Scintimetry after total knee arthroplasty.

Prospective 2-year study of 18 cases of arthrosis and 15 cases of rheumatoid arthritis

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33 consecutive patients (18 arthrosis, 15 rheumatoid arthritis), operated on with total knee arthroplasty and randomized to cemented (18 knees) or cementless fixation (15 knees), were investigated with scintimetry 3, 6, 12, and 24 months postoperatively. Migration was evaluated with simultaneous roentgen stereophotogrammetric (RSA) examinations. The scintimetric activity in the ipsilateral femoral diaphysis decreased and the activity in the tibial diaphysis increased during the observation period. Constant and low activity was recorded in front of the femoral component. This region was chosen as a reference. Three months after surgery, high activity was noted under the tibial component in knees with a preoperative varus deformity. After 2 years, the activity had decreased to the same level as in the patients with a valgus deformity. Diagnosis and mode of fixation did not influence the activity. Low postoperative activity was recorded in the tibial metaphyses if no rotatory displacement of the tibial component occurred.

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Submitted 91-06-29. Accepted 91-10-08

Radionuclide bone imaging has been found to be a reliable method to detect aseptic loosening of hip prostheses (Mjöberg et al. 1985, Mjöberg 1986, Snorrason et al. 1989). In total knee arthroplasties, both visual analysis of scintigraphs and scintimetry have been used, and divergent results have been reported (Rosenthall et al. 1987, Duus et al. 1987, 1990, Hofmann et al. 1990). It has been suggested that bone scans might detect loosening of knee replacements (Gelman et al. 1978, Hunter et al. 1980), but the correlation between radionuclide activity and prosthetic fixation has not been completely evaluated.

The aim of this investigation was to study changes in scintimetric activity between repeated postoperative examinations in patients operated on with total knee replacement and to evaluate the influence of prosthetic micromovements (Selvik 1974, Ryd 1986) on the scintimetric activity.

Patients and methods

39 consecutive patients were operated on with the Tricon-M knee prosthesis (Smith and Nephew Richards) between 1986 and 1988. Of these, 33 patients (27 women and 6 men) agreed to participate in this investigation. 18 patients had arthrosis (A) and 15 rheumatoid arthritis (RA). The mean age at the time of the operation was 68 (36–79) years. The patients were randomized to cemented (18 knees) or cementless fixation (15 knees) of the components (Table 1). A patellar prosthesis was used in all but one knee.

The patients were examined clinically at 3, 6, 12, and 24 months postoperatively. The Hospital for Special Surgery knee score was recorded preoperatively and at 24 months (Table 1). The preoperative and postoperative Hip-Knee-Ankle angle (HKA angle) was measured on radiographs obtained in the standing position (Hagstedt et al. 1980). The alignment of the separate prosthetic components was determined (Nilsson et al. 1991).

$^{99}Tc^m$-MDP scintimetry

The patients were examined with scintimetry 3, 6, 12, and 24 months postoperatively. The bone scans were obtained 3 to 4 hours after intravenous administration of 550 MBq of $^{99}Tc^m$-MDP with a gamma camera (General Electric 535) using a low-energy, general purpose collimator connected to a computer system (Digital Equipment PDP 11/34 gamma-11). Knee images were recorded in the anterior projection, as this was the routine at the time for the investigation.

At the scintimetric analysis, five regions of interest (ROI) were outlined on the scans (Figure 1). To determine the optimal location of the ROI planned to be

Table 1. Clinical and radiographic data for 33 patients with knee arthroplasty investigated with scintimetry

Case	Sex	Age	Weight	Diagnosis	Mode of fixation[a]	Knee score[b]		Leg alignment[d] (degrees)	
						preop	2 years[c]	preop	postop
1	F	62	85	RA	C	67	93	187	180
2	M	66	70	RA	C	39	91	170	176
3	F	76	70	A	N	54	92	195	182
4	F	73	53	A	N	58	95	169	179
5	F	66	74	A	C	64	R	200	178
6	F	71	60	RA	C	58	85	188	182
7	F	78	68	A	C	15	86	155	188
8	F	78	68	A	C	56	D	195	188
9	F	62	85	A	C	69	87	165	185
10	F	64	85	A	N	55	74	167	174
11	F	72	65	RA	C	41	86[e]	180	180
12	F	68	80	A	N	57	92	165	180
13	F	36	58	RA	N	64	74	183	182
14	F	76	70	A	C	58	65[e]	185	178
15	F	54	52	RA	N	25	90	186	183
16	M	70	93	A	N	58	96	165	184
17	F	60	85	A	C	41	95	175	185
18	M	55	83	RA	C	48	D	180	182
19	M	68	95	A	C	43	97	166	180
20	F	72	73	A	C	40	86	169	190
21	F	77	70	A	N	50	82	164	184
22	M	74	70	RA	N	13	70	180	180
23	F	62	60	RA	N	51	81	184	187
24	F	74	57	RA	C	23	82	188	189
25	F	71	83	A	N	52	88	196	189
26	F	73	58	RA	C	48	93	160	175
27	F	62	73	A	C	44	91	168	182
28	F	77	58	RA	N	42	93	187	183
29	F	71	56	RA	N	42	91	183	186
30	F	79	60	RA	N	37	90	174	185
31	F	78	67	RA	C	39	84	180	179
32	M	76	90	A	N	48	92	163	184
33	F	68	60	A	C	34	86	167	180

