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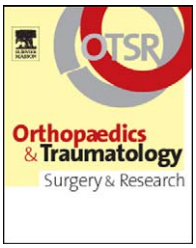

ORIGINAL ARTICLE

Complex proximal humeral fractures: A prospective study of 22 cases treated using the ''Bilboquet'' device

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KEYWORDS
Humerus fractures;
Internal fixation;
Three and four-part proximal humeral fractures;
Avascular necrosis

Summary
Introduction: Despite recent improvements in surgical devices, complex proximal humerus fractures internal fixation still encounters frequent mechanical failures.
Hypothesis: The aim of this study was to confirm that the Bilboquet device (a design mimicking the cup-and-ball game) helps solving mechanical difficulties associated with these fractures internal fixation and to present a simplified version of the original surgical procedure.
Patients and method: This non-randomised prospective study included 22 fractures in 22 patients, mean age: 70 years. According to the Neer classification there were three-part fractures in seven cases and four-part fractures in 15 cases. Fractures were all reduced and treated by internal fixation in a simplified surgical procedure using the Bilboquet device.
Results: Mean postoperative follow-up was 34 months. The mean Constant score was 66 and the weighted Constant score was 86. Mean active forward elevation was 108° and mean active external rotation was 28°. No per- or postoperative complications occurred. Initial reduction of the tuberosity was incomplete in four cases. Union was obtained in all fractures. There was no secondary tilting of the head, and no migration or pseudarthrosis of the tuberosities. Five patients developed postoperative avascular necrosis of the humeral head.
Discussion: The Bilboquet staple component provides a supporting platform for the entire humeral head area. This peripheral stabilization associated with tension band wiring explains the lack of secondary displacement in these cases. Although the Bilboquet device provides a solution to the mechanical problems of complex fractures of the proximal humerus, it does not solve the problem of secondary avascular necrosis of the humeral head, which occurred in 23% of the patients in this series and in 33% of patients in the four-part fractures subgroup.
Level of evidence: IV (non-randomised prospective study).

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Surgical treatment of complex fractures of the proximal humerus (CFPH), which are mainly Neer classification three- and four-part fractures on osteoporotic bone [1], is controversial [2—4]. When the therapeutic option is internal fixation, the surgeon is confronted with the difficulties of reduction and stabilization related to the small size of the fragments, osteoporosis and metaphyseal comminution. Despite recent innovations in internal fixation devices, the percentage of complications, which are usually mechanical, is still high ranging from 11—34% [5,6]. The aim of our study was to confirm the role of the Bilboquet device [7—9] in solving the mechanical difficulties of internal fixation for these fractures and to present a modification of the original surgical technique.

Patients and methods

Patients

Between April 2004 and June 2006, 99 patients underwent surgery in our institution for a proximal humeral fracture. Eighteen were treated by shoulder replacement surgery and 81 by reduction and internal fixation. Twenty-five of the latter patients received a Bilboquet device (Stryker France). Two patients with dementia and lost to follow-up and one patient with a fracture dislocation were excluded from the study. This non-randomised prospective study included 22 fractures in 22 patients.

There were 18 women and four men included in the study, mean age: 70 (45—84). Sixteen patients or 80% were retired when the trauma occurred. In 80% of the cases the trauma occurred on the dominant side.

In seven cases there were three-part fractures according to the Neer classification and in 15 cases there were four-part fractures. In 12 cases there was a medial metaphyseal head extension of 8 mm or more.

Surgical procedure

Patients were in the beach-chair position with a fluroscope in place. A lateral deltoid split approach was used. After debriding the hematoma, the cancellous bone of the humeral head was exposed, usually by raising the latter.

The Bilboquet (Fig. 1) includes two titanium components, one male and one female. The so-called head-staple component is cylindrical shaped with five peripheral spikes and a hollow female center that the Morse taper part of the male component, or humeral stem can be inserted into. The Morse taper of the humeral stem can if necessary accommodate a prosthetic humeral head replacement.

