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Tc-scintimetry in 56 cementless hip arthroplasties

A prospective, randomized comparison of two femoral components

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In a prospective, randomized study of cementless total hip arthroplasties, radionuclide images as well as radiographs were obtained at 6, 12, and 36 months postoperatively. The femoral component was porous-coated, rigid in 28 patients and smooth, isoelastic in 28. The radionuclide uptake was quantified in the regions of interest and correlated to the non-operated side. Among prostheses considered to be stable 3 years after surgery, the activity had normalized in the calcar region. The uptake was also reduced below the tip of the prostheses, but the activity was still 50 percent increased compared to the non-operated side. The isoelastic prosthesis showed less reduction of activity below the tip than the rigid prosthesis. Proximally, the isoelastic prosthesis showed no reduction of activity, whereas the rigid prosthesis had normalized the uptake at the 3-year control. A high rate of non-stable fixation was observed for the flexible prosthesis at the radiographic assessment, which may have contributed to the increased radionuclide activity.

Sequential scintimetry may be used as a complement to the radiographic evaluation of the femoral component of the hip prosthesis.

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Scintigraphy reflects the physiologic events in bone. Therefore it has become an important tool for the orthopedic surgeon in diagnosing diseases with altered skeletal turnover such as osteomyelitis, bone tumors, and fractures. It could also be an essential part in the diagnostic armament of early loosening of cemented arthroplasties (Gelman et al. 1978, Weiss et al. 1979, Rushton et al. 1982, deRossi and Focacci 1983, Lyons et al. 1985). However, the role of bone scanning in cementless total hip arthroplasties has not been clearly defined (Schicha et al. 1986, Oswald et al. 1989, Snorrason et al 1989, Lifeso et al. 1991, Rosenthall et al. 1991). Up till now there have been few reports quantifying the uptake (Rosenthall et al. 1991).

The aims of this study were to evaluate the scintimetric pattern in a prospective, randomized study of 2 mechanically different cementless hip prostheses. We also wanted to observe the remodeling process following surgery. Our third purpose was to determine if bone scanning could be used as a tool to detect early loosening.

Patients and methods

Between 1986 and 1990, 56 patients (52 ± 8 years), 24 women and 32 men, with unilateral hip affection were operated on at our department by 2 senior members. 42 patients had arthrosis, 5 slipped epiphysis, 3 Perthe's disease, 4 were traumatic in origin, 1 had osteonecrosis secondary to steroid treatment, and 1 patient was believed to have arthrosis secondary to infection. They were matched in pairs regarding sex, age, weight, and radiographic appearance and selected at random to receive either a Butel® (Smith and Nephew Richards, Memphis, TN) or a PCA® (Porous-Coated Anatomic; Howmedica, Rutherford, NJ) femoral component. The Butel prosthesis was designed to obtain flexibility similar to the proximal femur by using four rods (titanium alloy) connected proximally and distally. It has been shown to distribute the forces similar to the normal femur (Djerf and Gillquist 1987) and should therefore exhibit fewer signs of stress-shielding in the long run. In contrast the PCA femoral component is a rigid, anatomically-shaped prosthesis (chromium-cobalt alloy) with a proximal porous coating. Each pair was operated on by the same surgeon through a standardized dorsolateral approach. 3 different acetabular components were used: PCA (n 28), a press-

Table 1. The radiographic criteria of loosening at the 3-year follow-up. Stem breakage was considered as a definite criterion of loosening

Fixed if both are true	Possibly fixed if one is true	Possibly loose if one is true	Loose if two are true
≤ 1 mm zone in less than 50 percent of contact area	≤ 2 mm zone in less than 50 percent of contact area	≤ 2 mm zone in more than 50 percent of contact area	> 2 mm zone in more than 50 percent of contact area
no tilting nor migration	no or only initial migration	> 2 mm zone anywhere	tilting or migration > 5 mm
		progressive migration, < 5 mm	progressive loosening of beads
			pedestal formation

fit cup with 2 pegs; Ti-Fit (n 27) (Smith and Nephew Richards, Memphis, TN) and Romanus (n 1) (Biomet, Warsaw, Indiana), which are both threaded cups.

