Periprosthetic Fractures in the Upper Limb

Pierre Mansat

Abstract

Periprosthetic fractures around a shoulder or an elbow arthroplasty are not common, but remain a challenging complication. Osteopaenia, advanced age, female sex, and rheumatoid arthritis are medical co-morbid factors that may contribute to humeral or ulnar fractures and associated delayed healing and poorer function. Treatment strategy includes: identification of the cause of failure, exclusion the possibility of sepsis, evaluation of the local soft-tissue status, status of the prosthesis, selection of a prosthesis adapted to the revision procedure if needed and planning of the appropriate surgical technique. Classification must be used to determine the prognosis and treatment of these fractures: the location of the fracture in relation to the stem, the security of the fixation, and the quality of the bone. For fractures around an implant, if the fracture line overlaps most of the length of the prosthesis with a loose implant, revision with a long-stem implant should be considered. When the fracture overlaps the tip of the prosthesis and extends distally, open reduction and internal fixation is recommended. When the fracture is completely distal to the prosthesis and satisfactory alignment at the fracture site can be maintained with a fracture brace, then a trial of non-surgical treatment is recommended.

Peri-implant Fracture with Shoulder Arthroplasty

Incidence

Peri-prosthetic fracture during or following shoulder arthroplasty is not common with a frequency varying from 0.6 to 2.8 % [2, 5, 8, 15, 27, 29]. Reviewing 40 studies of humeral head replacement or total shoulder arthroplasty that included 3,584 patients, the rate of periprosthetic fracture was reported to be 1.2 % (range, 0–8 %) [28]. In studies of more

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than 2,500 primary total shoulder arthroplasties and 1,400 humeral head replacements performed over a 33-year period at the Mayo Clinic with a mean of 7 years of follow-up, the rate of intra-operative humeral fractures was 1.2 % (48 of 4,019) and the rate of post-operative humeral fractures was 0.9 % (36 of 4,019) [25]. Female sex and underlying diagnoses like rheumatoid arthritis and/or osteoporosis were significantly associated with a higher risk of intra-operative fractures, and co-morbidity was significantly associated with a higher risk of post-operative fractures [25, 26]. Campbell et al. [6] described osteopaenia of the humerus based on the ratio of the combined width of the mid-diaphyseal cortices to the diameter of the diaphysis at the same level. A ratio >50 % indicated normal bone, 25–50 % indicated mild osteopaenia, and <25 % indicated severe osteopaenia. Based on this definition, osteopaenia was a risk factor in 75 % of the periprosthetic humeral shaft fractures in their study.

Classification

Several classification systems exist for periprosthetic humerus fractures. The most accepted classification has been proposed by Wright and Cofield [30], which is based on the location of the fracture relative to the tip of the humeral prosthesis (Fig. 1).

- Type A fractures are centred near the tip of the stem and extend proximally;
- Type B fractures are centred at the tip of the stem but present with a variable amount of extension distally;
- Type C fractures are located distal to the tip of the stem.

Campbell et al. [6] proposed a classification system that included tuberosity and metaphyseal fractures and that may be more applicable for intra-operative fractures particularly those occurring with use of press-fit implants (Fig. 2).

- Region-1 fractures involve the greater and/or lesser tuberosities;
- Region-2 fractures involve the metaphysis of the proximal part of the humerus;
- Region-3 fractures involve the proximal part of the humeral shaft;
- Region-4 fractures involve the middle and distal parts of the humeral shaft.

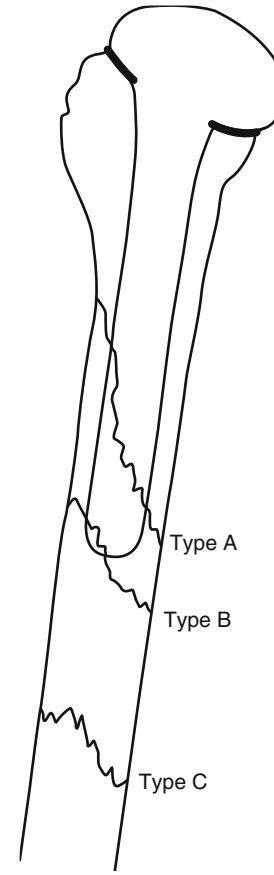

Fig. 1 Periprosthetic humeral fractures according to Wright and Cofield [30]

Treatment Strategy

The type of treatment is dictated by fracture location, displacement, and status of humeral component fixation.

Non-operative Treatment

A fracture with acceptable alignment occurring next to a well-fixed stem can be successfully managed non-operatively with functional bracing [6, 14]. Acceptable alignment can be defined as within 20° of flexion/extension, 20° of rotational and 30° of varus/valgus angulation [15]. Non-operative treatment can also be indicated when surgery is contra-indicated as with active infection and debilitating medical co-morbidities precluding the use of general anesthesia.