The cylindrical head-staple was positioned by fluroscopic control, then impacted into the cancellous bone of the humeral head (Fig. 2a). Two openings were drilled approximately 1 cm below the metaphyseal fracture line into the diaphysis for tension band sutures (Ethibond 5, Ethicon) (Fig. 2b). Then a small humeral stem was slipped into the diaphysis and its Morse taper was inserted into the staple cup (Fig. 2c). At this point the stem was more or less floating in the diaphysis and the surgeon could reduce the fracture. Using a grasping forceps on the wing of the stem, he pushed up on the stem to obtain height reduction while rotating the arm to obtain rotational reduction (Fig. 2d). Fluoroscopic control helped determine the best position for fracture reduction. When this position was determined, cement was inserted into the metaphyseal openings between the stem and the bone to block the stem in the optimal position (Fig. 2e). After the cement had hardened, the tuberosities were sutured in an anatomical position using two tension band wires passing through the diaphysis (Fig. 2f).

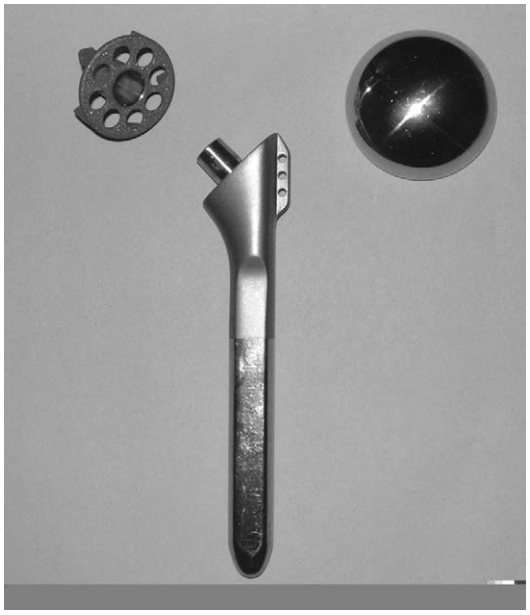

Figure 1 Bilboquet device. The stem's morse taper cone fits into the staple for internal fixation or into a humeral head prosthesis in case of hemiarthroplasty.

Mean duration of the procedure was 70 minutes (50—100). The mean hospital stay was 5 days (4—7).

Passive rehabilitation was begun on D4. Active rehabilitation was allowed 4 weeks after surgery and continued for at least 6 months. Only six patients went to a rehab center, the 16 others received outpatient rehabilitation.

All patients underwent regular clinical and radiological follow-up. Clinical parameters evaluated at the final follow-up included active and passive range of motion and Constant scores (absolute and sex and age-weighted) [10].

Radiological assessment was based on AP and profile X-rays and lesions were classified according to Neer [1]. The presence and size of medial metaphyseal head extensions were noted [11]. Aseptic necrosis of the humeral head was evaluated according to the Cruess classification [12].

Results

Overall results

The mean follow-up was 34 months (range 24—52). The mean Constant score was 66 and the weighted Constant score was 86. Mean active forward elevation was 108° (40—160), mean abduction was 85° (30—130) and mean active external rotation was approximately 28° (10—60) (Table 1).

No immediate per- or postoperative complications occurred. In four cases incomplete reduction of the tuberos-

Table 1 Individual characteristics and results in the series.

