Stem fracture with the Exeter prosthesis

3 of 27 hips followed for 10 years

Magne Røkkum, Kjell Bye, Karl R Hetland and Astor Reigstad

We report the results of a 9–11-year clinical and radiographic follow-up of 27 Exeter prostheses in which cement pressurizing technique was employed. 3 stems fractured and 3 other stems and 1 cup underwent aseptic loosening. The remaining prostheses had satisfactory clinical and radiographic results. Stem subsidence was seen only as part of a loosening process. We suspect that the pronounced taper design is responsible for the poor results. While the slender and weak distal end is fixed in a thick cement mantle, the wide proximal part allows only a thin cement layer, easily subjected to mechanical disintegration. Proximal debonding increases both the stress on the distal part of the stem and the distal bone–cement interface shear stress. Hence, we believe that the same process underlies both the loosenings and the stem fractures. The presently employed Exeter stem is manufactured from the stronger Orthinox steel, which may diminish the risk for fracture, but it has retained the extreme taper design. It is not likely that a polished surface or improved cementing will prevent stem fracture. Therefore, one should still be concerned about late fractures of the Exeter stem.

National Orthopedic Center, Kronprinsesse Märthas Institutt, Jørgen Løvlandsgt. 2, N-0570 Oslo, Norway
Tel. +47 22-95 43 00. Fax -95 45 23
Submitted 94-12-20. Accepted 95-07-24

The Exeter femoral stem is collarless and tapers on all surfaces. This design is intended to allow the stem to sink into the cement mantle and self-tighten, accommodated by creep and plastic deformation of the cement. The stem is believed to retain its stability during the subsidence, without loosening. Likewise, the cement mantle and the cement-bone interface are supposed to remain intact (Fowler at al. 1988). The acetabular component is an eccentric polyethylene cup, not substantially different from most cemented acetabular prostheses.

We studied our long-term results with the Exeter hip.

Patients and methods

We used the Exeter total hip replacement between 1983 and 1985. 39 hips were operated in 34 patients. 9 patients with 10 operated hips died, on average, 7 (2–9) years after surgery, for reasons unrelated to the hip. 2 patients without hip problems declined to return for follow-up because of advanced age and general disability. Thus, 23 patients (27 hips) were included in the follow-up. Mean age at operation was 67 (53–78) years (Table 1).

A lateral approach without trochanteric osteotomy was used. The cementing technique included washing, brushing and drying of the bone cavities. The femoral canal was plugged. The cement was pressurized in both the medullary canal and the acetabulum, before insertion of the prosthesis. High viscosity Palacos® cement with gentamicin was used. All stems had a slightly matt surface. A centralizing jig helped to maintain a mid-line position of the distal stem. We recommended a non-weight bearing period of 4 months after the operation.

Clinical and radiographic evaluations were carried out preoperatively, postoperatively, at 4 months, 1 year and thereafter at various intervals until the follow-up, a mean of 10 (9–11) years postoperatively. Radiolucent lines along the bone-cement interface were measured and localized according to DeLee and Charnley (1976) for the acetabular component and Gruen et al. (1979) for the femoral component. Migration was calculated using the bony contours of the pelvis, including the tear drop. Special attention was paid to the occurrence of stem subsidence, according to Fowler et al. (1988). Implant loosening was defined as a change in position combined with a radiolucency along the bone-cement interface, not seen at the immediate postoperative radiograph. Clinical rating was done by Charnley's method (1979). Cases with implant failure were excluded from the clinical rating.

Table 1. Patient data

Case	Diagnosis[a]	Sex	Age	Weight	Stem size[b]	Offset	Femoral lucency[c]	Subsidence mm	Acetabular lucency[d]	Failure	Revision
1	1	F	68	65	1	38	0	0	0	no	no
2	1	F	78	61	1	38	0	0	A	no	no
3	1	F	72	59	2	44	0	0	C	no	no
4	1	M	74	75	4	44	0	0	ABC	no	no
5	1	F	60	80	2	38	1–7	16	ABC	stem fract.	fem.+ac.
6	1	M	64	95	1	38	1,2,6,7	0	ABC	stem fract.	fem.+ac.
7	3	F	65	65	2	38	0	0	C	no	no
8	3	F	56	53	2	38	0	0	ABC	no	no
9	2	F	63	75	2	38	0	0	BC	no	no
10	1	F	75	63	3	38	1–7	3	0	stem loos.	fem.
11	4	F	70	56	3	44	1	0	C	no	no
12	1	F	72	62	2	38	0	0	0	no	no
13	1	F	66	60	1	38	0	0	0	no	no
14	1	F	66	60	3	38	0	0	0	no	no
15	2	F	53	38	1	38	0	0	C	no	no
16	2	F	53	38	1	38	0	0	ABC	ac.loos.	no
17	1	F	73	73	4	38	0	0	0	no	no
18	1	F	62	61	2	38	7	0	0	no	no
19	1	F	72	74	3	38	0	0	C	no	no
20	1	F	64	73	4	38	1	0	0	no	no
21	1	F	64	73	2	38	0	0	0	no	no
22	1	F	78	60	3	44	1–7	12	0	stem loos.	no
23	1	F	75	67	2	38	1	0	0	no	no
24	1	F	76	77	4	44	1–7	16	0	stem loos.	no
25	5	F	58	55	1	38	0	0	0	stem fract.	fem.+ac.
26	5	F	58	55	1	38	0	0	0	no	no
27	1	F	75	50	2	38	7	0	BC	no	no

