A new internal fixation technique for fractures of the proximal humerus—the Bilboquet device: A report on 26 cases

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We describe a novel internal fixation device and report on 26 patients (mean age, 70 years) whose proximal humeral fractures were managed with this technique. The 2-part titanium implant consists of a circular staple impacted into the humeral head cancellous bone and a spigoted diaphyseal stem that inserts into the staple "cup." Of the 26 cases reviewed, 16 had 3-part fractures and 10 had 4-part fractures. Mean follow-up was 25.9 months. In the 16 3-part fractures, the mean active forward elevation was 114° and the results were as follows: excellent, 7; good, 5; fair, 3; poor, 1. In the 10 4-part fracture patients, the mean active forward elevation was 101° and the results were as follows: excellent, 2; good, 4; fair, 3; poor, 1. There were 5 cases of avascular necrosis and 1 case of tuberosity nonunion. Only 2 cases needed conversion to hemiarthroplasty. The new technique should simplify the surgery of these fractures and reduce the need for arthroplasty.
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Complex fractures of the proximal humerus are seen mainly in elderly subjects and are notoriously difficult to manage. Many treatment modalities have been proposed, none of which has met with universal approval.*

Internal fixation is difficult because of the small size of the bone fragments and the poor quality of the osteoporotic bone stock. These mechanical problems are compounded by the risk of avascular necrosis (AVN) of the humeral head.[6,29,31,34,52] This is why some surgeons[8,14,22,39,42] prefer hemiarthroplasty. However, other authors† have found the functional outcome after humeral head replacement disappointing, and the present trend is toward minimal internal fixation.[12,13,24,28,29,32,47] The argument about the best management of such cases is complicated by the fact that there is no method that allows both anatomic reduction of these complex fractures in the elderly and sufficiently stable fixation to permit early exercise physiotherapy.

In an attempt to overcome these problems, we have devised a means of internal fixation to (1) provide stable fixation, (2) allow anatomic reduction and early exercise therapy, (3) preserve the bone stock, and (4) restore the length of the humerus. We report the results, at a mean follow-up of 25.9 months, of 26 displaced 3-part and 4-part fractures of the proximal humerus managed with the new device.

MATERIAL AND METHODS

Between 1989 and 1996, 41 patients were operated on through use of the new technique. Fractures were graded according to the Neer classification.[41] Eight 2-part fractures and 4 fracture dislocations were excluded. Of the remaining 29 patients, each with a displaced 3-part or 4-part fracture, 3 were lost to follow-up. In all, 26 patients were followed for a mean of 25.9 months (range, 16-46 months). There were 23 women and 3 men. The mean age at the time of injury was 70.4 years (range, 27-93 years). There were matching numbers of right and left shoulders involved.

The patients were divided into 2 groups. Group I consisted of 16 displaced 3-part fractures; the mean patient age in this group was 69.3 years (range, 47-93 years). Group II consisted of 10 displaced 4-part fractures; the mean patient age in this group was 72.2 years (range, 27-86 years).

The internal fixation device used is known as the Bilboquet (Stryker Implants, Cestas, France). It takes its name from a popular toy, the cup-and-ball game. The device consists of 2 parts made of titanium (Figure 1). The female part is of a novel design. A cylindric staple with a flange, it has 8 holes and 5 spikes; the center is shaped as a tapering cup that receives the spigot of the diaphyseal component. The male part inserts into the shaft of the humerus with a long vertical distal portion; proximally, it has a short spigot that forms a 135° angle with the stem and has a Morse

*References 3, 7, 8, 16, 25, 26, 28, 29, 32, 34, 39, 41, 44, 46, 49, 51, 57, 58.

†References 26, 27, 30, 33, 37, 45, 54, 59.

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Figure 1 Bilboquet device.

taper. The two parts are united by placing the spigot into the cup of the staple; in this way, the head fragment and the humeral shaft are fixed. The tuberosities are then reattached to complete the construct (Figure 2).