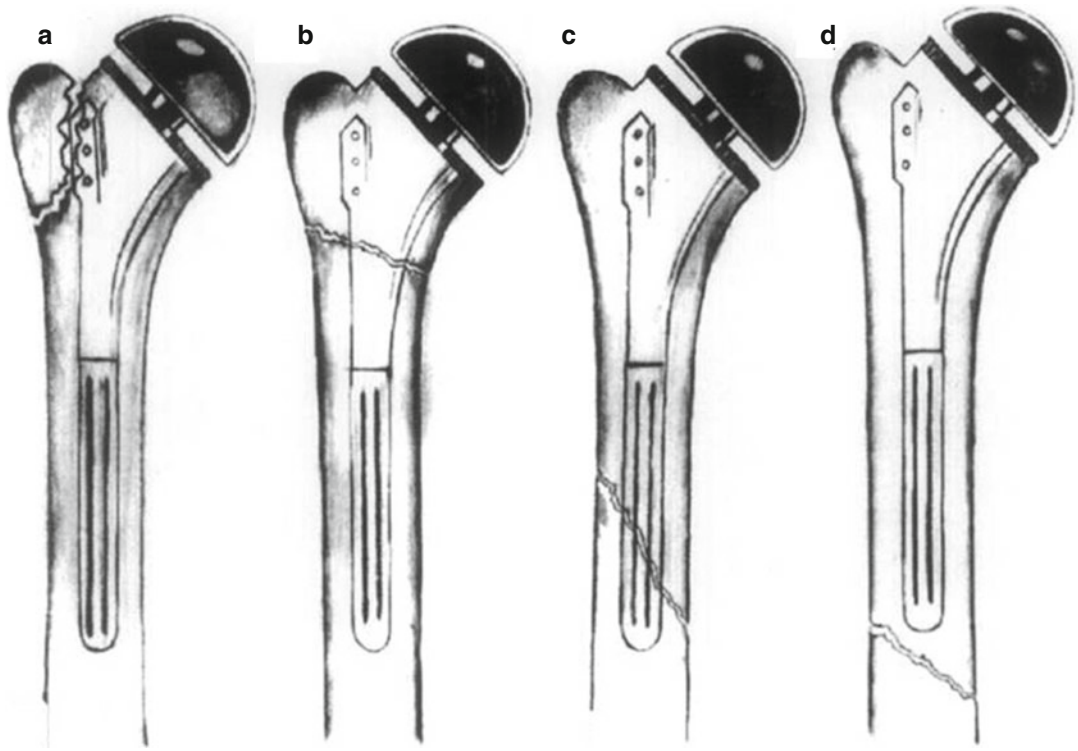

Fig. 2 Periprosthetic humeral fractures according to Campbell et al. [6] ((**a**) region 1; (**b**) region 2; (**c**) region 3; (**d**) region 4)

Surgical Treatment

Operative treatment may be indicated when there is prosthetic loosening, significant displacement, unacceptable angulation, or failure of a fracture to heal. Short oblique and transverse fractures as well as those distracted by the stem are more prone to delayed union and are more likely to require operative intervention. Surgery should be considered following failure to maintain fracture reduction. Pre-fracture loosening can be recognized by circumferential radiographic lucency or a shift in prosthesis position. When the prosthesis is loose the prosthesis should be revised with a long-stem humeral component. Revision stems may be cemented or, if there is adequate bone stock, may be cementless. The tip of the stem should extend two to three cortical diameters past the fracture site. Stable fixation at the fracture site can be augmented with allograft strut, cerclage wires, or plate-and-screw fixation. Autologous iliac crest or allograft bone graft can be used to supplement healing. Displaced fractures usually required operative intervention utilizing such implants as angular stable plates and cerclage as indicated. Humeral shaft fractures that are recognized intra-operatively should be managed with placement of a long-stem prosthesis and supplemental rigid fixation. Stable fixation allows for early range of motion (ROM) during rehabilitation as well as more satisfactory results from unrestricted shoulder and elbow movement. Union rates are better with this treatment than with non-surgical treatment of fractures located about the tip of the humeral prosthesis.

Surgical Technique – Indications

According to the Wright and Cofield classification [30], Steinmann and Cheung [26] have well described the surgical guidelines:

- Type A fracture: most type A fractures are minimally displaced and angulated due to the presence of the rigid intramedullary stem. Type A fractures may be comminuted or may be long and oblique, with substantial overlap

between the length of the fracture and the humeral stem. When there is substantial overlap between the length of the fracture and the humeral stem, as well as displacement >2 mm and angulation >20° in any plane, revision to a long-stem prosthesis is advised to by-pass the fracture by at least two cortical diameters (Fig. 3). Fixation should be supplemented distally with strut graft and cerclage wires. If necessary, plate and screws may be used instead of graft and wires to afford torsional rigidity.

- Type B fracture: for type B fractures with coexistent humeral stem loosening, revision to a long-stem prosthesis is recommended. In cases of severe osteopaenia, either a cortical strut graft with cerclage wires or plate fixation with cerclage wires is placed across the fracture site. Both cemented and cementless stems for periprosthetic humerus fractures have been used in small case series, with satisfactory union rates. A displaced or unstable type B fracture with a well-fixed humeral stem is managed with a hybrid plate. It is secured with cerclage wires or short locking screws proximally and screws distally, engaging eight cortices distally. Cortical onlay strut allografts act as biological plates, serving both a mechanical and a biological function, because allografts have the potential for remodelling and incorporation (Fig. 4).
- Type C fracture: ORIF of type C fractures is recommended after failed non-surgical treatment or failure to maintain reduction. This treatment is similar to that used for non-periprosthetic humeral shaft fracture. Plate-and-screw fixation is performed, with or without supplemental allograft struts. The length of the plate should be adequate to extend proximally. The plate should overlap the tip of the prosthesis by two cortical diameters to avoid the creation of the stress riser (Fig. 5).

Guidelines according to Campbell classification have also been proposed [6]:

- Region-1: these fractures are assessed for stability, and, if deemed stable, with the periosteum intact and without displacement, they may be treated with insertion of a standard implant without specific fixation. However, if any fracture motion exists or if there is any degree of displacement, suture fixation of the fractured tuberosity to the humeral implant and circumferentially around the proximal part of the humerus is recommended;
- Region-2: fractures are treated with a standard-length implant, cerclage fixation, and autologous bone-grafting.
- Region-3 and 4 fractures are best treated with longer stemmed implants with cerclage fixation and, in some cases, with supplementary allograft cortical struts.

