6 Failed Fixation of Proximal Humerus Fracture

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Aetiology of Failed Fixation

A consideration of the aetiology of failed fixation in the proximal humerus invites contemplation on the indications for fixation in the first place. The gut instinct of many on looking at a radiograph showing a displaced fracture is to recommend surgical management, usually by reduction and internal fixation of some sort. The reduction methods can be closed or open. The fixation may involve sutures, absorbable implants, pins, plates, screws or intramedullary devices alone or in combination. What is undoubted is that in most cases the radiological alignment of the fracture can be improved. The postoperative radiograph looks as though the shoulder should function better for the patient and therefore measurements of outcome reported by the patient (rather than measured from a radiograph by the surgeon) should be better. Increasingly, randomised controlled trials suggest that in many, or even most, cases we do not actually make a difference [1–3] and in some we make the patient worse. In this chapter, we will be considering how to salvage the latter situation—the challenge, therefore, is to research which patients with which fractures are actually likely to benefit from surgery. Currently, it seems, a large proportion do not, and that is not the best use of resources. Even some of those patients with an X-ray image that shows perfect reduction report an outcome no better than some patients with a significant malunion.

What then are the main aetiological factors leading to failed fixation? We can consider patient-related, fracture-related and surgery-related causes, though there is overlap and often more than one cause [4, 5].

Patient-related factors are those which affect bone healing, those which affect the strength of fixation and those that reduce resistance to infection. Internal fixation provides temporary stability at least to resist deforming forces until sufficient healing has occurred to resist physiological forces. Sometimes there is no intention to resist significant physiological loading for several weeks (e.g. percutaneous wires), whilst in other cases the intention is to allow loading as quickly as possible (some locking plates and intramedullary nails).

Patient factors that affect bone healing include diabetes and smoking.

Patient factors that affect the strength of the fixation are those that cause diminished bone quality, notably osteoporosis.

Patient factors that affect resistance to infection include any form of immune deficiency, but the most prevalent in the western world are diabetes and smoking.

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Note that there is limited scope for modifying the majority of these factors once the fracture has occurred—stopping smoking will be helpful as time elapses, but smokers who abstain from the point of fracture still have worse overall outcomes.

Fracture-related causes are those that affect the initial strength of fixation and those that have an effect on healing times. Prominent in both respects are factors related to the energy of injury. Initial stability of the construct is significantly greater if the fracture can be anatomically reduced to allow load transmission from one fragment to another rather than relying on the plate. This is much more difficult in multifragmentary fractures and impossible if there is bone loss. Higher energy injuries also take longer to heal, prolonging the time for which reliance is placed on the fixation, therefore increasing the likelihood of fixation failure. Indirectly related to energy of injury is the fracture pattern—if fracture lines lead to impaired blood supply or devascularisation of major fracture fragments (e.g. anatomical neck fractures), then not only does fracture healing prolong but the risk of avascular necrosis is substantially increased. In some proximal humerus fracture patterns, such as dislocations associated with anatomic neck fractures, or more commonly 3- and 4-part fracture dislocations, the risk is so high that currently arthroplasty is often favoured as the primary treatment.

Surgery-related factors are related to deficiencies in decision making (fixation of fractures that cannot be reduced adequately or have such a high risk of complications such as avascular necrosis (AVN) or infection that failure was predictable) or technique. Anatomic reduction is not essential for all fractures—if any part of the fracture line is visible on the postoperative X-ray, even as a thin line, the reduction is not, by definition, anatomical. However, it is desirable and it is also important to avoid fixation with significant malreduction. This can cause immediate problems with rehabilitation, increase the risk of failure of fixation and, even if the fracture heals, increase the risk of screw cut-out, avascular necrosis and poor outcomes in terms of function and pain.

Whatever the cause of failure of fixation the result is the same—an unhappy patient with a stiff, painful shoulder who looks to you to improve the situation for them. In this chapter, we will look at a case of internal fixation that developed avascular necrosis and went on the treatment by arthroplasty.