To allow for the possibility that the lesions may be found to be more severe than was suggested by the preoperative radiographs, humeral heads have been designed that will fit onto the shaft spigot. In this way, the device can be transformed into a humeral endoprosthesis at surgery.

The hardware was modified during the course of the study. The stem was made to more closely fit the conventional pattern of an endoprosthesis. In particular, the metaphyseal portion was thickened (the earlier pattern is shown in Figure 3 and the new pattern in Figures 4 and 5). The head staple, which was initially available in 2 diameters only, is now supplied in 3 diameters. The modified pattern was used in the last 12 patients in the series (6 3-part and 6 4-part fractures).

Surgical technique. In 22 cases, the incision was through the deltopectoral groove, without proximal detachment of the deltoid (Figure 2, *A*). In 4 cases, a deltoid-splitting approach was used. The first step involves exposure of the humeral shaft, care being taken to avoid any further damage to the humeral head blood supply. If the humeral head overlies the shaft, it must be gently lifted with a dissector and placed against the glenoid, with no excessive traction on the vessels supplying the humeral head. The shaft is freed sufficiently to allow the insertion of the diaphyseal component of the device, care being taken to protect the humeral head and its attachments by mobilizing only the shaft. Next, the canal is prepared to receive the cemented stem, and the holes for the sutures to reattach the tuberosities are made. The second step involves the search for and reduction of the tuberosities. In the third step, the cancellous bone of the head is exposed and the staple is inserted (Figure 2, *B* and *C*). The staple is placed over the cancellous bone in such a way as to obtain optimum coverage, the largest size that can be accommodated being used. The central Morse taper cup is designed to penetrate into the center of the head, and the peripheral spikes are impacted into the rim of the cancellous bed. The fourth step involves fixation of the stem in 20° to 30° retroversion through use of cement (Palacos Gentamicin, Kulzer & Co GmbH, Homburg, Germany; Figure 2, *D*). The most difficult aspect is control of the level of the implant to restore the length of the humerus—if the stem is inserted too high, reduction will be impossible; if it is inserted too low, the construct will be unstable. The level is assessed with reference to the position of the reduced tuberosities—chiefly by the medial border of the humeral shaft, which provides a useful landmark. A line drawn through the base of the implant neck should form a tangent to the medial cortex of the humeral shaft. In the fifth and final step, the two fixation components and the detached tuberosities are brought together. First, the two hardware components are coupled to fix the shaft to the head. Next, the tuberosities are attached (Figure 2, *E*).

Table I Ratings categories used in patient assessment

Pain	AFE	Rating
None or slight	≥120°	Excellent
Slight or moderate, not interfering with function	90° to 120°	Good
Moderate, interfering with function	60° to 90°	Fair
Disabling	<60°	Poor

AFE, Active forward elevation.

Postoperatively, the shoulder is immobilized with a Mayo Clinic bandage; an abduction cushion is used if required. Rehabilitation, as recommended by Neer,[42] is started between day 3 and day 8, depending on the patient's condition and postoperative pain.

The mean follow-up at the latest visit was 25.9 months (range, 16-46 months). The following clinical parameters were assessed:

1. Pain. This was graded none, slight, moderate, or severe.

2. Active range of motion (ROM). Overall active forward elevation and active external rotation were measured with a goniometer; active internal rotation was measured in terms of the highest segment that could be reached with the hand.

3. Muscle strength. This was graded 1 to 5.

The 4 rating categories adopted are shown in Table I.

In all patients, anteroposterior and scapulolateral radiographs were taken. In some patients, axillary lateral views were obtained. The radiographs were screened for changes in the position of the humeral head, signs of failure to heal, changes in the hardware and in its position with regard to the bony elements, and evidence of AVN of the humeral head.

RESULTS

The detailed results are presented in Table II.

