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ORIGINAL PAPER

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Periprosthetic fractures around cementless hydroxyapatite-coated femoral stems

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Abstract We studied 14 periprosthetic femoral fractures out of a series of 619 hydroxyapatite coated hip implants and compared the outcome to published treatment algorithms using the Vancouver classification. There were five type A fractures, six B1, two B2, and one type B3 fracture. All but one type A fractures were treated conservatively. Compared with the Vancouver classification, we observed a different fracture type in the type B fractures. No fractures at the tip of the stem were seen, as in cemented implants. Three B1 fractures were treated operatively due to fracture displacement, and three were treated conservatively. The B2 and B3 fractures were managed with long, uncemented, revision stems because of a disrupted bone–prosthesis interface. All fractures healed well. This study confirms that the modified algorithm of management of periprosthetic fractures, using the Vancouver classification, is a simple, reproducible, classification system for uncemented prostheses. Conservative treatment is a valid option if the implant is stable whilst surgical intervention is mandatory if the implant is loose.

Résumé Nous avons étudié 14 fractures fémorales péri prothétiques dans une série de 619 implants de la hanche recouverts d'hydroxyapatite et nous avons comparé le résultat à l'algorithme de traitement utilisant la classification de Vancouver. Il y avait cinq fractures de type A, six de type B1, deux de type B2 et une de type B3. Toutes les fractures de type A, sauf une, ont été traités d'une manière conservatrice. Comparé à la classification de Vancouver nous avons observé un type de fracture différent dans le type B. Aucune fracture à l'extrémité de la tige n'a été vue comme dans les implants cimentés. Trois fractures B1 ont été opérées à cause du déplacement et trois a été traité d'une manière conservatrice. Les fractures B2 et B3 ont été traités avec des tiges longues de révision, sans ciment, à cause d'une interface os-prothèse interrompu. Toutes les fractures ont consolidé. Cette étude confirme que l'algorithme modifié de gestion des fractures péri prothétiques, en utilisant la classification de Vancouver, est un système de classification simple, reproductible, pour les modalités du traitement avec des implants sans ciment. Le traitement conservateur est une option valable en cas d'implant stable, cependant qu'en cas d'implant descellé l'intervention chirurgicale est obligatoire.

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Introduction

The management of periprosthetic femoral fractures around cemented hip prostheses has been extensively described, but reports on femoral fractures around cementless femoral implants are scarce [15]. In cemented hip prostheses, periprosthetic femoral fractures mostly occur at the tip of the prosthesis. In cementless hip prostheses, periprosthetic fractures [1], occur at different locations and this has implications for fracture type and management.

The Vancouver classification, originally based primarily on periprosthetic fractures in cemented prostheses, provides guidelines for classification and management of all periprosthetic fractures [6]. Periprosthetic fractures around a stable implant can be treated conservatively, but with an unstable implant, surgical treatment is mandatory. Recently, a modified algorithm for management of periprosthetic fractures has been published by Learmonth [11] and Masri [14]. The latter has also expanded the system to cover intra-operative fractures.

We report a study of 14 periprosthetic femoral fractures around the same type of cementless stem. We have compared the treatment with the most recent management algorithm using the Vancouver classification [11, 14].

Patients and methods

From January 1990 to December 1996, we implanted 619 consecutive total hip prostheses (ABG-I): 464 in women and 155 in men. The prostheses had proximal coating of plasma sprayed hydroxyapatite (ABG, Stryker Howmedica, UK) and have been previously described [14, 17, 18]. Both the acetabular and femoral components were implanted in a cementless press-fit manner.

Patients were reviewed annually for physical and radiological examination and the Merle d'Aubigne hip score was calculated. The position of the femoral stem was judged as neutral when the position was within 2° valgus to 2° varus. Of the 619 ABG femoral implants, 59 were placed in varus and four in valgus. Mean age at implantation was 67.6 years, mean body mass index (BMI) 26.8, and mean stem size 4.6.

Fourteen patients (2.3%) (11 women and three men) presented with a fracture around the femoral component, the majority after a fall at home. Mean age at the implantation was 72.6 years, mean BMI 24.8, and mean stem size 5.5 (p=0.005). All femoral implants were graded as being in a neutral position. Average time interval from hip replacement was 6.9 (range 2.0–13.7) years. Average age at the time of the periprosthetic fracture was 79 (range 65–92) years. Until the time of fracture, all patients showed an uneventful postoperative course. The mean follow-up after the periprosthetic fracture was 3.2 years.

