

## ORIGINAL ARTICLE

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## The relationship between postoperative results and bone dynamics in RA patients who underwent cementless Ortholoc II TKA: histomorphometric study

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**Abstract** We previously reported a histomorphometric study of iliac bone obtained at the time of cementless total knee arthroplasty (TKA) in patients with rheumatoid arthritis (RA). In this paper, we further extended our analysis to investigate the postoperative results and radiographs after TKA in association with bone metabolism. All the patients were female, ranging in age from 38 to 68 years (mean, 56.8 years). Histomorphometric results demonstrated that bone volume and trabecular thickness were decreased, whereas bone absorption and bone formation rate (BFR) were increased. The bone in patients with mutilating disease (MUD) showed remarkably increased bone turnover and osteoporosis compared with those of the more erosive subset (MES) patients. Sixteen out of the 20 patients were alive at the time of follow-up (follow-up period between 5 years 10 months and 8 years 11 months). Among them, 10 patients could be further examined. Radiolucent lines (RLL) were assessed by the modified Knee Society evaluation (scoring) system. The number of RLL (N-RLL) were correlated with BFR in morphometric examination. In addition, the weight-bearing zones in the N-RLL were more significantly correlated with BFR. The Japanese Orthopedic Association (JOA) score and pain score negatively correlated with eroded bone surface. The present study indicated that bone dynamics, rather than the bone volume at the time of TKA, were involved in the presence of RLL and in pain after surgery for TKA.

**Key words** Rheumatoid arthritis · Osteoporosis · Histomorphometric study · Total knee arthroplasty · Radiolucent line

### Introduction

Osteoporosis associated with clinical articular rheumatism was thought to be characterized by juxta-articular osteoporosis. After the first report<sup>1</sup> on generalized osteoporosis, there have been studies on various methods of bone density measurement, and biochemical markers of bone metabolism have been reported.<sup>2–5</sup> However, there have been only a few studies on the relationship between the bone volume/dynamics at the time of artificial arthroplasty and the results of the operation in patients with rheumatoid arthritis. We have reported the results of histomorphometric measurement of cancellous bone in the iliac bone that had been labeled at the time of total knee arthroplasty performed in 20 rheumatoid arthritis (RA) patients.<sup>6</sup> The purpose of this paper was to clarify the effects of bone dynamics on the results of artificial arthroplasty. Histomorphometric data obtained at surgery was compared with radiographs and clinical results after the operation.

### Subjects

The subjects were 20 previously studied<sup>6</sup> patients with RA according to the criteria of the American Rheumatism Association. They were hospitalized in order to undergo total knee arthroplasty (TKA) between February and July 1989 (Table 1). All patients were female, ranging in age from 38 to 69 years (mean  $\pm$  SD, 56.8  $\pm$  9.1 years), and the duration of RA was 6–49 years (18.1  $\pm$  10.3 years). According to Steinbrocker's classification, 2 patients were in Class 2, 15 in Class 3, and 3 in Class 4 before the operation. The system of Ochi et al.<sup>7</sup> was used for clinical classification of the patients. The least erosive subset (LES) was not observed in any patient. Fourteen patients were classified as in the more

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**Table 1.** Subjects

No.	Age	Gender	During period of RA (years)	Years past menopause	Class	Classification of Ochi et al. <sup>7</sup>	Total amount of steroids
1	38	F	7		III	MES	S1
2	41	F	25		III	MUD	S2
3	46	F	6	0.5	II	MES	S0
4	48	F	12		III	MES	S1
5	49	F	19	6	III	MUD	S2
6	50	F	20	7	III	MUD	S2
7	52	F	14	4	IV	MUD	S2
8	53	F	16	10	III	MES	S0
9	56	F	17	8	III	MES	S1
10	58	F	7	5	III	MES	S0
11	59	F	16	24	IV	MES	S0
12	60	F	20	12	II	MES	S2
13	61	F	8	11	III	MUD	S1
14	62	F	40	14	III	MES	S1
15	63	F	23	14	III	MES	S0
16	66	F	19	14	III	MES	S0
17	68	F	11	15	III	MES	S0
18	68	F	49	21	III	MES	S1
19	68	F	17	19	IV	MUD	S2
20	69	F	16	15	III	MES	S1
Avg.	56.8		18.1	11.7			

