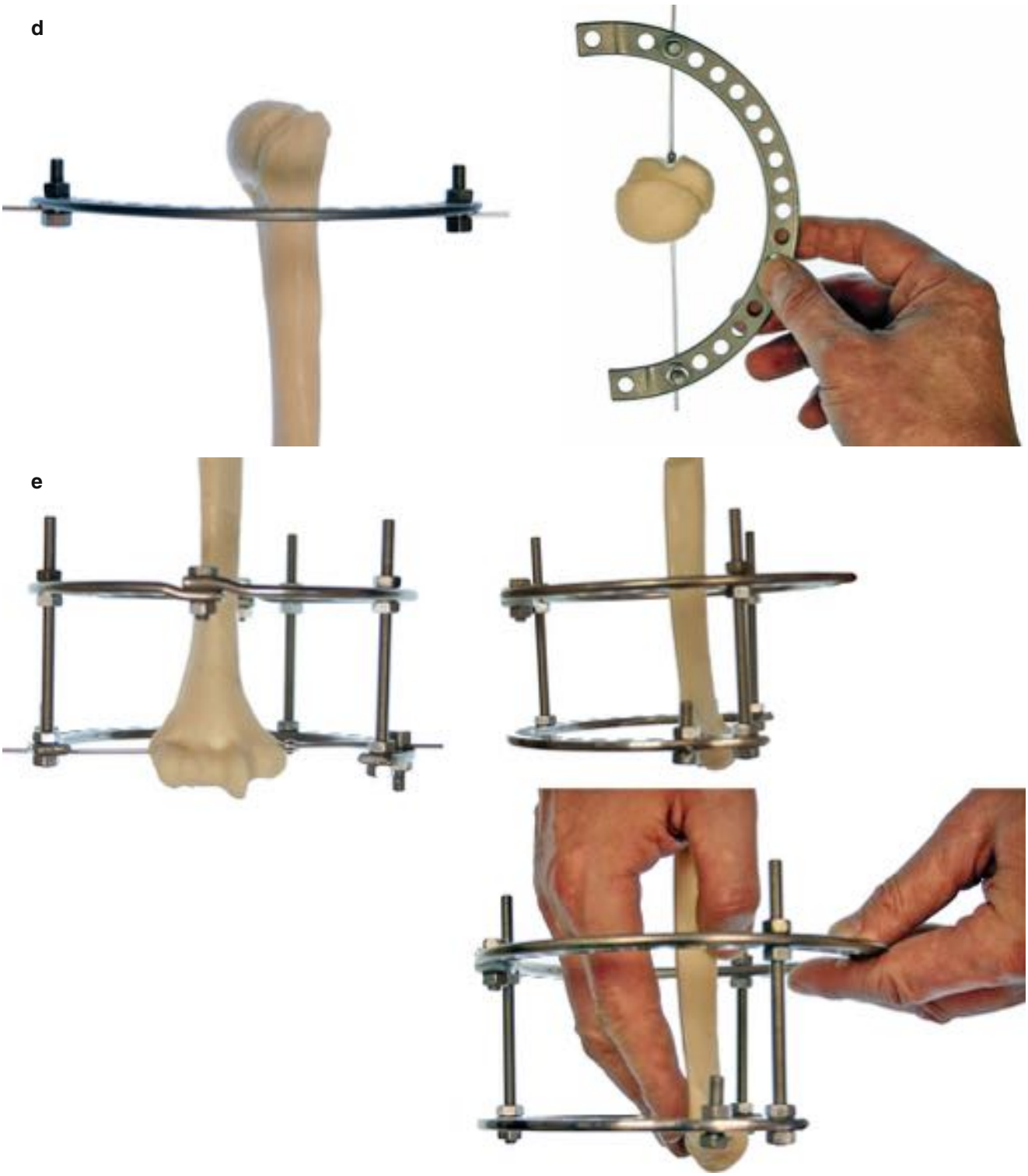


Fig. 10.10 (continued) (**d**) Orientation and fixation of the proximal basic support. (**e**) Orientation of the distal module perpendicular to the axis of the distal bone fragment and its fixation on wire VIII,**3**-9. The hand simulates the soft-tissue distribution on the dorsal surface of a shoulder

Fig. 10.10 (continued) (**f**) The basic wires are tensioned only after the proximal and distal transosseous modules have been connected (if they have not been tensioned as wires of the traction device or during skeletal extension). Distraction for a diastasis of 3–5 mm. Two-plane X-ray examination. (**g**) Insertion of reductionally fixing half-pin IV, 9,90 and its dynamic fixation to the reductionally fixing support. (**h**) Insertion of reductionally fixing half-pin V, 10,90 and its dynamic fixation to the distal reductionally fixing support

Fig. 10.10 (continued) (**i**) Subsequent two-plane bone fragment reduction. Two-plane X-ray examination. Static fixation of the reductionally fixing half-pins. (**j**) Insertion and fixation of proximal and distal stabilizing half-pins II,8,120 and VII,8,70. Elimination of the diastasis

Fig. 10.10 (continued) (**k**) First stage of module transformation (MT): removal of the basic supports. (**l**) Second stage of MT: removal of the medial half rings of the reductionally fixing supports