Patients	Sex	Age	Side	Type of fracture according to Neer	Cervical spine bone spur ≥ 8 mm	Follow-up (month)	Constant		Range of motion				Necrosis[a]
							Weighted	Absolute	AAE	Abd	Ext. rot	Int. rot	
1	F	70	R	4	Yes	38	74	52	40	40	20	Trochanter	4
2	M	56	R	4	Yes	27	90	66	130	90	30	L5	0
3	F	82	R	3	No	30	100	69	100	60	20	L2	0
4	F	82	R	4	No	24	48	35	40	30	10	Trochanter	5
5	F	72	R	4	No	38	100	80	100	90	30	L1	0
6	F	60	R	4	No	34	80	59	110	95	30	L2	0
7	M	71	L	3	Yes	40	91	69	140	120	30	L2	0
8	F	70	L	4	No	40	70	52	40	30	15	L5	4
9	F	75	L	3	No	34	100	72	130	90	40	T12	0
10	M	56	R	4	Yes	43	100	93	150	130	60	T12	0
11	F	72	L	4	Yes	25	100	69	110	95	40	L2	0
12	F	64	L	4	Yes	25	100	87	160	130	45	L2	0
13	F	75	L	4	Yes	24	94	71	120	100	30	L2	0
14	F	72	R	4	No	27	100	75	130	110	30	L3	0
15	F	50	R	3	Yes	36	80	66	120	90	20	Sacrum	0
16	F	78	R	4	Yes	34	84	63	90	60	15	L5	0
17	F	81	R	3	No	28	100	81	125	100	30	L3	0
18	F	84	R	4	Yes	52	100	71	140	120	20	L3	0
19	M	45	R	3	No	32	62	70	120	100	30	L3	0
20	F	68	R	4	Yes	44	75	62	90	60	20	L5	4
21	F	84	R	3	Yes	42	76	49	90	80	20	L3	0
22	F	72	L	4	No	31	66	44	90	40	20	Trochanter	4
Average		70				34	86	66	108	85	28		
Minimum		45				24	48	35	40	30	10		
Maximum		84				52	100	93	160	130	60		

AAE: active anterior elevation.

[a] Avascular necrosis according to Cruess.