In group I (3-part fractures), the results were as follows: excellent, 7; good, 5; fair, 3; poor, 1. Mean ROM values were 114.4° for forward elevation (range, 60°

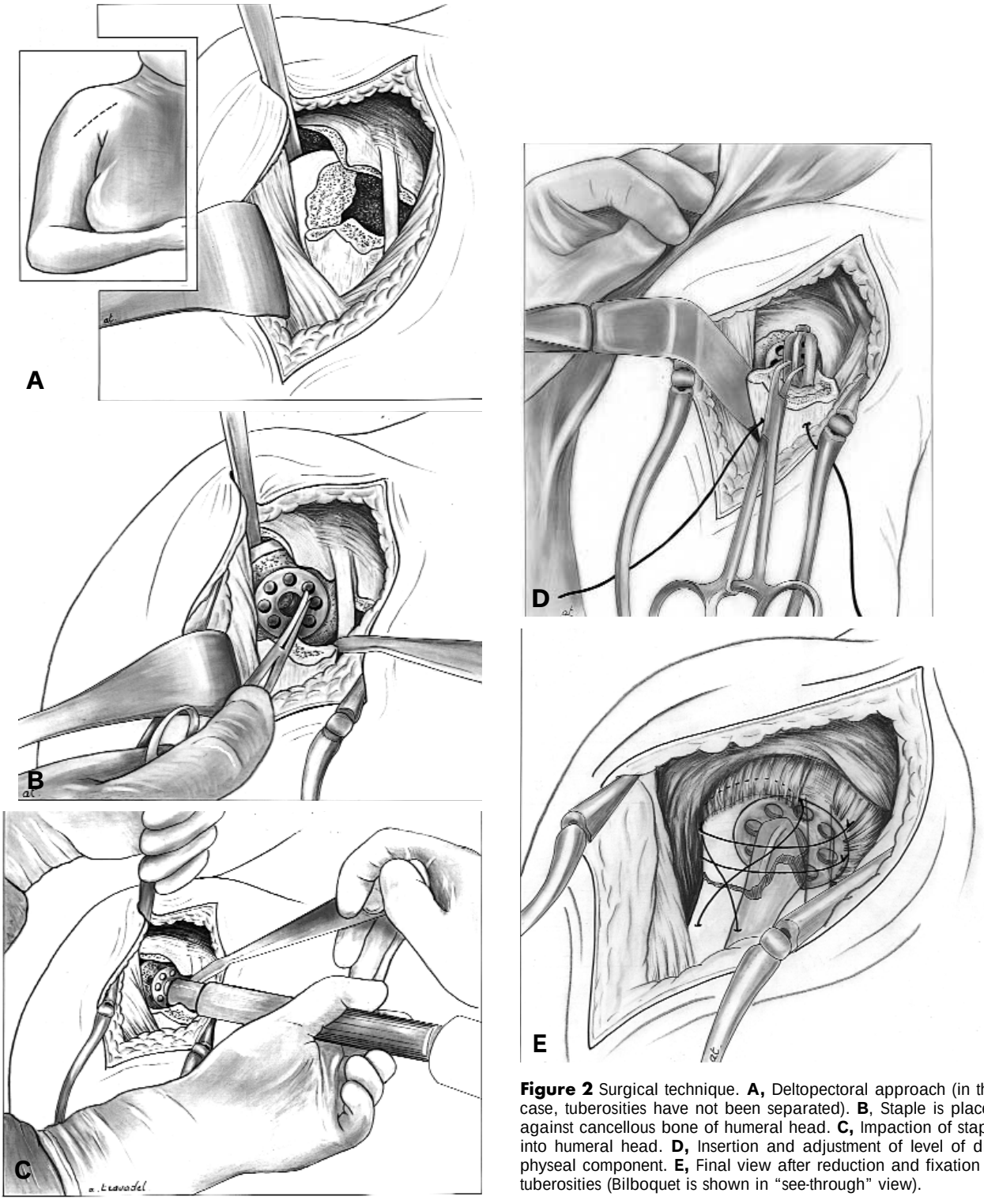

Figure 2 Surgical technique. **A,** Deltopectoral approach (in this case, tuberosities have not been separated). **B**, Staple is placed against cancellous bone of humeral head. **C,** Impaction of staple into humeral head. **D,** Insertion and adjustment of level of diaphyseal component. **E,** Final view after reduction and fixation of tuberosities (Bilboquet is shown in "see-through" view).

to 160°) and 31.6° for external rotation (range, 10° to 60°); internal rotation was to L1 (range, T8 to L5). The mean muscle strength rating was 4.4 (range, 3-5).