Fractures were classified according to the Vancouver classification and treatment retrospectively compared with the recently published management algorithm [10, 12].

Statistical analysis

The two groups of patients were analysed using the unpaired t test or chi-square test, and p values <0.05 were considered statistically significant.

Results

There were five type A fractures (four A_G, one A_L) and six B_1, two B_2, and one B_3. There were no type C fractures (Table 1).

Type A

Three patients sustained a fracture of the greater trochanter without significant displacement and with a stable stem (type A_G fractures). The fractures occurred in the area between the proximal and middle lateral Gruen zones, in which an acute bone density gradient was seen radiographically. Two patients were treated by bed rest followed by gradual weight bearing while the third patient was treated with gradual weight bearing only. One patient sustained a fracture of the lesser trochanter and was also treated by gradual weight bearing. In all four cases, the treatment was uneventful without complications. At follow-up, the patients were satisfied and had adequate hip function. Radiographical consolidation was seen at 6 weeks. The fifth patient sustained a fracture of the greater trochanter (type A_G) with severe displacement and was treated surgically (Fig. 1).

Table 1 Details on 14 patients with periprosthetic fractures. *BMI* body mass index, *OA* osteoarthritis, *RA* rheumatoid arthritis, *AN* avascular necrosis

	Gender	Primary diagnosis	BMI	Age at primary operation	Stem size	Cause of fracture	Age at second operation (PPF)	Years until fracture	Fracture type	Treatment
1	F	OA	23	69	7	Fall	71	2	B_1	Traction 6 weeks
2	F	OA	25	81	6	Fall	86	5	A_G	Bed rest 4 weeks
3	F	OA	27	83	6	Fall	88	5	B_1	Traction 6 weeks
4	M	OA	33	68	5	Fall	73	5	B_1	Cable grip wiring
5	F	OA	23	78	4	Fall	84	6	A_G	Bed rest 10 days
6[a]	F	RA	21	59	6	Fall	64	6	B_2	Long-stem revision, plate, cerclage
7	M	RA	28	70	7	Fall	78	8	B_1	Gradual weight bearing
8	F	OA	23	80	5	Fall	87	7	B_2	Long stem revision+cerclage
9	F	OA	23	82	3	Fall	91	10	B_1	Zimmer-trochanter plate, cerclage
10	F	AN	25	65	6	Fall	71	5	A_G	Gradual weightbearing
11	F	OA	23	70	5	Fall	81	11	A_G	Zimmer-trochanter plate, cerclage
12	M	RA	19	63	6	Fall	69	6	A_L	Gradual weight bearing
13	F	OA	26	73	5	Fall	87	13	B_3	Long-stem revision+Zimmer-trochanter plate+cerclage+femoral allograft
14	F	OA	25	70	6	Fall	82	11	B_1	Three cerclage wires, 6 weeks no weight bearing

[a]Sustained a new periprosthetic fracture 53 months after the revision operation

Fig. 1 **a** Fracture (type A) of the greater trochanter with severe displacement. **b** Fracture treated with trochanter plate and cerclage wires.

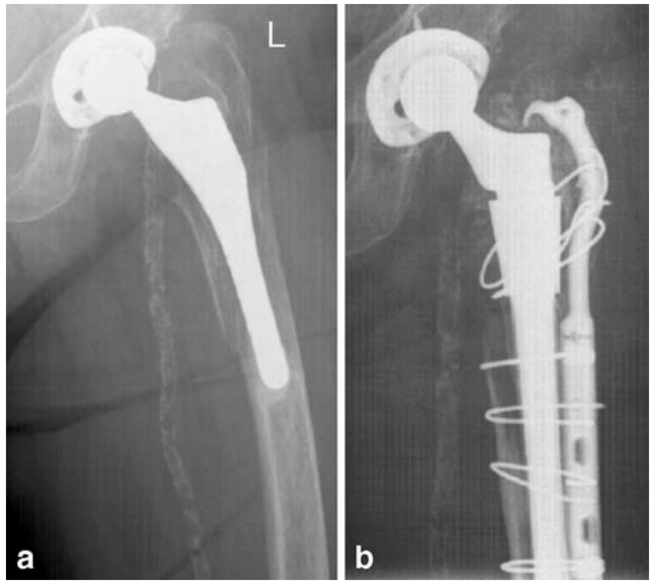

Fig. 2 **a** Unstable fracture (type B_3) with loose stem and poor bone stock. **b** Fracture treated with femoral component with long stem, plating, cerclage wiring, and a femoral allograft.

