4 Forearm

Introduction

In forearm fractures, it is important to correct both angulation and rotational deformities. The axis of rotation of the forearm bone extends from the center of the head of the radius to the insertion of the triangular fibrocartilage at the base of the styloid process of the ulna. If the relation of the forearm bones to this axis is altered by angulation, the mechanics of the radioulnar joints are deranged and permanent limitation of rotation is inevitable. Rotation deformity also limits radioulnar movement, thus affecting supination and pronation movements. Intramedullary straight K-wire and fracture transfixation cross K-wires are the two different types of K-wire fixation in forearm fractures.

K-Wire Fixation of Shaft of Radius and Ulna

Displacement of both-bone forearm fracture in children aged between 8 and 14 years can be treated by either closed manipulation, reduction, and intramedullary K-wiring or by open reduction technique and intramedullary K-wire fixation.

Closed Reduction and Intramedullary K-Wiring

In the ulna, a long K-wire of diameter 2.0 to 2.5 mm, depending on the size of the medullary canal, can be introduced in an antegrade manner from the tip of olecranon crossing the olecranon physis aiming toward the center of medullary canal in anteroposterior and lateral views under the C-arm control. Once the K-wire crosses the metaphyseal area, a cannulated plier is used to negotiate it down the medullary canal by gentle to-and-fro rotating and reciprocating movements. Once the K-wire reaches the fracture site, by traction and appropriate rotation, and by correcting the angulation, the fracture is reduced; the wire is passed across into the opposite fragment medullary canal and the tip positioned up to the metaphyseal area of the ulna head without crossing the distal physis. Wire entering from epiphysis, crossing the physis to pass into the intramedullary canal must be done with minimal attempts. Too many pricks through the epiphysis are not advisable in order to prevent growth disturbance. Passing a single wire does not cause any growth disturbance.

Radius fracture is fixed by passing a K-wire from the mid-dorsum of the distal radius in retrograde fashion. An entry point was made by a drill in an oblique fashion at metaphyseal area proximal to the distal physis. By volar flexing the wrist fully, the K-wire is introduced through the drill hole with slight bend at tip to become parallel to the shaft of the distal fragment for easy entry into the medullary canal. Sometimes the K-wire does not enter the medullary canal easily; it may go in an oblique manner hitching the volar cortex and may not proceed further. A small short bend at the tip of the K-wire may help to pass into the medullary canal by hitching the convex surface of the bend on the far cortex and tip pointing intramedullary. Always ensure this by checking the anteroposterior and lateral views for the placement of wire, their direction, and progress. By gentle rocking movement using a cannulated plier or cannulated T-clamp Jacob chuck, the wire can be advanced in, negotiating through the fracture site with the usual manipulative technique and into the proximal fragment. The wire can be positioned proximally up to the metaphyseal area of the radial neck without crossing the radial head physis. These wires are kept outside the skin. An above-elbow slab is given at the end of the procedure to control rotation for a minimum period of 6 weeks until the fracture heals and the wires are removed after radiological evidence of healing.

If the fracture radius is in distal one-fourth of shaft, it may be difficult to get a stable fixation with this type of entry. Other techniques of K-wire entry as described below are also useful for stable fixation of radius.

Radius wire can also be entered through the tip of styloid process but one need to cross the physis which is not necessary in dorsal entry. The advantage is easy entry and negotiation into the medullary canal compared to dorsal entry, which is in a more straight-line course. The first choice is metaphyseal entry rather than the epiphyseal entry and only in attempted failure through metaphysis, an epiphyseal entry is done.

Intramedullary wire passed in the distal radius from radial styloid needs prebending as it may touch the opposite cortex in an angle without entering the medullary canal. The sequence of steps in performing this technique is as follows:

1. Pass a K-wire (2.5 mm) from styloid into the medullary canal in a desired angle after predrilling.
2. The K-wire sharp tip is cut slightly prebent and negotiated through the same entry point using cannulated plier by rocking movements (**Fig. 4.1a, b**).
3. Metaphyseal fractures may require cross K-wire instaed of intramedullary K-wire.

Radius wire can also be entered easily from middorsum along the line of medullary canal from dorsal articular surface by volar flexing the wrist completely. Though it is technically easy, it is theoretically damaging the articular surface and also has the disadvantage of crossing the physis. Antegrade K-wire through fracture site in open reduction also exits in the same manner for ante-retrograde wiring.

Open Reduction and Intramedullary K-Wiring

In open reduction of ulna fracture, the K-wire is introduced in a retrograde manner into the proximal fragment first, through the fracture site to exit at olecranon tip. The fracture is reduced anatomically and the wire is driven in an antegrade manner into the distal ulnar shaft to park at the distal ulnar head metaphysis. In open reduction of radius fracture, the K-wire is introduced in an antegrade manner into the distal fragment first through the fracture site to exit at wrist level dorsally, by keeping the wrist in maximum palmar flexion. The wire is then driven in a retrograde manner into the proximal radial shaft after perfect reduction up to the proximal metaphyseal level.

Many times displaced pediatric/adolescent both-bone fractures of forearm are treated with intramedullary K-wiring of both radius and ulna fractures after closed reduction. Sometimes single-bone K-wiring is done and other bone fracture is treated with plaster of Paris (POP) cast after closed manipulation. The indications for single-bone K-wiring in both-bone fractures are as follows:

- Most displaced fractures are fixed with percutaneous K-wire and other bone may be undisplaced or greenstick fracture which can be maintained with closed reduction and above-elbow cast application.
- In displaced both-bone fracture, ulna fracture reduction is the key as this bone is nice and straight; achieving the length and correcting the angulation with straight K-wire from olecranon tip will get the radius out of length. If there is no angulation of radius even if there is complete translation, it can be treated with above-elbow POP cast in ideal forearm rotation.

Case Scenarios

Case Scenario 1

Displaced both-bone forearm fractures treated with intramedullary K-wire. The entry point for the K-wire is the dorsum of the distal end for the radius and olecranon for the ulna. (**Fig. 4.2a–f**).