They were followed clinically with the Harris (1969) hip score and radiographically with 3- and 6-month, 1-, 2-, and 3-year follow-ups. Scintimetry was performed at 6 months, 1 year and 3 years postoperatively and images were obtained in 54, 53, and 51 patients, respectively. In 3 patients, the 3-year bone scans were not obtained because of prior revision of the femoral components. 1 patient had a total hip arthroplasty on the contralateral side 2 years after the index procedure. In another 5 cases we did not succeed in obtaining the complete series of images. No early or late septic complications were recorded.

The plain radiographs were analyzed at the 3-year follow-up according to our criteria of loosening, and the femoral components were graded as fixed, possibly fixed, possibly loose, and loose (Table 1). Heterotopic bone formation was classified in accordance with Brooker et al. (1973). The medial area of the femoral neck was estimated in the A/P view and the reduction in relation to the postoperative view was graded as slight (0–25 percent), moderate (25–50 percent), or marked (> 50 percent) and the occurrence of distal cortical thickening was registered.

Images were taken with a gamma camera 3–4 hours after intravenous administration of 600 MBq of ^{99}Tc-MDP. Both anterior and posterior views were taken. The 2 regions of interest, where data were analyzed, were the medial femoral neck and the tip of the femoral prosthesis. The mean count was registered in these regions and then divided by the corresponding value on the contralateral side to define scintigraphic indices (Figure 1). Both the anterior and posterior images were used in the mathematical process. Therefore, these indexes express the uptake of the radionuclide in relation to the non-operated side. The uptake on the acetabular side was not recorded because of technical difficulties in obtaining images that allowed adequate analyses.

A two-sided Student's *t*-test was used in the statistical analysis. The difference was considered significant when $P < 0.05$. Values are expressed as mean *SD*. n represents the number of eligible patients in the scintimetric comparison.

Results (Table 2)

The ratios in Gruen's zones 4 and 7 (Gruen et al. 1979) versus time are shown in Table 3. The reduction between the 6-month and 3-year uptakes was 18 percent (*P* 0.001) for Butel and 44 percent (*P* 0.001) for PCA referring to zone 4. The corresponding values in zone 7 were 9 percent (*P* 0.1) and 28 percent (*P* 0.001).

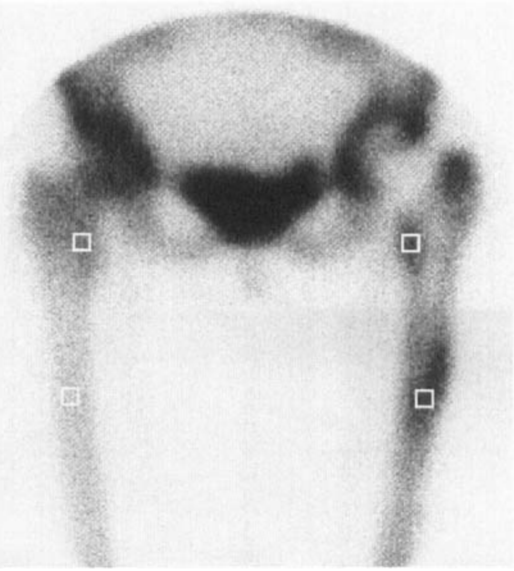

Figure 1. Regions of interest in the scintigraphic evaluation.