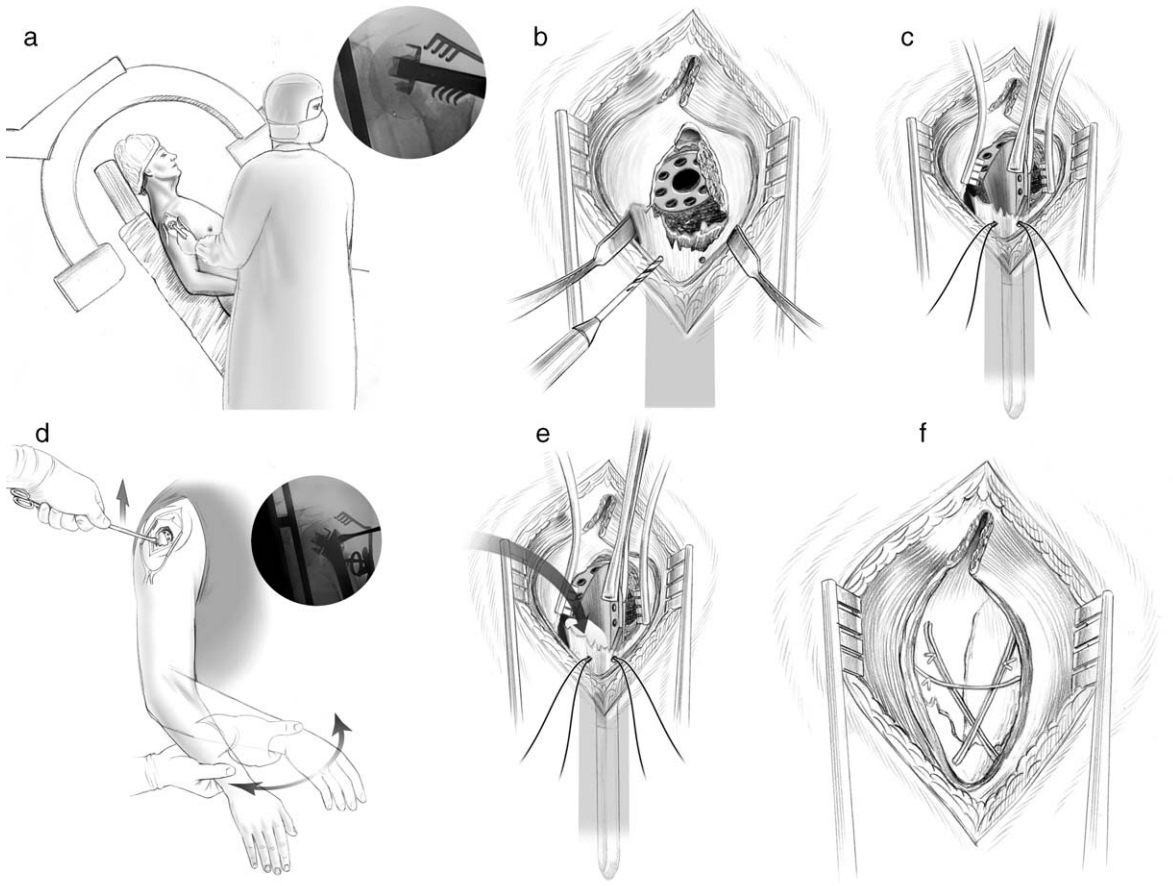

Figure 2 a: placement of the cephalic staple under fluoroscopic control; b: staple in place, holes drilled to pass tension band wire; c: insertion of a small stem into the diaphysis and of the Morse taper into the staple; d: reduction manoeuvres; height is restored by pushing the stem up; rotation is restored by rotating the arm; e: cement inserted from above to block the stem in the correction reduction; f: the greater tuberosity is reduced and stabilized by tension band wiring through the cuff.

ity resulted in malunion: once in the lesser tuberosity and three times in the greater tuberosity. Union was obtained in all fractures after 3 months except in one case where union was obtained after 6 months. No secondary tilting of the head occurred, and there was no migration or pseudarthrosis of the tuberosities (Fig. 3). The postoperative course included avascular necrosis of the humeral head in five patients.

Results in seven three-part fractures

The mean Constant score was 68 and the weighted Constant score was 87. Pain was evaluated as 13 out of 15 (Constant score). Mean active forward elevation was 118° (90—140) and active external rotation was 27° (20—40). In one case there was malunion of the greater tuberosity above the humeral head. There were no cases of avascular necrosis at the final follow-up.

Results in the 15 four-part fractures

The mean Constant score was 65 and the weighted Constant score was 85. Pain was evaluated as 11 out of 15 (Constant score). Mean active forward elevation was 103° (40—160) and active external rotation was 28° (10—60). In one case there was medial malunion in the lesser tuberosity and in two cases there was malunion in the greater tuberosity, upper in one case and lower in the other. Five cases of avascular necrosis (or 33%) were observed at the final follow-up, in female patients, mean age 72. There were four cases of Cruess stage IV avascular necrosis (Fig. 4) and one stage V.

The mean Constant score in these cases of necrosis was 49 (weighted Constant score 67). Avascular necrosis was associated with reduced active range of motion (mean forward elevation: 60° and external rotation: 17°). Pain on the Constant score was approximately 9 out of 15. Pain recurred in all cases after the sixth month and radiological anomalies were visible 1 year after surgery. In two of these five cases of necrosis, there was a medial metaphyseal head extension of at least 8 mm. In the 10 cases without necrosis, there were seven cases of medial metaphyseal head extension of at least 8 mm.

Patients presenting with necrosis were informed that the device could be converted into a humeral hemiarthroplasty, but to date none have agreed to revision surgery.

Discussion

There is no consensus about the best treatment for complex fractures of the proximal humerus [2—4]; both of the two