[a] Cemented C, noncemented N.
[b] Hospital for Special Surgery Knee score, maximum 100 points.
[c] Revised R, deceased D.
[d] Leg alignment (HKA angle) > 180° valgus, < 180° varus alignment of the knee.
[e] Refused examination with scintimetry at 2 years.

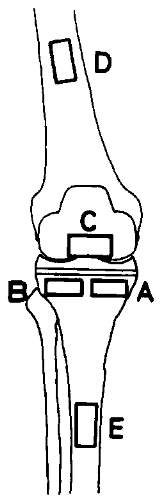

Figure 1. Five regions of interest (ROI) were outlined on the scintigraphs. Areas A and B were used to evaluate the activity under the tibial component. The activity in areas C, D, and E was determined to locate the most suitable reference region.

used as a reference, 2 ROIs were outlined corresponding to the ipsilateral distal femoral and proximal tibial diaphyses, respectively, and one ROI in front of the metallic part of the femoral component. The activity under the tibial component was evaluated using one medial and one lateral ROI in the proximal tibial metaphysis. Counts per pixel for each ROI were recorded. The activity under the tibial component was expressed as a ratio of the chosen reference region.

The activity in front of the femoral component (C in Figure 1) was lower than that of the femoral or tibial diaphyses, and did not change between 3 and 24 months (Table 2). The activity in the patient without a patellar prosthesis was almost the same as the mean value. This ROI was used as the reference in the subsequent calculations because of a low and constant activity.

Table 2. Mean total activity (counts/pixel) in front of the femoral component, and total and relative activity in the distal femoral and proximal tibial diaphyses (mean *SD*; see Figure 1)

	Months postoperatively											
Location of ROI	3		*P*[c]	6		*P*[c]	12		*P*[c]	24		*P*[c]
C In front of the femoral component[a]	32	*10.8*		31	*11.1*		30	*11.9*		31	*10.1*	
D Distal femoral diaphysis[a]	51	*16.8*		46	*13.1*		43	*16.8*		46	*20.9*	
E Proximal tibial diaphysis[a]	39	*15.7*		41	*13.2*		43	*19.3*		48	*23.8*	
D/C[b]	1.67	*0.48*	< 0.001	1.53	*0.36*	< 0.01	1.52	*0.45*	NS	1.51	*0.43*	< 0.05
E/C[b]	1.30	*0.55*		1.37	*0.35*		1.49	*0.50*		1.60	*0.51*	

[a] C versus D or E at 3, 6,12, and 24 months: $0.0005 < P < 0.05$ (ANOVA).

[b] D/C and E/C; difference 3 versus 24 months: $P < 0.05$ (paired *t*-test).

[c] D/C versus E/C at 3, 6,12, and 24 months (paired *t*-test).

Roentgen stereophotogrammetric analysis (RSA)

At the operation, four to nine tantalum markers (diameter 0.8 mm) were inserted into the proximal tibial metaphysis and into the polyethylene of the tibial component. RSA (Selvik 1974, Ryd 1986, Kärrholm 1989, Nilsson et al. 1991) was performed within 1 week and at 3, 6, 12, and 24 months postoperatively.

Micromovements of the tibial prostheses were analyzed as internal/external rotation, varus/valgus and anterior/posterior tilt, subsidence of the prosthetic center and of the prosthetic edge, and maximum migration (MTPM), which is the vectorial sum of the transverse, vertical, and sagittal translations when measured at the most unstable part of the prosthesis (Ryd 1986, Nilsson et al. 1991).