Table 2. Observations in 56 cases of uncemented total hip arthroplasties

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	34	m	100	48	ti-fit	butel	–	–	2.37	–	–	0.02	4	1	2	no	no	0	0	1.5	3	3			
2	59	m	95	96	ti-fit	butel	1.45	–	1.46	3.42	–	2.25	0	1	2	no	no	0	0	1.5	2	2			
3	59	m	93	96	ti-fit	butel	1.61	1.42	0.03	2.24	0.02	0.02	0	1	1	no	no	0	0	0	1	2			
4	56	m	65	54	ti-fit	butel	1.06	1.24	1.24	2.12	2.07	0.02	3	2	3	no	no	0	0	3	7	4			
5	45	f	68	56	ti-fit	butel	1.47	1.15	0.01	2.57	0.02	1.24	2	1	1	no	no	0	0	2.5	2.5	3			
6	58	f	80	81	ti-fit	butel	0.98	0.01	0.01	1.57	0.02	1.31	0	2	2	no	no	0	3	0	2	3			
7	56	f	100	96	ti-fit	butel	2.21	2.57	2.08	0.03	2.25	1.34	1	1	2	no	no	0	2	1.5	6	3			
8	59	m	93	67	ti-fit	butel	2.08	1.09	0.02	0.03	2.28	2.41	3	1	1	no	no	0	0	0.5	2.5	4	3.2	a, b	s
9	56	f	80	83	ti-fit	butel	1.43	1.43	1.58	0.02	0.02	0.02	0	3	3	no	yes	0	0	5	7	4			
10	39	m	91	100	ti-fit	butel	1.76	0.02	2.14	2.16	3.56	2.50	2	1	1	no	no	1	1	1	3	4	3	c	s
11	46	m	67	67	ti-fit	butel	2.14	2.18	0.02	0.04	0.03	0.04	0	1	2	no	no	0	0	1	3	3			
12	61	f	63	88	ti-fit	butel	1.54	1.46	1.56	0.02	1.44	0.02	0	2	2	no	no	1	4	2	6	3			
13	57	f	82	81	ti-fit	butel	1.54	1.42	1.49	0.02	0.02	0.02	0	1	2	no	yes	0	1.5	1	2	4			
14	61	f	94	93	ti-fit	butel	2.19	1.49	1.24	0.02	1.58	1.19	3	1	1	no	no	0	0.5	1	2.5	3			
15	55	m	86	100	rom	butel	1.51	1.45	01.30	0.03	0.02	2.42	1	2	2	no	no	0	0	0	4	3			
16	51	m	96	96	pca	butel	2.03	2.14	2.44	0.03	2.09	0.02	2	1	1	no	no	0.5	2	1.5	2	2			
17	57	m	87	86	pca	butel	1.55	1.38	1.25	0.02	1.46	1.29	3	1	1	no	no	1	1	1	2	3			
18	60	m	85	52	pca	butel	1.19	1.12	0.01	2.12	0.02	0.02	1	1	1	no	no	0	1	1	2.5	3	2.9	a, b	s
19	49	f	73	65	pca	butel	1.71	1.31	1.09	1.32	1.16	0.01	1	1	1	no	no	0	0	1.5	5	3			
20	23	f	100	93	pca	butel	1.53	1.49	1.25	0.02	0.02	2.19	0	2	3	no	no	0.5	0.5	5	6	3			
21	46	m	96	97	pca	butel	1.79	1.58	01.20	0.02	1.53	1.37	0	1	1	no	no	0	0	1.5	2	3			
22	51	f	70	64	pca	butel	1.87	0.02	1.33	0.02	2.58	1.57	2	1	1	no	no	0	0	3.5	4	3			
23	59	m	83	73	pca	butel	1.37	1.42	1.53	1.46	1.54	1.36	3	1	1	no	no	0	0	2	7	4			
24	61	m	96	93	pca	butel	1.75	1.58	1.48	0.03	2.10	0.02	3	1	1	no	no	0	0	1	2	1			
25	55	m	73	42	pca	butel	1.50	1.24	1.37	0.02	0.02	1.59	3	1	1	no	no	0	0	1.5	3	3			
26	56	f	50	75	pca	butel	1.20	1.02	–	0.02	0.02	–	0	1	1	no	no	0.5	1.5	1.5	2	3			
27	49	m	91	–	pca	butel	1.54	0.02	–	2.37	3.28	–	3	2	–	no	–	0	–	2	–	4	2.6	a, b	c+s