In group II (4-part fractures), the results were as follows: excellent, 2; good, 4; fair, 3; poor, 1. Mean ROM values were 101° for forward elevation (range, 70° to 150°) and 21.5° for external rotation (range, –30° to 30°); internal rotation was to L2 (range, trochanter

Table II Patient details and results

Case no.	Age (y)	Sex	Fracture type	FU (mo)	Pain	AFE (degrees)
Group I						
1	59	M	3-part	36	None	100
2	47	M	3-part	36	Slight	160
3	71	F	3-part	32	Slight	120
4	62	F	3-part	24	Severe	110
5	77	F	3-part	24	Slight	95
6	93	F	3-part	45	Slight	60
7	79	F	3-part	24	None	100
8	63	F	3-part	24	None	150
9	64	F	3-part	24	None	110
10	73	F	3-part	28	None	160
11	75	F	3-part	28	Moderate	100
12	73	F	3-part	24	None	130
13	68	F	3-part	18	None	150
14	69	F	3-part	26	Moderate	80
15	54	F	3-part	18	None	120
16	82	F	3-part	18	Moderate	85
Group II						
1	82	F	4-part	25	Moderate	90
2	63	M	4-part	46	Slight	110
3	27	F	4-part	24	None	150
4	82	F	4-part	28	Slight	80
5	75	F	4-part	28	None	130
6	73	F	4-part	16	None	100
7	73	F	4-part	18	Severe	80
8	83	F	4-part	18	Moderate	70
9	78	F	4-part	24	None	100
10	86	F	4-part	18	Slight	100

FU, Follow-up; *AFE,* active forward elevation; *AER,* active external rotation; *AIR,* active internal rotation; *M,* male; *F,* female; *T,* thoracic vertebra; *L,* lumbar vertebra; *AVN3,* stage 3 avascular necrosis; stage 4 avascular necrosis.

to T10). The mean muscle strength rating was 4.4 (range, 3-5).

With the exception of 1 nonunion of the tuberosities (case 6 in the 4-part fracture group), all of the fractures healed. There were no cases of infection.

Complications. In 3 cases, partial protrusion of the staple was observed. In 1 case, there was axial impaction of the humeral with distal protrusion of one of the head-staple spikes; the patient remained asymptomatic. In 2 cases, there was secondary displacement of the construct into varus, with proximal protrusion of one of the head-staple spikes.

Only 1 patient (case 4 in the 3-part fracture group) had severe pain. The pain was inflammatory in character, and reoperation was required. At surgery, an ulceration was found on the underside of the rotator cuff, over one of the head-staple spikes. The situation was managed with removal of the humeral head (including the staple) and replacement with a prosthetic head that was fitted onto the Morse taper spigot of the diaphyseal component. The final outcome was good; however, the case was rated poor with respect to technique, inasmuch as reoperation was required to deal with the complication.

Humeral head AVN occurred in 5 cases. In terms of the classification of Arlet and Ficat[1] as modified by Cruess,[11] there were 1 stage 3 case and 1 stage 4 case of AVN in the 3-part fracture group and 1 stage 3 case and 2 stage 4 cases of AVN in the 4-part fracture group.