The accuracy of RSA in this series was determined by 76 double examinations made at different occasions. Tibial component rotations were considered to be present if they exceeded the 95 percent confidence interval (0.3° internal/external rotation, 0.45° varus/valgus, and anterior/posterior tilt). The corresponding values for translations varied between 0.15 mm (single axis translation) and 0.2 mm (MTPM, Ryd 1986).

One-way analysis of variance (ANOVA), analysis of variance taking into account effects of synergy (SAS), logistic regression analysis, linear regression analysis, paired *t*-test, chi-2 test, and nonparametric tests were used.

Results

Clinical results

The mean preoperative knee score increased from 46 (13–69) to 87 (65–97) at 24 months. All but 1 patient was painfree in the operated on knee during the investigations. This patient (Case 5, Table 1) developed clinical symptoms and radiographic signs of loosening of the patellar component 18 months postoperatively. She also had pain upon weight bearing. Twenty-one months after the index operation, revision of the tibial and patellar components was performed.

Scintimetric results

23 patients were examined with scintimetry at 3 months, 30 patients at 6 months, and all the patients (33) at 12 months. At 24 months, 28 patients were examined; 2 patients had died of unrelated diseases, 1 patient had been reoperated on, and 2 patients refused to attend.

Femoral and tibial diaphyses. The mean activity of the femoral diaphysis decreased, whereas the activity of the tibial diaphysis increased between 3 and 24 months (Table 2). This tendency was noted in both A and RA patients. At 3 months, patients with preoperative varus deformity had higher activity in both the distal femoral and proximal tibial diaphyses than those with valgus deformity ($P < 0.05$; Wilcoxon's rank sum test). This difference disappeared at the subsequent examinations.

Tibial metaphysis. The preoperative alignment of the knee differed between the A and RA groups. A varus deformity occurred in 13/18 A knees and in 3/15 RA knees, 5 A and 8 RA knees had a valgus deformity, and 4 RA knees were not malaligned preoperatively ($P < 0.01$, chi-2 test, Table 1). At 3 months, the activity in the RA and A knees with a preoperative varus deformity was 9.9 ± 1.9 and 8.9 ± 2.2 (mean ± SD), respectively, in the knees with a valgus alignment 6.3 ± 2.2 (RA) and 6.5 ± 1.8 (A), and in the RA knees without malalignment 5.8 ± 2.8 (NS, Kruskal-Wallis test).

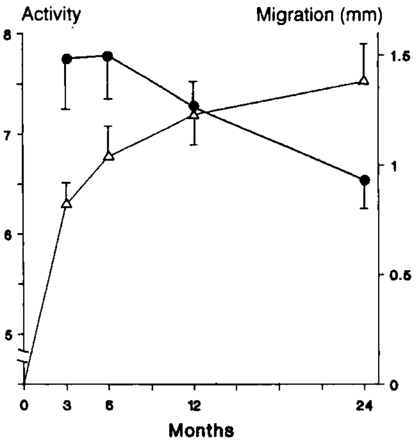

Figure 2. Scintimetric activity (●) and migration (△) for the tibial components in the total material during the first 2 postoperative years (mean, SEM). The total activity decreased between 3 and 24 months ($P < 0.05$; paired *t*-test). The migration of the tibial components (MTPM) was most pronounced during the first 3 to 6 months.

In the total material, the activity decreased from 7.8 ± 2.5 at 3 months to 6.5 ± 1.5 at 24 months (Figure 2). Analysis of variance taking into account effects of synergy revealed that the increased activity at 3 months could only be explained by the preoperative knee alignment, but not by diagnosis, mode of fixation, or weight. Patients with a preoperative varus deformity had 1.4 times higher activity under the tibial component at 3 months than those with a valgus deformity. At 24 months, there were no differences in activity between the two types of deformity, modes of fixation, diagnoses, or weight (Table 3).

At 3 months, knees with preoperative varus deformity displayed higher activity in both the medial and lateral tibial metaphyses than did the knees with preoperative valgus deformity (Figure 3).

Postoperative alignment of the knee or of the separate prosthetic components did not influence the scintimetric activity (linear regression analysis).

Scintimetry and micromotion

The roentgen stereophotogrammetric analysis revealed that the tibial components displayed the largest micromotions during the first 3 to 6 months. Thereafter, the migration tended to level off (Figure 2).

There were no numeric correlations at any time between the scintimetric activity and translatory micromotions or single axis rotations of the tibial components.

Significant rotations of the tibial components about any of the three cardinal axes were found in 19 out of 24 tibial components at 3 months and in 24 out of 28 at 2 years. Absence of significant tibial component rotation at 3 months implied remaining stability at the subsequent examinations, whereas early tibial tray rotations were associated with increasing micromotions between 3 and 24 months. The metaphyseal activity was higher in knees with rotating components than in those with stable components (Table 3). Increasing magnitude of the rotations between 3 and 24 months was not associated with a corresponding increase in the scintimetric activity during the follow-up period.