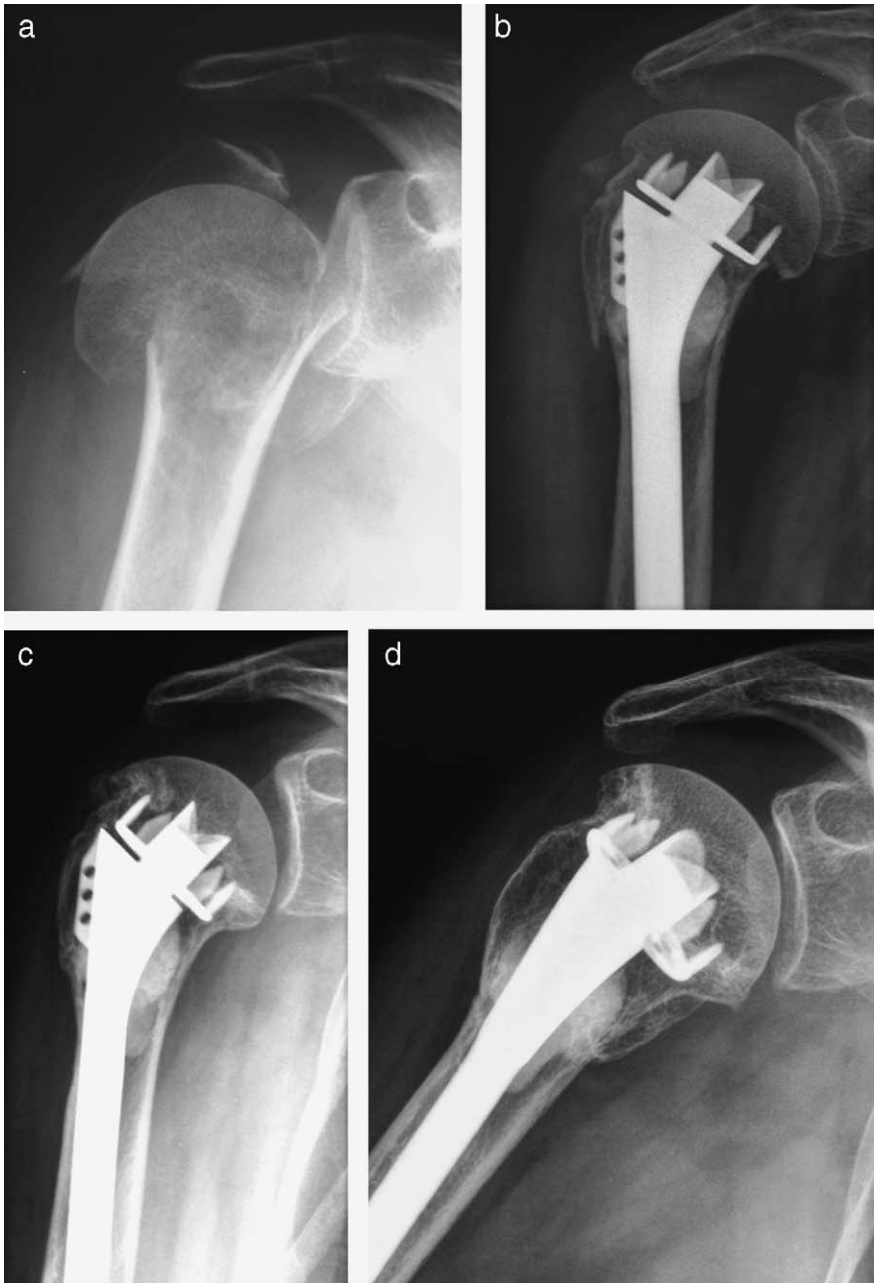

Figure 3 a: four-part fracture; case No. 6 in Table 1; b: postoperative results at 3 months; the absence of a medial metaphyseal head extension is observed and cement in the metaphysis to block the stem; c and d: radiographic results at 34 months on AP view with internal rotation.

main types of surgical treatment, internal fixation and shoulder replacement, have received support in different studies and the meta-analysis in 2008 by Lanting et al. [2] comparing these two surgical procedures was not conclusive.

Despite the substantial progress that has been made in shoulder replacements, and the particular attention paid to repairing the tuberosities, the results of hemiarthroplasties for traumatic injuries have not been shown to be better than internal fixation [2—4]. The use of specific prostheses for traumatic injuries does not seem to significantly improve these results [13].