Results

Relatively limited information has been published on the outcome of treatment of periprosthetic humerus fractures after shoulder arthroplasty. Results have been categorized in terms of fracture union, pain relief, and ROM (Table 1). Reported complication rates have been relatively high varying from 0 to 100 %. Complications included: hardware failure, delayed union, non-union. Other complications included neurapraxias (axillary nerve, radial nerve), frozen shoulder, and infection. Unsatisfactory results were primarily due to loss of motion.

Summary

The full spectrum of periprosthetic fractures around a shoulder arthroplasty has been classified. Implications of treatment and results naturally follow from the fracture type and the stem status.

Peri-implant Fracture with a Total Elbow Arthroplasty

Incidence

Periprosthetic fractures around a total elbow arthroplasty is not common but are being observed with increasing frequency and carry with them some very specific treatment considerations. Based on the Mayo Clinic experience with more than 1,000 linked Coonrad-Morrey implant

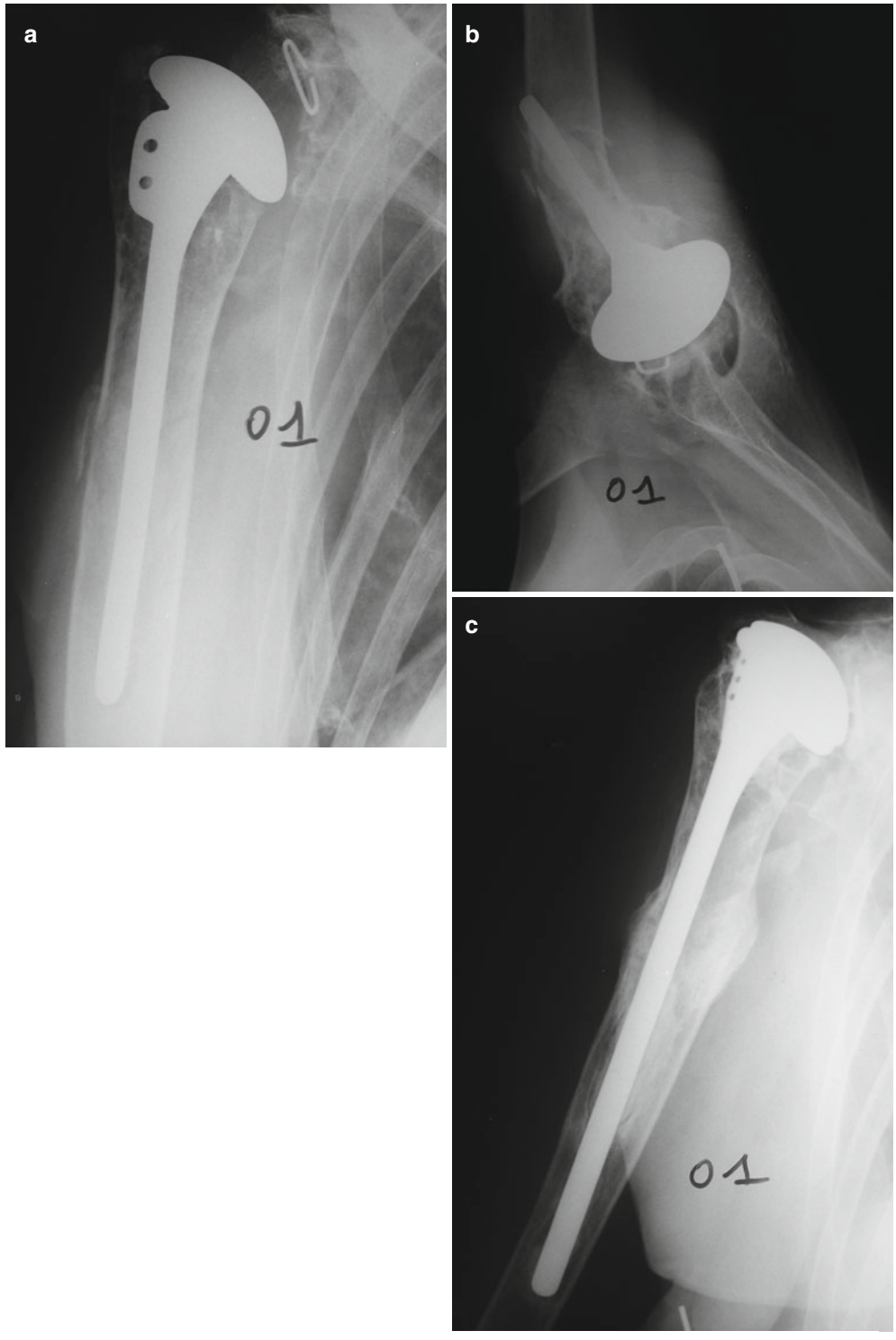

Fig. 3 Type A periprosthetic humeral fracture (**a**, **b**) treated by revision to a long-stem prosthesis (**c**)