Fig. 10.10 (continued) (**m**) The patient after the second stage of MT

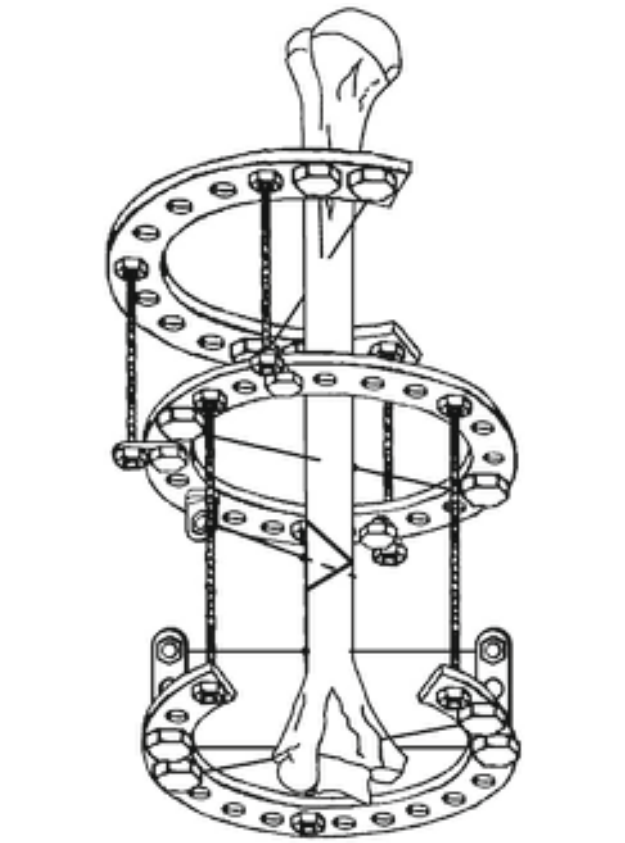


Fig. 10.11 Ilizarov external fixation device for the fixation of fracture 12-B2.3

10.2.4 Radial Nerve Injury

A quite frequent complication of diaphyseal fractures of the humerus is *injury to the radial nerve*. When clinical and laboratory examinations confirm functional nerve injury and immediate recovery is not possible, the method of Shved et al. is used. After precise reduction and stable external fixation of the humeral fragments, a diastasis of 5–8 mm is created between the bone fragments. This results in moderate tension on the radial nerve, which prevents it from becoming trapped and compressed between bone fragments. After formation of the primary bone commissure, step-wise coaptation of the bone fragments is carried out (0.25 mm 4× per day). A complete course of simultaneous treatment is prescribed to recover the function of the nerve.

When full-volume external fixation of diaphyseal fractures of the upper arm is not possible, for example in the event of multiple and massive trauma, the "fixation" variant of external fixation can be performed. Wires I,**5**-11 and VII,**3**-9 are inserted in the case of fracture of the *proximal third* of the humeral diaphysis. The proximal wire is tensioned and fixed to the half-ring while the distal wire is fixed to a three-quarter ring support. Moderate distraction is created between the supports: I,**5**-11 ↔ VII,**3**-9.

For temporary fixation of fractures of the *middle and distal thirds* of the humeral diaphysis, the following devices are used: II,**5**-11 ↔ VII,**3**-9 and III,**6**-12 ↔ VIII,**3**-9, respectively (Fig. 10.14).

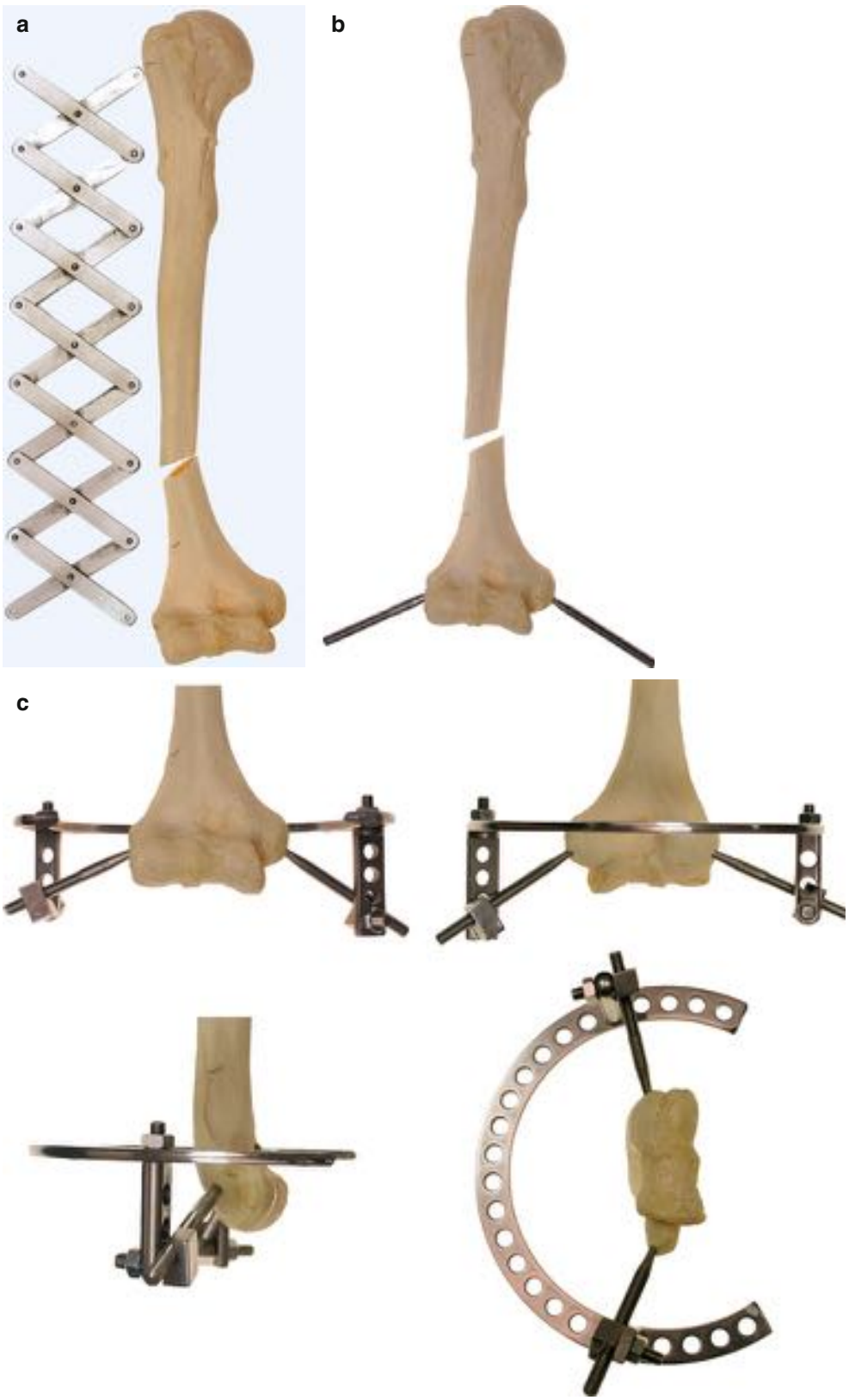


Fig. 10.12 (**a–k**) Combined external fixation device for the fixation of segmentary fractures is presented on Fig. 10.13. (**a**) Application of skeletal traction using wire olecr.,3-9. If a traction device was used (Fig. 10.10a), wire II,7-1 is the proximal basic one. Two-plane radiological control. (**b**) Insertion of distal basic half-pins VIII,4,120 and VIII,8,120. (**c**) Orientation and fixation of the distal basic support perpendicular to the anatomic axes of the distal bone fragment in two planes