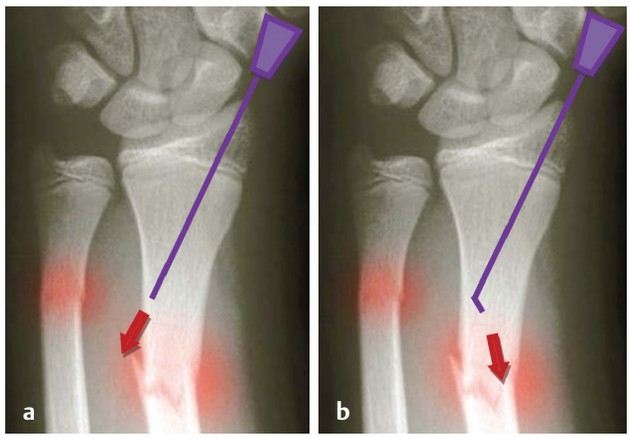

Fig. 4.1 **(a, b)** Sharp tip of K-wire was cut to make it blunt and then a small bend was given at the tip to negotiate the far cortex to enter intramedullary in the radius.

Fig. 4.2 **(a–f)** Displaced fracture forearm treated with intramedullary K-wire through olecranon tip for ulna fracture and through the Lister tubercle for radius fracture.

Case Scenario 2

Displaced both-bone forearm fracture and K-wiring both radius and ulna in a 13-year-old boy (**Fig. 4.3**). Closed anatomical reduction was obtained. Ulna intramedullary 3 mm K-wire was passed from the olecranon tip straight into the shaft reducing the fracture. Radius K-wire was inserted from mid-dorsum of wrist straight intramedullary through the shaft reducing the fracture spanning the whole length as shown in the picture.

Case Scenario 3

Single-bone radius forearm fracture with angulation corrected with intramedullary K-wire from the distal radius (**Fig. 4.4a, b**).

Case Scenario 4

Blunt-tip K-wire with slight prebend to negotiate into the medullary canal without abutting far cortex (**Fig. 4.5a, b**). A 9-year-old boy had proximal third

Fig. 4.3 **(a–c)** Closed anatomical reduction obtained. Ulna intramedullary 3-mm K-wire passed from the olecranon tip straight into the shaft reducing the fracture. Radius K-wire inserted from mid-dorsum of wrist straight intramedullary through the shaft, reducing the fracture spanning the whole length.

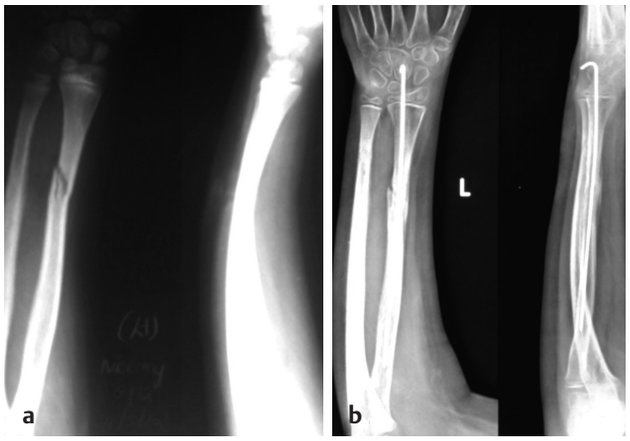

Fig. 4.4 **(a, b)** Displaced single-bone radius fracture of forearm treated with intramedullary K-wire.

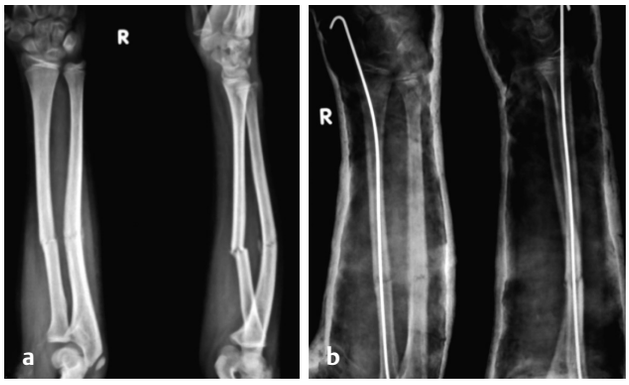

Fig. 4.5 **(a, b)** Displaced radius fracture was reduced with intramedullary K-wire which reduced the greenstick ulna fracture without the need for an ulnar wire and above-elbow POP cast was given.

both-bone fracture, with displacement of the radius fracture and angulation of the ulna fracture. As mentioned previously, the K-wire was passed from radial styloid after predrilling. The tip of the K-wire was prebent and negotiated through the medullary canal by gentle oscillatory movement, negotiated and passed through the fracture site, and parked just beneath the proximal radius physis. As the angulation of the ulna got corrected spontaneously, it was decided to treat with plaster. A snug-fitting above-elbow POP cast was given for 6 weeks.

Case Scenario 5

In a displaced both-bone fracture forearm, it is routine to start K-wiring of the ulna through olecranon tip being in a straight line and easy to pass. Subsequently, if the radius falls into place anatomically, this can be treated by application of an above-elbow cast as shown here and there is no need for K-wiring of the radius (**Fig. 4.6a–c**).

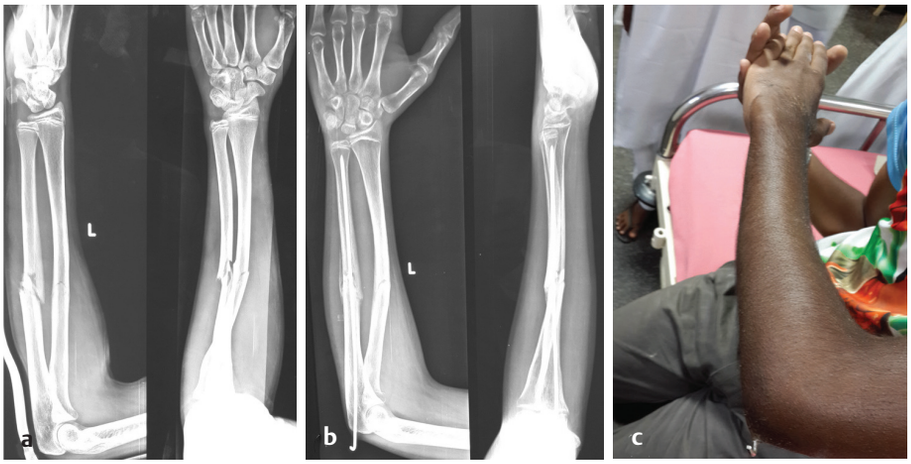

Fig. 4.6 **(a–c)** Both-bone forearm fracture treated with intramedullary K-wire for ulna and above elbow cast.