DISCUSSION

In complex fractures of the proximal humerus, bone stock will be lost at the tuberosities, and when it comes to internal fixation, it may not be possible to retrieve all the parts of the "jigsaw puzzle." The surgeon is thus confronted with the question of how, under these unfavorable conditions, the pattern of the proximal humerus can be restored and the reduction fixed in the appropriate position. In elderly patients, conventional techniques of internal fixation do not, as a rule, produce the desired results. In some cases, such as the 4-part vagus impacted fracture described by Jakob et al,[29] raising the head will restore the anatomic pattern and give a good outcome; however, in badly displaced fractures, fixation is associated with a greater or lesser degree of impaction of the fracture fragments. To ensure a correct morphologic pattern of the proximal humerus, the nor-

AER (degrees)	AIR (segment)	Strength	Rating
45	L3	5	Good
45	T12	5	Excellent
60	T10	5	Excellent
30	L5	3	Poor
45	L3	4	Good
25	Sacrum	4	Fair
20	T8	4	Good
20	T8	5	Excellent
30	T10	5	Good
30	T12	5	Excellent
20	L3	4	Good (AVN3)
25	L1	5	Excellent
40	T12	5	Excellent
10	L3	4	Fair (AVN4)
30	L3	4	Excellent
30	T12	4	Fair
–30	T12	3	Fair
30	L1	5	Good
60	T12	5	Excellent
30	L1	4	Fair
45	T10	5	Excellent
15	L5	4	Good
20	Buttock		Poor (AVN4)
–15	Trochanter	4	Fair (AVN4)
40	T10	5	Good (AVN3)
20	L2	5	Good

mal distance between the shaft and the head must be restored and the tuberosities must be reattached at their correct sites. The intramedullary and extramedullary devices currently available do not give sufficient support to the humeral head; as a result, the head often tilts into varus postoperatively or the hardware penetrates the head. Because of the known difficulties of internal fixation, surgeons have resorted to arthroplasty. However, arthroplasty could often be avoided if there were a more efficient means of internal fixation.

With the Bilboquet, the distance between the shaft and the head is maintained as a result of the central and, above all, the peripheral support on the humeral head, which optimally counteracts any tendency toward displacement into varus (Figures 3-5). Once the tuberosities have been reduced onto the hardware, they will be in contact with bone. The system also has the advantage of being fixed inside the bone, thereby obviating impingement on adjacent anatomic structures and being readily convertible into a prosthesis in the event of AVN.

The foremost concern raised by this intraosseous device is the risk of AVN. The reported rates of AVN after operative treatment are 12% to 25% for 3-part fractures and 41% to 59% for 4-part fractures.[20] It will be seen that our results compare favorably with those of other series in the literature.[6,15,18,29,34,43,52] Among the 16 cases in our 3-part fracture group, there were 2 cases of AVN: 1 stage 3, which was well tolerated, and 1 stage 4. Among the 10 cases in the 4-part fracture group, there were 3 cases of AVN: 1 stage 3, which was well tolerated, and 2 stage 4. When operating on 4-part fractures, we were often concerned about the fate of the humeral head, considering that it had lost its major source of blood supply, the ascending branch of the anterior circumflex humeral artery.[19,35] However, careful mobilization of the head fragment in such fracture patterns showed that it was still tethered by a medial sheet of capsuloligamentous tissue. These soft tissues are traversed by the posteromedial vessels, whose role in the continued vascularization of the humeral head in 4-part fractures has been noted by Brooks et al.[5] This continued blood supply via the posteromedial vessels may account for the fact that necrosis is not an inevitable outcome of all 4-part fractures. Another favorable factor, suggested by Lee and Hansen,[36] is that creeping substitution takes place more often and more extensively in the humeral head than in the femoral head, possibly because the surface area of the fracture is large in comparison with the thickness of the humeral head, with a subsequent decrease in mechanical stress as it heals. In all of our AVN cases, only 1 patient had symptoms that necessitated revision to a prosthesis.