MES, more erosive subset; MUD, mutilating disease  
(From [6] with permission)

erosive subset (MES) and 6 as having mutilating disease (MUD). In preoperative treatment, no steroids were administered to 7 patients (S0 group), steroids which were equivalent to 10g prednisolone were administered to 7 patients (S1 group), and steroids which were equivalent to more than 10g prednisolone were administered to 6 patients (S2 group). No patients were given methotrexate. The patients had neither abnormal results in blood or urine examinations nor a history of other collagen diseases, hormonal disease, or chronic renal failure. Three patients (38–48 years old) had menstruation, and the remaining 17 patients (48–69 years old) had been in the postmenopausal stage for 0.5–24 years ( $11.7 \pm 6.1$  years).

## Methods

### Histomorphometric measurements

Sample bones that had been labeled twice with tetracycline were taken from the iliac bone during TKA, and histomorphometric measurements were performed using a semi-automatic measurement system. All patients gave consent to bone collection. Fifteen of the parameters of bone metabolism reported by Parfitt et al.<sup>8</sup> were chosen for this study. The patients performed exercises such as strengthening of the muscles in the lower limbs, range of motion (ROM) exercises, and walking in a pool for 4–5 weeks before surgery. The surface-displacement-type Ortholoc II was used without cement for TKA in all patients. ROM exercises started on the 3rd day after surgery. Half-weight bearing was performed in the 4th week after surgery, and full weight bearing was performed in the 6th week after surgery.

### Examination of the patients' postoperative conditions

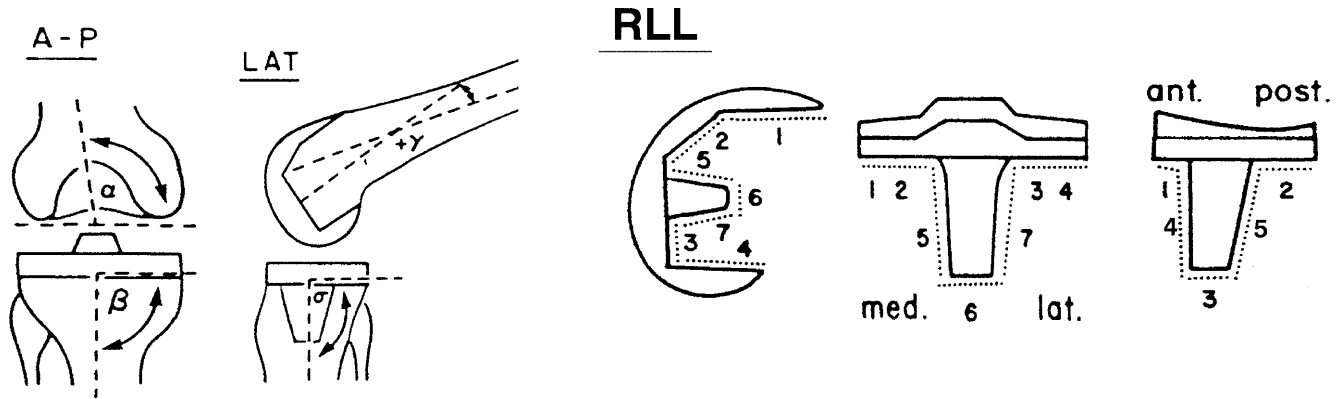
Examinations of the patients' postoperative conditions were performed by direct examination, including radiography or written inquiries to local physicians.

Examination or radiographs was performed using a modified scoring system of The Knee Society.<sup>9</sup> We modified the scoring system so that the lateral image obtained on the tibia side was divided into 5 zones (originally 3 zones). Zones 1 and 4 on the femur side and zones 5 and 7 on the anteroposterior image on the tibia side, as well as zones 4 and 5 on the lateral image, were regarded as the non-weight-bearing surfaces. The remaining 13 zones were regarded as the weight-bearing surfaces (Fig. 1). The numbers of zones with radiolucent lines (RLL) around the implant (N-RLL) were measured, and the sums of the maximum depths (mm) of the RLL for each zone (D-RLL) were calculated. We then took the average of the RLLs divided by the number of the zone and the patient ( $1/\text{zone} \cdot N$ ).