Table 3. Changes of activity in the tibial metaphysis 3 to 24 months postoperatively (mean *SD*)

Category	Months postoperatively											
	3		*P*	6		*P*	12		*P*	24		*P*
Preop varus deformity (n 16)	9.13	*2.13*	< 0.05[a]	8.54	*2.36*	NS[a]	7.74	*2.61*	NS[a]	6.94	*1.39*	NS[a]
Preop valgus deformity (n 13)	6.33	*2.0*		7.44	*2.49*		6.73	*1.75*		6.23	*1.73*	
A (n 18)	8.50	*2.29*	NS[a]	8.43	*1.83*	NS[a]	7.45	*2.43*	NS[a]	6.92	*1.41*	NS[a]
RA (n 15)	7.12	*2.62*		6.98	*2.86*		7.18	*2.06*		6.10	*1.67*	
Cemented knees (n 18)	8.89	*2.63*	NS[a]	8.21	*2.33*	NS[a]	7.85	*2.43*	NS[a]	6.95	*1.55*	NS[a]
Cementless knees (n 15)	6.89	*2.09*		7.28	*2.49*		6.70	*1.88*		6.19	*1.54*	
"Unstable" (significant rotations)	8.66	*2.26*	< 0.05[b]	8.12	*2.56*	NS[b]	7.64	*2.17*	< 0.05[b]	6.84	*1.45*	< 0.05[b]
"Stable" (insignificant rotations)	5.07	*1.15*		6.94	*1.81*		5.92	*2.14*		4.78	*1.07*	
Case 5 (revised because of loosening)				11.7			10.5			8.9[c]		

[a] Analysis of variance taking into account effects of synergy.
[b] Logistic regression analysis.
[c] At 21 months before revision.

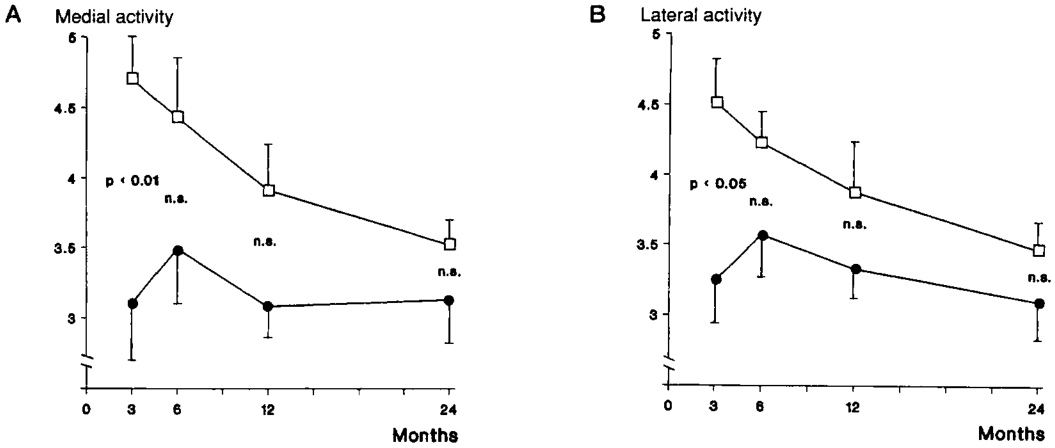

Figure 3. Scintimetric activity (mean, SEM) under the tibial components in preoperative varus knees (□) and valgus knees (●), (Wilcoxon's rank sum test). A. Activity in the medial condyle. B. Activity in the lateral condyle.

In the patient that subsequently was revised (Case 5), RSA revealed an outward rotation (2.5°) and anterior tilting (1.1°) of the tibial component, and a maximum migration (MTPM) of 2.4 mm. High scintimetric activity was found 6 months after the operation and before the onset of symptoms (Table 3).

Discussion

Scintimetry eliminates interobserver variability and provides more reliable information than visual evaluation of scintigraphs (Duus et al. 1990). In scintimetry the identification of the region of interest used as a reference is important. In our series the area in front of the femoral component displayed the lowest activity throughout the observation period. This was probably due to the shielding of the distal femoral metaphysis by the femoral component, leaving only activity from the patella and the soft tissues in front of the knee to be detected (Hofmann et al. 1990). The activity of the distal femoral diaphysis decreased and that of the proximal tibial diaphysis increased during the investigative period. If either of these regions had been used as a reference, the results would have been different. Choosing a reference ROI on the opposite leg would imply that changed activity due to any progression of the usually present arthrosis or subsequent knee-replacement surgery would have influenced the evaluation.