Fig. 4.7 **(a, b)** Both-bone forearm fracture with displaced radius treated with intramedullary K-wire fixation for radius and above elbow cast

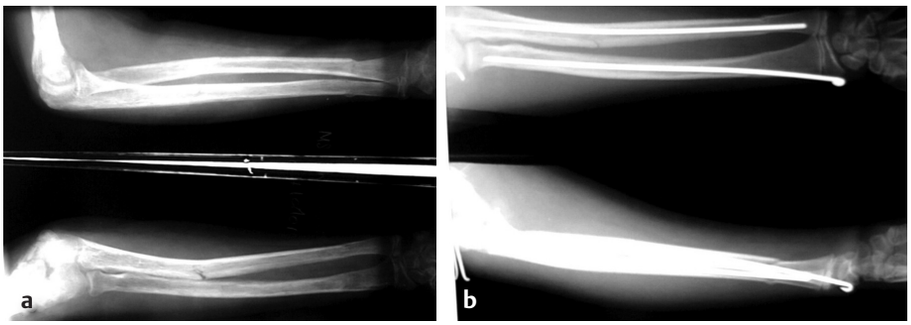

Fig. 4.8 **(a, b)** Intramedullary K-wire is definitely a better option in segmental fracture forearm in children.

Case Scenario 6

Displaced radius fracture with greenstick fracture of ulna (**Fig. 4.7a, b**). The angulated, displaced radius fracture was manipulated but acceptable reduction was not obtained. Hence a percutaneous straight 2.5-mm K-wire from mid-dorsum of radius was passed intramedullary through the fracture site after obtaining good reduction by closed means. The greenstick fracture of ulna was corrected and an above-elbow cast was applied. The K-wire and cast was retained for a period of 6 weeks.

Case Scenario 7

Segmental radius fracture with ulna fracture treated with intramedullary K-wire (**Fig. 4.8a, b**).

Case Scenario 8

Distal-third both-bone forearm fracture (**Fig. 4.9a–q**). Distal-third both-bone fracture of forearm in a kid can be treated by closed manipulation with or without K-wire fixation and an above-elbow cast. In an obese or a big child or when the fracture is unstable, a percutaneous K-wire fixation is mandatory. Here after closed manipulation and reduction two cross K-wires were inserted to transfix the radius fracture in good alignment because the child was obese. The fracture transfixation done with one mediolateral K-wire and the other K-wire in an anteroposterior direction. It was started from distal fragment which was a wide metaphyseal zone to the proximal shaft which is narrow thick cortex. The starting point of entry was at 1 cm distal to the fracture site and entered the near cortex at an angle of 30 degrees to the shaft of radius. After crossing the fracture site, the far cortex entry into the proximal fragment will be better felt with the resistance. A counterpressure while entering the far cortex might be necessary. Too much of axial force at this point of time may displace the fragments. It is preferable to run the drill in high speed and with less axial pressure. Once the far cortex penetration was done, the drill must be stopped abruptly without too much of overshooting of K-wire into the soft tissues. Generally backing out of K-wire because of overshooting tip will weaken the fixation and loosening can happen. As the reduction of ulna was satisfactory after fixing the radius it was left alone to be immobilized with above-elbow molded cast in the midprone position.

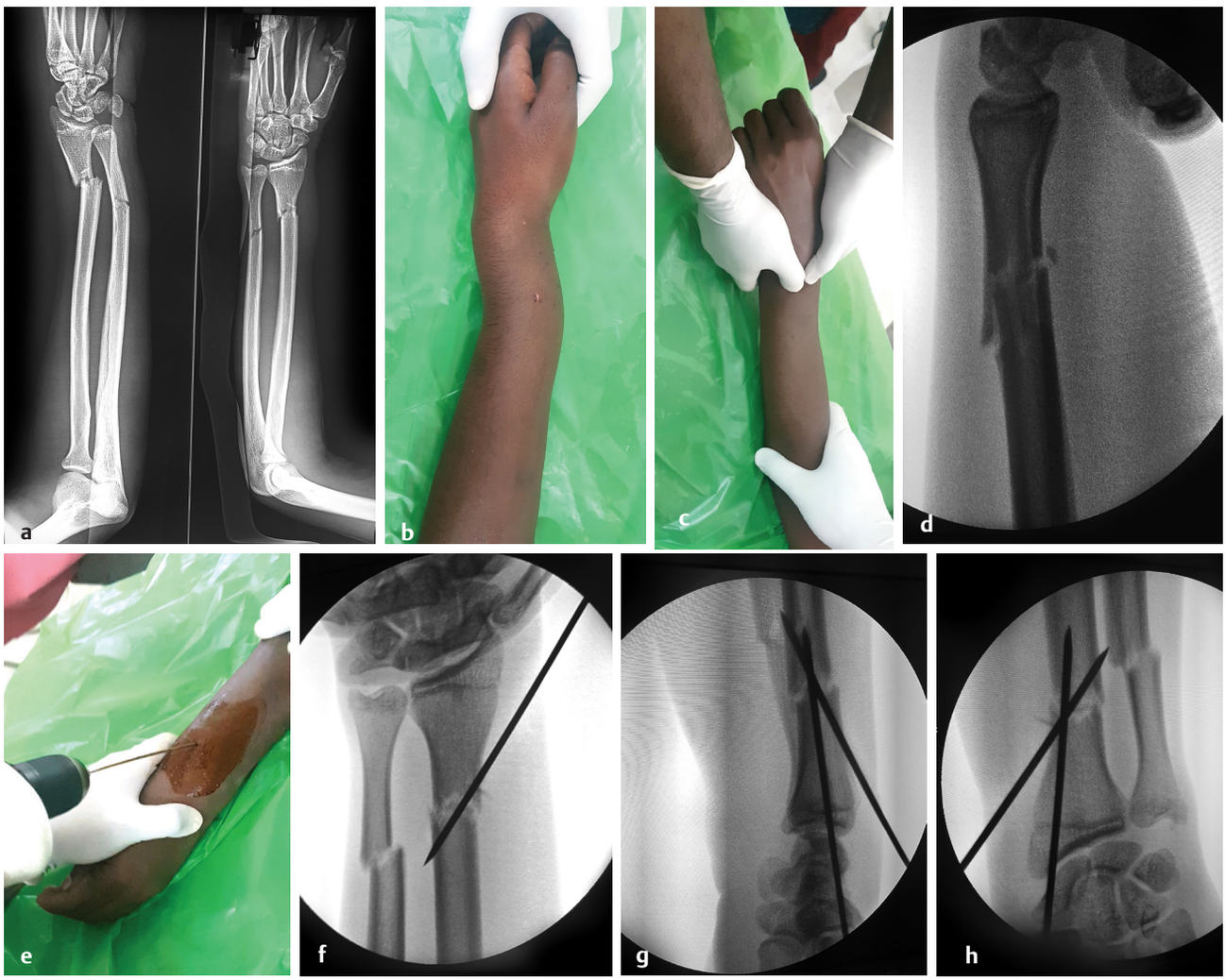

Fig. 4.9 **(a–h)** Distal third both bone fracture in a kid treated by closed manipulation and two transfixation K-wires in two planes. (*Continued*)

Fig. 4.9 (*Continued*) **(i–q)** Distal third both bone fracture in a kid treated by closed manipulation and two transfixation K-wires in two planes.

