

Results of Surgical Treatment of Multifragmented Fractures of the Humeral Head

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Summary. This paper reports the results of 27 multifragmented fractures of the proximal humerus treated between 1972 and 1976. Only 3- and 4-part fractures as well as fracture dislocations were included. Internal fixation was performed in 17 cases with buttress plates and in 10 patients by minimal fixation with a tension band wire or simple lag screw. On an average of 3.5 years postoperatively out of 27 patients eight had excellent, eight a good, six a fair, and five a poor overall result. Radiologically six cases of avascular necrosis of the humeral head (22.2%) were detectable in one 3-part, four 4-part and one fracture dislocation.

Five times necrosis was observed after plate fixation (34%) once after wiring of the greater tuberosity. The incidence of unfavorable head necrosis is dependent on the primary fracture type. The results point to the fact that further damage due to surgery and its risk to the remaining blood supply is less prominent in gentle exploration and minimal osteosynthesis than with a generous exposure needed for plate fixation. Minimal fixation thus should be preferred.

Zusammenfassung. Wir berichten über die Resultate von 27 zwischen 1972 und 1976 operierten mehrfragmentären Humeruskopffrakturen. Es wurden nur Brüche mit mindestens drei bzw. vier Hauptfragmenten sowie Trümmer- und Luxationsfrakturen berücksichtigt. Die Osteosynthese erfolgte bei 17 Patienten mit Abstützplatten, bei 10 Patienten mit einer Minimalfixation durch eine Zuggurtungsschlinge oder Einzelschrauben.

Mindestens 3,5 Jahre postoperativ wiesen von 27 Patienten acht ein sehr gutes, acht ein gutes, sechs ein mäßiges und fünf ein unbefriedigendes Gesamtergebnis auf.

Radiologisch wurden nebst passageren Dystrophien sechs (22,2%) avaskuläre Nekrosen des Humeruskopfes festgestellt (bei einer Dreifragment-, einer Vierfragmentfraktur, drei Trümmerbrüchen und einer Luxationsfraktur).

Fünf Nekrosen (34%) traten nach Plattenosteosynthese, eine Nekrose (10%) nach alleiniger Drahtcercelage des Tuberculum majus auf. Die Inzidenz der prognostisch ungünstigen Kopfnekrose ist vorwiegend abhängig von der primär vorliegenden Frakturform. Ein zusätzliches operationsbedingtes Nekrosenrisiko ist laut unseren Ergebnissen bei schonender Exploration und sparsamer Osteosynthese geringer als bei der bezüglich Zugang aufwendigeren Plattenosteosynthese. Wir glauben daher heute, der bewegungsstabilen Minimalfixation den Vorzug geben zu können.

In the majority of fractures of the proximal humerus a good result can be expected with conservative management and early mobilization. Especially in the elderly indications for surgery are restricted. The insufficient holding power of screws in osteoporotic bone necessitates external splintage with the risk of further loss of motion. Furthermore, it appears that a good functional result can be expected even with an incomplete reduction of the fracture area.

Axillary and subcoracoid fracture dislocations, as well as surgical neck fractures displaced by more than the width of the shaft, may be considered indications for surgery. Avulsions of the greater tuberosity with subacromial entrapment and unstable fractures with interposition of soft tissue parts, particularly the periosteal sleeve of the tendon of the long head of the biceps offer further indications. In comminuted frac-

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tures with impaction of the humeral head indication for surgery is relative, partly due to the inherent risk of avascular necrosis of the humeral head and partly due to the technical difficulties of fixation [11].

Several methods of internal fixation have been described [15]. Especially in multifragmented intra-capsular fractures the selection of the ideal technique is important and will be discussed, particularly the use of buttress plate versus tension band fixation with cerclage wires. Plate fixation aims for stability but needs extensile exposure. Tension band fixation needs much less dissection but the stability is marginal, the fixation neutralizing only the main deforming forces. In this study the results of treatment in multi-fragmented humeral head fractures shall be evaluated. The frequency of avascular necrosis and the resulting functional impairment to the fracture types will be examined. The occurrence of vascular disturbance depending on the selection of internal fixation shall be studied. The main emphasis is put on the question, whether avascular necrosis is exclusively determined by the fracture form, or if it is promoted by the use of large implants and extensile exposure.