A standardized lateral scintimetric projection of the knee was not available. According to Hofmann et al. (1990) this view does not add significant information to the anterior projection in the evaluation of the proximal tibial metaphysis. However, a lateral projection might have been beneficial, but the evaluation of such a projection would have been difficult due to the problems of finding a constant and low reference ROI.

The decrease in activity in the femoral shaft and the increase in activity in the tibial shaft may be an expression of several surgical effects, such as altered biomechanics of the lower extremity, interference with the osteoarthritic process, and the vascularization of proximal tibia.

Persistent high activity under the tibial component in asymptomatic patients was found up to 2 years postoperatively in our series, as has been reported earlier (Rozing et al. 1982, Schneider and Soudry 1986, Rosenthall et al. 1987, Hofmann et al. 1990, Kantor et al. 1990). This is in contrast to what is usually found in scintigraphy after total hip arthroplasty (THA). In THA, the diseased femoral bone is more or less completely resected. This implies that the effects of surgery and (later) abnormal stress distribution or prosthetic migration can be more easily studied (Mjöberg 1986, Mjöberg et al. 1985, Snorrason et al. 1989). Postoperative $^{99}Tc^{m}$-MDP uptake in the acetabulum may, to some extent, correspond to the proximal tibia because of similar bone structure, but it is difficult to study because of high activity in the urinary bladder.

The postoperative level and the change of scintimetric activity during the 2 postoperative years was found to be influenced by the type of preoperative knee deformity, but not by diagnosis. $^{99}Tc^{m}$-MDP adheres to the mineral phase of the bone, and the increased activity seen in arthrotic joints reflects the increased remodeling processes of the subchondral bone (Radin et al. 1973, Christensen 1985). The bone strength at the proximal tibia is strongly influenced by the preoperative deformity, but not by the diagnosis (Hvid 1988a). Bone strength is strongly correlated with bone density as measured by quantitative computed tomography (Bentzen et al. 1987). Bone density is higher in preoperative varus knees than in valgus knees irrespective of diagnosis (Hvid et al. 1988). This may explain why the RA knees with varus deformity showed as high mean activity in our study as the A knees with a varus deformity. After total knee arthroplasty, the bone density of the preoperatively more loaded condyle decreases with time, whereas the less loaded condyle has unchanged density. In knees with a varus deformity, this decrease in bone mass takes a longer time than in the lateral condyle of valgus knees (Hvid et al. 1988). Initially increased bone mass in preoperative varus knees and postoperative changes of the bone metabolism due to altered loading conditions may explain the pattern of condylar scintimetric activity during the 2 postoperative years in our study.

Osteoporosis is common in long-standing RA, and locally weak trabecular bone is often found at knee surgery (Sledge and Walker 1984). However, only small differences of bone strength have been found between A and RA populations (Lereim et al. 1974, Hvid 1988a), indicating small differences in bone density (Bentzen et al. 1987, Hvid et al. 1988). This may explain the rather equal activity in patients with A and RA in our series. The tendency to generalized loss of bone in RA may be counteracted by the bone pathology related to the development of secondary arthrosis (Hvid 1988b).

Most tibial components displayed significant movements during the study period, making a proper evaluation of the influence of micromotion on the scintimetric activity difficult. In all the patients the largest migrations occurred during the first 3 to 6 months (Nilsson et al. 1991), and thereafter the migration tended to level off, consistent with decreasing scintimetric activity. Even if there seems to be a relation between micromotion and scintimetric activity, this relation is obscured by the effect of the normal postoperative remodeling on the activity.

During the 2 postoperative years, the scintimetric activity in total knee arthroplasty is significantly influenced by the type of preoperative deformity. The exact time period for the remodeling of the subchondral bone after surgery is difficult to establish; but after 2 years, low scintimetric activity indicates absence of prosthetic tilting, whereas high activity indicates prosthetic instability or a high bone remodeling for some other reasons.

Acknowledgements

The statistical advice and calculations of Bo Segerstedt, Department of Statistics, University of Umeå, is gratefully acknowledged. This study was supported by grants from the Swedish Medical Research Council (MFR B91-17x-07941-05A), Riksförbundet mot reumatism, LIC Ortopedi, Samverkansnämnden i Norra Regionen and Medicinska fakultetens fonder vid Umeå Universitet.

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