28	52	f	80	78	pca	butel	3.30	2.53	2.48	2.41	2.27	0.02	0	1	1	no	no	0	0	4	8	3			
29	38	m	96	100	pca	pca	–	1.37	0.02	–	0.03	2.25	2	2	2	no	yes	1.5	0	0	0	1			
30	57	m	93	100	ti-fit	pca	0.99	–	0.01	2.26	–	0.02	0	1	1	no	no	0	0	0.5	1	1			
31	60	m	93	100	ti-fit	pca	1.22	1.14	0.01	2.43	0.02	1.27	0	1	2	no	no	0	0	0.5	1	2			
32	51	m	100	100	ti-fit	pca	1.32	0.01	0.01	2.47	0.02	1.15	0	2	2	yes	no	0	0	1	1	2			
33	44	f	73	100	ti-fit	pca	0.95	0.01	–	0.02	1.43	–	0	2	2	no	no	0	0	0	0	1			
34	55	f	100	100	ti-fit	pca	1.37	1.15	0.01	0.02	2.21	1.21	3	1	1	no	yes	0	0	0.5	0.5	1			
35	59	f	93	97	ti-fit	pca	1.10	0.01	0.01	3.56	0.02	1.22	4	1	2	yes	yes	0	0	0.5	1	1			
36	59	m	93	100	ti-fit	pca	2.00	0.03	1.33	0.03	2.17	1.56	3	2	2	no	no	2	2	1	1	2			
37	52	f	86	91	ti-fit	pca	1.05	0.01	0.01	2.26	0.02	0.01	0	2	2	no	no	0	0	0.5	1	1			
38	41	m	76	89	pca	pca	1.89	1.29	1.09	2.54	2.13	1.54	3	1	1	no	yes	0	0	0.5	0.5	1			
39	39	m	100	100	ti-fit	pca	1.66	0.01	0.01	0.03	2.31	0.02	0	2	2	no	yes	0	0	0.5	1	1			
40	56	f	100	100	ti-fit	pca	1.47	1.28	0.01	0.02	1.53	1.09	0	2	3	no	no	0	2.5	0.5	1.5	1			
41	59	f	100	96	ti-fit	pca	1.20	1.29	0.01	2.26	1.55	1.25	4	3	3	no	no	0	0	0	0.5	1			
42	62	f	58	59	ti-fit	pca	1.13	1.06	0.01	2.41	2.01	0.02	3	1	2	yes	yes	0	0	1	1.5	2	3.4	a, b	c
43	57	m	29	–	ti-fit	pca	2.26	2.31	–	4.17	0.05	–	3	2	–	yes	***	0	–	1.5	–	4	2	a, b	s
44	54	m	61	67	pca	pca	1.43	1.32	01.10	2.16	0.02	1.08	1	1	1	yes	yes	0	0	0	0	2			
45	53	m	100	–	pca	pca	1.52	1.15	–	3.18	0.02	–	3	2	–	yes	***	0	–	1	–	3	2.6	a, b	s
46	58	m	100	96	pca	pca	1.16	0.01	0.01	0.03	3.35	2.36	3	1	1	yes	yes	0	0	0.5	1	2			
47	49	f	95	100	pca	pca	1.10	0.01	0.01	02.50	0.02	0.01	4	2	2	yes	yes	0	0	0	0	1			
48	30	f	93	93	pca	pca	1.0	1.13	0.01	0.03	2.09	1.25	0	2	2	yes	yes	0	0	0	0	1			
49	44	m	96	100	pca	pca	1.63	1.48	0.01	0.03	3.04	0.02	1	2	2	yes	yes	0	0	0	0	1			
50	52	f	100	100	pca	pca	1.47	1.26	1.01	0.02	1.54	1.45	3	1	1	no	yes	0	0	0	0	1			
51	55	m	95	91	pca	pca	1.17	1.11	0.01	0.04	2.06	0.02	0	1	1	no	no	0	0	0	1	1			
52	59	m	83	100	pca	pca	1.31	1.02	0.01	0.03	2.12	1.48	3	1	1	no	no	0.5	1	0	0.5	1			
53	52	m	73	93	pca	pca	2.54	0.02	1.31	2.15	2.24	1.21	4	2	2	no	no	0	0.5	0.5	0.5	3			
54	54	f	93	100	pca	pca	1.18	01.10	0.01	0.03	01.10	0.01	0	1	2	yes	yes	0	0	0	2	2			
55	47	m	90	87	pca	pca	1.13	1.41	1.22	3.15	0.02	0.02	0	1	1	no	no	2	4	0	1	3			
56	55	f	97	96	pca	pca	1.66	1.17	1.47	2.2	1.3	1.34	0	1	1	no	no	0.5	0.5	0	3	4			