[a]1 primary arthrosis, 2 secondary arthrosis due to dysplasia, 3 congenital hip dislocation, 4 rheumatoid arthritis, 5 posttraumatic arthrosis
[b]1 lightweight, 2 narrow, 3 standard, 4 heavy duty
[c]Gruen zones
[d]DeLee and Charnley zones

Results

No intra- or postoperative complication was recorded, and no infection was seen.

3 cases of femoral stem fracture occurred after 1.3, 8.6, and 9.0 years and were reoperated. The hip pain had started suddenly during plain walking. In 2 cases, pronounced lucencies between cement and bone in zones 1 and 7 developed during the first postoperative year (Figure 1). 1 stem lost proximal support due to pseudarthrosis of a femoral osteotomy (Figure 2). The fracture levels measured from the tip of the stem were at 7.7, 7.7, and 7.6 cm. Fracture waves consistent with fatigue failure were clearly visible on the cut surfaces, starting anterolaterally and propagating to the medial side, ending in a lip of metal. No bending of the fragments was seen. Stem defects, which could have contributed to the fractures, were not observed.

1 case of loosening between cement and bone was revised 3.4 years postoperatively. 2 loose stems, 1 with moderate and 1 with significant symptoms, were not revised because of advanced age and cardiovascular risk factors. The radiolucencies started proximally, enveloping the cement mantle within 1 year and coinciding with stem subsidence. In cases 22 and 24, there were cement fractures about 11 cm from the tip of the stem. Stem-sinking together with the intact distal part of the cement mantle followed, while the proximal cement remained in place (Figure 3). In case 10, no cement fracture occurred, but the whole cement mantle accompanied the stem intimately during subsidence.

None of the failing stems had been inserted into the varus position and no radiolucent lines were demonstrated on the postoperative radiographs, indicating satisfactory cementing technique. No significant difference regarding body weight, age, size or offset of the prostheses was seen between failing and well-functioning stems.

1 acetabular cup, which had a complete thin radiolucent line after 1 year, loosened and was exchanged at 11 years.

The remaining 19 hips showed excellent clinical results (Table 2).

Figure 1. Case 5.

At 1 year small lucencies have developed between cement and bone proximally. 0.1 cm subsidence of the stem within the cement.

At 5 years there are endosteal erosions in zones 2 and 6. Fracture of the cement and centralizing jig is seen, of which the distal part is sinking together with the stem. 0.5 cm of stem subsidence has taken place.

Stem fracture after 8.6 years. Endosteal bone lysis surrounds the proximal half of the stem. The stem has subsided 1.6 cm, partly within the cement, partly together with the distal cement mantle.

Figure 2. Case 25.

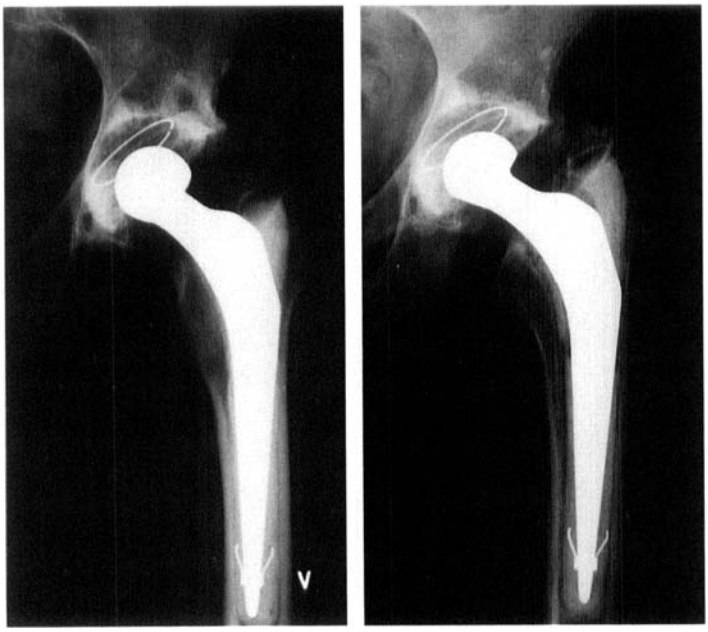
Shortening osteotomy of the femur was achieved simultaneously with the primary total hip replacement.