Type B

Nine patients sustained a diaphyseal fracture (B_1) around the femoral stem. The fractures occurred in the region between the proximal (1and 7) and middle (2 and 6) Gruen zones in which an acute bone density gradient was seen.

In six cases, the stem was considered stable. One patient was treated by gradual weight bearing, and two by traction and bed rest for 6 weeks. All three had uncomplicated recoveries with radiographically consolidated fractures after 3 months. In the remaining three patients, the fractures were treated with cable wiring and a supplementary trochanter plate because of severe displacement of the proximal fragments. During surgery, it was confirmed that the stem was not loose. In two cases, the patients were allowed immediate full weight bearing postoperatively, leading to a fast recovery and proximal osteointegration within 3 months. The third case was treated postoperatively with partial weight bearing for 6 weeks.

In three patients, the diaphyseal fractures were classified as type B_2–B_3, as no osteointegration could be demonstrated in the distal Gruen zones 3–5. The stems were completely loose and were revised using a long revision stem and plating with cerclage wiring. In one patient (type B_3), the bone was poor and the patient was treated with a supplementary femoral allograft (Fig. 2). One patient (B_2 fracture) sustained a second periprosthetic fracture distal to the revision stem 4 years later. Fracture stabilization was achieved by plate and cerclage wiring.

All but one type A fractures were treated conservatively. Of the B_1 fractures, three were treated surgically because of fracture displacement, and three were treated conservatively. The $B_{2–3}$ fractures were all managed surgically with long, uncemented, revision femoral components.

Discussion

The estimated prevalence of periprosthetic femoral fractures ranges from 0.1% to 2.1% [12]; however, this usually relates to cemented hip prostheses [1, 2]. An increased prevalence has been reported after uncemented implants [6]. Our prevalence of 2.3% matches this. In a retrospective study, Wu [21] reported a prevalence of 3.5% in uncemented hip implants.

The major risk factors for periprosthetic fractures include osteoporosis, osteolysis/particulate debris-induced osteolysis [8], and revision arthroplasty [6]. The increased risk seen after revision total hip arthroplasty is probably due to the compromised bone quality and to focal bone deficiencies [2]. Periprosthetic stress fractures may occur spontaneously in areas of high stress [11], as in osteopenia in combination with femoral varus angulation [4, 7, 9]. However, we saw, no such varus angulation in our series. A slight preponderance of periprosthetic fractures in women has been noted [2], as in our series (2.4% versus 1.9%) although this difference was insignificant, as was the difference in BMI between the groups. No specific period after a total hip replacement has been reported to show an increased prevalence for periprosthetic fractures. The cause of periprosthetic fractures is usually a minor traumatic episode [4], as also described in this study.

In our study however, the mean stem size in patients with a periprosthetic fracture was significantly larger than the mean stem size in the whole group. The larger stem size might influence the fracture rate because the greater stiffness of the stem increases stress shielding, and the subsequent bone resorption induces fracture risk. The larger stem size in patients with periprosthetic fractures may have been caused by their higher age at the index operation although the difference was not significant.

The site of fracture in our series was always in an area where an acute bone density gradient in the cortex had developed between the proximal and the middle Gruen zones. The ABG-I prosthesis is proximally hydroxyapatite coated and designed for proximal-stem bonding and stress transfer. Indeed, this process does occur, as was shown in retrieval histological studies and finite element studies [18, 20], but studies using dual-energy X-ray absorptiometry showed general periprosthetic bone resorption in all Gruen zones during the first half year after implantation, and was most prominent in proximal Gruen zones 1 and 7 [15]. Later, a balance between bone resorption and bone formation occurred between 12 and 24 months after implantation, suggesting that the load transfer was sufficient to prevent any further bone loss. In comparison, the periprosthetic bone loss in Gruen zones 2–6 stabilized by 3 months. In Gruen zone 6, the bone mineral density (BMD) increased progressively after the 3-month time point, and the total recovery of 5% at the end of 3 years was statistically significant [15]. These findings suggest that in the ABG-1 stem, the load transfer occurred mostly distally to Gruen zones 1 and 7 after the initial proximal osteointegration [14, 17, 18]. Thus, with time, a rather acute gradient in bone density develops at the transition between Gruen zone 1–7 and Gruen zone 2–6 acting as a local stress raiser with an increased fracture risk. When the patient falls on the operated hip, a fracture may occur at that particular location. The fracture may propagate as a transtrochanteric fracture (type A) or, when the impact is larger, may propagate further distally (type B). There is, therefore, always a