Clinical Examination

Inspection is important as it may show prominent metalwork, will reveal any scars related to the original trauma, indicate the surgical approach to fracture fixation and the state of wound healing, with clues as to whether infection has been an issue in the past even if there are no active signs. Deltoid wasting can be due to disuse of a painful shoulder or denervation due to axillary nerve injury.

The majority of proximal humerus fractures will have been approached via a deltopectoral route, but a more lateral scar could indicate an anterosuperior approach or a deltoid splitting approach, and the relationship of the axillary nerve to the scar and the fixation device should be worked out (ideally by obtaining the operation note of the original surgery). The issues going through the surgeons mind are ‘can I reuse a previous scar without compromising my planned surgery, and if not can I make a new approach that doesn’t compromise the skin’ and ‘is the skin quality good enough to allow healing after another operation.’ If unsure about the latter, then involving a colleague from plastic surgery may be appropriate, and this should also be taken into account in deciding whether surgery is in the best interests of the patient after all. If there are signs of ongoing infection, then this requires a multidisciplinary team approach.

In the case, we are considering there was fortunately a well-healed deltopectoral scar and by using the same scar we could approach the proximal humerus with minimal risk to the axillary nerve.

Palpation of any unexpected prominence can reveal whether this is the fixation device, commonly appearing anterosuperiorly in failed proximal humerus fixations, or bone that is either a result of malunion or is a normal landmark, such as the coracoid or acromion, thrown into relief by deformity. Palpation will also reveal any tenderness (of metalwork, normal landmarks or the shoulder or acromioclavicular joints).

In our case, the deltoid was thin and there was a slightly tender anterosuperior prominence that was the remains of the humeral head and attached fixation device brought to the front by internal rotation contracture of the shoulder.

Moving the joint will reveal the range of motion and identify if any parts of the range are painful. Almost all patients with failed fixation will have some, usually substantial, deficits in motion and at least end-range pain. This is usually why they are asking you to do something about it!

Our patient had about 50 degrees of combined elevation, an internal rotation contracture of 30 degrees and could internally rotate to reach the buttock. Only the end of the range of motion was painful, increasing significantly if attempted passive movement beyond the active range was tested.

Investigations

In most cases of failed fixation of the proximal humerus, a plain anteroposterior (AP) and axial radiograph will provide most, if not all, of the information needed for successful management. However, it is important to ensure that the whole management pathway is clear and if not, to consider whether further imaging, blood or pathology tests are required.

A plain X-ray can give a sufficient picture to plan many interventions. If there are loose screws or screws penetrating the humeral head, then a plan can be instituted to remove these, even if it may need an image intensifier to identify the appropriate screw in theatre. In our case, a four-part fracture was initially managed by open reduction and internal fixation using a locking plate (Fig. 6.1a and b) but AVN has caused collapse of the humeral head around the fixation