Anatomical Considerations

Laing [8] demonstrated in 1956 the following vessels at the proximal humerus (Fig. 1). An anterolateral artery from the anterior humeral circumflex artery, which arises from the third portion of the axillary artery. It contributes several branches to both tuberosities and enters the bone at the proximal end of the bicipital groove. A few posteromedial vessels cross the cortex at the base of the anatomical neck coming from the posterior circumflex artery. Smaller vessels accompany the insertion of the rotator cuff.

Therefore, the whole vascular supply of the humeral head enters the bone distal to the anatomical neck. In his classification Neer [12] takes this fact into account pointing to the various muscular attachments (Fig. 2). His experience shows that humeral head necrosis does not occur in pure subcapital fractures without marked displacement. To allow vascular disturbance to occur the presence of at least a 3-part, usually 4-part fracture, or a fracture with marked displacement of the surgical neck is required. In the latter case the inherent vessels may have been destroyed by an extensive exposure needed for plate fixation. As long as one of the two tuberosities with intact muscular and ligamentous insertions stay attached to the head fragment, the vascularity suffices. The proximal injury to the axillary artery increases the risk of necrosis. Ischemia due to increased intraarticular pressure as postulated by Kuehne [7] is less likely since the

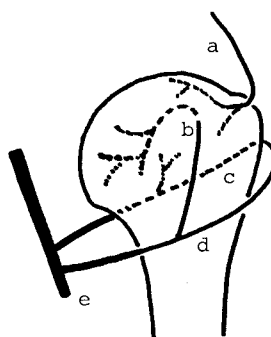


Fig. 1. Modified after Graham. *a* Vessels from the rotator cuff. *b* Arcuate artery. *c* Posterior humeral circumflex artery. *d* Anterior humeral circumflex artery. *e* Axillary artery. All vessels enter the humeral head below the anatomical neck

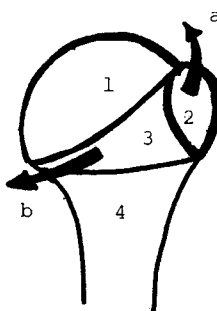


Fig. 2. Modified after Graham. *a* Traction of *m. supraspinatus*. *b* Traction of *m. subscapularis*. Main fragments: 1 Head fragment; 2 greater tuberosity; 3 lesser tuberosity; 4 humeral shaft

Table 1. Classification of the fractures according to Neer

Number of main fragments		2	3	4
I	Minimal displacement			
II	Anatomical neck			
III	Surgical neck			
IV	Greater tuberosity		6 (1) ^a	5 (1) ^a
V	Lesser tuberosity		2	
VI	Fracture dislocation impaction of articular surface	2 (1) ^a	4	8 (3) ^a

^a Healing with avascular necrosis

hemarthrosis can escape from the joint much easier than it is the case at the hip joint.

Materials and Methods

Between 1972 and 1976 forty multi-fragmented fractures of the humeral head in 16 women and 24 men have been treated surgically in the orthopedic departments at the University of Berne and the Kantonsspital, St. Gallen, Switzerland. The average age was 51 (27 to 87) years. After an average of 5 years

Table 2. Modified after Saillant et al., clinical results

Number of cases		Total	Fracture type			Internal fixation	
			3-part	4-part	Fracture dislocation	Plate fixation	Mini-fixation
		27	8	5	14	17	10
Pain	0 severe	0	0	0	0	0	0
	1 moderate	4	2	0	2	2	2
	2 slight	14	3	2	9	9	5
	3 none	9	3	3	3	6	3
Glenohumeral abduction	0 - 30°	4	0	0	4	3	1
	1 35- 70°	6	1	2	3	4	2
	2 75-110°	8	1	2	5	4	4
	3 115- °	9	6	1	2	6	3
Rotation abduction 0°	0 - 30°	2	0	0	2	2	0
	1 35- 60°	4	1	0	3	2	2
	2 65-100°	12	3	3	6	8	4
	3 105- °	9	4	2	3	5	4
Rotation abduction 90° or max.	0 - 30°	4	0	1	3	2	2
	1 35- 60°	5	1	2	2	4	1
	2 65-100°	7	1	1	5	3	4
	3 105- °	11	6	1	4	8	3
Functional impairment (patient)	0 severe	3	0	0	3	2	1
	1 moderate	5	1	0	4	4	1
	2 slight	10	1	3	6	3	7
	3 none	9	6	2	1	8	1
Clinical result (doctor)	0 poor	2	1	0	1	2	0
	1 moderate	7	0	0	7	3	4
	2 good	13	3	5	5	9	4
	3 excellent	5	4	0	1	3	2
Total score	0- 6 poor	5	1 ^a	0	4 (3) ^a	4 ^a	1
	7-10 moderate	6	0	1 ^a	5 (1) ^a	2 (1) ^a	4
	11-14 good	8	1	3	4	5	3
	15-18 excellent	8	6	1	1	6	2