Pseudarthrosis developed which resulted in loss of support of the proximal part of the stem. Stem fracture at 9.0 years.

Discussion

Our material is small, but the number of complications is alarming, especially the incidence of stem fracture seen in 3/27 hips. Apart from one report of 11% stem fractures with the Müller prosthesis of the earlier design (Martens et al. 1974), less than 5% of stem fractures have been reported with other prostheses (Charnley 1975, Carlsson et al. 1977, Willert et al. 1980, Chao and Coventry 1981, Wroblewski 1982, Ritter and Campbell 1986, Amstutz et al. 1990, Munuera and Garcia-Cimbrelo 1990). The total failure rate in our series exceeds that reported with the Charnley prosthesis with longer follow-ups (Wroblewski and Siney 1991, Dall et al. 1993, Schulte et al. 1993).

Figure 3. Case 22.



Postoperatively.

At 10 years a lucency is enveloping the cement. Cement fracture 11 cm proximal to the tip of the stem. A total of 1.2 cm of stem-sinking occurred, 0.1 cm within the distal cement mantle, as indicated by the dissociation of the centralizing jig.

Table 2. Clinical results according to Charnley (mean, range)

	Preop.	Follow-up
Pain	2.0 (1–3)	5.8 (5–6)
Motion	3.2 (2–4)	5.0 (4–6)
Walking	1.9 (1–3)	5.2 (3–6)
Total	7.1 (4–9)	16.0 (13–18)

In spite of the fact that the Exeter prosthesis has been in use for 25 years, surprisingly few clinical results have been published. The inventors of the concept reported 2% fractures of the matt stem in a series with an average follow-up of 13 years (Fowler et al. 1988); 3.5% of neck fractures were confined to a group of structurally defective stems. After slightly increasing the stem section in 1976, a stem fracture incidence of 0.03% was found at a 4–5 year follow-up of 2,968 hips. Only 1.6% of the stems were considered to be loose at 13 years, although distal migration was reported in 84% of the stems and 25% had a subsidence of 3 mm or more. A subsidence exceeding 2 mm is commonly held to be a true sign of loosening (Harris et al. 1982). We saw stem-sinking only as part of a loosening process. Rockborn and Olsson (1993) noted no fractures, but 19% loosening of the matt Exeter stem after more than 5 years.

The same fracture level in our cases indicates that the stem design is an important factor. Due to the pronounced taper design, the slender and weak distal end of the stem is fixed in a comparatively thick cement mantle. Bending of the stem during loading may cause disruption of the proximal bone-cement interface. Proximal debonding increases both the fatigue stress of the distal part of the stem and the distal bone-cement interface shear stress. Hence, we believe that the same process underlies both the loosenings and the stem fractures. The non-union of the femoral osteotomy (Figure 2) results in a similar stress distribution to the stem as proximal bone—cement debonding.

In 1986, the 316L stainless steel was exchanged for wrought high nitrogen stainless steel (Orthinox) with a higher ultimate tensile strength, and the original polished finish of the Exeter stem was reintroduced. The matt surface was supposed to obstruct distal movement of the stem in the cement, interfering with the proximal stem impaction at the upper end of the femur. Proximal stem impaction was considered necessary to prevent fracture of the slender distal third of the stem (Fowler et al. 1988). However, present evidence indicates that the stem is always completely separated from the cement by a fibrous membrane up to 100 µm in thickness (Fornasier and Cameron 1976, Anthony et al. 1990). Considering also the forces transmitted by the stem, it seems unlikely that the slightly matt finish can prevent stem subsidence. On the other hand, case 5 (Figure 1), where a protracted and considerable stem-sinking took place, shows that subsidence does not prevent stem fracture. It is still a matter of controversy whether the cement-metal interface should be slippery or as strong as possible to protect the cement-bone interface (Jasty et al. 1991, Harris 1992, Ling 1992). A matt stem surface is expected to increase wear debris production and endosteal bone lysis (Anthony et al. 1990), but our material does not

indicate that this was a main reason for the stem fractures.