Fig. 10.12 (continued) (**d**) Insertion of proximal basic wire II,**7**-1. Assembly and orientation of the proximal basic support. (**e**) Assembly of the frame; distraction to achieve a 3–5 mm diastasis. (**f**) Insertion of reductionally fixing half-pin V, 10,90 and its dynamic fixation to the support

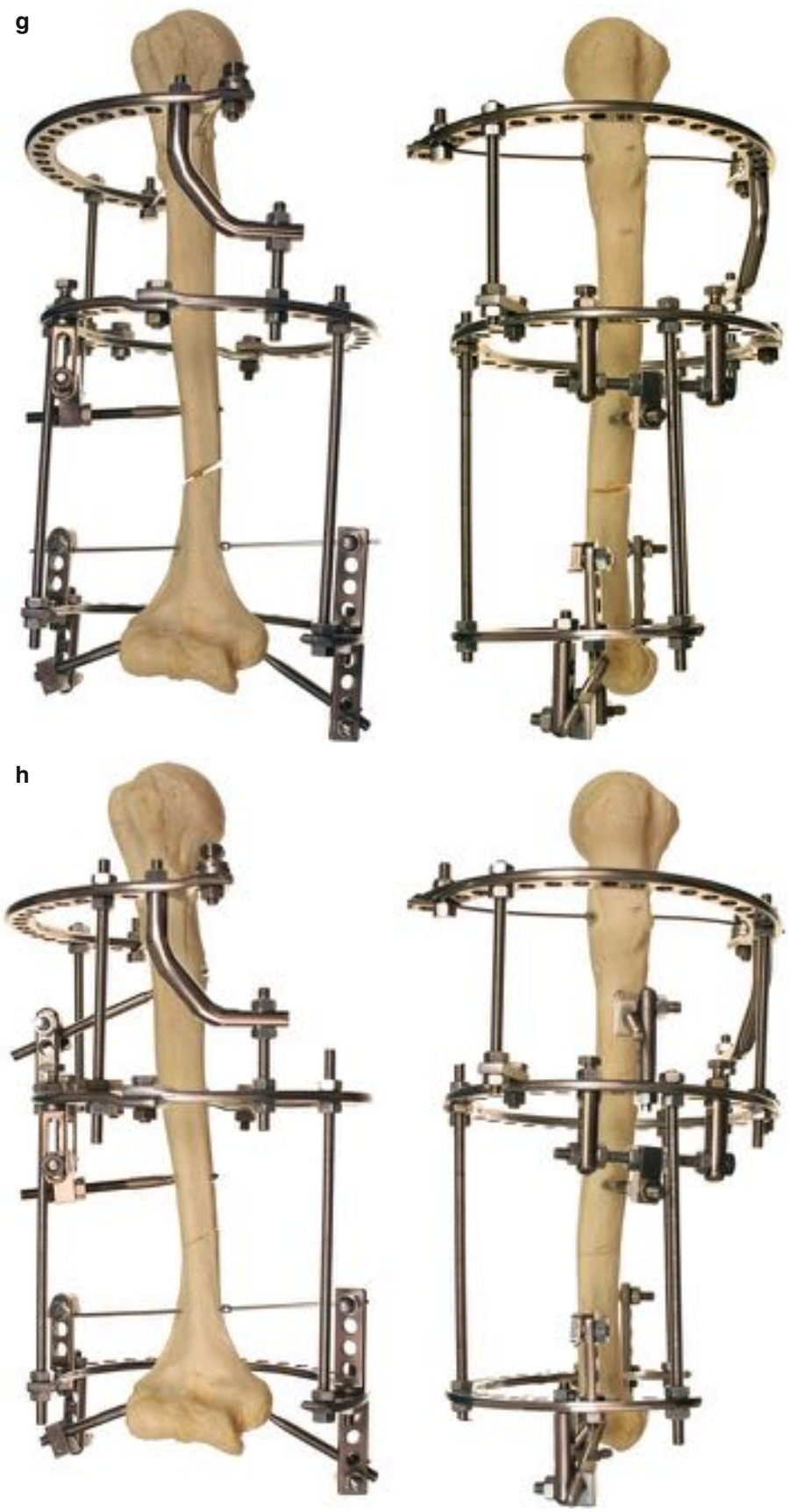


Fig. 10.12 (continued) (**g**) Insertion of distal reductionally fixing wire VII,**3**-9 with subsequent two-plane bone fragment reduction. Two-plane X-ray examination. Static fixation of the reductionally fixing transosseous elements. (**h**) Insertion and fixation of proximal stabilizing half-pin III,9,120. Elimination of the diastasis

Fig. 10.12 (continued) (**i**) First stage of module transformation (MT): removal of proximal basic support VII,**3**-9. (**j**) Second stage of MT: removal of the medial half rings of the reductionally fixing support