^a Cases with avascular necrosis

27 patients could be evaluated. The fractures were classified according to the classification of Neer [12] (Table 1). Multifragmented fractures or fracture dislocations composed over 50% of the cases. The evaluation of the result of treatment was based on functional examination and radiological assessment. Clinical evaluation followed the point scale of Saillant et al. [13]. Based on criteria of pain, mobility, subjective limitation of function, and objective clinical performance the end result was determined. The scores from the various categories were added in order to arrive at this determination. Fracture forms and types of osteosynthesis were evaluated separately.

Clinical Results

In the analysis of the clinical results according to the system of Saillant, a difference was found for the various fracture types as shown in Table 2. In three fragment fractures the overall results were good with the exception of one patient who sustained a subcapital refracture after mobilization under anesthesia with subsequent humeral head necrosis. Four fragment

Table 3. Material of osteosynthesis used

	Bern (n=18)	St. Gallen (n=9)
T-plate alone	10 (2) ^a	0
with single screws	3 (2) ^a	0
Spoon plate with single screws	1	2 (1) ^a
Cloverleaf plate	1	0
Straight plate alone	0	1
Single lag screws	3	0
Tension band wiring with Kirschner wire	0	4 (1) ^a
with screws	0	2

^a Cases with avascular necrosis**Table 4.** Radiological appearance

Bone structure	- normal	7
	- <i>necrotic collapse</i>	6 ^a
	- dystrophy	14
	- marked sclerosis	2
	- osteoporosis	4 (2 Rh.A.)
Osteoarthrosis	- none	13
	- moderate	11
	- marked	3 ^a
Soft tissue calcification	- none	17 (4) ^a
	- moderate	10
	- severe	0
Deformity	- none	6
	- shortening	13 (6) ^a
	- varus	6 (2) ^a
	- valgus	5
	- subluxation	2 (1) ^a

^a Cases with avascular necrosis

fractures of the categories 4 and 5 without dislocation achieved a better result than those fractures of the category 6 with dislocation or impaction of the articular surface with five fair and four poor results. The evaluation of the functional result did not show any difference between the two types of internal fixation, e.g., the plate fixation used in Berne and the type of minimal osteosynthesis with tension band wiring inaugurated in St. Gallen [10] (Table 3).

Complications

With exception of one superficial disturbance of wound healing, there were no infections. In two patients we observed a neuropraxia of the axillary

nerve with associated hypesthesia and atrophy of the deltoid muscle. One patient complained of dysesthesia in the innervation of the ulnar nerve without motor disturbance. A further sixth patient showed impaired function with loss of power due to inactivity.

Reoperations were necessary in five cases: one subcapital refracture, two rotational and varus malpositions, one entrapment of the greater tuberosity with recurrent subluxation, as well as one 4-part fracture with an unstable tension band wiring resulting in varus tilt.

In six patients avascular necrosis was observed with an associated unsatisfactory functional result.

Radiological Findings (Table 4)

Cases with Avascular Necrosis. To exclude late occurrence of avascular necrosis we demanded a follow-up period of at least 3.5 years. Radiological criteria of humeral head necrosis were related to the alterations found in the humeral head [1, 5, 9] which are characterized by areas of marked sclerosis with osteolysis as well as deformation of the humeral head with destruction of the trabecular architecture.

Six out of 27 cases (22.2%) showed avascular necrosis. The necrosis was seen in one 3-part fracture, one 4-part fracture with marked subcapital displacement as well as three fractures with impaction of the articular surface and one fracture dislocation with injury to the axillary artery. Evaluating the results according to the implants used we observed five cases of avascular necrosis (34%) in 17 plate fixations versus only one avascular necrosis (104) in ten cases of minimal osteosynthesis (wire circlage or single lag screw fixation). After 1 year follow-up we observed in one case slight dystrophy and in two more cases marked dystrophy. Two humeral heads were already partially collapsed. In all cases marked progression of avascular changes were observed over the following years. Besides the humeral head necrosis, all of the joints presented with osteoarthritic changes of moderate or severe degree.