Case Scenario 9

Distal shaft radius and ulna fracture in a 14-year-old child (**Fig. 4.10a–e**). Most of distal forearm fractures in children above the age of 10 and below 14 years may require closed reduction and percutaneous K-wire fixation. In distal radius maintaining the traction, two cross K-wires in anteroposterior and mediolateral plane were passed from distal to proximal fragment starting 1 cm below the fracture line and entering obliquely at an angle of 30 degrees to the shaft to cross the fracture and engage on the far cortex of the proximal fragment. One must be gentle in passing the first wire as too much pressure while drilling the cortices may displace the fragments. Before entering the far cortex, both views must be done to ensure there is no angulation or displacement or marginal fixation. The second wire was passed in similar fashion in the other plane. Note the obliquity of the K-wire must not be parallel to the fracture plane and it must be perpendicular or at obtuse angle to the fracture

Fig. 4.10 **(a–e)** Distal radius and ulna fracture fixed with two transfixation K-wires in different planes. The wrong placement of the K-wires as shown in **(c)** may not hold the proximal fragment. Here the K-wire was parallel to fracture fragment, instead it should be perpendicular.

plane for better biomechanical fixation. An above-elbow cast is necessary for a period of 5 to 6 weeks. Wires were removed after adequate callus formation by the end of 6 weeks and mobilized further.

Case Scenario 10

Fracture midshaft radius and ulna in a 10-year-old child treated with single-bone K-wiring (**Fig. 4.11a, b**). Generally displaced angulated both-bone forearm fracture in a child can be treated by closed manipulation and above-elbow POP cast if the reduction is stable or acceptable. If not, percutaneous K-wiring would be sufficient to maintain the reduction. Normally ulna fracture is reduced and fixed with percutaneous K-wire from the tip of olecranon correcting the length and alignment. Ulna being a straight bone and along the subcutaneous border, it is easy to fix and reduce by a straight K-wire from the tip of olecranon through the olecranon epiphysis into the medullary canal. In the present case, once ulna was fixed, radius fracture came into alignment and the reduction was maintained by an above-elbow POP cast. For anterior angulation of radius, above-elbow forearm cast in pronation was done (Mnemonic: Andhra Pradesh Police Station, A-Anterior angulation, P-Pronation and P-Posterior Angulation, S-Supination).

Quadratus Fracture Forearm

Distal one-fourth both-bone fracture of the forearm in a child is common and it can be reduced by closed manipulation. Maintenance of unstable fracture or remanipulation because of loss of reduction in POP cast warrants K-wire fixation. First K-wire was passed from the dorsal cortex of distal radius 1 cm away from the fracture site in an oblique angulation of 30 to 60 degrees in order to pass through the fracture and engage the volar cortex of proximal radius. It is not passed through the epiphysis. The lateral view was checked now to ensure that there was no angulation at the fracture site. Second K-wire was passed from the lateral cortex of distal radius 1 cm distal to the fracture site in an oblique angulation and advanced through the fracture and to the medial cortex of proximal fragment. Again, the position was checked in both anteroposterior and lateral views in image intensifier. Once two cross K-wires were applied in two different planes to secure the radius fracture in anatomical position, an above-elbow POP cast was applied in midprone position and ulna fracture was kept in a reasonable position of reduction without additional fixation (**Fig. 4.12a–d**).

Another example of distal-fourth radius and ulna fracture treated with cross K-wiring of radius fracture after closed manipulation and reduction (**Fig. 4.13a, b**). The ulna fracture was taken care by above-elbow cast immobilization.

Radial Neck with Both-Bone Shaft Fracture

Open reduction and internal fixation with plate and screws were done for the radius and ulna shaft fractures

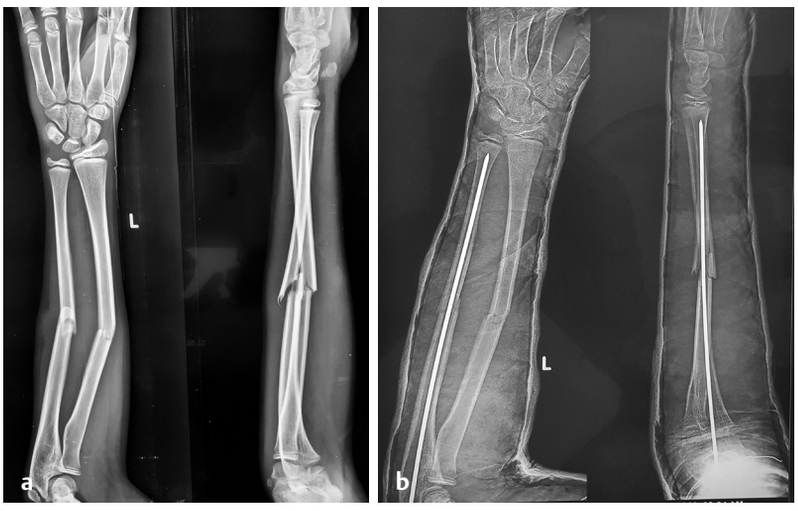

Fig. 4.11 **(a, b)** Displaced angulated both-bone fragment in a child treated with single intramedullary K-wire for ulna fracture and above elbow cast applied to hold the reduction of radius fracture.