The cases of AVN were interesting in several respects. The necrosis that occurred in case 14 of the 3-part fracture group was probably iatrogenic in origin; the head may have been distracted excessively during reduction. The 3 cases of necrosis among the 4-part fractures were not invariably associated with a poor outcome; case 9 (Figure 5) was that of a 78-year-old female patient who underwent very little physiotherapy and yet had an astonishingly good result at 2 years. This difference in functional tolerance has been noted by several authors.[36,40,49] In our series, the good functional outcome may have been attributable to the fact that the tuberosities healed in their correct positions. In fact, healing of the tuberosities in cases of partial humeral head necrosis may be the key to a good result. This hypothesis may also explain why the functional outcome is unpredictable in fractures that have been managed with humeral hemiarthroplasty: in that procedure, the bulk of the metal component does not encourage union of the tuberosities, whereas the Bilboquet puts the tuberosities in contact with the cancellous bone of the head fragment.

Complex fractures of the proximal humerus are customarily managed either with open reduction and internal fixation (ORIF) or with hemiarthroplasty. The results of hemiarthroplasty vary widely. Some authors* have reported satisfactory outcomes that were close to

*References 8, 14, 23, 39, 48, 50, 51, 53.

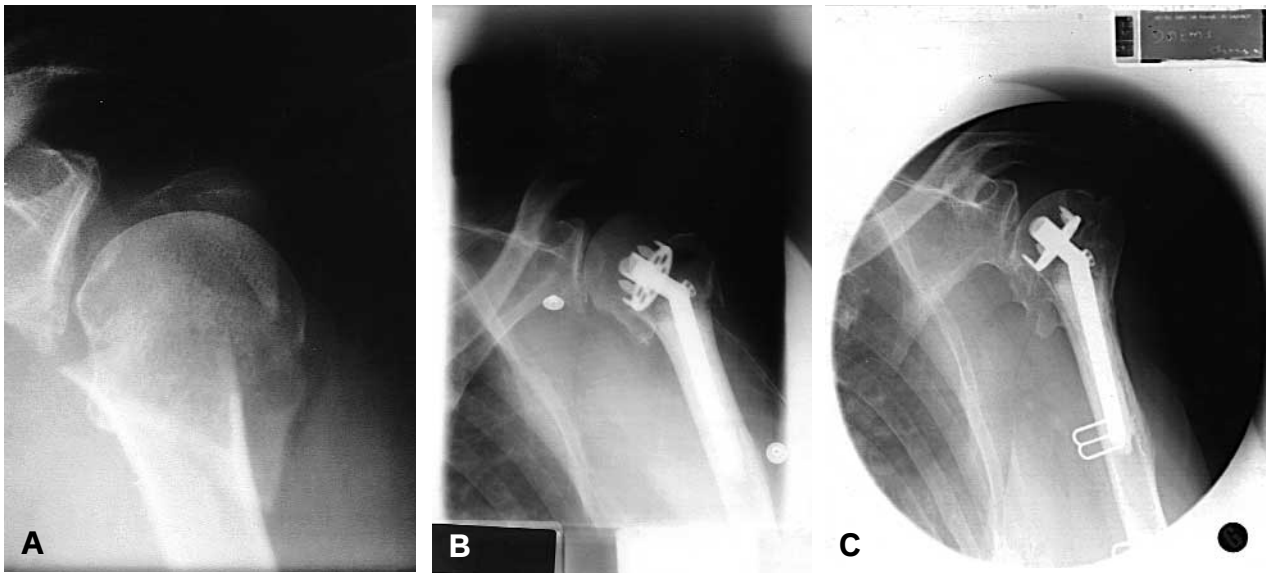

Figure 3 Case 2 of 4-part fracture group. **A,** Four-part fracture in 63-year-old female patient. **B,** Postoperative radiograph. **C,** Good result at 3 years.