Cases without Frank Humeral Head Necrosis. Dystrophic changes were observed in some cases already one year postoperatively. In five cases they were detectable only later.

Hypertrophic callus formation was present in seven cases without impairment of function. Soft tissue calcification was not frequently observed. In 13 cases shortening was detected due to the desired impaction at the subcapital area of comminution. In one case without humeral head necrosis varus position of 50° with resultant shortening lead to marked limitation of abduction due to subacromial entrapment of the greater tuberosity. Five cases healed in



Fig. 3. a R.H., male, 1951: Open fracture dislocation (cat. VI) with lesion of the axillary artery. Plate fixation 4. 2. 1973). b After 30 weeks: Normal osseous contours of the humeral head with healed fracture. c After 52 weeks: Avascular necrosis with beginning collapse of the humeral head. Despite marked functional impairment only little pain. d After 395 weeks (7½ years): Severe osteoarthrosis following headnecrosis with ankylosis of the shoulder joint, but only moderate pain

valgus position. In three this was caused by the valgus effect of tension band wiring.

Discussion

The results obtained confirm the experience of Neer and other authors [2, 6, 13, 15] that the quality of the end result is influenced by the original fracture form. The more fragments the worse the prognosis. Fractures with marked comminution and fracture dislocations Group 6 scored the most unsatisfactory results.

Humeral Head Necrosis

The overall incidence of humeral head necrosis of 22% with six cases in 27 fractures has to be evaluated

with the consideration that cases with primary endoprosthetic replacement were excluded. Neer observed two necroses in 33 fractures; in 13 4-fragment fractures the humeral head was excised primarily 5 times. In six more cases maintenance of the humeral head lead to avascular collapse. Our material shows a somewhat more favorable distribution: one necrosis among 3-part fractures, five cases of necrosis in 19 4-part fractures and fracture dislocations. Boehler [2] and Graham [5] described this complication as a result of fractures running through the anatomical neck with accessory avulsion of both tuberosities. Knight and Mayne [6] have even observed avascular alterations of various degrees in all comminuted fractures. The primary type of fracture thus determines the outcome.

A purely radiological evaluation for progression of avascular necrosis is, however, inexact. It has to be



Fig. 4. a S.R., male, 1925: Four-part-fracture dislocation with humeral head impression, subacromial displacement of the greater tuberosity and interposition of the biceps tendon. b Plate fixation (18.6.1976). c After 50 weeks: Beginning necrosis with partial collapse and penetration of one screw in the joint. Clinically only moderate impairment of function. d After 210 weeks (4 years): Humeral head necrosis with pseudarthrosis of the greater tuberosity. Ankylosed shoulder joint with moderate pain