A Case
B Age
C Gender
Harris hip score:
D 1-year
E 3-year
F Acetabular component
G Femoral component
Scintigraphic index in calcar region:
H 6-month
I 1-year
J 3-year
Scintigraphic index below the tip:
K 6-month
L 1-year
M 3-year

N Ectopic bone formation
 0 no
 1 islands
 2 < 1 cm
 3 ≥ 1 cm
 4 bridging
Percent reduction of the calcar region:
O 1-year
P 3-year
 1 < 25%
 2 25–50%
 3 > 50%
Distal sclerosis:
Q 1-year
R 3-year
Radiolucency (mm) in zone III:
S 1-year

T 3-year
Radiolucency (mm) in zone I:
U 1-year
V 3-year
W Criteria of loosening of the stem (Table 1)
 1 fixed
 2 possibly fixed
 3 possibly loose
 4 loose
X Time lapse to revision (years)
Y Cause of revision
 a loosening
 b pain
 c stem breakage
Z Component exchange
 c cup
 s stem

Table 3. Scintigraphic activity in relation to the non-operated side at the prosthetic tip and in the calcar region. Mean *SD*

	Zone 4			Zone 7		
Follow-up	Butel	PCA	*P*	Butel	PCA	*P*
1/2-year	2.17 *0.60*	2.61 *0.59*	0.008	1.68 *0.46*	1.42 *0.39*	0.03
1-year	2.00 *0.57*	2.07 *0.73*	0.7	1.53 *0.41*	1.25 *0.40*	0.02
3-year	1.79 *0.56*	1.46 *0.40*	0.02	1.58 *0.53*	1.03 *0.22*	<0.001

Table 4. Scintigraphic uptake in relation to the non-operated side in patients with femoral components considered as fixed or loose at the 3-year follow-up. Mean *SD*

	Fixed	n	Loose	n	*P*
Zone 4					
6 m	2.54 *0.58*	16	2.32 *0.79*	9	0.4
1 y	2.02 *0.43*	16	2.47 *1.17*	9	0.1
3 y	1.48 *0.39*	16	1.89 *0.46*	7	0.04
6 m–3 y	1.15 *0.54*	15	0.16 *0.38*	7	<0.001
Zone 7					
6 m	1.34 *0.28*		1.63 *0.37*		0.03
1 y	1.17 *0.20*		1.50 *0.37*		0.009
3 y	1.01 *0.24*		1.59 *0.28*		<0.001
6 m–3 y	0.40 *0.21*		−0.04 *0.26*		<0.001

The patients with distal cortical hypertrophy at the 3-year review had a mean ratio in zone 4 of 1.54 *0.44* (n 15) while the others had a mean ratio of 1.66 *0.54* (n 36), (*P* 0.5). When the rigid stem was analyzed alone the corresponding values were 1.42 *0.36* (n 12) and 1.50 *0.45* (n 13). We found no correlation between scintigraphic activity and grade of proximal bone loss. Patients with a Harris score of 100 were compared to those with a score less than 80, regarding the scintigraphic activity in zone 4 at the 3-year follow-up; no difference was observed, 1.59 *0.5* (n 15) and 1.75 *0.70* (n 14). Those who developed heterotopic bone, Grades III and IV (n 21), did not show a higher uptake in the proximal femur at the 6-month follow-up than the patients graded as 0 or I (n 29).

5/28 of the rigid prostheses were considered as loose or possibly loose compared to 24/28 in the isoelastic group. The scintigraphic uptake of the fixed and the loose group are compared in Table 4.

