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FRACTURE OF THE FEMORAL PROSTHESIS IN TOTAL HIP REPLACEMENT ACCORDING TO CHARNLEY

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An analysis of 14 fractures of the stem of the early design of low friction arthroplasty showed a predominance of heavy, bilaterally operated males. The total incidence was 0.67 per cent. The fractures occurred between 14 months and 5 years postoperatively. Every fracture was preceded by radiological signs of loosening caused by varus positioning of the femoral head prosthesis and defective cement support medially at the femoral calcar.

Key words: hip; arthroplasty

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Fracture of the metallic stem of the femoral head prosthesis in total hip replacement (THR) has been reported for many prosthetic designs (Buchholz & Noack 1973, Charnley 1975, Dandy & Theodorou 1975, Leinbach & Barlow 1973, Martens et al. 1974, Wilson & Scales 1973).

The low friction arthroplasty, *ad modum* Charnley, was introduced into Sweden in 1967. A questionnaire sent to the orthopaedic clinics using this method revealed 14 stem fractures. All prostheses were of the so-called first generation with a flat back. They were made of wrought air-melted 316-L stainless steel and all came from the same manufacturer (Thackray, Leeds, England). Revision operations were performed on every hip. In no instance was there any suspicion of infection at the clinical, radiographic, bacteriological or laboratory investigations.

The aim of the present investigation has been to collect the clinical details and technical data of the 14 fractures. The analysis is based on all hips operated upon according to the method of Charnley during the period 1967–1974 in the orthopaedic departments of the General Hospital in Malmö, Södersjukhuset in Stockholm, the Central Hospital in Falun and the University Hospital in Lund.

MATERIAL AND RESULTS

A summary of the pertinent data of the 14 cases is given in Table 1.

Diagnosis

In all 14 patients the arthroplasty was a primary operation because of osteoarthrosis of the hip.

Age

The age at the primary intervention ranged from 56 to 81 years. The average—64.1 ± 6.8 years—did not deviate significantly from the average age of all 309 patients undergoing low-friction arthroplasty at Malmö General Hospital between 1968 and 1972 (65.5 ± 9.1).

Table 1. Pertinent data of the 14 patients with fracture of the femoral prosthesis following total hip replacement.

Hospital*)	Name	No.	Age	Sex	Weight (kg)	Op. date (month/year)	Op. to fracture (months)	X-ray delay (months)	Site of the fracture (mm)	The other hip	Cement thickness at calcar (mm)	Cement below the prosthesis (mm)	Lateral radio-lucent zone (mm)	Appearance of lateral zone (months)	Fract. of cement (months)	Position of the stem prosthesis
MGH	EN	1	61	M	93	9/70	41	14	71	THR	1	25	3	13	25	varus
MGH	EM	2	62	F	62	3/73	30	–	79	THR	3	40	4	3	3	varus
MGH	DJ	3	57	F	60	10/72	44	–	85	THR	6	50	–	–	no	neutral
MGH	EE	4	60	F	85	4/70	65	3	90	OA	2	20	5	5	no	varus
SÖS	HB	5	59	M	90	12/70	44	2	83	OA	7	12	5	27	no	neutral
SÖS	CD	6	70	M	98	11/73	14	–	72	Normal	5	30	13	13	no	varus
SÖS	SHL	7	56	M	115	5/69	58	–	84	THR	5	25	2	24	no	varus
SÖS	OG	8	64	M	90	3/69	62	–	66	OA	5	22	5	32	no	varus
SÖS	HL	9	67	M	95	4/70	40	12	81	THR	3	30	3	4	4	neutral
SÖS	SL	10	64	M	102	10/70	46	13	75	OA	3	28	9	6	6	varus
FL	KH	11	81	M	93	4/72	40	–	77	Arthrodesis	–	–	–	–	–	varus
FL	AA	12	73	M	81	11/72	38	6	82	OA	–	–	–	–	–	varus
UHL	HH	13	60	M	84	4/71	66	–	61	THR	0	16	3	2	no	varus
UHL	UH	14	63	F	57	11/73	35	1	100	THR	13	42	2	6	no	varus

*) MGH = Malmö General Hospital
SÖS = Södersjukhuset, Stockholm
FL = Falu Lasarett, Falun
UHL = University Hospital, Lund

Table 2. Details of the contralateral hip in the seven patients in the fracture group with bilateral THR.