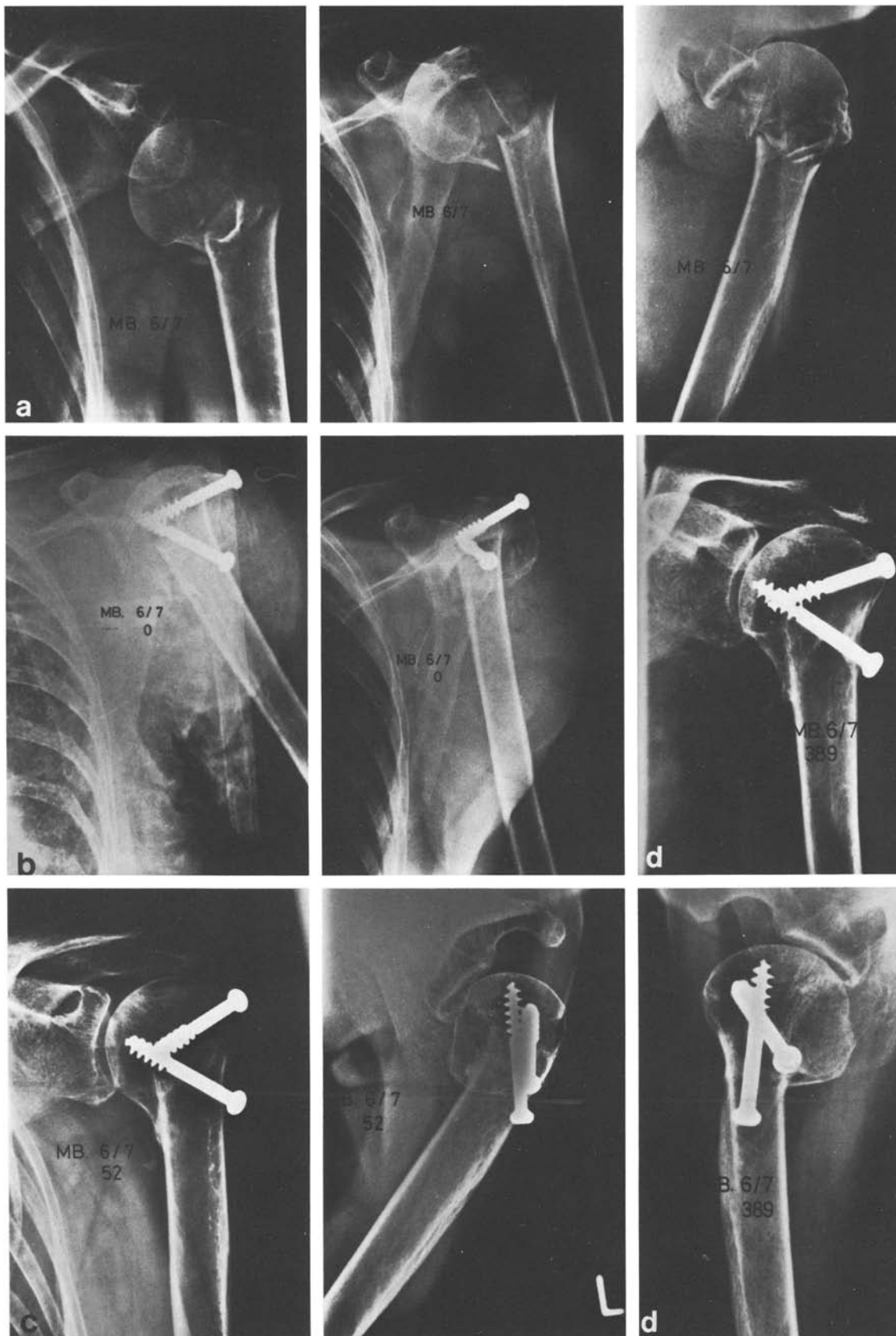
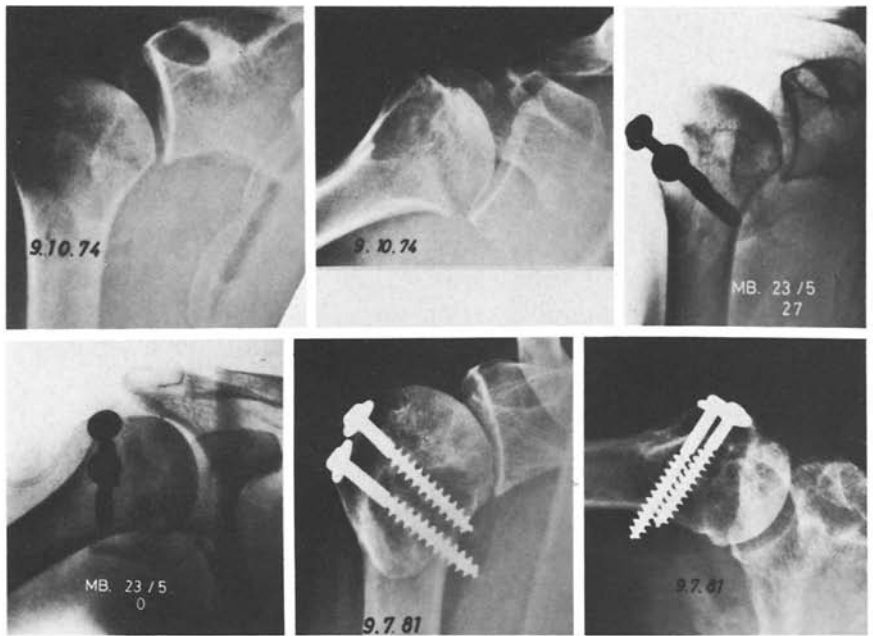