Improved cementing was also believed to reduce the incidence of stem fracture (Fowler et al. 1988). This is not supported by our findings, in which cement pressurizing technique was employed. The Swedish national multicenter study (Malchau et al. 1993) indicates better short-term results with polished Exeter stems than with the matt ones, but this could also be an effect of improved cementing. Long-term results are necessary to establish the fracture-resistance of the present Exeter stem design, since 2 of our stems did not fracture until nearly 10 years postoperatively.

References

Amstutz H C, Yao J, Markolf K, Dorey F. Stem fracture incidence in Trapezoidal-28 stainless steel hip arthroplasty. Clin Orthop 1990; 256: 105-14.

Anthony P P, Gie G A, Howie C R, Ling R S M. Localised endosteal bone lysis in relation to the femoral components of cemented total hip arthroplasties. J Bone Joint Surg (Br) 1990; 72 (6): 971-9.

Carlsson Å S, Gentz C-F, Stenport J. Fracture of the femoral prosthesis in total hip replacement according to Charnley. Acta Orthop Scand 1977; 48: 650-5.

Chao E Y S, Coventry M B. Fracture of the femoral component after total hip replacement. J Bone Joint Surg (Am) 1981; 63 (7): 1078-94.

Charnley J. Fracture of the femoral prostheses in total hip replacement. Clin Orthop 1975; 111: 105-20.

Charnley J. Low-friction arthroplasty of the hip. Theory and practice. Springer-Verlag. Berlin Heidelberg New York 1979; 21-4.

Dall D M, Learmonth I D, Solomon M I, Miles A W, Davenport J M. Fracture and loosening of the Charnley femoral stems. J Bone Joint Surg (Br) 1993; 75 (2): 259-65.

DeLee J G, Charnley J. Radiological demarcation of cemented sockets in total hip replacement. Clin Orthop 1976; 121: 20-32.

Fornasier V L, Cameron H Y. The femoral stem/cement interface in total hip replacement. Clin Orthop 1976; 116: 248-52.

Fowler J L, Gie G A, Lee A J C, Ling R S M. Experience with the Exeter total hip replacement since 1970. Orthop Clin North Am 1988; 19: 477-89.

Gruen T A, McNiece G M, Amstutz H C. Modes of failure of cemented stem-type femoral component: a radiographic analysis of loosening. Clin Orthop 1979; 141: 17-27.

Harris W H. Is it advantageous to strengthen the cement-metal interface and use a collar for cemented femoral components of total hip replacements? Clin Orthop 1992; 285: 67-72.

Harris W H, McCarthy J C Jr, O'Neill D A. Femoral component loosening, using contemporary techniques of femoral cement fixation. J Bone Joint Surg (Am) 1982; 64 (7): 1063-7.

Jasty M, Maloney W J, Bragdon C R, O'Connor D O, Haire T, Harris W H. The initiation of failure in cemented femoral components of hip arthroplasties. J Bone Joint Surg (Br) 1991; 73 (4): 551-8.

Ling R S M. The use of a collar and precoating on cemented femoral stems is unnecessary and detrimental. Clin Orthop 1992; 285: 73-83.

Malchau H, Herberts P, Ahnfeldt L. Prognosis of total hip replacement in Sweden. Follow-up of 92,675 operations performed 1978-1990. Acta Orthop Scand 1993; 64 (5): 407-506.

Martens M, Aernoudt E, De Meester P, Ducheyne P, Mulier J, De Langh R, Kestelijn P. Factors in the mechanical failure of the femoral component in total hip prosthesis. Acta Orthop Scand 1974; 45: 693-710.

Munuera L, Garcia-Cimbrelo E. The femoral component in low-friction arthroplasty after ten years. Clin Orth 1990; 279: 163-75.

Ritter M A, Campbell E D. An evaluation of Trapezoidal-28 femoral stem fractures. Clin Orthop 1986; 212: 237-44.

Rockborn P, Olsson S. Loosening and bone resorption in Exeter hip arthroplasties. J Bone Joint Surg (Br) 1993; 75 (6): 865-8.

Schulte K R, Callaghan J J, Kelley S S, Johnston R C. The outcome of Charnley total hip arthroplasty with cement after a minimum twenty-year follow-up. J Bone Joint Surg (Am) 1993; 75 (7): 961-75.

Willert H-G, Buchhorn U, Zichner L. Clinical experience with Mueller total hip endoprostheses of different design and material. Arch Orthop Trauma Surg 1980; 97: 197-205.

Wroblewski B M. Fractured stem in total hip replacement. A clinical review of 120 cases. Acta Orthop Scand 1982; 53: 279-84.

Wroblewski B M, Siney P D. Charnley arthroplasty of the hip. Clin Orthop 1991; 292: 191-201.