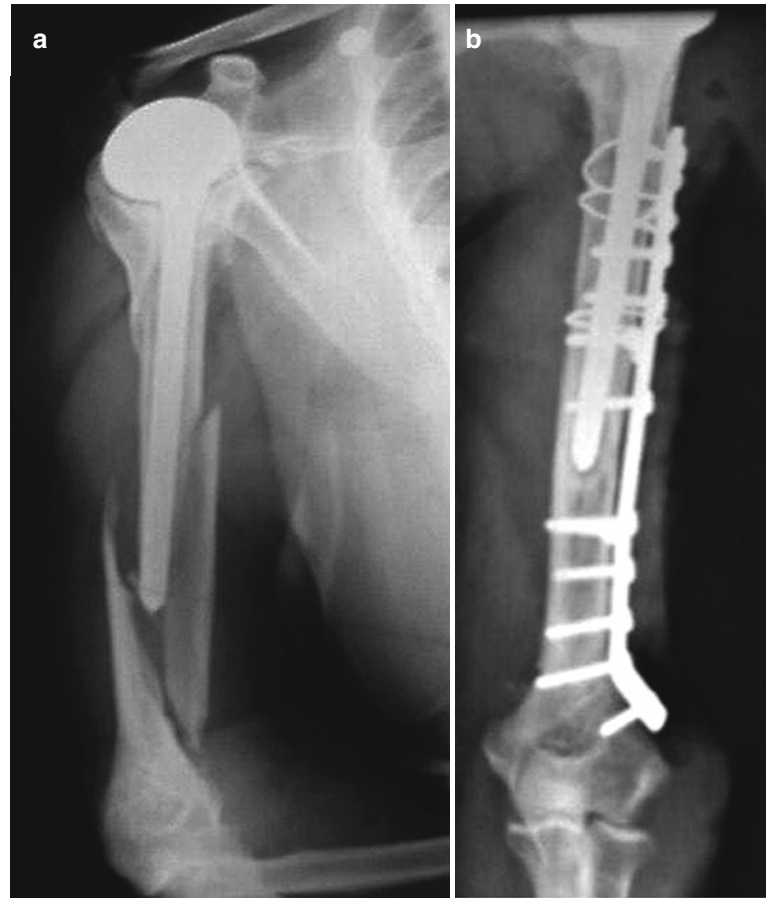

Fig. 4 Type B periprosthetic humeral fracture (**a**) treated with ORIF (**b**)

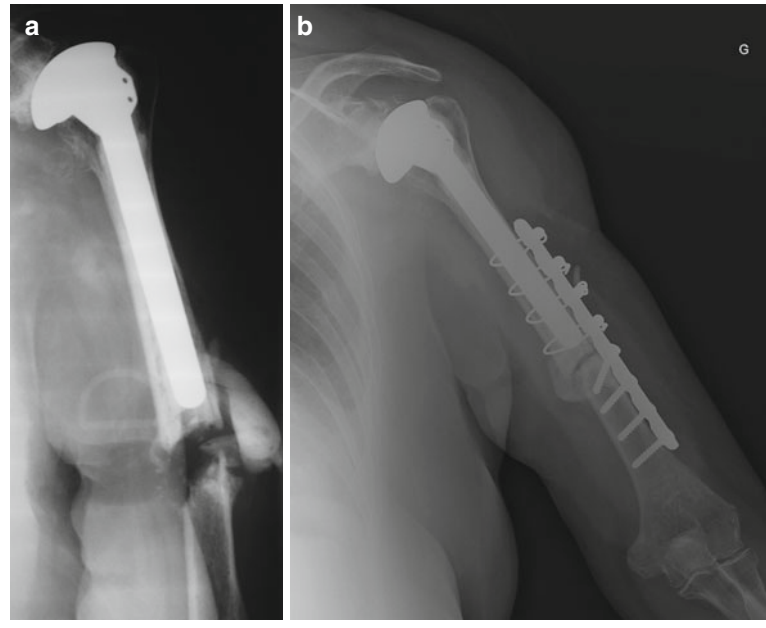

Fig. 5 Type C periprosthetic humeral fracture (**a**) treated with ORIF (**b**)

Table 1 Results of treatment of fracture around shoulder arthroplasties

Authors	N	Treatment	Age (year)	F/u (month)	Results
Boyd et al. [4]	7	–	–	–	All experienced complications 5 required surgery to achieve union 5 of 7 had reduced ROM
Wright and Cofield [30]	9	Nonsurgical (5) ORIF (2) Revision arthroplasty (2)	70 (45–85)	47 (4–196)	8 unions 3 satisf/6 unsatisf
Campbell et al. [6]		Nonsurgical (5) Standard arthroplasty (8) Long-stem arthroplasty (8)			
Worland et al. [29]	6	Nonsurgical (1) ORIF (1) Revision arthroplasty (4)	72 (67–94)	43 (13–85)	100 % union All satisfactory
Kumar et al. [15]	16	Nonsurgical (6) ORIF (10)	63 (37–76)	67 (4–191)	Union: 180 days nonsurgical to 278 days with ORIF 3 exc/4 satisf/9 unsatisf
Groh et al. [10]	15	Nonsurgical (5) ORIF + long-stem prosthesis (10)	58 (40–70)		100 % union rate (11 weeks)
Athwal et al. [2]	45	28 during primary TSA 3 during HHR 14 during revision arthroplasty			Complication rate: 36 %
Wutzler et al. [31]	6	ORIF (6)	75 (51–83)	15 (6–39)	100 % union rate
Singh et al. [25]	178	–	–	–	Female sex, underlying diagnosis risk factors of fracture
Sewell et al. [24]	22	Rev prosthesis (22)	75 (61–90)	42 (12–91)	12 very satisf/3 satisf/3 dissatisf
Andersen et al. [1]	36	ORIF (17) Revision arthroplasty (19)			Union rate: 97 % Complication rate: 39 %
Minéo et al. [20]	7	ORIF (7)	72 (68–75)		Union rate: 100 % Mean-time: 5 months

procedures a fracture was documented before, during, or subsequent to surgery in approximately 13 %. The complication was recorded in 9 % of primary surgery and in 23 % of revision procedures. The anatomical site of the lesion involves in an equivalent way the humerus and the ulna.