		The fractured side	The contralateral hip					
Pat. no.	Name	Operation to fracture (months)	Operation to present date—Dec. 31, 1976 (months)	Design C=Charnley B=Brunswik	Cement thickness at the calcar (mm)	Cement below the prosthesis	Position of the prosthesis	Lateral radio-lucent zone (mm)
1	EN	41	55	C	1	45	varus	1
2	EM	30	38	B	0	60	varus	none
3	DJ	44	42	C	3	15	neutral	1
7	SHL	58	78	C	3	5	varus	2
9	HL	46	71	C	5	55	varus	4
13	HH	66	76	C	2	5	varus	2
14	UH	35	38	C	4	25	varus	1

Sex

Four of the 14 fractures were in women. In the total material the female preponderance is about three:two. The difference in sex distribution between the fractured and the unfractured group is statistically significant ($P < 0.001$) (Table 3).

Weight

In order to compare the weights of patients with and without fractured stems, 234 weights were sampled, distributed with regard to age and hospital in the same way as the 10 men in the fracture group. The weight of the 10 men was 94.1 ± 9.6 kg as compared with 77.0 ± 12.2 kg in the controls. The difference was highly significant ($P < 0.001$).

The other hip

Of the 14 patients, seven had a THR, five osteoarthrosis and one an arthrodesis on the contralateral side. In only one patient was the other hip normal.

Of the 984 patients undergoing THR at Malmö General Hospital and Södersjukhuset, Stockholm between 1967 and 1974, 130 were operated on both sides and in this latter group there were more fractures of the stem (the difference was significant, $P < 0.01$). In five out of seven cases the fractured side was the first operated.

As seen in Table 2, one unfractured hip had been implanted for almost as long a period as the fractured prosthesis, and the other six unfractured hips survived the fractured hips by 3 to 20 months. This could not be explained on the basis of superior surgical technique. Only in case no. 3 was the position of the stem prosthesis entirely correct on both sides.

Time of fracture

The fractures occurred between 14 months and 5 years and 6 months after the operation (average 44.5 ± 14.4 months) (Figure 1). As 7 out of the 14 fractures were overlooked at one radiographic examination, the diagnosis was delayed for 1, 2, 3, 6, 12, 13 and 14 months, respectively. The average delay was 7.3 months. In patient no. 4 the fracture was revealed at operation, performed because of severe pain and radiographic signs of loosening of the stem prosthesis. There was no tendency for the very heavy patients to fracture their prostheses earlier.

The hips were revised between 1 month and 1 year and 9 months after the fracture.

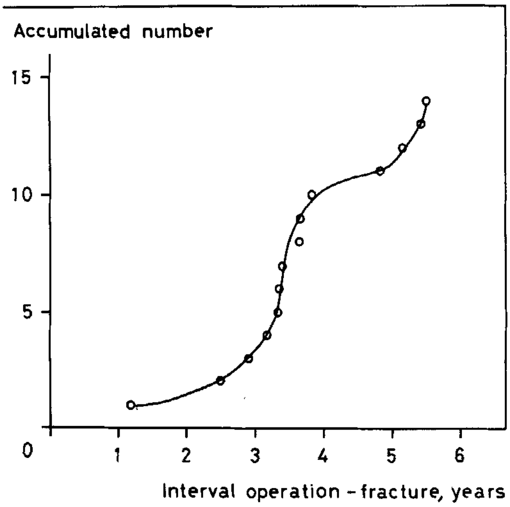

Figure 1. Accumulated number of fractured stems and year after surgery.