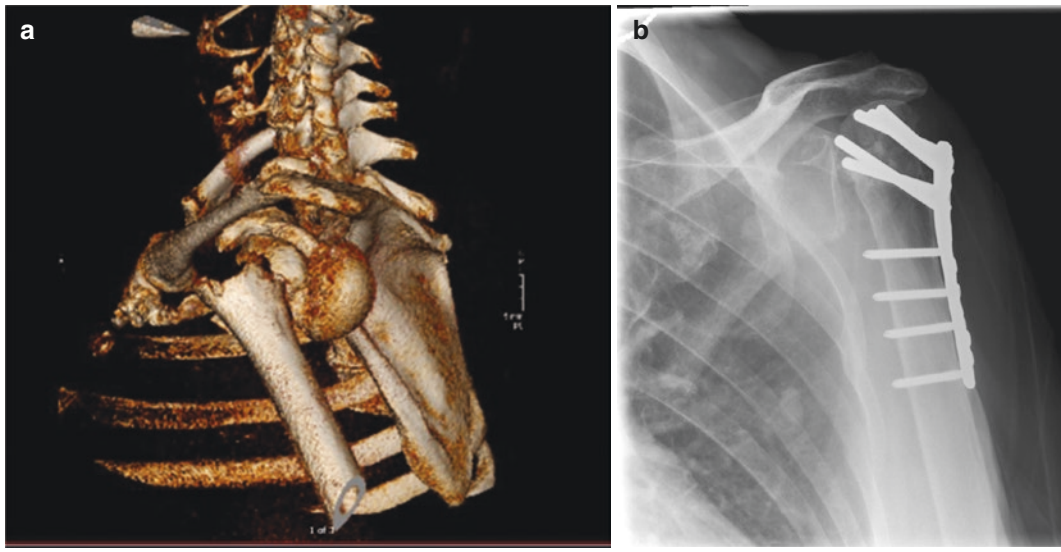

Fig. 6.1 (**a** and **b**) The patient's original injury—a displaced proximal humeral fracture with dislocation. The patient was considered rather young for a primary arthroplasty, therefore, initial management was open reduction and internal fixation with a locking plate

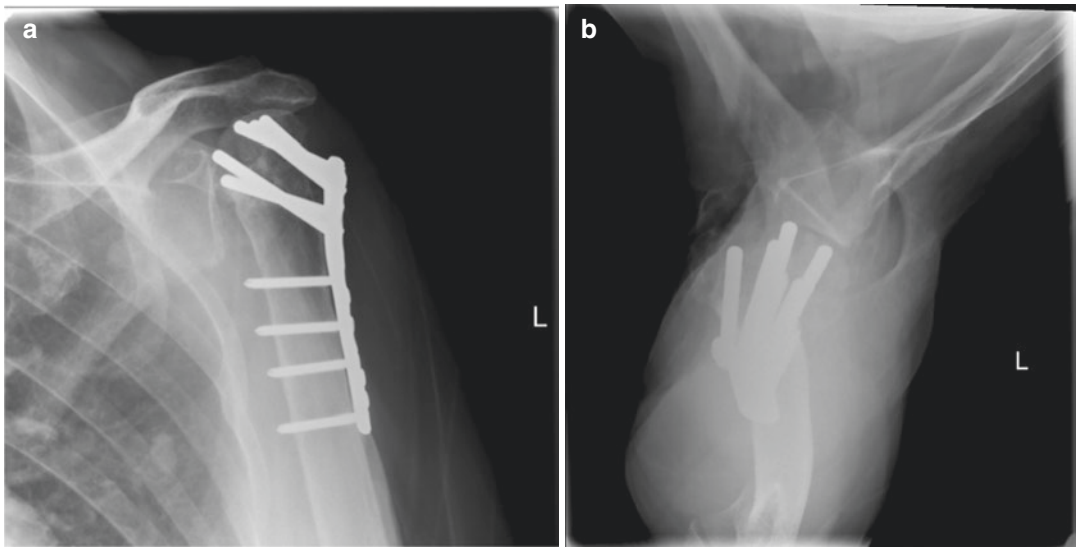

Fig. 6.2 (**a** and **b**) The patient continued to complain of pain and AVN led to penetration of the humeral head though there was no damage to the glenoid

pegs, leading to penetration of the head, but there is no significant damage to the glenoid (Fig. 6.2a and b). The subacromial space is narrow and this usually means that the cuff is torn, though after trauma this can occur if the tuberosities are reduced and fixed non-anatomically with a gap between subscapularis and supraspinatus. A plain X-ray may in itself give sufficient information to allow a revision fixation and grafting of an ununited surgical neck component with increasing deformity. However, if the state of union of other fragments is unsure or the extent of bone loss, then a computed tomography (CT) may be considered. Some cases of AVN may be planned for revision to an anatomic arthroplasty. Nonetheless, if the state of the bone stock, particularly in the glenoid, is unclear, then CT may again be needed and many would consider it essential before proceeding to total anatomic, or increasingly commonly reverse, shoulder arthroplasty. CT is less often needed for elucidating the biology of nonunion, unlike nonunion in long bones. Vascularity issues in the proximal humerus almost always manifest as AVN and humeral head collapse.