Postoperative clinical results were assessed by the Japanese Orthopedic Association Rheumatoid Knee Scoring System (JOA score), and the pain assessment portion of the JOA score was used as the pain score (Table 2). The relationship between these results and the histomorphometric parameters was analyzed.

Control values for postoperative clinical results were obtained from 38 other RA patients (71 knees) who underwent cementless Ortholoc II TKA in our hospital between July 1988 and June 1991.

Intergroup JOA score or pain score and histomorphometric data were analyzed by Spearman's rank correlation test, and other differences were evaluated by the unpaired *t*-test. Differences were regarded as significant at  $P < 0.05$ .



**Fig. 1.** The Knee Society TKA roentgenographic evaluation and scoring system (modified). We modified the scoring system so that the lateral image obtained on the tibia side was divided into 5 zones instead of 3. The number of zones with radiolucent lines (RLL) around the implant (N-RLL) was measured, and the sums of the maximum depths

(mm) of the RLL for each zone (W-RLL) were calculated. Zones 1 and 4 on the femur side, zones 5 and 7 on the A-P image, and 5 on the lateral image obtained on the tibia side were regarded as the non-weight-bearing surface, and the remaining 13 zones as the weight-bearing surface

**Table 2.** Pain score, taken from the pain assessment part of the JOA score

	Points
No pain	40
Occasional pain during exercise	30
Consistent pain during exercise	20
Immobility caused by pain	10
Constant severe pain	0

## Results

### Evaluation of the histomorphometric parameters

Taking the bone parameters of postmenopausal women given by Recker et al.<sup>10</sup> as normal, the RA patients tended to show a decrease in bone volume (BV/TV) and trabecular thickness (Tb.Th), increases in osteoid surface (OS/BS) and eroded surface (ES/BS), and enhancement of mineral apposition rate (MAR) and bone formation rate (BFR/BS' and BFR/BV''). There were no characteristic differences between the three groups classified by the total amount of steroids that had been administered. According to the classification rate of Ochi et al.,<sup>7</sup> the MUD group had a smaller bone volume, a larger osteoid volume (OV/BV), and slightly higher bone formation than the MES group (Fig. 2 and Table 3).

### Postoperative results

Of the 20 patients for whom histomorphometric measurements were taken, postoperative examination was performed in 16 patients (direct examination in 11 patients, examination by a local physician in 5 patients), while the remaining 4 patients died before this was possible. The follow-up period was between 5 years 10 months and 8 years 11 months (mean, 7 years 2 months). Two patients had undergone replacement of the implant in the tibia be-

cause of early loosening. One of these was due to particle disease as a result of technical errors, and the other was due to late infection. Four patients were bed-ridden, needing help for all daily activities, because of aggravation of spinal diseases and multiarticular disorders. These 6 patients were excluded from the evaluation, and the remaining 10 patients (9 MES patients and 1 MUD patient) were evaluated.