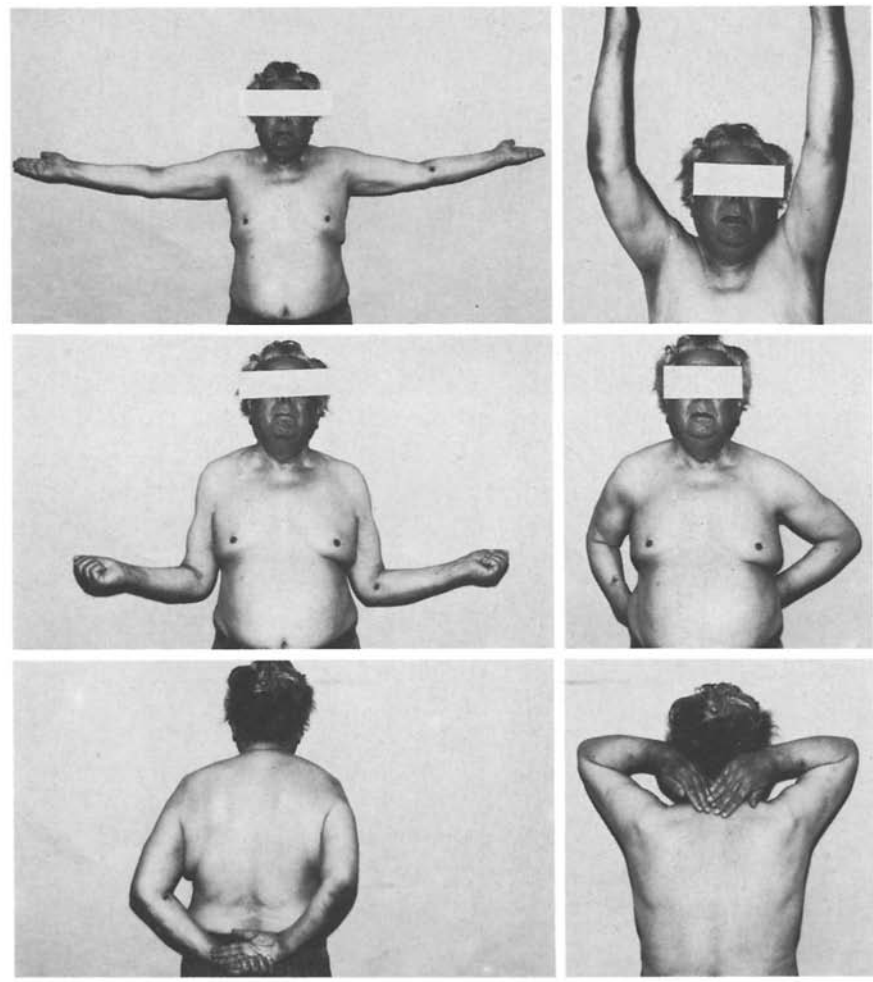
Fig. 5. a T. D., female, 1906: Four-part-fracture dislocation (group VI): Conservative trial of reduction with dislocation of the humeral head in a irreducible position. b Open reduction and internal fixation (20. 1. 1973). c After 52 weeks: Fracture consolidated with restored function. d After 389 weeks (7 years): Unchanged good result without osteoarthritis



a



b



c

Fig. 6. a J.J., male, 1920: Three-fragment-fracture with avulsion of the greater tuberosity, impaction between anatomical and surgical neck with marked valgus impaction. **b** Fixation of the greater tuberosity maintaining valgus impaction. Risk of avascular necrosis when trying to lift up the impacted head into a normal anatomical position filling the gap with cancellous bone. **c** Radiologically almost normal structure of the humeral head. Signs of osteoarthrosis minimal in spite of marked incongruency. Excellent functional result 7 years after the fracture



Fig. 7. a H.M., female, 1959: Four-part-fracture with open reduction and minimal internal fixation 14.9.1979. **b** After 8 weeks: Fracture healed, abduction limited