Magnetic resonance (MR) imaging is less useful than may be thought. Many proximal humeral fractures appear to have avascular necrosis on imaging taken soon after fixation, only to go on to heal uneventfully with no clinical or radiological evidence of AVN. It is useful, however, if infection is suspected. MR does give an indication as to the integrity of the rotator cuff and can, therefore, be important if revision fixation or osteotomy is considered, and especially if anatomic arthroplasty is being contemplated. Ultrasound can, in many cases, provide this information quickly and more cheaply, but not if there is deformity of the tuberosities or rotation of the humeral head, which can make ultrasound very difficult to perform and interpret. As technology develops it is possible MR and Ultrasound may have increased indications in the future [6].

Infection within the differential diagnosis is also the main reason why a range of other investigations may be considered ranging from simple blood tests such as the full blood count, through established inflammatory markers to a range of new indicators in various states of clinical assessment. Biopsy may be indicated to obtain tissue samples and although aspiration may be helpful, open biopsy of multiple specimens using clean instrument sets for each is far more accurate and if arthroplasty is being contemplated will help plan antibiotic management in one- or two-stage arthroplasty implantation.

Preoperative Planning

Preoperative planning is intimately linked to investigations—investigations will determine if there is sufficient articular surface, rotator cuff and bone stock to manage a nonunion by revision internal fixation with or without bone grafting. If arthroplasty is being considered CT is particularly useful, though can be degraded by metalwork in situ. Removal of metalwork as the first stage in dealing with failed fixation, particularly if arthroplasty is being considered, is well worth considering. In any event the radiographs, but preferably the operation note from the primary procedure, will indicate the type of implant that has to be removed and plans can be made to ensure the correct size(s) and type(s) of screwdriver(s) and any kit for removing, for example, intramedullary nails, is available.

CT can help predict problems such as occlusion or deformity of the medullary canal that could interfere with stem insertion, head/shaft deformity that can affect the seating of the metaphyseal component of an arthroplasty, heterotopic bone and displaced, separated tuberosity fragments that could interfere with range of movement, glenoid deficiencies and scapular deformities that might interfere with glenoid component insertion and alignment. The scan also allows templating and, if necessary, the creation of patient-specific guides or prosthetic components.

Implant Selection

After determining the operative strategy, which could involve revision fixation with or without grafting, but in our case replacement arthroplasty, implant selection can take place. Shoulder arthroplasty is available in both anatomic and reverse variants. Anatomic replacement can be in hemiarthroplasty form or total arthroplasty, and the humeral component can be resurfacing, stemless or stemmed. However, all of these rely on a functional rotator cuff. Reverse arthroplasty is a form of total arthroplasty and although the humeral stem length can vary, stemmed components are the norm. Reverse arthroplasty does not require a functional rotator cuff, and when it first began to be used for trauma it was indicated for the elderly who were assumed to have a deficient rotator cuff [7]. However, it can still be carried out in the presence of a rotator cuff and in trauma cases there is some evidence that preserving the tuberosities and their attached cuff tendons improves the functional outcome [8].

Irrespective of whether or not the rotator cuff is intact (as shown in our case on an ultrasound scan) and functioning well (difficult to tell in our case because of stiffness but there was some fatty atrophy of the supraspinatus muscle belly on ultrasound scanning, suggesting a degree of chronic dysfunction), the patient themselves has to be considered in the decision-making algorithm. It has been observed that shoulder replacement in general, when carried out in patients under 60, is significantly likely to need revision in the patient's lifetime. Over the age of 80 the prosthesis is very likely to outlast the patient. Anatomic shoulder replacements are associated with better functional scores, but the main reason for revision of anatomic shoulder replacements in the UK National Joint Registry is rotator cuff failure (see—https://reports.njrcentre.org.uk/). In elderly patients, therefore, the cuff is likely to be of poorer quality and a reverse prosthesis is likely to last the patient's lifetime, so a reverse prosthesis is most often selected [9]. In a young, higher demand patient, the cuff is likely to be of better quality and revision is more likely to be required in the future, irrespective of the prosthesis used; therefore, an anatomic replacement is more likely to be appropriate.