Treatment Strategy

Treatment strategy includes: identification of the cause of failure, exclusion the possibility of sepsis, evaluation of the local soft-tissue status, status of the prosthesis, selection of a prosthesis adapted to the revision procedure if needed and Planning of appropriate surgical technique.

Classification

Periprosthetic fractures in the elbow are classified according to the factors that determine their prognosis and treatment: the location of the fracture in relation to the stem, the security of the

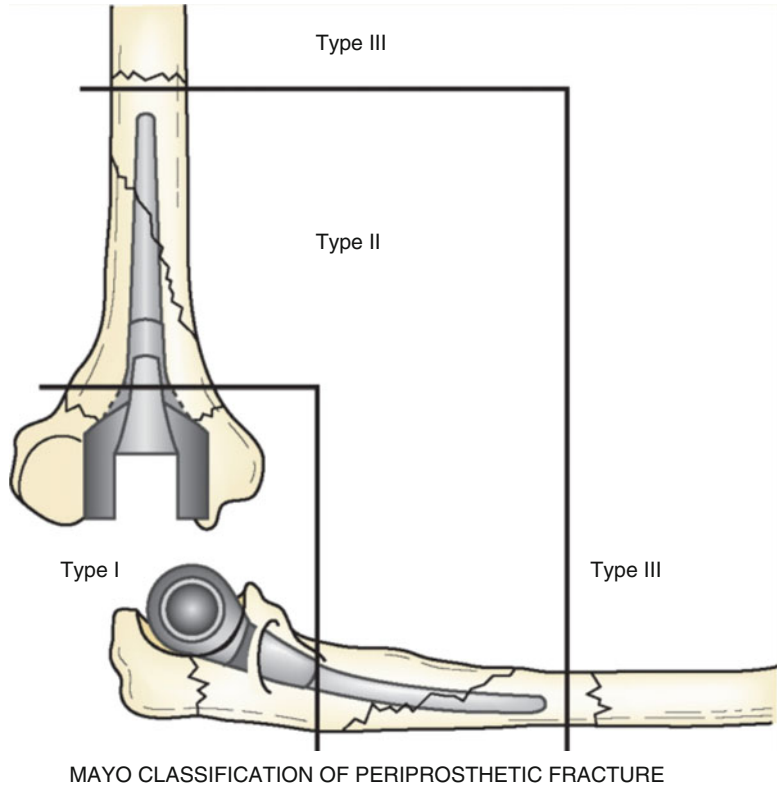

Fig. 6 Mayo classification of peri-prosthetic fractures around total elbow arthroplasties

fixation, and the quality of the bone. Dr Morrey has developed a classification system according to three anatomical locations of either the humerus or ulna [23]: metaphyseal (type I), stemmed shaft (type II) and beyond the stem (type III) (Fig. 6). The fracture is further characterized as associated with a well-fixed or a loose stem. Finally the bone stock is assessed as preserved or compromised.

Surgical Technique

The technical features of all revision options must address the management of the triceps, identity and protection of the nerves and protection of the osseous integrity. In all cases the ipsilateral iliac crest must be prepared. The previous posterior incision is used if possible. The ulnar nerve is always identified. The radial nerve is identified by palpation or isolated if an extensive approach of the humeral diaphysis is planned. The triceps is detached from the olecranon from medial to lateral but can be split. Per-operative specimens are always sent for cultures.

The fracture site is then identified. If the implant is well-fixed fixation of the fracture is performed. However, if the implant is loose it is removed and the medulla is cleaned of membranes, cement, and debris. The surgical reconstruction technique in each case is based on the severity of bone loss. Bone loss is considered to be moderate when techniques to augment the bone stock is not needed. Bone loss is considered to be severe when the cortical bone around the prosthetic stem is too thin, brittle, or even absent, such that bone stock augmentation by means of iliac bone graft, strut graft or an allograft-prosthetic composite is necessary.

Humeral Fracture

Type I – Humerus

Fractures of the condyles often occur intra-operatively but can also occur due to stress or fatigue failure post-operatively. There are minimal implications regarding treatment or prognosis with the linked Coonrad-Morrey device and nothing must be done. However, an intact condyle

Fig. 7 Type I humerus fracture around a Latitude total elbow arthroplasty treated with ORIF

is essential for the stability of the linked GSBIII prosthesis or an unlinked arthroplasty. Hence, repair or reconstruction of the condyles is necessary (Fig. 7).

Type II – Humerus

Humeral shaft fractures around the stem or at its tip typically occur due to trauma or pathological fracture due to loosening or osteolysis around the component. Depending on the quality of the bone and the aetiology, the treatment varies but usually requires open reduction and internal fixation with cerclage wires, with or without additional onlay allograft struts or cerclage or plates [16, 23]. Fractures around a well-fixed stem are usually at the tip of the prosthesis. There are treated by open reduction and internal fixation. Fractures around a loose stem usually occur in the presence of osteolysis. Revision is almost always required with or without bone grafting depending of the remaining bone stock. If there is moderate bone loss around the humeral stem it is recommended to use strut graft to re-inforce the fixation [23]. Ideally the curvature of the strut is retained since this provides some angular stability to the construct when compressed with cerclage wires. The goal is to by-pass the fracture by a sufficient distance to provide stability. At least two circumferential wires are placed proximal and two distal to the fracture. If the stem is loose it has to be changed to a longer stem to by-pass the location of the fracture (Fig. 8). However, when the fracture is associated with a loose implant and severe bone loss, such that no cortical strut allograft augmentation could restore the diaphysis of the humerus and securely contain a new humeral component, massive allograft must be used [17]. The allograft is fashioned in such a way as to serve as a strut graft proximally at the humerus, while affording circumferential coverage of the implant at the articulation. Fixation is performed with cerclage wires (Fig. 9). Kawano and co-authors [13] have proposed an original method to treat this type of fracture using a locking nail threaded around the stem of the prosthesis.