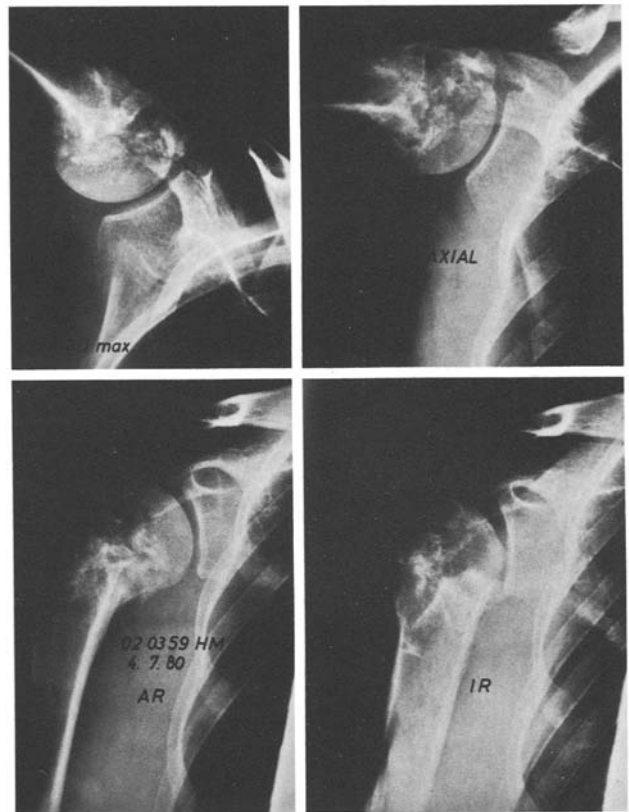
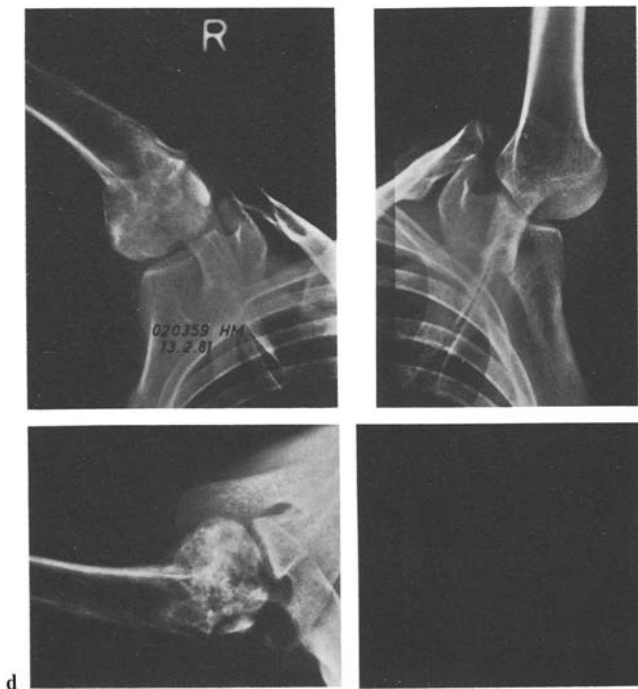


Fig. 7. c After 34 weeks: Consolidation, good mobility with painless motion

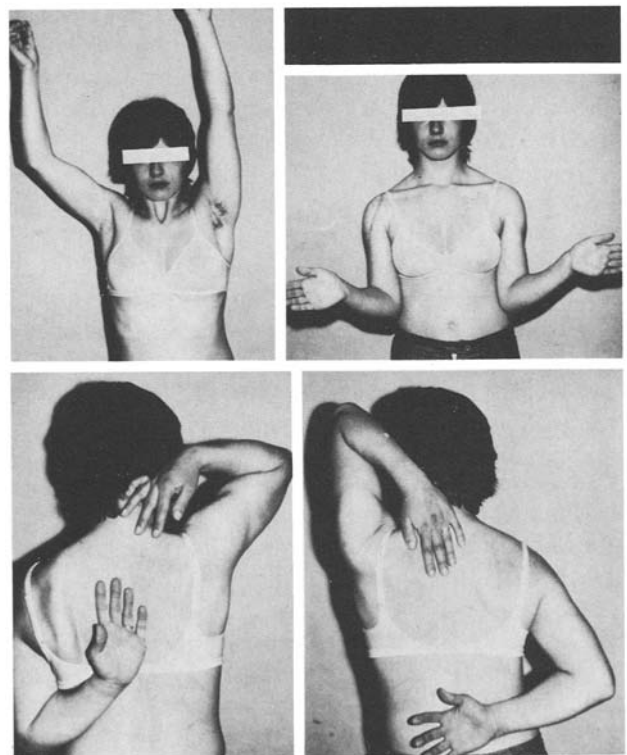


Fig. 7. d, e After 67 weeks: Partial humeral head necrosis with satisfactory function