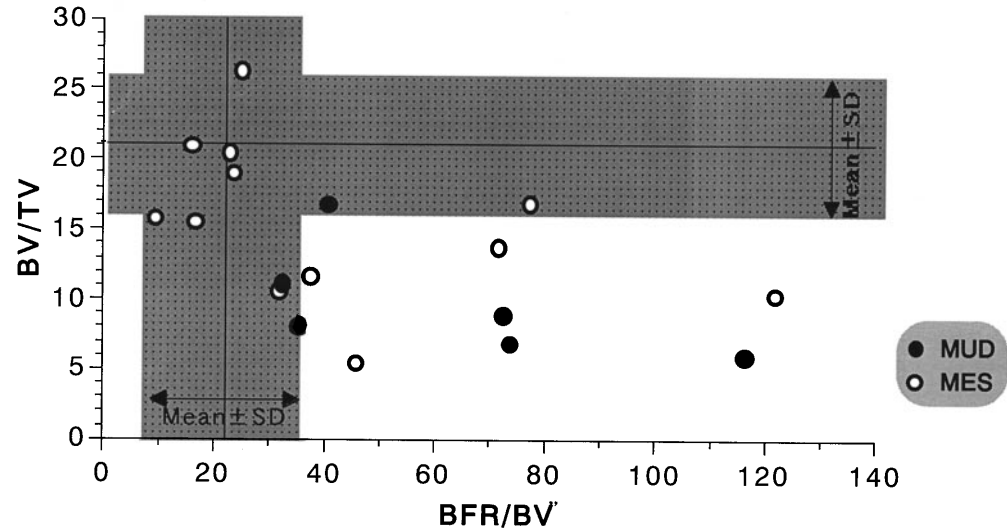
Postoperative examination was performed in 32 control patients (51 knees), and 20 patients (31 knees) were given JOA scores. The follow-up period was between 2 years 6 months and 5 years 8 months (mean, 3 years 8 months). The relationship between the two groups (control group vs. subjects) was analyzed by femorotibial angle (FTA), four alignment angles on postoperative radiographs, and JOA score. However, there were no correlations between the two groups (Table 4).

RLL was less than 2 mm in 6 patients, but greater than 2 mm in 3 patients. RLL on the femur side was observed in 8 patients, and RLL on the tibia side was noted in 7 patients. In 6 patients, RLL was observed in zone 1 on the femur side. The mean N-RLL and D-RLL were 0.20 and 0.29 mm, respectively, on the femur side, and 0.16 and 0.18 mm, respectively, on the tibia side; the differences were not significant. The mean N-RLL and D-RLL on the weight-bearing surfaces were 0.10 and 0.13 mm, respectively, and those on the non-weight-bearing surfaces were 0.33 and 0.40 mm, respectively, showing higher N-RLL and D-RLL on the non-weight-bearing surfaces than on the weight-bearing surfaces (Table 5).

There was a correlation between N-RLL and BFR/BS' (Spearman's rank correlation, Fig. 3). In the joints with a high turnover in bone dynamics, there were many zones with RLL, but D-RLL did not correlate with BFR/BS''. There was a correlation between BFR/BS' and the N-RLL on the weight-bearing surfaces (Spearman's rank correlation, Fig. 3), but not on the non-weight-bearing surfaces.

The JOA score of the 10 patients ranged from 35 to 92 (mean,  $66.1 \pm 21.1$ ) points. The pain scores ranged from 20 to 40 (mean,  $32.0 \pm 7.9$ ) points. The JOA score and pain

**Fig. 2.** Comparison between mutilating disease (MUD) and more erosive subset (MES). BFR/BV<sup>tr</sup> is higher and BV/TV is slightly lower in MUD than in MES (From [6] with permission)