Type III – Humerus

Fractures beyond the tip of the stem are treated as routine humeral shaft fractures with immobilization and functional bracing if non-displaced or with ORIF if displaced (Fig. 10). If the stem is not well fixed then the implant is revised. A longer-stemmed device is used as an intramedullary alignment and assists in the fixation. Struts can be employed to bridge the fracture. However with extensive osteolysis a massive allograft must be used [23]. However, when there is at the same time osteolysis in zone II and III, a massive allograft is preferred.

Ulnar Fracture

Type I – Ulnar

Peri-articular fractures of the ulna usually involve the olecranon because the coronoid is rarely fractured. The olecranon is particularly

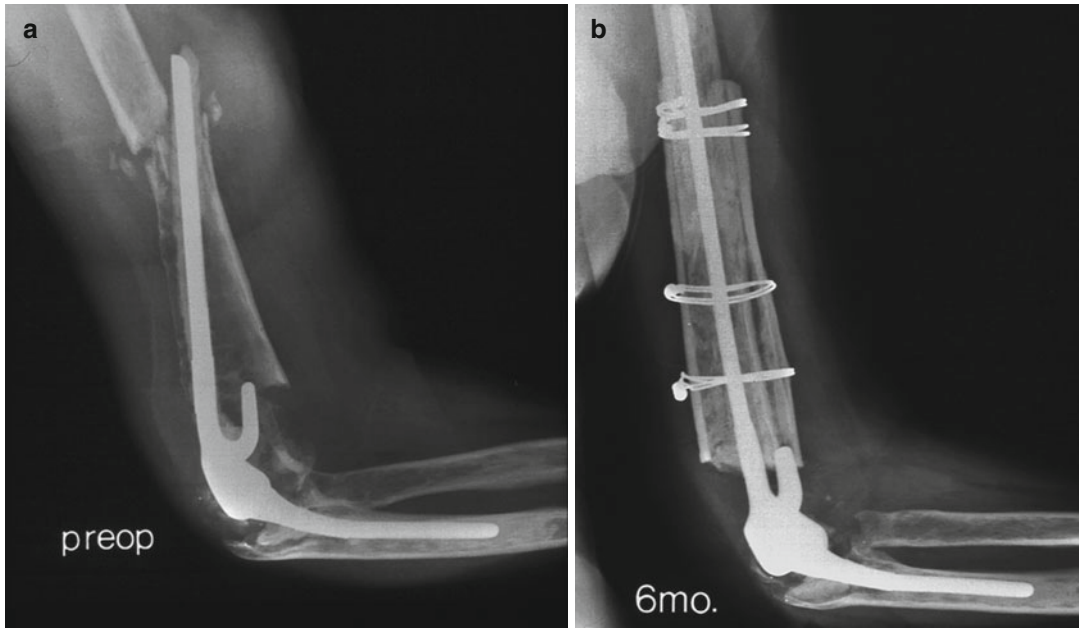

Fig. 8 Type II humerus fracture with preservation of bone stock (**a**) treated with revision to a long-stem implant and strut graft around the diaphysis (**b**)

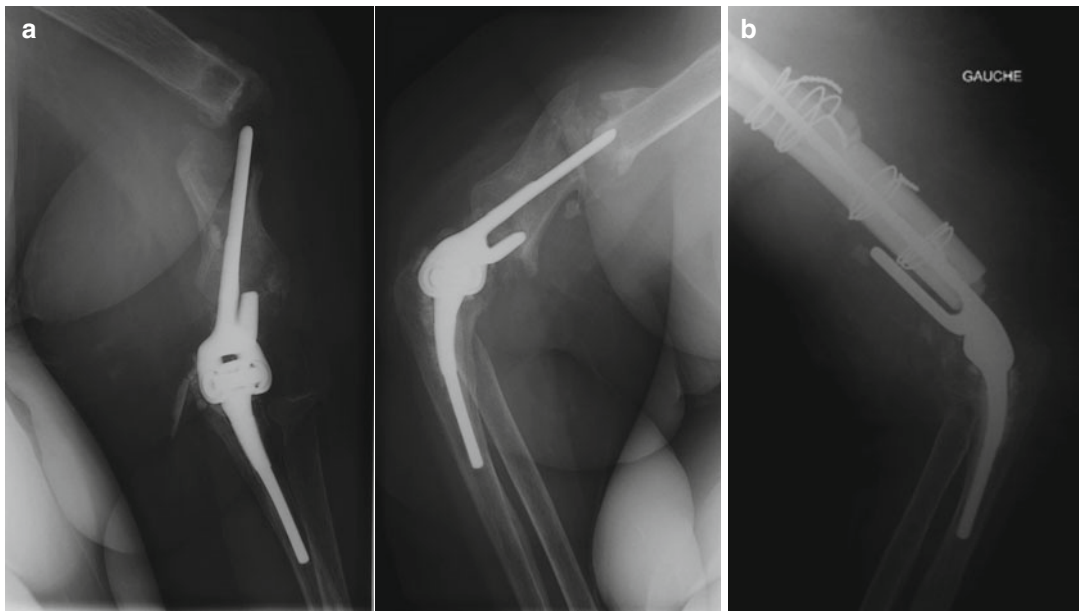

Fig. 9 Type II humerus with loss of bone stock (**a**) treated with an allogaft-prosthesis-composite (**b**)