Misalignment or secondary displacement of the tuberosities is the main complication of traumatic hemiarthroplasties [14—17]. Plausinis et al. [18] have reported that complications during surgery are the main factor affecting clinical results. Thus component misalignment can reach 40%, detachment or misalignment of the tuberosities 23 and 27% while tuberosity resorption varies between 0 and 7%. Several studies have confirmed that functional results are better when union of the tuberosities is obtained than in cases of pseudarthrosis or displacement of the tuberosities greater than 5 mm [19—21]. Because of the difficulty of obtaining tuberosity union in hemiarthroplasties, the use of a reverse shoulder prosthesis has been proposed for the treatment of complex proximal humeral fractures [22—24]. An indication for a reverse prosthesis in these

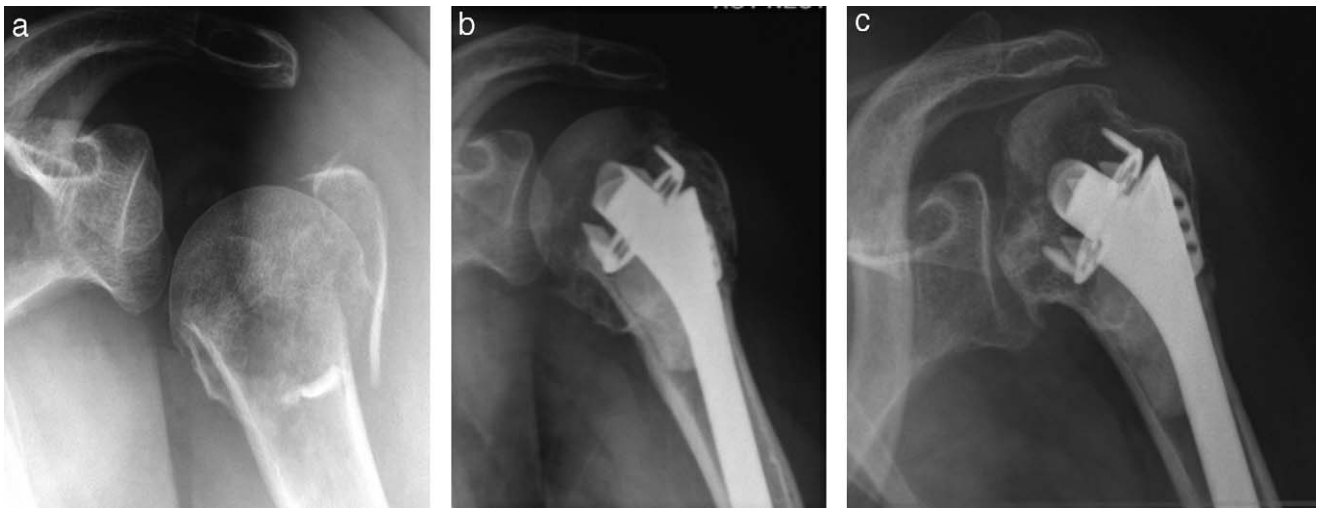

Figure 4 a: four-part fractures; case No. 8 in Table 1; b: radiographic results at 10 months of follow-up; c: radiographic results at 36 months of follow-up; Cruess stage 4 avascular necrosis.

cases would significantly increase the invasiveness of treatment.

For all these reasons, or because the goal is to keep surgery as conservative as possible, numerous surgeons continue to use internal fixation. The many existing methods that use nailing or plates to stabilize fractures such as those reported in the paper by Razemont and Baux [25] do not resolve the need to control varus, which can cause tilting of the humeral head. In elderly patients, the stability of fractures can often only be obtained if the humeral head is impacted on the diaphysis as described in the article by Zyto et al. [26] with minimal internal fixation or as recommended by Lee and Shin [27].

Despite the high rate of complications, the recent improvement in nail and plate systems has renewed interest in internal fixation techniques [2,4—6].

The use of proximal nailing with locking screws is now quite frequent but published results are contradictory. After a mean follow-up of 11 months with the Telegraph® nail, Cuny et al. [28] obtained a mean Constant score of 63% and a weighted Constant score of 88%. Kazakos et al. [29] obtained similar results with the Polarus® nail in patients with two- or three-part fractures (there was no significant difference between the two groups) after a mean follow-up of 20 months. Mittelmeier et al. [30] reported a complication rate of 51% with the Targon® nail, 22.6% of which were screw migrations. Cuny et al. [31] reported 10 cases of revision surgery (15%) in a series of 67 patients for mechanical problems with the Telegraph® system as well as six cases of secondary tuberosity displacement.