In our case, the patient was 75 years old and independent, but with no high demands such as sporting pastimes, and there was evidence of rotator cuff deficiency; therefore, a reverse total shoulder replacement was selected.

Surgery

The patient was involved throughout in debates about the risks and rewards and the impact of imaging findings. They were happy to proceed

with revision of the failed internal fixation to a reverse total shoulder arthroplasty. Preoperative examination and blood tests, along with a consideration of the clinical course since the original surgery and the current imaging, meant that there was no suspicion of infection. A one-stage procedure was, therefore, chosen, removing the locking plate and screws and inserting a reverse total shoulder replacement under the same anaesthetic.

Anaesthesia consisted of an interscalene block and general anaesthesia. The interscalene block effectively deals with pain control both during and after surgery; therefore, the general anaesthetic can be very light, allowing rapid patient recovery after surgery. Prophylactic antibiotics are administered before surgery starts according to local policy. The patient was placed in the Beach chair position with the arm draped free.

The surgical approach mirrors that used in the original surgery—the previous scar is reopened and deepened to the deltopectoral interval (Fig. 6.3). The cephalic vein may or may not have been preserved in the primary surgery, and sometimes landmarks and planes can be difficult to identify. If there is any difficulty, it is useful to simply extend the skin wound by 1 or 2 cm and utilise a region not previously disturbed, and therefore with preserved fat and tissue planes, to direct one to the humeral shaft in the subdeltoid plane and the coracoid process with its attached conjoint tendon.

Having identified these landmarks, the subdeltoid region can be opened, following round the humeral shaft and releasing scar tissue from this in an upwards and lateral direction until one is all the way around the shaft and tuberosities, exposing the plate. The dissection can then be continued above the plate to enter the subacromial space and sharp dissection may be needed to release subacromial scar. Rotating the free arm reveals planes of movement, which are the planes that have to be released to properly expose the proximal humerus. In the same plane, dissecting medially will take one beneath the conjoint tendon on the superficial surface of subscapularis and care has to be taken beneath the conjoint tendon not to threaten the musculocutaneous nerve.

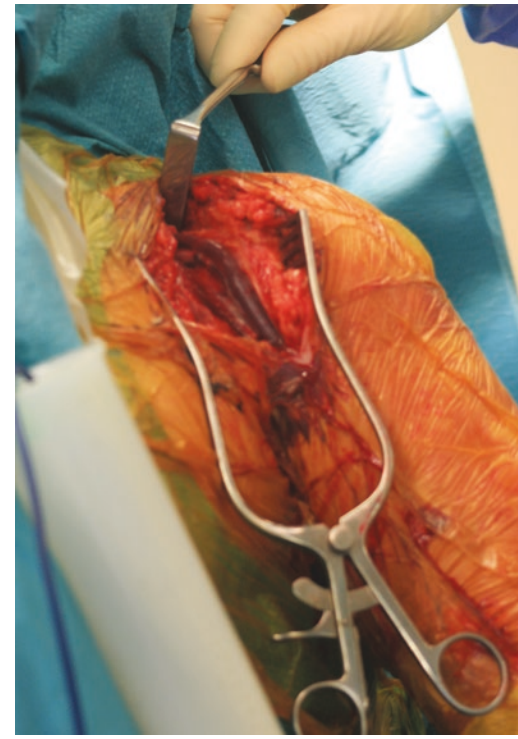

Fig. 6.3 The original deltopectoral approach was reused to allow access to the proximal humerus for removal of the metalwork, then the glenohumeral joint for arthroplasty

Once the proximal humerus has been adequately exposed, a process which often improves the range of movement in any event, the defunct metalwork can be removed. After removing all screws/pegs from the plate, a check should be made for strong suture material such as fibre wire which may have been used to fix the rotator cuff and tuberosities to the plate through specifically designed holes in the plate. Any such sutures have to be at least cut, if not removed, to allow the plate to be lifted out.