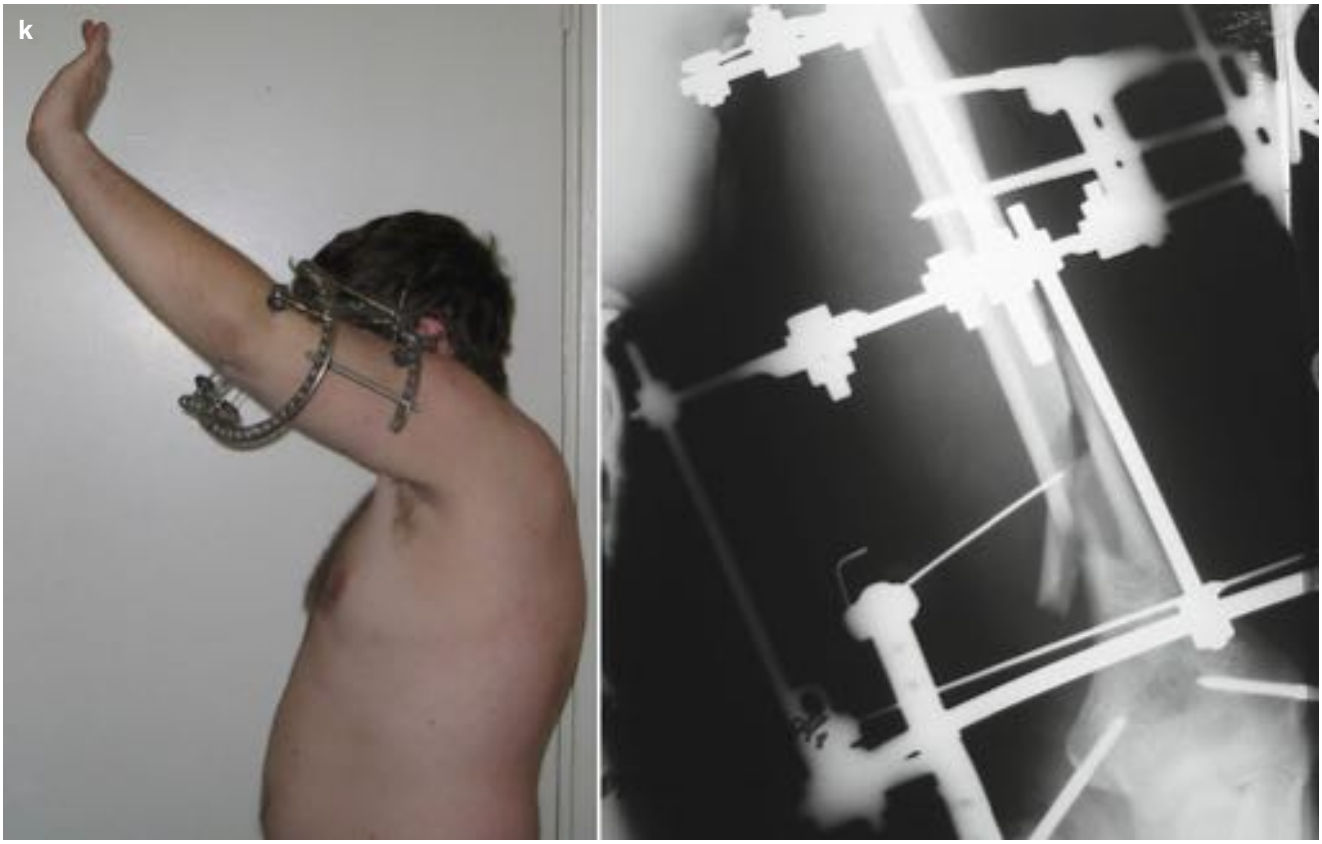


Fig. 10.12 (continued) (**k**) The patient after MT

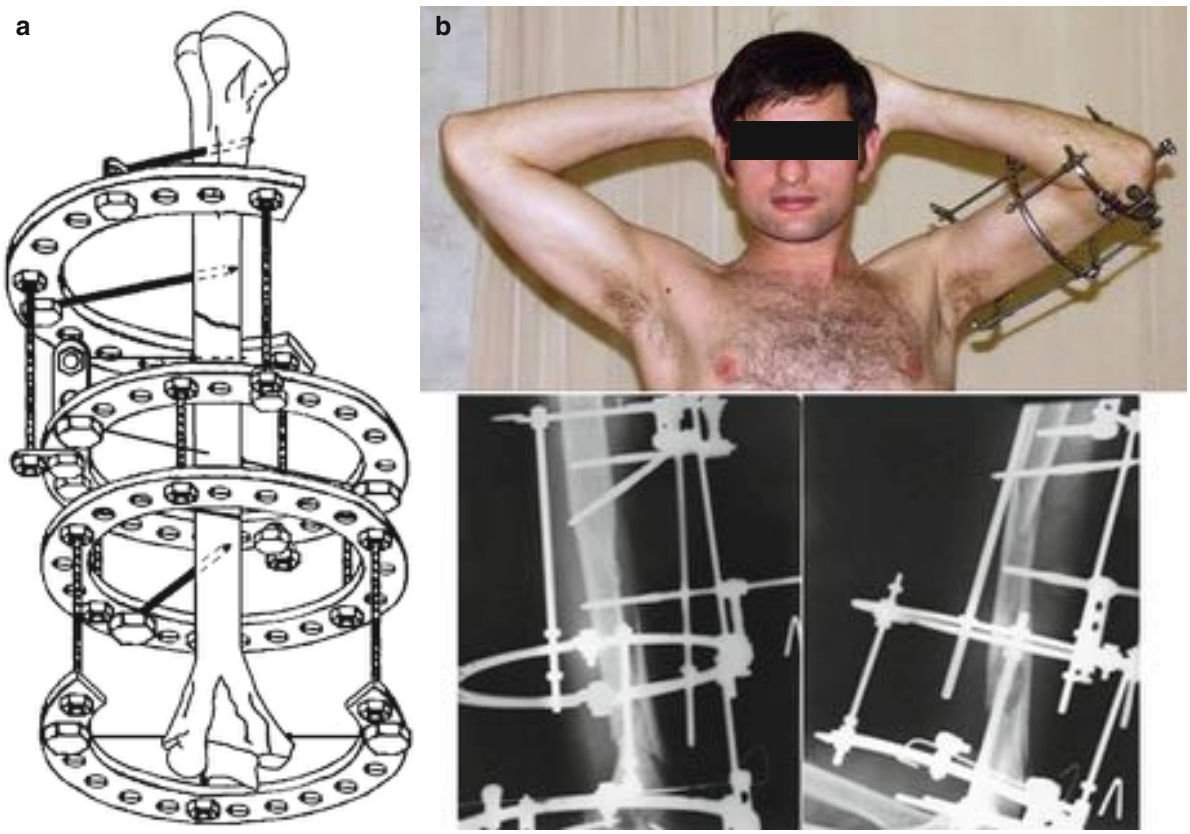


Fig. 10.13 (**a, b**) Combined external fixation device for the fixation of segmentary fractures 12-C2.1. It is crucial to ensure that the proximal and distal basic supports are installed perpendicular to the anatomic axis of the bone fragments to which they are fixed

Fig. 10.14 "Fixation" device for fractures of the humeral bone shaft. Joining of the telescopic rods with the support by means of connection plates facilitates the installation of reductionally fixing supports at the next stage

The "fixation" variant of external fixation has advantages over skeletal traction: it is less bulky, the patient is more mobile, and reduction may be achieved using both skeletal traction (elastic traction) and external fixation, which enables dismantling of the device.