The development of locking plate systems has also increased the use of screws and plates. Kettler et al. [32] reported results in 176 patients treated with the Philos® locking plate system. Complications included 11% intra-articular screws, 8% cases of secondary tilting of the humeral head and 4.5% material fractures. However the mean age in this study was 66, and 35% of the cases were two-part fractures with only 9 months of postoperative follow-up. After 1 year of follow-up in 187 patients who underwent LPHP internal fixation, Südkamp et al. [5] reported an absolute Constant score of 71 and a relative score of 85. The mean overall active forward elevation of 132% was higher than in our series, although the average age of their patients was only 63, the follow-up 12 months and especially most fractures were Muller-AO type A or B1 (that is, two- or three-part fragments on the Neer classification). Nevertheless the reported rate of complications was 34% and of surgical revisions was 19%. In a meta-analysis of 12 publications on locking plate systems, Thanasas et al. [6] reported a mean Constant score of 74 in a population with a mean age of 63. The rate of secondary displacements was 11.6% although 27.8% of these were two-part fractures. All the publications on locking plate systems emphasize the difficulty of obtaining stable internal fixation in cases of osteoporosis. A biomechanical study by Tingart et al. [33] showed that there were significant differences in the cancellous bone in the humeral heads of patients with osteoporosis resulting in stabilization failures. Several authors have mentioned the importance of adding medial head support to internal fixation either with screws or internal plate fixation, cement or bone graft to prevent loss of fixation [27,34—38].

The Bilboquet device was developed to solve the mechanical problems of internal fixation in complex proximal humeral head fractures, in particular in elderly patients [7,8]. In our experience the use of screws that lock into a nail or a plate is not enough to obtain stability in osteoporotic bones in three- or four-part fractures, except for certain cases such as a Jakob fracture [39], which is relatively stable after reduction. In most cases metaphyseal comminution does not result in meshing of the fragments after anatomical reduction and to obtain stability with screws the bone deficit must be compensated with some sort of structural support. The Bilboquet cylindrical staple provides a platform of support for the humeral head so that the diaphyseal stem can provide ascending force for reduction with little risk of going through the head or of creating varus tilt in the head, as long as it is associated with an external tension band wire. No displacement of the initial Bilboquet device was found in our series even if the fractures were reduced by distraction. In 33 cases of internal fixation with the Bilbo-

quet device, Le Dû and Favard [40] report only one case of mechanical failure because of staple malposition. Doursounian et al. [9] reported three cases of varus tilt of the head (5%) in a series of 61 cases of internal fixation. Anatomical reduction of the humeral head on the diaphysis facilitates anatomical reduction of the tuberosities, which naturally fall into place during tension band wiring. Because of the natural environment of the bone, union is obtained in the tuberosities nearly systematically. This systematic union of the tuberosities is one of the advantages of internal fixation with the Bilboquet system. In a series of 26 cases using internal fixation, Doursounian et al. [8] only reported one case of pseudarthrosis of the tuberosity. In their series of 61 cases using internal fixation [9], they reported two cases of pseudarthrosis of the tuberosity. Le Dû and Favard [40] only reported one case of pseudarthrosis of the tuberosity out of 26 cases of internal fixation confirming the excellent results for union of the tuberosities with the Bilboquet system. It is difficult to find studies to compare functional results with this system compared to other types of internal fixation, because most studies include all types of fractures and the mean age of patients is younger than in our study. The results of the series by Solberg et al. [4] with 38 cases of internal fixation with screw-plate systems for three- and four-part fractures of 66.5 mean age with a mean follow-up of 36 months were similar to ours. The global Constant score of 68 (72 for three-part fractures and 65 for four-part) is similar to the global Constant score in our study of 66 (68 for three-part fractures, 65 for four-part fractures). Six patients in the Solberg et al. [4] series underwent revision surgery for incorrect positioning of screws (16%). Four patients (11%) presented with loosening of the internal fixation, while there were no mechanical incidents in this series of fixation with the Bilboquet system.