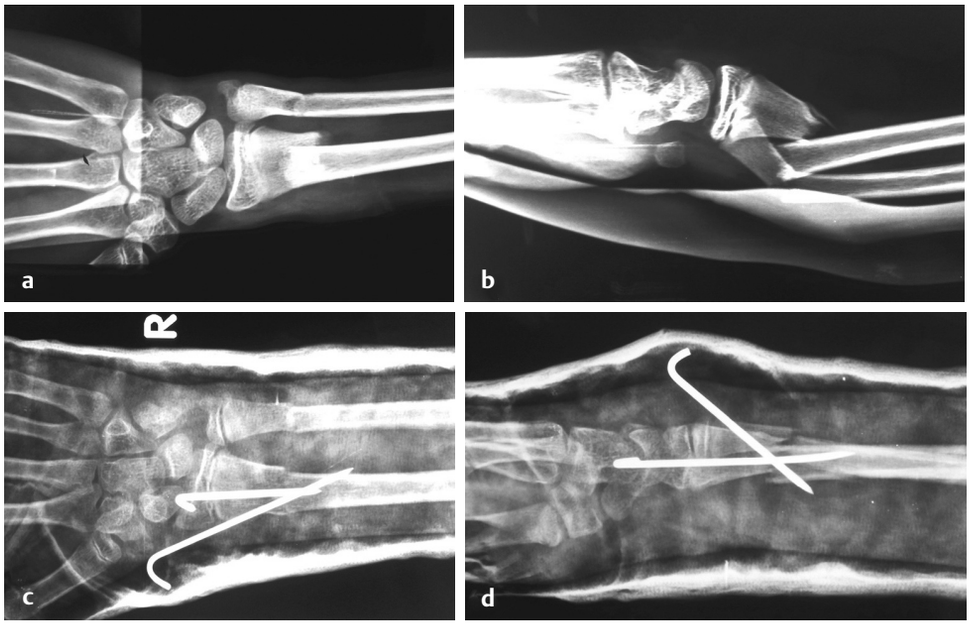

Fig. 4.12 (a–d) Displaced distal-fourth forearm fracture reduced and fixed with two metaphyseal cross K-wires in two dimensions.

Fig. 4.13 (a, b) Displaced quadratus fracture treated with closed manipulation reduction and percutaneous cross K-wiring.

of the forearm. The radial neck fracture was transfixed with a percutaneous K-wire from lateral aspect of the head through the safe zone by a transfixation K-wire and immobilized further with above-elbow POP splint, as shown in **Fig. 4.14a–g**.

Marginal Fracture Radial Head

Displaced marginal fracture radial head can be reduced by closed means using K-wire as a joystick to manipulate. Percutaneous K-wire was passed through the safe zone, that is, 90-degree horizontal position in supination and 90-degree vertical position in pronation. The fracture is reduced and transfixed as shown in **Fig. 4.15a–e**.

Monteggia Fracture Dislocation

As shown in **Fig. 4.16a–c**, a small child with Monteggia fracture dislocation with anterior displacement and angulation was treated by percutaneous K-wire passed from the tip of the olecranon intramedullary into the ulna shaft fracture. Fracture was reduced and fixed by intramedullary K-wire spanning the ulnar length out. This automatically reduced the radial head dislocation. An above-elbow POP slab in supination was given to maintain the reduction for a period of 4 weeks until adequate callus was formed.

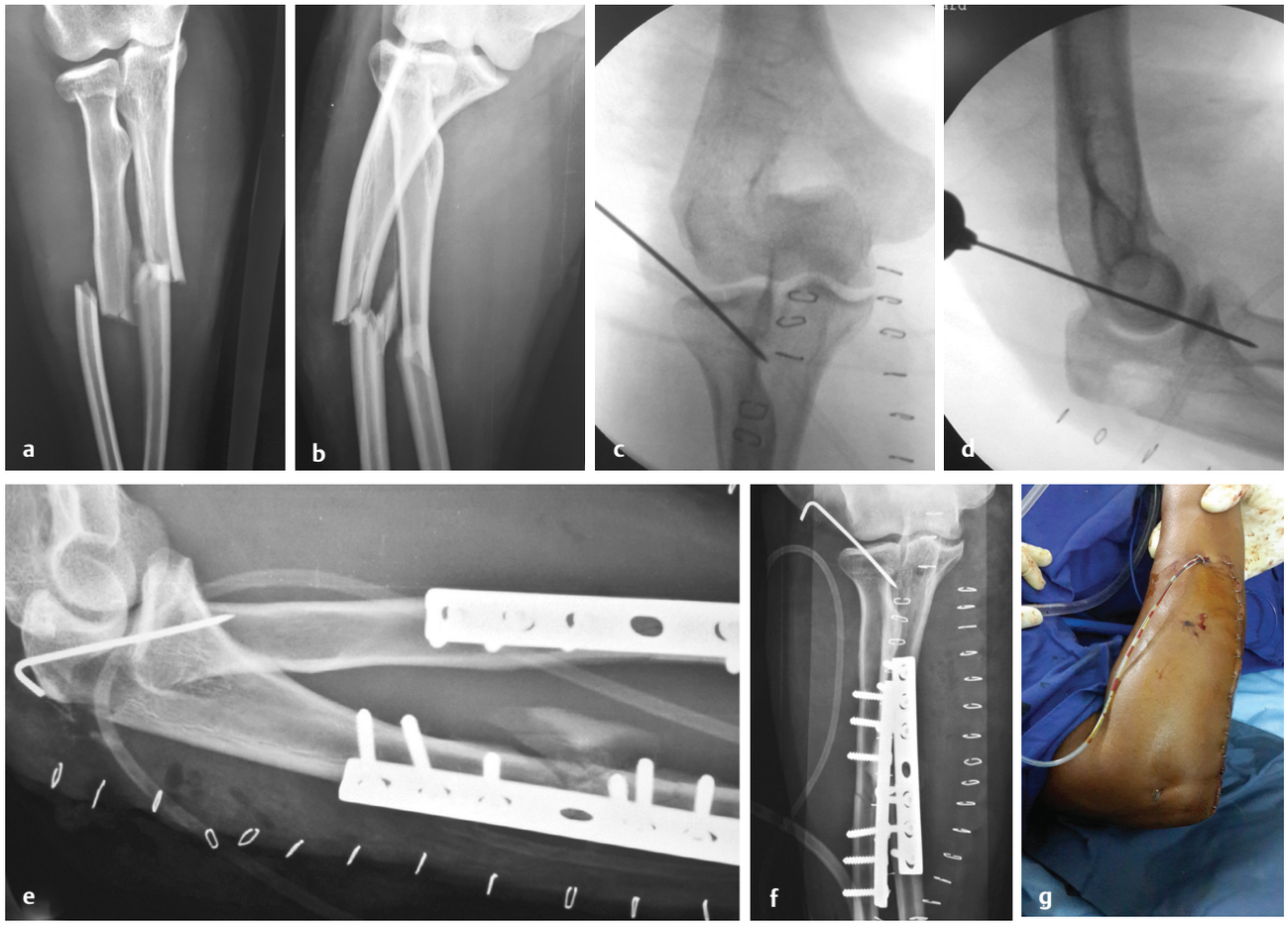

Fig. 4.14 **(a–g)** Radial neck with radius and ulna diaphyseal fracture treated with plating of shaft fracture, and radial neck secured with percutaneous K-wire through safe zone from head to shaft and the clinical picture showing the entry.