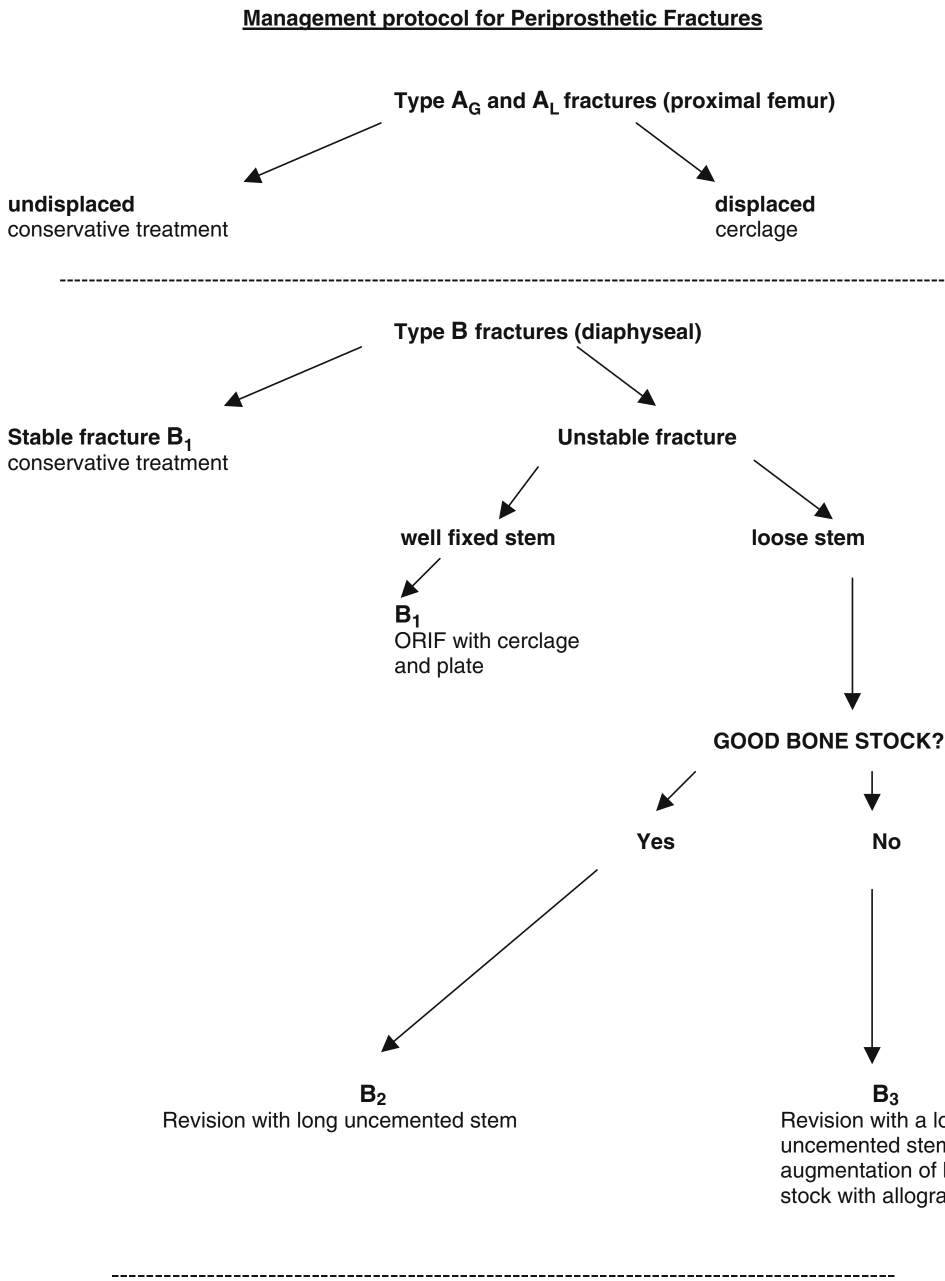

Fig. 3 Type C fractures (below tip of femoral stem). Treatment as of a fracture in the distal femur.