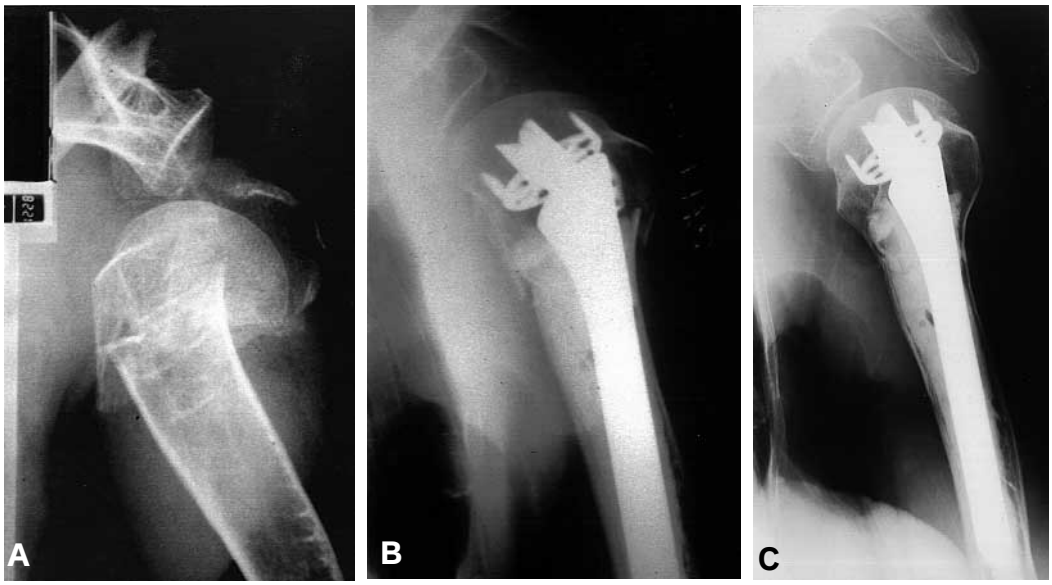

Figure 4 Case 5 of 4-part fracture group. **A,** Four-part fracture in 75-year-old female patient. **B,** Postoperative radiograph. **C,** Excellent result at 2 years.

the results obtained by Neer[43]; in other studies,[17,26,27,30,54,55,59] outcomes were less satisfactory. Except for the results obtained in 2 studies,[8,43] active mobility has often been poor (<100° of active forward elevation), the chief benefit to the patients being pain relief. It should also be noted that in the series in which good results were achieved, mean patient age was low (56 years in the study by Neer[43] and 62 years in the study by Compito et al[8]), the only exception being the study by Moeckel et al,[39] in which the mean patient age was 70 years. As a general rule, the outcome tends to be worse with increasing patient age. It should also be borne in mind that with the exception of the Neer study,[43] follow-up to date has been comparatively short. There are thus no data indicating how well these prostheses are tolerated in the long term; in particular, nothing is known about the eventual fate of the glenoid.

For ORIF, many different methods have been used. Intramedullary nailing appears to give good results in 2-part fractures of the surgical neck[4]; however, this technique cannot be used for the management of 3-part or

Figure 5 Case 9 of 4-part fracture group. **A,** Four-part fracture in 78-year-old female patient. **B,** Postoperative radiograph. **C,** At 3 months. **D,** At 2 years: no pain, no limitation in activities; stage 3 AVN.

4-part fractures or fracture dislocations because it does not provide sufficiently stable fixation of the head fragment to allow exercise physiotherapy immediately after surgery. The results of fixation of 3-part and 4-part fractures and fracture dislocations with plates or nail plates vary widely. Some authors[6,15,34,42,44] have reported poor outcomes: in their studies, the rates of good results ranged from 7% to 60%, the usual rate being approximately 30% and lower rates being associated with more complex fracture patterns. Other authors appear to have done better, either by using conventional internal fixation[16,38,56] or with minimal internal fixation, as originally recommended by Jakob et al.[12,29,32,47] It should be noted, however, that all of the studies with satisfactory results were performed in patients of very low mean age (<40 years in the study by Moda et al[38]), which might account for the quality of the results. Zyto et al,[58] in a recent article comparing minimal internal fixation and conservative management in elderly patients (mean age, 70 years), found that, paradoxically, conservative management was superior. However, this finding is explained by the radiographs of the fractures managed with minimal fixation: the technique used was one of tension-band wiring impacting the fragments, which means that the anatomic pattern of the proximal humerus was not restored.