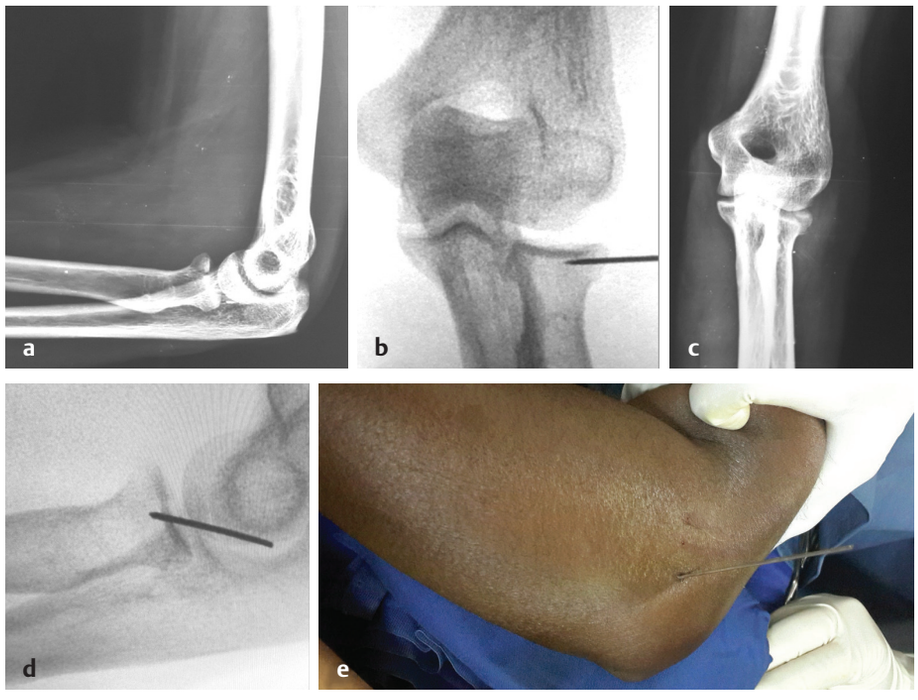

Fig. 4.15 **(a–e)** Marginal fracture radial head fixed with subchondral K-wire through safe zone.

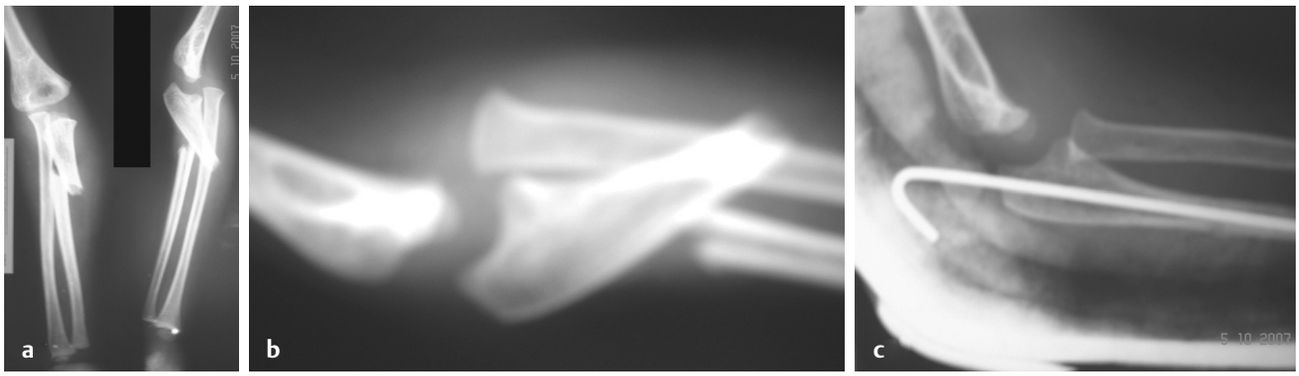

Fig. 4.16 **(a–c)** Monteggia fracture dislocation reduced with percutaneous K-wire passed through olecranon physis to reduce the ulna fracture. Once the ulna fracture was reduced and out of length, radial head dislocation was reduced automatically.

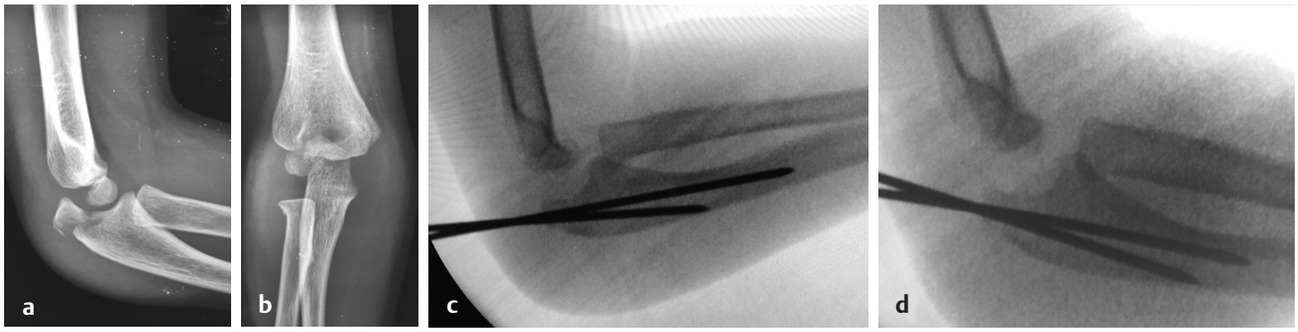

Fig. 4.17 **(a–d)** Intra-articular fracture olecranon treated with two olecranon transfixation K-wires.