After removal of the metalwork, attention can be paid to the arthroplasty. Depending on the state of the rotator cuff, whether it is intact and mobile, a decision can be made as to whether an osteotomy of the lesser tuberosity is to be carried out in order to preserve and repair the subscapularis afterwards, or whether the cuff is to be sacrificed. In our case, the cuff was completely deficient above the prosthesis and the remaining

cuff anterior and posterior was scarred and stiff, so a decision was taken to excise it. Of course, this improves access to the glenohumeral joint which can then be dislocated and, using appropriate jigs, the flattened and necrotic humeral head can be removed at the correct level and angle to accommodate the planned humeral stem. Using the broaches and jigs appropriate for the device to be used, the humeral canal can be prepared and usually a trial stem can be left within the canal, with a flat plate attached to it that sits on the cut surface and protects it whist the glenoid is prepared.

Access to the glenoid is achieved in the same way as it is in primary arthroplasty—even in primary osteoarthrosis the capsule is often scarred and thick, and obtaining a good release around the glenoid is essential to allow the humeral shaft to be retracted backwards and inferiorly to allow access to the glenoid.

If the glenoid has been damaged by projecting screws, for example, managing the glenoid can become complex with a need for patient-specific guides or augments to the glenoid component. However, in most cases this is not necessary and after trauma, such as in the case we are managing, there may even be residual cartilage on the glenoid that needs reaming to the subchondral bone surface.

Preparation and insertion of the glenoid should be carried out using the specific instruments for the prosthesis to be inserted. The glenosphere should be placed low on the glenoid and not in the central position used for the glenoid component of an anatomic shoulder. Slight inferior overhang of the glenosphere is one measure that reduces the risk of impingement and scapular notching, with the possibility of early loosening. After inserting the glenosphere, a polyethylene liner of appropriate size to fit the glenosphere and produce adequate tension in deltoid can be fixed to the stem. The joint is then reduced and, if it was planned, the subscapularis and other components of the rotator cuff can be repaired around the prosthesis (not needed in our case). After a thorough washout and check for stability through range of movement, the shoulder can be reduced. The deltopectoral interval should close as retractors are removed and only the fat and skin layers need closing.

Postoperative Management

The intention of arthroplasty is to allow early functional movement and although the patient will need a sling until their interscalene block has worn off, they should be allowed to use their arm for activities of daily living as soon as that has occurred. Drains are not usually needed nor are postoperative antibiotics. An X-ray is taken after surgery to confirm satisfactory postoperative appearances (Fig. 6.4a and b). The patient can usually be discharged from hospital within 24 h of surgery, but loaded use of the arm is restricted at first, being gradually resumed over 3 months after surgery.

There is a difference in the complication rates after anatomic and reverse total shoulder replacement—a reverse prosthesis carries a higher risk of infection and dislocation than an anatomic prosthesis. The risk of revision is higher in the first 3 years after implantation, but beyond 9 years anatomic shoulder replacements overtake reverse shoulders in terms of revision rate. Postoperative review should account for this, with exercises and their progression supervised by a physiotherapist and the patient warned to report back quickly if there is any redness, discharge, pain or loss of movement. However, if a postoperative X-ray taken before discharge is satisfactory, no further imaging is usually necessary in the first year or two after surgery if the patient progresses satisfactorily with their rehabilitation. Outpatient review can, therefore, be arranged according to local protocols—our patient was contacted for telephone review 6 weeks after surgery and attended physiotherapy once a month for a review of rehabilitation exercises. She was seen after 1 year and X-rays at this stage were compared to postoperative films and deemed suitable for the patient to be followed up in a virtual clinic thereafter, with X-rays after 2 more years and patient reported outcome measures