After the final radiographs have been obtained to confirm the positions of the fragments, the arm is placed in abduction at an angle of 45–60° using a wedge-shaped pillow and the patient is transported to the ward.

10.3 Distal Humerus (13-)

Ilizarov external fixation of fractures 13 starts with insertion of the intercrossing proximal basic wires into the upper third of the humerus. One wire is inserted in the sagittal plane and the other wire at an angle of 30° to it: III,**6**-12 and III,1-7. The proximal basic support is a two-thirds ring placed at level III of the upper arm and oriented relative to the bone and soft tissue. After tensioning, wires III,**6**-12 and III,1-7 are fixed to the proximal basic support. At level V, an intermediate ring is installed and connected by three rods to the proximal basic ring. When the proximal basic support is properly installed, the connection rods are parallel to the axis of the proximal bone fragment.

In cases of *extra-articular fractures* (13-A2, 13-A3) or a slipped epiphysis or osteoepiphysis, two wires are inserted through the distal fragment strictly perpendicular to its longitudinal axis. One is inserted in the frontal plane and the other at an angle of 30° to it: VIII,**3**-9 and VIII,8-2. After tensioning, the wires are fixed to a three-quarter ring external support. The distal basic support is connected to the intermediate ring by three rods.

Distraction is then applied to create an interfragment diastasis of 4–5 mm, if this was not previously done by skeletal traction. Radiographs in two standard planes are obtained or an image intensifier is used.

To eliminate residual displacement of the proximal fragment, a reductionally fixing wire is inserted at the level of the intermediate ring. To avoid injury to the great vessels and nerves, only safe positions as specified in the atlas for level IV of the upper arm are used. Figure 10.15 shows, as an example, wire V,**4**-10.

The distal fragment is reduced using a stop and/or arched bending of the wire. If required, reduction is achieved by displacement of the external supports. Large splinters are fixed using either Kirschner wires with stops or console wires with stops.

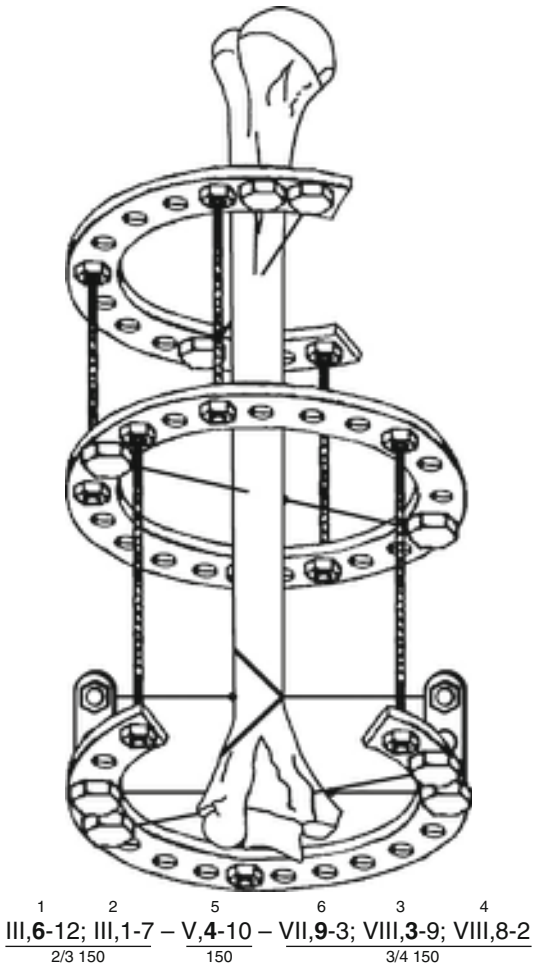


Fig. 10.15 Ilizarov external fixation device for the fixation of fracture 13-A3.1

Figure 10.16 shows the scheme for the combined external fixation of extra-articular fractures of the distal part of the humerus.

It is also beneficial to perform external fixation of *intra-articular fractures* of the distal humerus (injuries 13-B and 13-C) under conditions of skeletal traction on the orthopedic traction table. However, it should be kept in mind that tension to the collateral ligaments of the elbow as a result of excessive traction can aggravate displacement of the fragments.

In fractures 13-B and 13-C, closed external fixation can only be performed when it is possible to recover joint congruity by moderate skeletal traction or by manual techniques (including the use of a thin hook or an awl). Fluoroscopy considerably facilitates the manipulation. If closed reduction fails, then open reduction becomes necessary.