However, although the Bilboquet system provides a solution to the mechanical problems of complex proximal humeral fractures, it does not solve the biological problem of avascular necrosis of the humeral head. In this series there were five cases of necrosis which all occurred in four-part fractures. The lack of necrosis in three-part fractures may be because follow-up was insufficiently long; although in our fairly extensive experience with the Bilboquet, all cases of necrosis developed within 18 months and we have not yet encountered any cases of late necrosis. Our rate of necrosis was 23% for the entire series and 33% for four-part fractures. In the series by Le Dû and Favard [40], the overall rate was 22%. In the series of 61 patients by Doursounian et al. [9], the rate was 15% in three-part fractures and 37% for four-part fractures. This percentage remains within the range reported in other studies: 35% for Gerber et al. [36] and 37% in the meta-analysis by Lanting et al. [2].

Although these cases of necrosis are revealed by functional deterioration, they are well tolerated, probably because of the anatomical union of the tuberosities. In any case, this tolerance of post-traumatic avascular necrosis has been observed by many authors [41—43]. In the series of 61 cases of internal fixation by Bilboquet [9] with 13 cases of avascular necrosis, three were converted to hemiarthroplaty and in the study dated 2000 of 26 cases, two were converted to hemiarthroplasty This was also the number of conversions to hemiarthroplasty performed in the series of 33 patients by Le Dû and Favard [40]. Therefore the conversion of internal fixation with the Bilboquet system into hemiarthroplasty is not frequent, as feared when the implant was developed.

The size of our population makes it impossible to draw firm conclusions about the role of medial metaphyseal head extension for the prediction of avascular necrosis, according to criteria by Hertel et al. [11] but confirms the impression that the prognosis is better in the presence of a medial metaphyseal head extension. In the five cases of avascular necrosis there were only two cases of medial metaphyseal head extension of at least 8 mm and in the 10 cases that did not progress to necrosis a medial metaphyseal head extension of at least 8 mm was present in seven cases.

Despite the good results, the Bilboquet device is not frequently used for internal fixation. The only published series which supports the developer's results is the study by Le Dû and Favard [40]. The fact that the implant is permanent should not limit its use since hemiarthroplasty is also permanent. The reason which is most frequently mentioned for surgeons not to use this type of internal fixation is difficulty adjusting stem height. Indeed anatomical reduction of the fracture depends on adjusting stem retroversion and especially height. If it is too low, the component is unstable because the maximum length of the vertical muscles will not be restored and the tuberosities will not be in an anatomical position, which will also result in a functional deficit in the horizontal muscles. On the other hand, if the stem is too high, it is impossible to introduce the Morse taper into the staple. Trial stems help solve this problem in part but always require several tries in the fracture site (insertion and removal of the trial stem, with a risk of extracting the staple) and since fixation of the final stem is with acrylic cement, it is not easy to revise any malposition. To avoid these problems we developed a simplified version of the original procedure, which does not use trial stems, but which directly uses a small definitive stem. This stem slips easily into the diaphysis and its Morse taper fits into the staple. The position is adjusted under direct fluoroscopic control. When the shoulder girdle is restored and retroversion has been controlled, the device is stabilized by inserting cement around the stem through the opening in the metaphysis. Thus there is less risk of cementing the stem in an incorrect position. Although this method of cementing is not conventional, it solidly blocks the stem. In this series no stem migration occurred. These stems obviously undergo very little stress since bony union is obtained within a few weeks. Nevertheless, because this system may need to be converted into a hemiarthroplasty, fixation of the stem might need to be improved.

In conclusion, this study of 22 cases shows that the Bilboquet device, with a simple surgical procedure, effectively solves the mechanical difficulties of complex proximal humeral fractures by providing stable fixation and reliable union of tuberosities. However, the risk of avascular necrosis of the humeral head which complicates all types of internal fixation is not improved.

Conflict of interest statement

None.

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