degree of de-bonding of the proximal osteointegration and, depending on the status of the distal bonding, the stem will or will not remain fixed. For similar reasons, most fractures around cemented prostheses occur in the area around the prosthetic tip where there is an area with an acute gradient in stiffness between the cemented part of the femur and the uncemented part.

The Vancouver classification system provides clear assistance in formulating a strategy for management of periprosthetic fractures, and an algorithm of management has recently been published [10, 12] (Fig. 3).

In our study, patients with type A fractures were managed conservatively, except one with severe displacement of the greater trochanter. This treatment is in accordance with the management algorithms for periprosthetic fractures [10, 12].

The treatment of B_1 fractures around ingrown prostheses essentially differs from the treatment of similar diaphyseal fractures around cemented prostheses, which would be mainly surgical [3, 16]. In the recently published management algorithm by Masri [12], open reduction and internal fixation with or without strut allograft for B_1 fractures is advised. However, we tend to agree with Learmonth's management algorithm [10] that in cases with a stable prosthesis, conservative treatment is a viable option. Two patients were treated by bed rest and traction for 6 weeks. However, such treatment in an elderly patient bears the risk pulmonary and thromboembolic complications and the development of decubitus ulcers. One can therefore speculate that the patients could perhaps have been better treated by gradual weight bearing.

Due to severe displacement of the loose proximal fracture fragments, we found it necessary to perform open reduction and internal fixation in three patients with type B_1 fractures. Although Masri and Learmonth [10, 12] recommend open reduction and internal fixation with cerclage and struts or with a plate in cases of unstable B_1 fractures, we used only cerclage wiring in two patients with good results. However, Mont et al. [13] showed that in fractures around the mid and distal stem, cerclage cables and bone graft or revision to a longer prosthetic stem were superior to screw-plate fixation or traction. Only cerclage cables seem to be a good option. In our study, one patient was not allowed to start weight bearing immediately. This patient could probably have been mobilized earlier if struts or plates with cerclage wiring were used.

The two B_2 fractures and one B_3 fracture in our series were treated with a long, uncemented, revision stem (DPM Stryker Europe). Treatment by specially designed revision stems is clearly indicated in any periprosthetic fracture in which the implant is loose. Type B_3 fractures are fractures with unstable implants associated with deficient bone stock, and they need some bone augmentation [3, 16]. There is controversy in the literature as to whether cemented or uncemented long-stemmed implants should be used in B_2 or B_3 fractures [3, 19]. On the one hand, a sufficiently long-stemmed, porous-coated prostheses achieving distal fixation seems adequate. On the other hand, the use of cement bears a risk of cement interposition between fracture fragments. However, this is probably technique-related, and special care is needed to expose the diaphysis, avoiding cement interposition. In cases of a B_3 fracture in the elderly patient, both Learmonth [10] and Masri et al. [12] advocate a prosthetic proximal femoral replacement or even using a tumour prosthesis. In our series, we used a long-stem revision implant together with a plate and cerclage supplemented with a femoral allograft to augment bone stock. So, except for the B_3 fracture, our treatment algorithm followed the management algorithm of Learmonth [10] and Masri et al. [12].

In the future, the number of periprosthetic fractures around uncemented prostheses will probably create an increasing therapeutic problem [10]. As has been shown in our study, the fracture patterns differ from those seen in cemented hip prostheses. Our study also confirms that the algorithms of management of periprosthetic fractures by Learmonth [10] and Masri et al. [12], based on the Vancouver classification, are adequate for the uncemented treatment modality. Conservative treatment is a valid option in cases with a stable implant unless the displacement is too large. In cases with a loose implant, surgical intervention is always mandatory.

The goal of operative treatment is to return the patient to the same activity level as before the fracture. Careful preoperative planning based on the status of the prosthetic interfaces and fracture types will increase the chance of a favourable outcome.

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