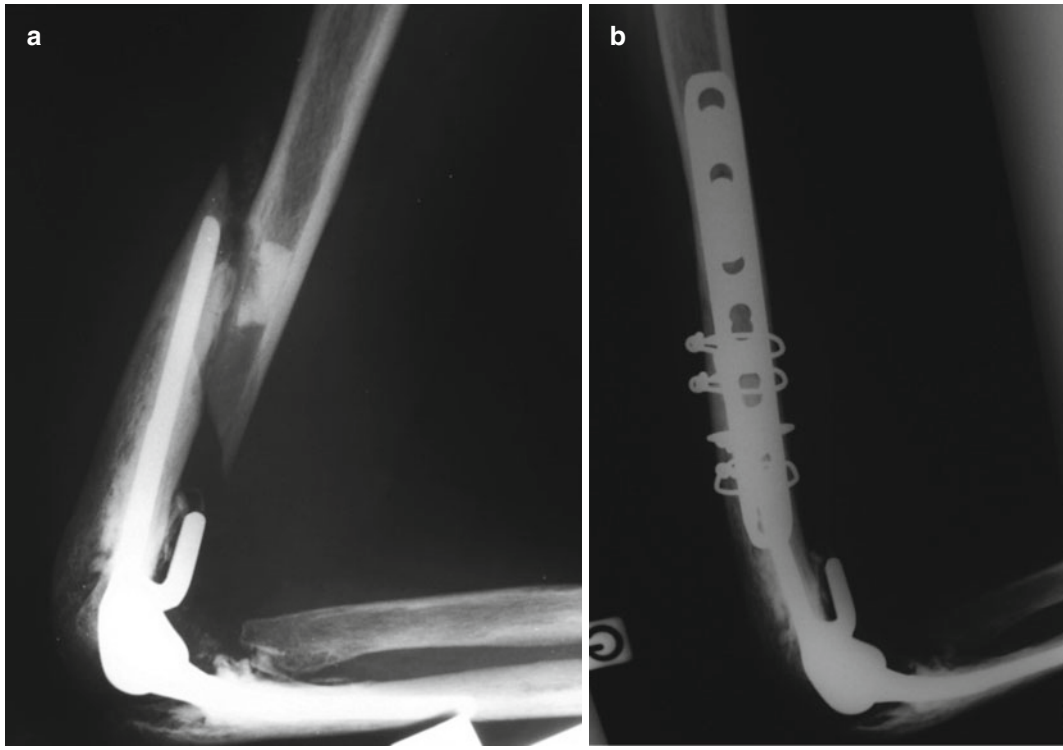

Fig. 10 Type III humerus fracture with a well-fixed implant (**a**) treated with ORIF (**b**)

prone to fracture in patients with rheumatoid arthritis, due to erosive thinning of the semilunar notch. Fracture can occur post-operatively due to forceful triceps contraction or as stress fracture. Treatment is usually determined according to whether or not the olecranon fragment is displaced. If not displaced, a period of immobilization is recommended. If there is significant displacement, the triceps will be weakened and open reduction is preferred. If the bone is thin, as is usually the case, it is simply reduced and held with heavy (N°. 5) non-absorbable suture through drill holes in the ulna. If the bone fragment is substantial, internal fixation is performed either with tension-band wiring or with a plate [18]. If the fracture displaces and involves the canal it can compromise ulnar stem fixation. Osteolysis may dictate reconstruction of the proximal ulna with an allograft ulna or fibular strut graft secured with circumferential wire.

Type II – Ulnar

Fractures around a well-fixed stem usually occur right at the tip of the stem. If there are displaced, they are treated by open reduction and internal fixation; if they are undisplaced, oblique and stable, they are managed by a period of immobilization. Transverse fractures tend not to heal. Fractures around a loose stem usually occur through a portion of the ulna that is weakened due to erosion from loosening or osteolysis. Some of these may present with minimally-displaced fractures, but revision is required for two reasons. First, the fracture is not likely to unite. Secondly, the loose stem will remain symptomatic and cause further endosteal erosion and the fracture is likely to displace. The primary objective is to by-pass the fracture with a longer stem and thereby stabilize it. Bicknell and co-authors [3] have proposed the use of iliac crest bone around the proximal ulnar component to replace a metaphyseal deficit (Fig. 11). Allograft strut reconstruction is used

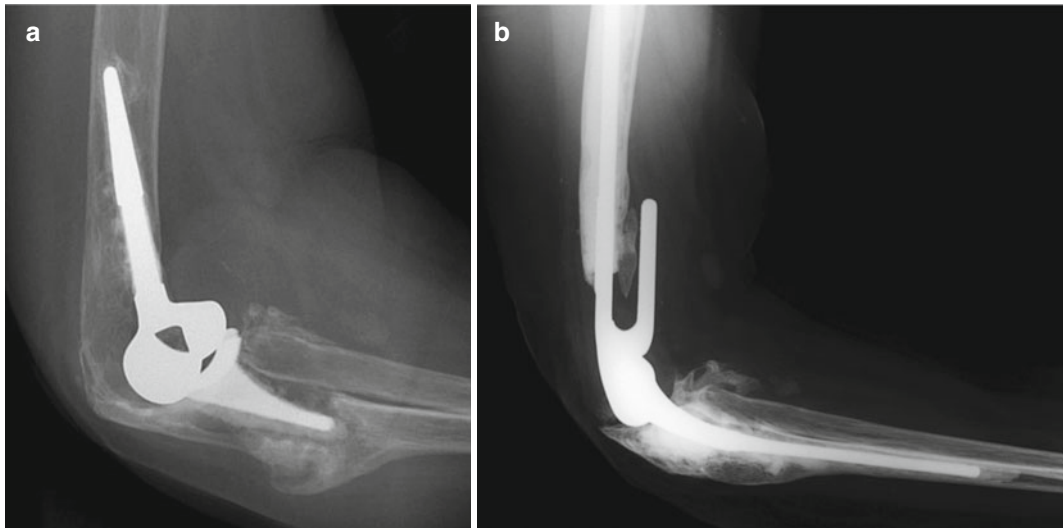

Fig. 11 Type II ulnar fracture (**a**) treated with revision to a long-stem implant with cortical bone graft from the iliac crest (**b**)