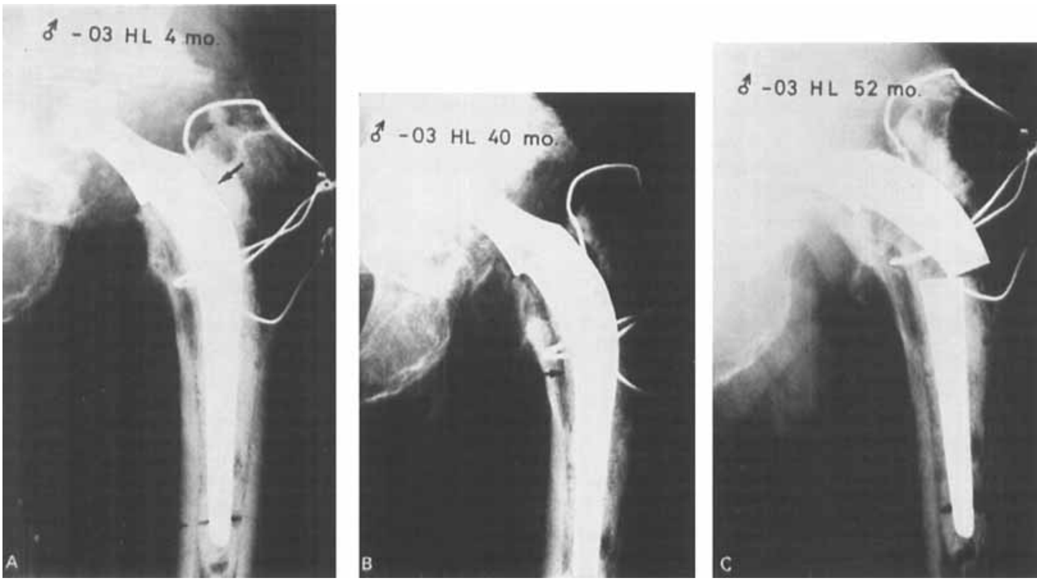

Figure 2. a) Patient no. 9, 4 months postoperatively. A radiolucent zone is already seen at the lateral proximal border of the stem. b) The same patient 40 months postoperatively. The fracture was overlooked. c) The same patient 52 months postoperatively.

Pain and trauma

The result of the primary operation was in every case excellent and all patients walked without a stick. In nine patients there was a history of slowly increasing pain, in four cases preceded by a moderate trauma. The remaining five patients suddenly felt pain without any kind of trauma or previous discomfort.

Torsion of the prosthesis

At the time of this investigation six of the fractured prostheses could be traced. Of these, three were not only fractured but their proximal fragments were slightly twisted. The proximal fragment of prosthesis no. 8 was also bent.

Radiological findings

Level of the fracture. The level of the fractures, as calculated from the radiographs and corrected for magnification, ranged from 61 to 100 mm from the tip of the stem (average 80 ± 10 mm).

Cement-support at the femoral calcar. The thickness of the cement-layer between the metal and the medial cut surface of the femoral neck could be measured in 12 cases, and ranged from 0 to 13 mm (average 4 ± 3). In two cases the cement did not contain radio-opaque material and therefore it was not possible to calculate the thickness.

Cement-support below the tip of the stem prosthesis. In the 12 cases where radio-opaque cement was used, the amount of cement below the tip of the stem was measured and varied between 12 and 50 mm (average 28 ± 11 mm).

All prostheses were rigidly fixed distally in the marrow cavity.

Lateral radiolucent zone. Loosening of the femoral head prosthesis within the cement bed can be seen as a radiolucent zone at the lateral border of the proximal stem (Figure 2a). This phenomenon could be studied in 11 of the 14 hips. In two cases, non-opaque cement, and in one case, dislocation of the greater trochanter, made calculation impossible.

All 11 fractures were preceded by the appearance of a zone of radiolucency, which was first seen between 2 and 32 months postoperatively (average 12 ± 11 months) or between one and 64 months before fracture (average 33 ± 18 months). The maximal width of this zone, measured before the fracture occurred, ranged from 2 to 13 mm (average 5 ± 3 mm).