Monteggia Variant Fracture

As shown in **Fig. 4.17a–d**, a child with displaced proximal ulna fracture with radial neck fracture was treated with closed percutaneous K-wire fixation because of associated blistering of skin and swelling. The ulna fracture was reduced anatomically with no step in the joint and two K-wires were used here as one was directly entering the medullary canal without much hold and the other wire purchase was good in both cortices. This also helps in rotational stability.

Old Monteggia Fracture Dislocation

Anterior dislocation of radial head with malunited ulna with anterior angulation was treated by corrective osteotomy of the ulna at previous fracture site, reduction of radial head dislocation, and fixation of the ulna in the desired degree of posterior angulation in order to maintain radial head articulation with capitellum. After fixation of the ulna with plate, the radial head was subluxing; hence, a radiocapitellar K-wire was passed to maintain the reduction for a period of 4 weeks, as shown in **Fig. 4.18a–c**. Above-elbow POP slab was applied and the K-wire was removed after 4 weeks.

Distal Radius and Ulna Fracture with Supracondylar Fracture of Ipsilateral Arm

A 14-year-old boy sustained roller machine injury with distal radius and distal ulna metaphyseal fracture, and supracondylar humerus comminuted fracture. Supracondylar fracture was fixed first after closed manipulation and reduction of the fracture with two medial and two lateral K-wires as shown in **Fig. 4.19a–e**.

The distal radius quadratus fracture was reduced anatomically and maintained with two K-wires, one passed from the dorsal cortex of distal fragment about 1 cm away from the fracture with 60-degrees angulation, so that it crossed the fracture and engaged the proximal fragment 1 cm away. Fixation in another plane was done

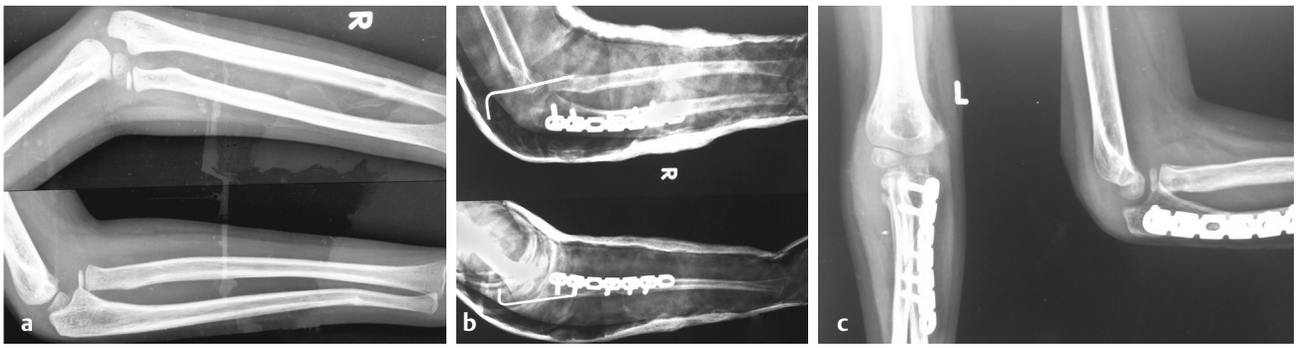

Fig. 4.18 **(a–c)** Malunited Monteggia fracture dislocation treated by ulna osteotomy and plating with radial head relocation maintained with capitelloradial transarticular K-wire. Six months follow-up X-ray shows radiocapitellar congruency and maintenance of reduction.

Fig. 4.19 **(a–e)** Intercondylar with supracondylar fracture humerus with distal radius and ulna fracture treated with multiple K-wires starting from proximal to distal fixation.

in a similar fashion from radial aspect of distal fragment transfixing the fracture to the ulnar aspect of proximal fragment.

An additional fracture transfixation K-wire was used to fix the ulna fracture from the tip of the styloid process as shown in **Fig 4.19c**. Above-elbow slab was given.

Displaced Radial Neck Fracture in a Child

In a displaced or angulated radial neck fracture (>45 degrees) in a child, the reduction can be achieved by percutaneous manipulation using a K-wire under image intensifier control. The thick K-wire (3.5 mm) was passed laterally percutaneously under the displaced head fragment. The K-wire was then hinged on to the metaphyseal shaft. Keeping that as a fulcrum, the head is lifted up; the angulation and translation were corrected by gentle manipulation with the wire. Once reduced, the K-wire was withdrawn and the reduction was maintained by above-elbow slab in supination for 3 weeks (**Fig. 4.20a–e**).

Single Bone Forearm

A young man with open fracture forearm and loss of bone, treated initially with open reduction and plating in a primary center, got infected. He had multiple procedures with debridement and external fixation that resulted in huge segmental loss of bone in the radius and ulna. Eventually after a good control of infection, it was decided to do fixation of the proximal ulna to distal radial shaft after discussing with the patient. An intramedullary square nail was used to secure the ulna to radius. The docking area was secured with additional thin cross K-wires in order to prevent rotation and provide more stability, and then bone grafting was done. These wires were cut flush to the bone and left inside. An above-elbow POP cast was given for a period of 10 weeks until solid healing was seen clinically and radiologically. One wire was removed later because of local irritation (**Fig. 4.21a–d** and **Fig. 4.22a–d**).