**Table 3.** Histomorphometric data

	Vs control (postmenopause)		Total amount of steroids			Classification of Ochi et al.	
	Control (n = 34)	RA (n = 17)	S0 (n = 7)	S1 (n = 7)	S2 (n = 6)	MES (n = 14)	MUD (n = 6)
AGE		56.8 ± 9.1	59.0 ± 7.7	57.4 ± 11.2	53.3 ± 9.4	58.1 ± 8.9	53.5 ± 8.7
Disease duration	–	18.1 ± 10.3	13.6 ± 5.9	22.3 ± 15.1	19.2 ± 3.3	16.4 ± 8.3	17.2 ± 5.3
BV/TV	21.17 ± 4.90	13.33 ± 5.79	14.89 ± 5.95	13.91 ± 4.80	11.28 ± 6.10	15.38 ± 4.79	9.00 ± 3.91
Tb.Th	132.4 ± 27.9	80.1 ± 27.1	86.7 ± 26.3	87.5 ± 25.6	79.2 ± 46.0	90.0 ± 23.1	73.0 ± 41.2
Tb.N	1.61 ± 0.27	1.63 ± 0.34	1.69 ± 0.28	1.58 ± 0.27	1.49 ± 0.50	1.70 ± 0.23	1.33 ± 0.40
Tb.Sp	629 ± 134	563.6 ± 162.1	522.4 ± 126.7	563.1 ± 135.0	655 ± 217.9	510.3 ± 95.5	731.1 ± 168.2
OV/BV	1.85 ± 1.07	7.99 ± 5.73	4.29 ± 2.77	8.38 ± 6.68	9.72 ± 5.15	4.98 ± 2.50	12.87 ± 6.59
O.Th	9.27 ± 2.10	13.26 ± 5.52	9.19 ± 2.39	15.84 ± 4.78	14.97 ± 6.01	12.05 ± 4.25	16.1 ± 6.0
ES/BS	4.0 ± 2.0	6.11 ± 2.50	7.14 ± 2.85	6.96 ± 4.68	5.27 ± 1.12	6.85 ± 3.70	5.79 ± 0.88
OS/BS	14.3 ± 6.3	25.5 ± 10.3	23.3 ± 13.1	25.1 ± 11.4	25.7 ± 8.8	22.5 ± 10.8	29.6 ± 7.8
Oc.S/BS	0.7 ± 0.7	0.46 ± 0.46	0.55 ± 0.68	0.41 ± 0.41	0.44 ± 0.31	0.50 ± 0.52	0.35 ± 0.18
MAR	0.53 ± 0.08	0.72 ± 0.18	0.83 ± 0.35	0.77 ± 0.20	0.72 ± 0.24	0.79 ± 0.30	0.75 ± 0.21
MS/BS <sup>tr</sup>	7.00 ± 4.10	7.87 ± 4.69	8.32 ± 7.19	5.77 ± 3.00	8.27 ± 2.64	6.84 ± 5.21	8.75 ± 2.33
Omt	17.7 ± 3.8	19.8 ± 10.6	13.3 ± 6.2	21.5 ± 7.4	24.0 ± 15.5	16.6 ± 7.1	24.2 ± 14.2
BFR/BS <sup>tr</sup>	0.014 ± 0.008	0.021 ± 0.013	0.026 ± 0.023	0.022 ± 0.011	0.022 ± 0.012	0.022 ± 0.018	0.024 ± 0.010
BFR/BV <sup>tr</sup>	21.2 ± 12.9	48.8 ± 33.4	53.8 ± 58.2	43.4 ± 27.5	55.0 ± 34.6	45.18 ± 44.33	63.57 ± 28.42
FP <sup>tr</sup>	0.49 ± 0.45	0.37 ± 0.25	0.33 ± 0.33	0.48 ± 0.26	0.28 ± 0.07	0.38 ± 0.29	0.30 ± 0.07

(From [6] with permission)

The shaded values indicate significant differences (*t*-test, *P* < 0.05)

The bone parameters of postmenopausal women given by Recker et al.<sup>10</sup> were taken as normal (From [10] with permission)

**Table 4.** Comparison with control group by postoperative radiography and JOA score

	FTA°	α-angle°	β-angle°	γ-angle°	δ-angle°
Subject (20 patients, 20 knees)	175.1 ± 2.9	96.2 ± 2.4	89.1 ± 2.5	2.7 ± 3.6	89.3 ± 3.0
Control group (38 patients, 71 knees)	175.6 ± 3.2	95.3 ± 2.7	88.6 ± 3.1	2.6 ± 3.4	90.0 ± 4.1
Unpaired <i>t</i> -test	NS	NS	NS	NS	NS
JOA score					
Subjects (10 patients, 10 knees)	65.4 ± 19.3				
Control group (20 patients, 31 knees)	76.7 ± 17.0				
Spearman's rank correlation	NS				