With the radiographic analysis as a basis, sensitivity, specificity, and accuracy were defined in different conditions (Table 5). A single scintigraphic image showed a low correlation to the radiographic appearance. However, when a difference of 0.4 or less between scintigraphic indices in zone 4 at the 6-month and 3-year follow-ups was used as an indication of loosening, the sensitivity was 0.86, the specificity 0.74, and the accuracy 0.76. No reduction of the scintigraphic index in the calcar area gave a sensitivity of 0.57, a specificity of 0.88 with an accuracy of 0.84.

Discussion

There seems to be a general consensus that bone scintigraphy can be of value in the diagnosis of septic loosening in cemented total hip arthroplasties.

Table 5. Sensitivity, specificity, and accuracy of the scintigraphic activity expressed with reference to the radiographic assessment

Scintigraphic index	Conditions	True pos.	False pos.	True neg.	False neg.	Sensitivity	Specificity	Accuracy
Zone 4 x zone 7	≤ 2 fixed	7	8	28	10	0.41	0.78	0.66
1 year	≥ 4 loose	3	7	37	6	0.33	0.84	0.75
Zone 4 x zone 7	≤ 1.5 fixed	10	8	26	7	0.59	0.76	0.71
3 years	≥ 3 loose	2	8	36	5	0.29	0.82	0.75
Zone 4	≥ 1.0 fixed	10	10	24	5	0.67	0.71	0.69
0.5–3 years	≤ 0.4 loose	6	11	31	1	0.86	0.74	0.76
Zone 7	≥ 0.4 fixed	7	9	25	8	0.47	0.74	0.65
0.5–3 years	≤ 0.0 loose	4	5	37	3	0.57	0.88	0.84

Sensitivity = true positive / (true positive + false negative).
Specificity = true negative / (true negative + false positive).
Accuracy = (true positive + true negative) / total number

However, the opinions differ concerning painful hips and aseptic loosening (Gelman et al. 1978, Weiss et al. 1979, Rushton et al. 1982, deRossi and Focacci 1983, Sonne-Holm et al. 1983, Lyons et al. 1985, Tehranzadeh et al. 1988, Steen-Jensen and Lysgaard-Madsen 1990). Josef Utz et al. (1986) evaluated the natural history of bone scintigraphy in asymptomatic patients. He concluded that the activity had normalized within 1 year in the majority of patients, although 20 percent showed an increased uptake beyond 1 year.

There is mounting evidence that the pattern of scintigraphic activity in cementless total hip arthroplasties differs from that seen with cemented prostheses (Oswald et al. 1989, Lifeso et al. 1991, Rosenthall et al. 1991). Some authors claim that each prosthetic design has its own scintigraphic pattern (Rosenthall et al. 1991).

One of our aims was to evaluate the bone remodeling process scintigraphically. The hypothesis was that the isoelastic prosthesis should result in fewer signs of stress shielding, and this fact should in turn be reflected in a lower scintigraphic activity. The analysis of the plain radiograms (Jacobsson et al. 1993) confirmed the stress-shielding theory, but the results of the scintigraphy did not seem to accord with the hypothesis. In contrast to Schicha et al. (1986) we could not demonstrate any association between distal cortical thickening and increased activity at the tip of the prosthesis. Nor did we notice any correlation between proximal bone resorption and scintigraphic activity. One possible explanation of the increased activity around the flexible stem might have been the high rate of non-stable fixation.

To our knowledge there are few prospective studies reported in the literature evaluating the bone uptake quantitatively in cementless total hip arthroplasties (Brecht-Krauss et al. 1990, Eckart et al. 1990). Our results indicate that in a well-fixed implant the activity is reduced with time and normalized within 3 years in the calcar region, whereas the activity at the tip is still 50 percent increased compared to the normal femur.

Due to individual variation, a single value does not give sufficient information regarding early loosening. As with plain radiographs, sequential images provide more substantial data concerning loosening (cf. Rosenthall et al. 1991).

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