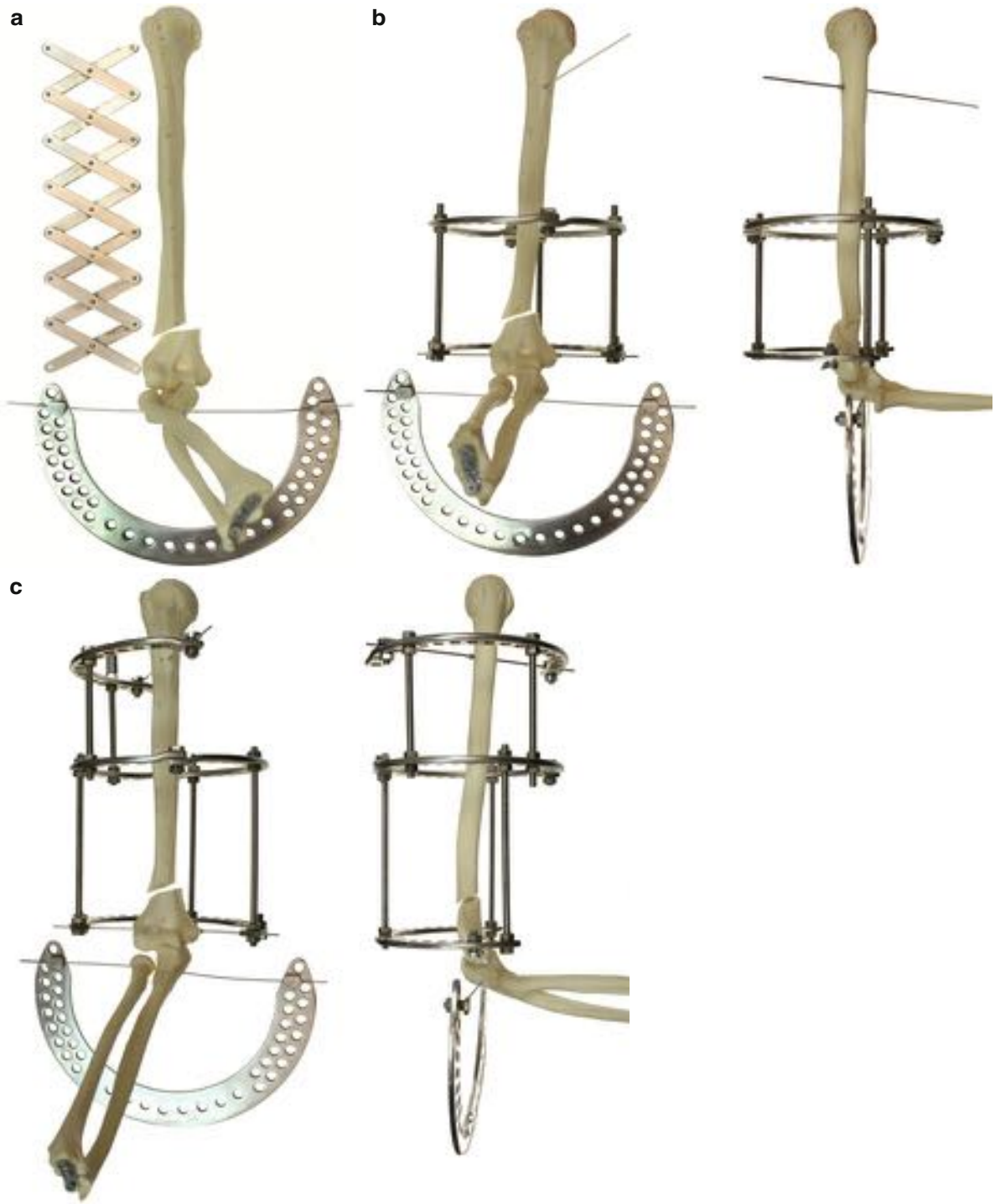


Fig. 10.16 (**a–g**) Combined external fixation device for the fixation of extra-articular fractures of the distal part of the humerus. Module transformation of the device for fractures of the distal part of the humerus is shown in Fig. 10.18. (**a**) Application of skeletal traction, division of the segment into levels. Two-plane X-ray examination using radiopaque. (**b**) Insertion of basic wires II,**5**-11 and VIII,**3**-9. Assembly and alignment of distal reductionally fixing and basic supports. (**c**) Frame mounting, tensioning and fixation of the wires, and distraction for a 3–5 mm diastasis. Two-plane X-ray examination