In our study, we had 17 satisfactory results, which is comparable with results in the studies in which ORIF or hemiarthroplasty was used. However, our patients were, on average, 70 years old, which makes the mean age in our study markedly higher than that in studies by other authors whose results after ORIF or hemiarthroplasty were better than ours. The quality of the eventual outcome is predicated on the quality of the rehabilitation provided and on the patient's compliance with the physiotherapy regimen. In our series, each of 8 elderly patients was resolutely against a continuation of physiotherapy beyond 7 weeks; the usual comment was, "Doctor, that's all the movement I need. I don't want to be bothered any more."

One important issue is the assessment of results and the unresolved problem of the different evaluation methods used in the different studies. The functional assessment method of Constant and Murley[9] is widely used in Europe in patients who have been treated for rotator cuff lesions; its use in the assessment of the outcome of fracture treatment, however, is more recent and more controversial. The method of measuring strength for the Constant score is, in fact, difficult to use in elderly sedentary subjects, and proposals for a standard method have been published only recently.[2] Like Huten and Duparc,[27] we have found active elevation and pain to be the most sensitive indicators of the clinical outcome. This is borne out in a recent study by Gleyze et al,[21] who compared 3 methods of shoulder assessment (Constant score, ASES score, and forward elevation) in 288 patients and found that active pain-free elevation appears to be more sensitive than Constant score and assessment of daily activities.

The soundness of the construct depends on the fixation of the head staple. In the early part of our series, only 2 staple sizes were available; this meant that some cases were managed with staples that were too small with respect to head fragment circumference. This size mismatch may explain why the hardware tilted secondarily. However, reoperation was required in only 1 case in which the staple had penetrated into the rotator cuff and was causing pain. The single case of tuberosity nonunion was in a patient who was pain-free and satisfied with the functional outcome up to her death at 16 months after surgery (from gastrointestinal tract cancer). There was no instance of infection. However, it is obvious that if the Bilboquet had to be removed, the humeral head would have to be sacrificed, inasmuch as the device cannot be retrieved.

Although there are still some questions to be resolved, the Bilboquet has one definite advantage: it makes proximal humeral fracture surgery vastly easier. Obviously, experience and judgment are required to position the head staple correctly and to place the diaphyseal component at the correct level and degree of retroversion. However, the procedure involved is not as difficult as the management of complex fractures with conventional internal fixation hardware. Unlike percutaneous minimal fixation techniques, use of the Bilboquet does not expose the surgical team to radiation. The fracture management problem boils down to a biologic rather than a mechanical question: how great an effort should one make to preserve the humeral head? In the management of fresh fractures in elderly patients, we have adopted a policy of preserving the head unless it has become completely severed from its soft-tissue attachments; in younger subjects, we would never sacrifice the humeral head, which even if completely stripped of soft tissues can provide an osteocartilaginous autograft.

In conclusion, the Bilboquet internal fixation device allows complex proximal humeral fractures to be reduced and fixed. The results obtained compare favorably with those achieved by other methods of internal fixation in current use. The Bilboquet obviates hemiarthroplasty. If AVN occurs, it tends to be well tolerated because of the good healing of the tuberosities, and though the hardware has been designed for ease of conversion to a hemiarthroplasty, the need for such revision occurred in only 2 of the 26 patients in our study. The only disadvantage of the Bilboquet is the fact that once it is inserted, it cannot be removed.

In the light of the use, improvement, and clinical follow-up of the device over a period of 7 years, we feel that the hardware has arrived at a stage where it may be offered to the orthopedic community to help with the management of difficult fracture patterns. The Bilboquet should now receive wider exposure, in multicenter use, to see whether our favorable impression of its utility in the treatment of complex proximal humeral fractures is confirmed by the experience of other surgeons.

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