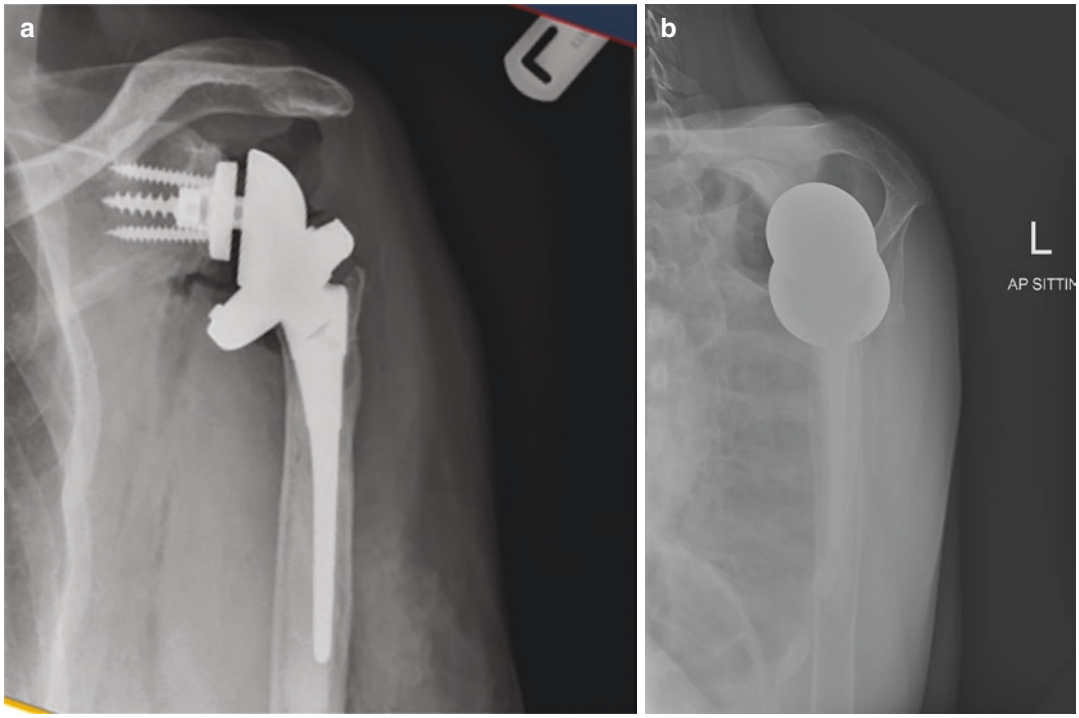

Fig. 6.4 (**a** and **b**) Postoperative X-rays showing replacement of the necrotic humeral head with a total reverse shoulder arthroplasty

compared to the previous year to flag up any deterioration that might trigger a face-to-face review.

Summary: Lessons Learned

This patient underwent open reduction and internal fixation of a displaced proximal humerus fracture in which there was no contact between the shaft and head fragments; therefore, this is not the sort of fracture that was considered in the ProfHer trial [1] (which suggested no difference between operatively and nonoperatively treated proximal humerus fractures in the majority of cases). Unfortunately, AVN ensued and of course if this could have been predicted, then arthroplasty would have been considered as the primary operation. However, it is better to restore the natural joint than to replace it and this was attempted but failed due to collapse of the humeral head, penetration of pegs into the glenohumeral joint and failure of the rotator cuff. In the future, we might develop algorithms to identify those patients in whom this is an inevitability and those who are more likely to retain their natural joint, but for now cases such as ours will continue to arise.

Once failure had manifest itself the decision-making process was one of recognising that arthroplasty was the only real operative option, and balancing then the relative risks and rewards of the various variants of anatomic and reverse shoulder replacement. Unlike many cases in which revision of a fracture fixation is contemplated, the revision of fixation to an arthroplasty, particularly in the shoulder, is a decision-making process that intimately involves the patient right down to the variant of implant to be used. Securing union after previous failed fixation of a fracture can be followed by removal or retention of the implant and no significant consequences for the patient. Revision to an arthroplasty, however, leaves the patient with an articulation sub-

ject to wear for the rest of their lives and may, even if completely successful, require further revision surgery in the future.

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