considered that revascularization starting from the surviving areas of the head as well as from the healing fracture may precede the avascular collapse, so that a temporary avascularity may go unknown. Dead bone is reossified by apposition of new osteoid (Bobechko and Harris [1] which is detectable on the radiographs by spotty sclerotic areas. This can appear already after a few weeks adjacent to areas of osteoporosis.

In persisting ischemic collapse of the humeral head follows only late. Neer [12] noted it most frequently after 12 to 24 months postoperatively. In our own patient material it could be traced after 12 months in only two cases. Finally, the shoulder joint is less vulnerable to pressure loads than the hip joint thus the head is at less risk of collapse and the resulting limitation less profound [3, 4, 9]. Laine points out that in the younger patients still growing the tendency for reconstitution of necrotic areas seems to be more pronounced. An intracapsular fracture line was observed in all cases intraoperatively which later underwent avascular necrosis. It runs from the area of the fractured greater tuberosity. In one case the lesion of the axillary artery may have been the cause of the necrosis (Fig. 3). Here marked dystrophy was present already three months postoperatively. It is well known that the articular cartilage over the dead subchondral bone remains alive before the humeral head collapses, since it is nourished by the synovium [4]. Once the head has collapsed the mechanism is compromised and post-traumatic osteoarthritis develops. Our six cases with head destruction all lead to marked impairment of function, although pain was not the most prominent symptom. In this regard Boehler's statement could not be confirmed, namely, that in spite of a collapsed humeral head the possibility of good function remained [2]. To the contrary, we confirmed the opinions of Stewart and Hundley [14] as well as that of Knight and Mayne [6] who observed routinely a marked limitation of abduction and advocated the displaced greater tuberosity be correctly reduced in the presence of a desintegrated humeral head. The same deformity is responsible for limitation of motion after collapse of the humeral head, as there is entrapment of the greater tuberosity under the acromion.

Finally, once a collapse is established the material of osteosynthesis can penetrate the joint and damage the cartilage remaining resulting in further progression of osteoarthritis (Fig. 4). Although the incidence of avascular necrosis is greatly determined by the fracture form with a risk that cannot be avoided, our results indicate that the selection of mode of fixation can influence the radiological result with an incidence of humeral head necrosis and plate fixation of 30% versus 10% in minimal osteosynthesis. Despite the limited number of cases we believe that careful exposure and

minimal osteosynthesis have to be given preference. With a tension band wiring over the greater tuberosity or the single lag screws, threaded K-wires (2.5 mm) and transosseous sutures the unstable varus position is over-corrected into a more stable valgus, enabling an early protected functional after-treatment [10]. Further fragments can be fixed if necessary with additional lag screws without increasing the exposure. Through minimal use of implants it is possible to minimize the risk of further vascular damage even in cases of 4-part fractures (Figs. 5, 6). Besides the minimal exposure, this method offers advantage of technical simplicity in an area of already jeopardized vascular supply. The stability permits for an early motion of the shoulder joint with sufficient range after a short time (Fig. 7).

In all 27 cases periarticular calcification was minimal. Despite extensive internal fixation the calcification could be rarely traced on radiographs. Its pathogenesis did not seem to be influenced by intraoperative damage. In Neer's opinion it is promoted by massive displacement, repeated conservative trials of reduction and measures for stabilization performed after 7 days. Despite this fact, we demand careful surgical techniques since scarring of the surrounding soft tissues may promote later limitation of motion.

In summary, our results of minimal osteosynthesis neutralizing the main deforming forces are promising. This can be carried out closed by percutaneous pinning with threaded wires, or if unreducible by closed methods, by careful open exposure with minimal internal fixation considering the insecure prognosis in comminuted fractures of the proximal humerus and the risk of avascular necrosis. We, however, think that minimal osteosynthesis offers a true alternative to the unpredictable results of primary endoprosthetic replacement.

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