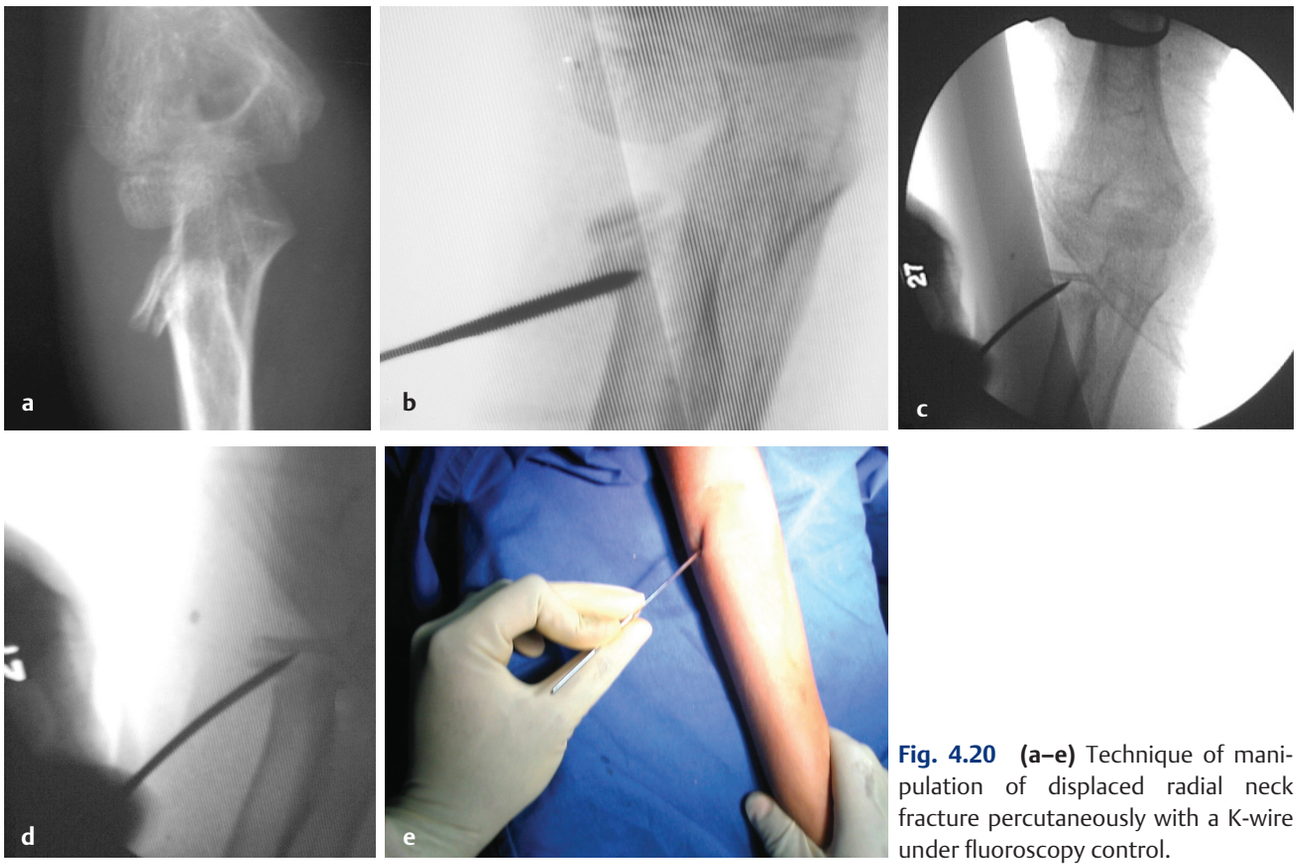

Fig. 4.20 **(a–e)** Technique of manipulation of displaced radial neck fracture percutaneously with a K-wire under fluoroscopy control.

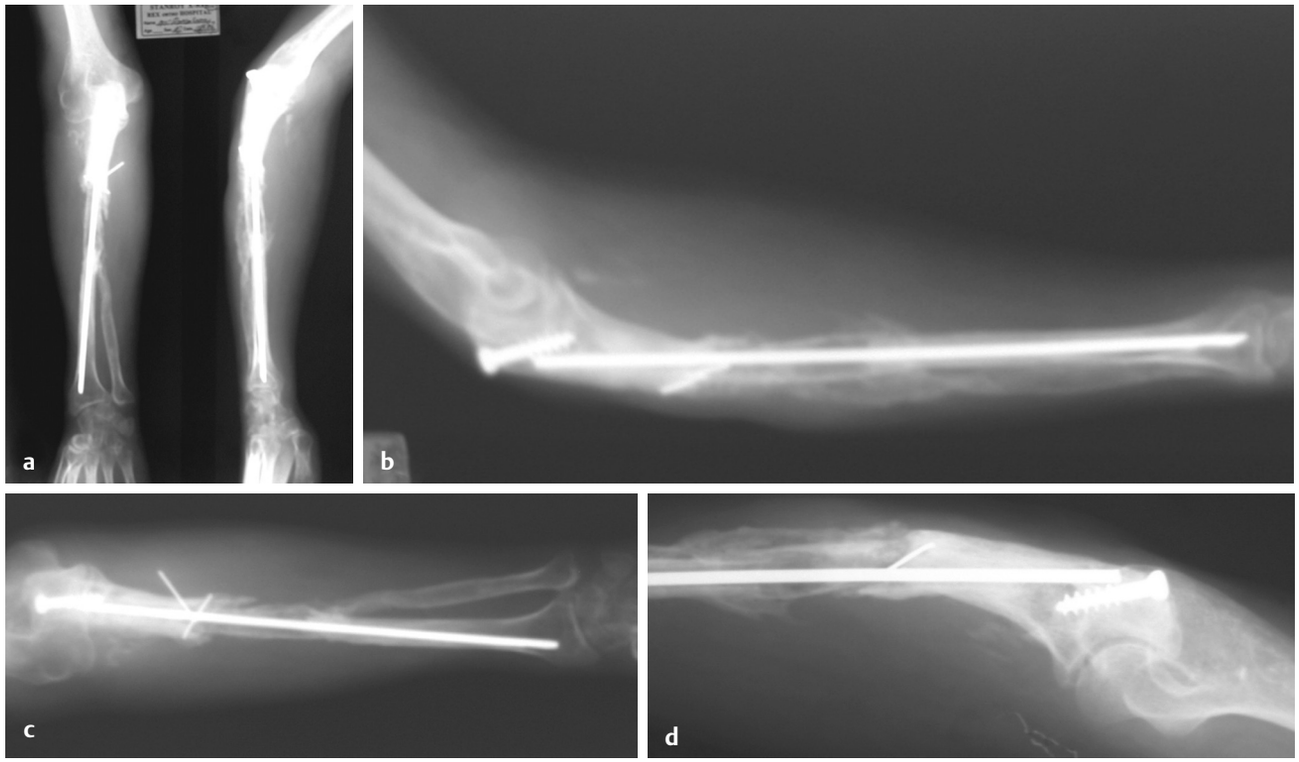

Fig. 4.21 **(a–d)** Extensive bone and soft tissue loss in the forearm treated with fusion of the ulna to radius by a square intramedullary nail and bone grafting at cross union site with transfixation K-wire for rotational stability.

Fig. 4.22 **(a–d)** Clinical outcome showing the relative supination/pronation movement preservation and presently, he is a truck driver by occupation.