to re-inforce osseous deficiency with cortical defects around the prosthesis when it is not amenable to reconstruction with an iliac bone graft [12]. Cerclage wires are preferred to plate and screws to secure the graft around the prosthesis. Another method is the use of a fibular strut graft around the ulnar component. The goal is to bypass the fracture by a sufficient distance to provide stability. At least two circumferential wires are placed proximal and two distal to the fracture. One unique feature of ulna strut grafting is that the strut can be extended proximally to reconstruct an absent olecranon, thus providing a lever arm against which the triceps may function more effectively.

In massive, circumferential bone loss of the ulna, a massive allograft is needed. Morrey has described three type of allograft [21]. In Type I, the implant is inserted into a circumferential allograft, which is in turn inserted into an expanded lytic bone (Fig. 12). In Type II, the circumferential graft is modified to create a strut distally. The implant passes through the circumferential graft, which addresses the deficiency requirement for implant fixation. The strut part of the composite is fixed to the host bone by circumferential wire. In Type III, the implant is cemented in the proximal portion of an extended allograft. The allograft is secured "side by side" to the host bone with circumferential wire. A right fibula opposed to a left ulna works well as the flat side of the fibula opposes very well to the flat side of the ulna.

Fig. 12 Implant is inserted into a circumferential allograft, which is in turn inserted into an expanded lytic bone

Type III – Ulnar

Fractures distal to the ulnar stem are not common. They have been related to a specific trauma, or to a loose implant. The significance and management differs considerably depending upon whether or not the implant stem is stable or loose. If non-displaced it can be treated conservatively. If displaced with a well-fixed implant internal stabilization is needed usually with a

Table 2 Results of treatment of fracture around total elbow arthroplasty

Authors	N	Treatment	F/u	Results
Sanchez-Sotelo et al. [23]	11	Humeral fracture Strut graft	3 years	MEPS = 79 pts Union: 10/11 Compl: fracture (2), ulnar nerve (1), triceps (1), hum fract (1)
Mansat et al. [17]	13	Humeral and ulnar fracture Allograft-prosthesis-composite	42 months	MEPS = 67 pts Compl: infection (4), hum fract (1), allograft nonunion (1), ulnar nerve (2)
Kamineni and Morrey [12]	21	Ulna fracture Allograft bone strut	4 years	MEPS = 79 pts Compl: 4 soft tissues, 4 osseous
Loebenberg et al. [16]	12	Impaction grafting	2 years	MEPS = 83 pts Compl: loosening (2), fracture component (1), infection (1)
Marra et al. [18]	25	Ulna fracture Tension band (16) Excision (4) Suture (2)	66 months	MEPS = 86 pts 50 % bone union 45 % stable fibrous nonunion
Foruria et al. [9]	30	Ulna fracture Long-stem ulnar compoment + strut graft ± impaction graft ± allograft	5 years	MEPS = 82 pts Fracture healing = 100 % Compl: 4 infections, 1 loose component, 1 nerve dysfunction
Morrey et al. [21]	25	Humeral and ulnar fracture Allograft-prosthesis-composite		MEPS = 84 pts 92 % of allograft incorporated Compl: infection (3), fracture (3), nonunion (1), malunion (1), skin necrosis (1), triceps insufficiency (2), ulnar nerve (1)

plate. However, if it is associated with a loose implant, revision of the component is needed with often bone reconstruction [9].

Results

Treating peri-prosthetic fractures around a total elbow arthroplasty can be challenging. Experience with elbow surgery is needed for the appropriate therapeutic indication and adapted treatment. Usually good results can be expected with conservative treatment or ORIF of this fracture. Strut grafts give satisfying results varying from 70 to 90 % of the cases with an incorporation of the bone in more than 90 % of the cases [9, 12, 23]. However, with APC, results are less predictable [17]. However, Morrey and co-authors [23] have shown recently that better results are to be expected with larger graft-host contact areas in the three types of APC's with a 91 % rate of union. Complications are not uncommon and included infection, ulnar and radial nerve involvement, haematoma and wound problems, triceps insufficiency, and lack of incorporation of the graft in some cases (Table 2).

Summary

The full spectrum of periprosthetic fractures at the elbow is well defined by the proposed classification system. Implications of treatment and results naturally follow from the fracture type. For Type II and III fractures, principles of management are similar to those for periprosthetic fractures of the hip and long bones. If there is moderate or severe bone loss strut grafts are preferred to massive

allografts if possible. For Type I fractures the management is dependent on the implant type in the humerus, and a satisfactory outcome simply requires healing of the olecranon fragment in a minimally-displaced position.

Humeral Fracture Between Total Shoulder and Total Elbow Arthroplasties

Non-operative treatment with functional bracing can be proposed for periprosthetic humeral fractures occurring between ipsilateral shoulder and elbow arthroplasties. However, these fractures may not heal with non-operative treatment. Most often surgical intervention should be considered with osteosynthesis and autograft to maximize the healing potential. Strut allograft can also be used to improve fixation. Osteosynthesis can be performed with a locking plate, but dual plating constructs have been proposed to increase stability [7, 11, 19, 22].

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