Fracture of the cement. Fracture of the cement is another sign indicating a loose stem prosthesis. Such a fracture was seen, usually in the vicinity of the tip of the stem, in 4 of the 12 cases before the stem fractured. For the reasons previously mentioned, two hips could not be judged.

Position of the femoral head prosthesis in the *shaft.* Eleven stem prostheses had been placed in a varus position and the remaining three in a neutral position. None was placed in valgus.

Incidence of fracture

The incidence of fracture calculated with a minimum observation time of 2 years was 0.67 per cent. The incidence for females was 0.33 per cent and for males 1.14 per cent (Table 3).

Table 3. Number of fractured and unfractured hips in males and females at the four orthopaedic departments contributing to this investigation.

	No fracture	Fracture	Total
Female	1213	4	1217(0.33 %)
Male	860	10	870(1.14 %)
Total	2073	14	2087(0.67 %)

DISCUSSION

Charnley (1975) reported 17 fatigue fractures of the femoral head prosthesis and pointed to the mechanism—poor proximal and rigid distal fixation. Our findings agree entirely with this.

Possibly excluding defects of the material, fracture of the metal is merely the ultimate fate of a loosened prosthesis. When the stem is loose within the cement, the stresses in the stem increase significantly (Amstutz & Markolf 1974). This may cause fatigue or corrosion or a combination of both factors which presumably will not occur in a properly placed and cemented prosthesis.

Not one of the failed hips was infected. This is in line with the conditions necessary for fracture to occur—rigid distal fixation. In an infected femoral shaft, the zone of resorption between bone and cement increases and the femoral prosthesis, together with the surrounding cement, becomes loose within the marrow cavity. At the same time, severe pain usually prevents normal use of the hip.

At first we expected the patients with fractured stems to be younger than the average. That this was not the case may reflect the discrepancy between chronological and biological ages as these patients were all very active. The great preponderance of men over women is presumably a reflection of their greater weight—in no case less than 81 kg.

Like Charnley (1975), we found an over-representation of bilateral arthroplasties—a most confusing finding. By measuring the wear of the socket, Charnley (1975) found no indication that the unfractured side had been noticeably spared. Could it be that a normal hip on the contralateral side spares the prosthetic hip, even when the patient is free from symptoms?

The level of the fracture and time of failure are in accordance with Charnley's (1975) findings. He also noted the risk of the fracture being overlooked at the radiographic examination, especially if this is performed soon after the fracture has occurred. This is not a catastrophe, but in three of our seven overlooked cases the diagnosis was delayed for 1 year or more. The result was unnecessary suffering for these patients. In cases with THR and pain, especially acute pain, we suggest that the possibility of stem fracture be drawn to the attention of the radiologist so that adequate exposures and projections can be obtained.

The observation that the fractured prostheses were twisted shows that important multidirectional forces act on the hip joint. Except for the vertical and medial forces, the most important is probably a posterio-anterior force acting on the flexed hip joint. Here the sharp corners of the flat-backed prosthesis could be weak points.

The present development in the field of metallurgy has resulted in a vacuum remelted low-carbon stainless steel with improved properties. Also the design of the low-friction arthroplasty has been considerably improved. The sharp corners have disappeared and the back is rounded and strengthened. Flanges of the proximal stem are introduced so that the prosthesis is now more able to withstand the medial directed force. At the same time the flanges prevent the stem from close bone contact anteriorly or posteriorly thus permitting a thick layer of cement around the whole stem.

The incidence, 0.67 per cent is significantly above ($P < 0.01$) Charnley's (1975) 0.23 per cent incidence although he excludes fractures occurring less than 3.5 years postoperatively. Considering the great risk of overlooking the fracture and the fact that the majority of the fractures appear more than 2 years postoperatively, there is reason to believe that the true incidence is somewhat greater than that calculated from our observations.

The patient at risk is obviously a heavy male patient with bilateral total hip replacements, with prostheses placed in varus position having weak proximal and rigid distal fixation.

The above-mentioned improvements in material and design as well as improvements in surgical technique, especially the valgus position, will probably cause a decreased incidence of stem fractures in the future.

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