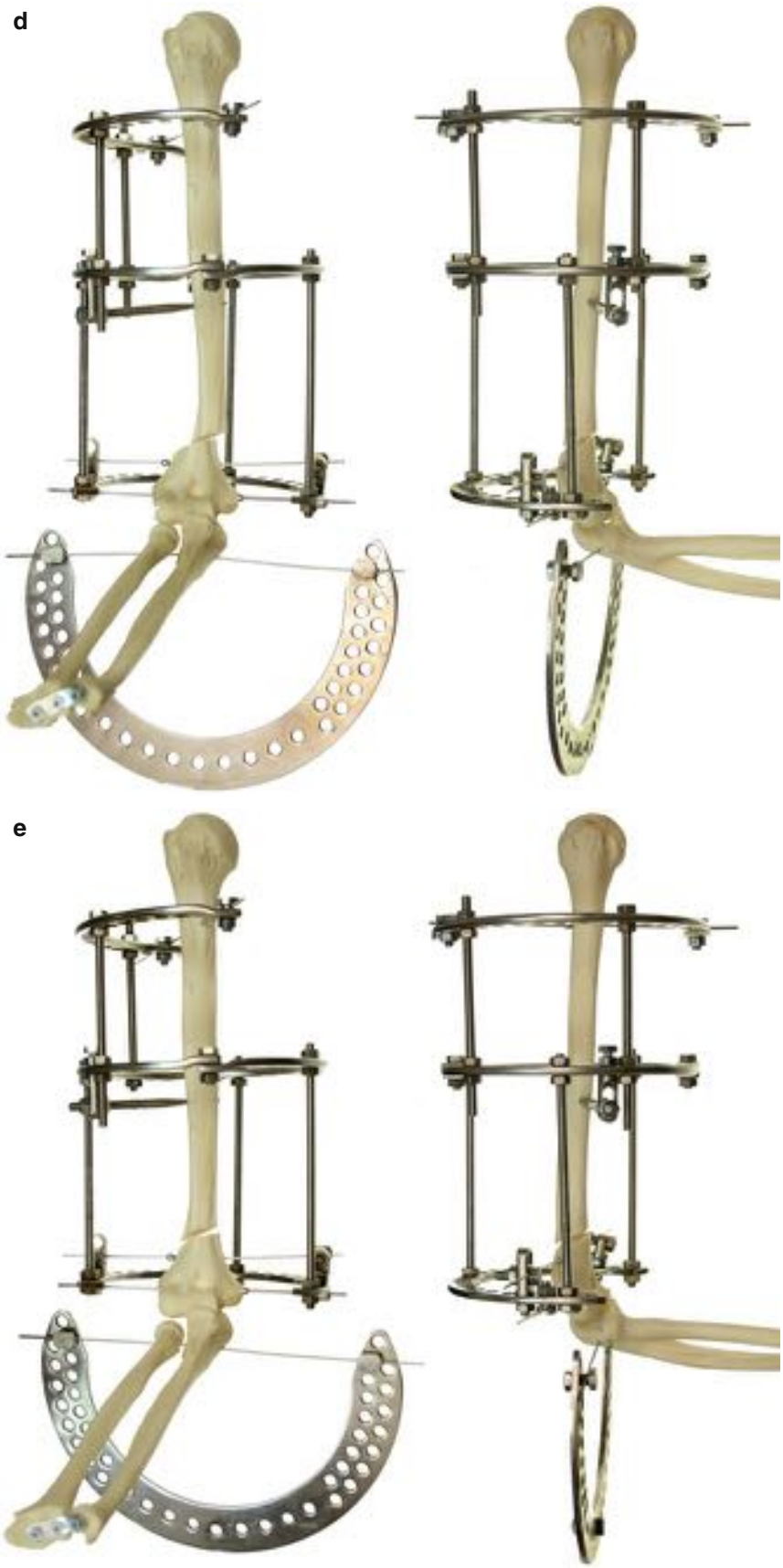


Fig. 10.16 (continued) (**d**) Insertion of reductionally fixing transosseous elements V,10,90 and VII,**9**-3, followed by their dynamic fixation to the supports. (**e**) Reduction of the bone fragments in two planes, static fixation of the reductionally fixing transosseous elements. Two-plane X-ray examination

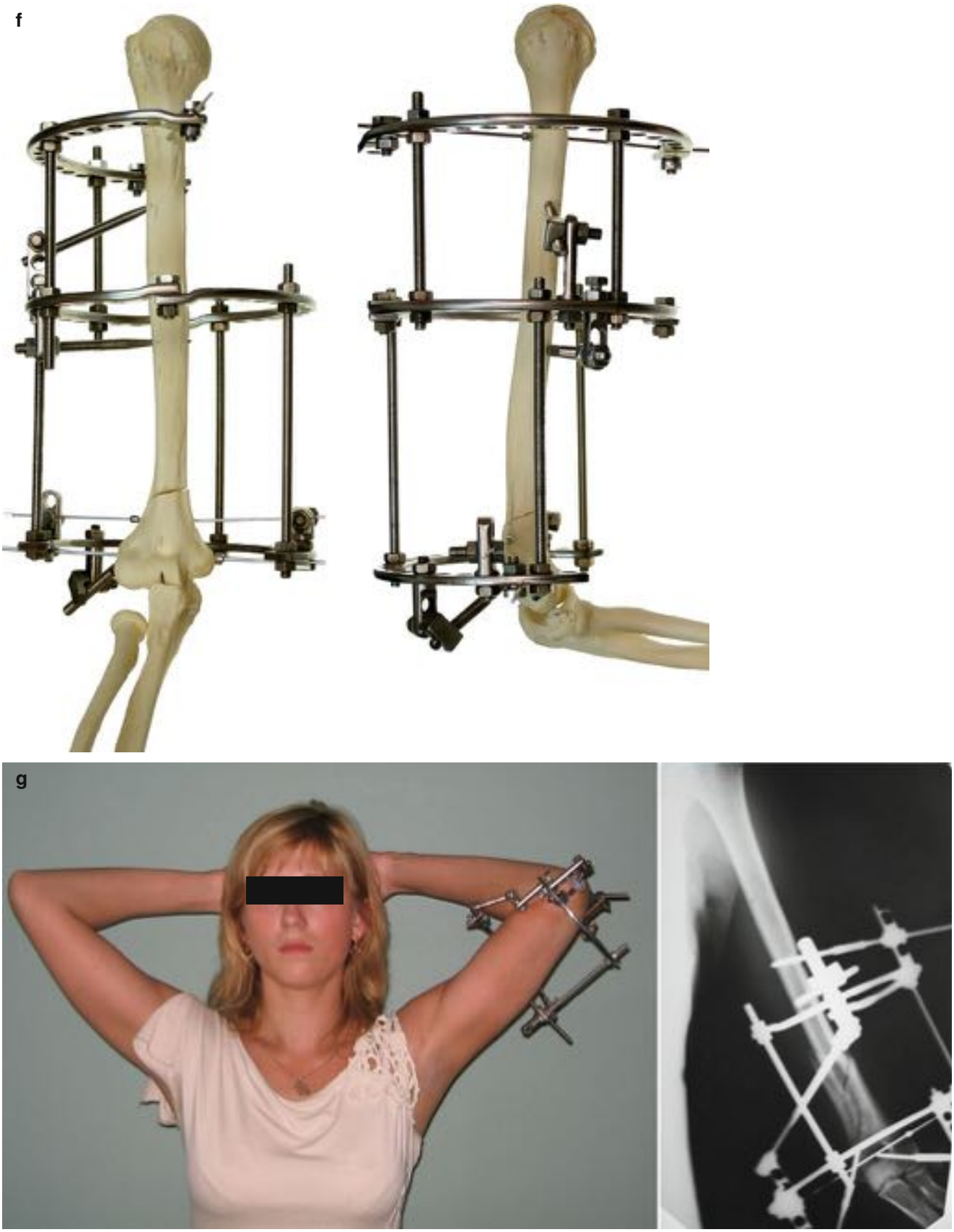


Fig. 10.16 (continued) (**f**) Insertion and fixation to supports of stabilizing half-pins III,9,120 and VIII,8,120. Elimination of the diastasis. Dismantling of skeletal traction. (**g**) Patient after module transformation

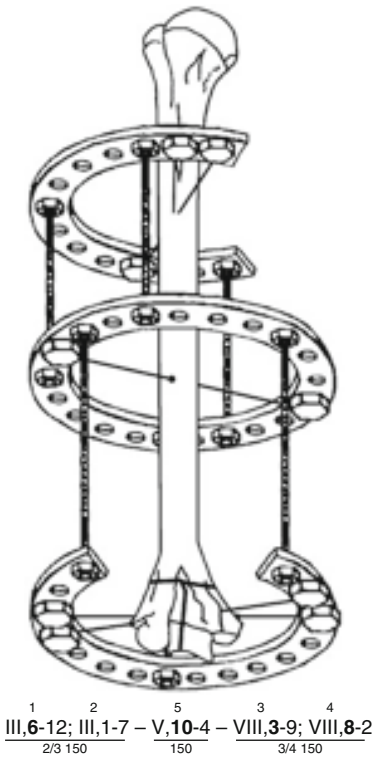


Fig. 10.17 Ilizarov external fixation device for the fixation of fracture 13-C10

After the fragments of the humeral condyle have been properly put together, they are fixed by wires with stops inserted head to head. To eliminate residual displacement of the proximal fragment and to ensure its stable fixation, a reduction wire is inserted at the level of the intermediate ring. Figure 10.17 shows, as an example, wire V,**10**-4.

In intra-articular fractures accompanied by injury to the collateral ligaments, with apparent hemarthrosis, as well as in open fractures, the elbow joint must be temporarily immobilized after open reduction. This a achieved by applying a single-support module to the forearm and connecting the module to the main device by three hinges as shown in Fig. 10.18.

When it is impossible to perform full external fixation, for example in the event of multiple and massive trauma, the fracture can be immobilized by a "fixation" device. This type of external fixation can be used when an open reduction is temporarily precluded. Wire IV,**4**-10 is tensioned and fixed to the ring support. A second wire is inserted through the base of the olecranon: olecr.,**9**-3. This wire is fixed after tensioning to a three-quarter ring support. The forearm is placed in flexion at an angle of 90–100° and fixed in this position with a sling. Moderate distraction is applied between the

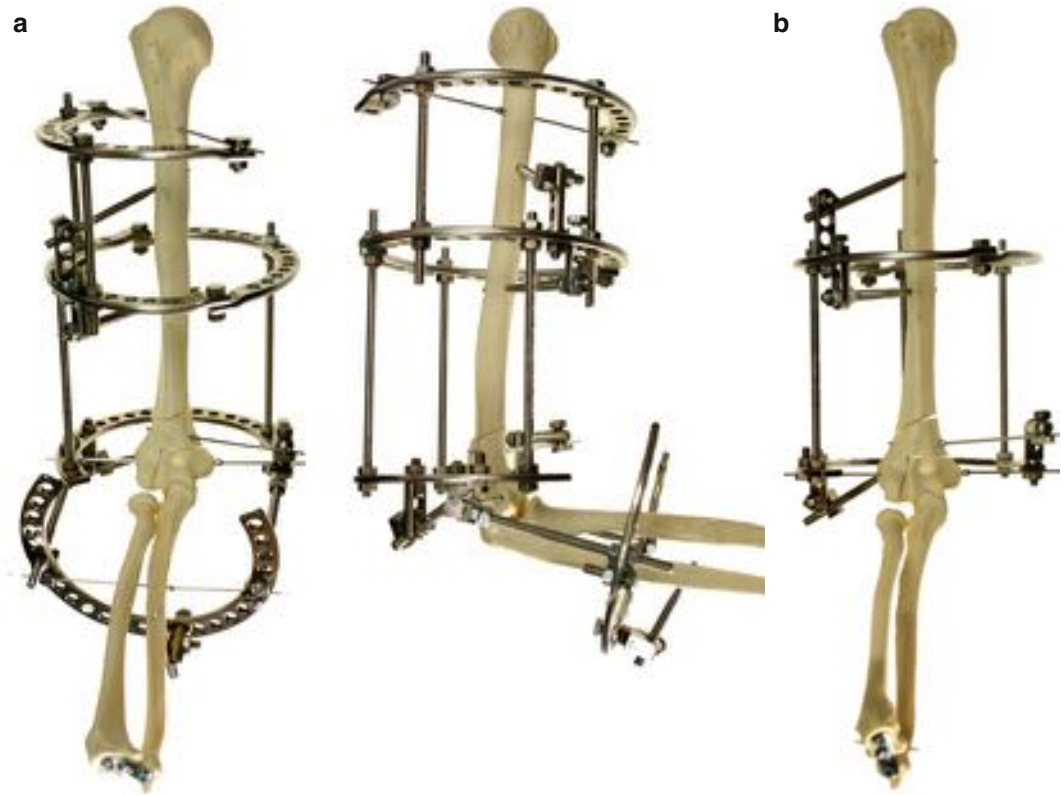


Fig. 10.18 (**a**) General configuration of the device used in the osteosynthesis of an intra-articular fractures of the distal part of the humerus. (**b**) First stage of module transformation (MT): removal of both the proximal basic support and the forearm support

Fig. 10.18 (continued) (**c**) Second stage of MT: partial removal of the reductionally fixing support

$$\frac{1}{\text{II,}\mathbf{5}\text{-11}}\ \underline{\ }\ \frac{6}{\text{III,9,120; V,10,90}}\ \underline{\ }\ \frac{4\quad 2\quad 5}{\text{VII,3,90; VIII,}\mathbf{3}\text{-9; VIII,8,120}}\ \text{--o--}\ \frac{7\quad 8}{\text{III,}\mathbf{3}\text{-9; IV,6,70}}\ \text{(a)}$$

$$\frac{\text{III,9,120; V,10,90}}{140}\ \underline{\ }\ \frac{\text{VII,3,90; VIII,}\mathbf{3}\text{-9; VIII,8,120}}{3/4\ 140}\ \text{(b)}$$

$$\frac{\text{III,9,120; V,10,90}}{1/2\ 140}\ \underline{\ }\ \frac{\text{VII,3,90; VIII,}\mathbf{3}\text{-9; VIII,8,120}}{3/4\ 140}\ \text{(c)}$$

supports: IV,**4**-10 ↔ olecr.,**9**-3. Later, the device can be converted to a full assembly.

The "fixation" variant of external fixation has advantages over skeletal traction: it is less bulky and the patient is more mobile. Compared to the use of plaster immobilization, injured soft tissue can be more readily prepared for open intervention.

After the final radiographs have been obtained, the patient is transported to the ward.