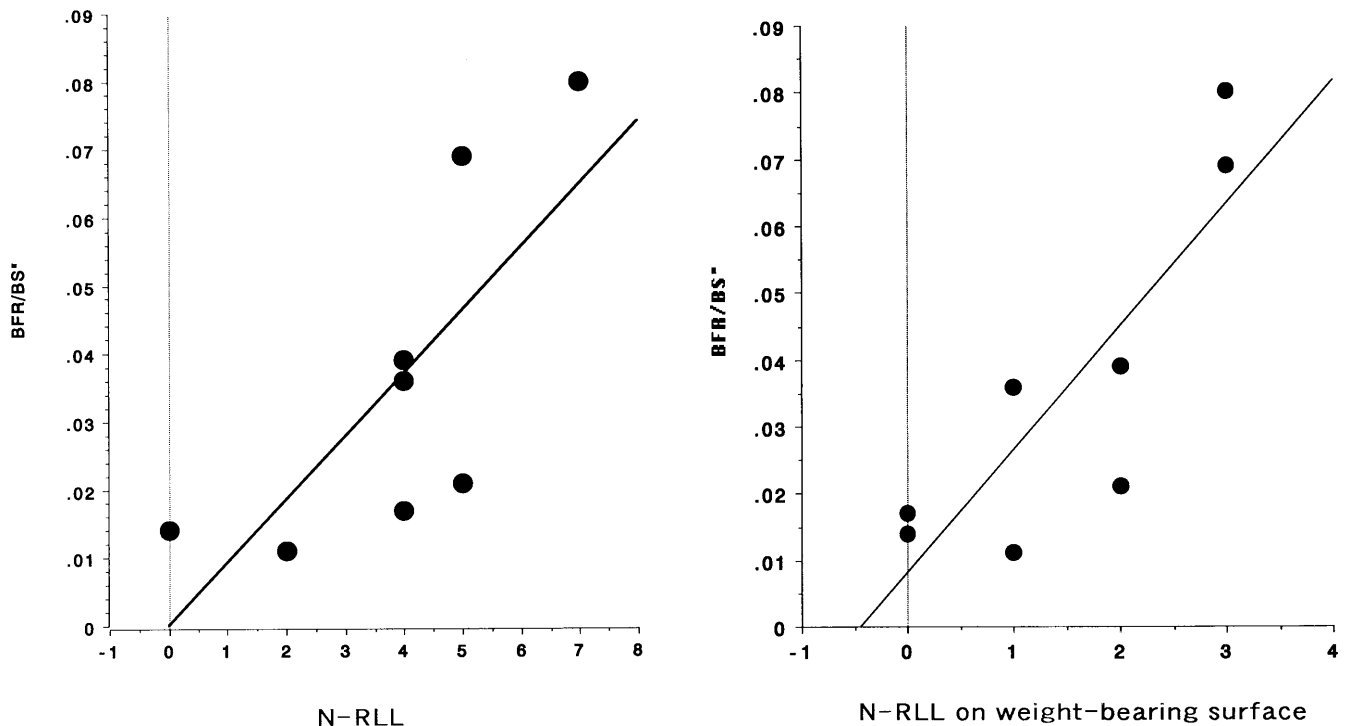
NS, not significant

There was no correlation between subjects and control group

**Table 5.** Radiolucent lines

Case	Femur (7 zones)		Tibia (12 zones)		Weight-bearing zone (13 zones)		Non-weight-bearing zone (6 zones)	
	N-RLL	W-RLL	N-RLL	W-RLL	N-RLL	W-RLL	N-RLL	W-RLL
1	1	1	0	0	0	0	1	1
2	2	2	2	2	2	2	2	2
3	3	4	4	4	3	4	3	4
4	1	1	0	0	1	1	0	0
5	0	0	0	0	0	0	0	0
6	2	4	3	5	3	4	2	5
7	2	4	2	2	0	0	4	6
8	0	0	5	5	2	2	3	3
9	2	3	2	2	1	3	3	2
10	1	1	1	1	1	1	1	1
Total	14	20	19	21	13	17	20	24
Avg. (/zone · N)	0.20	0.29	0.16	0.18	0.10	0.13	0.33	0.40

N-RLL, number of zones with the RLL; W-RLL, the sum of the maximum depths (mm) of the RLL for each zone



**Fig. 3.** Correlation between BFR and N-RLL. *Left:*  $\rho = 0.822$ ,  $n = 8$ ,  $P < 0.05$ . *Right:*  $\rho = 0.833$ ,  $n = 8$ ,  $P < 0.05$

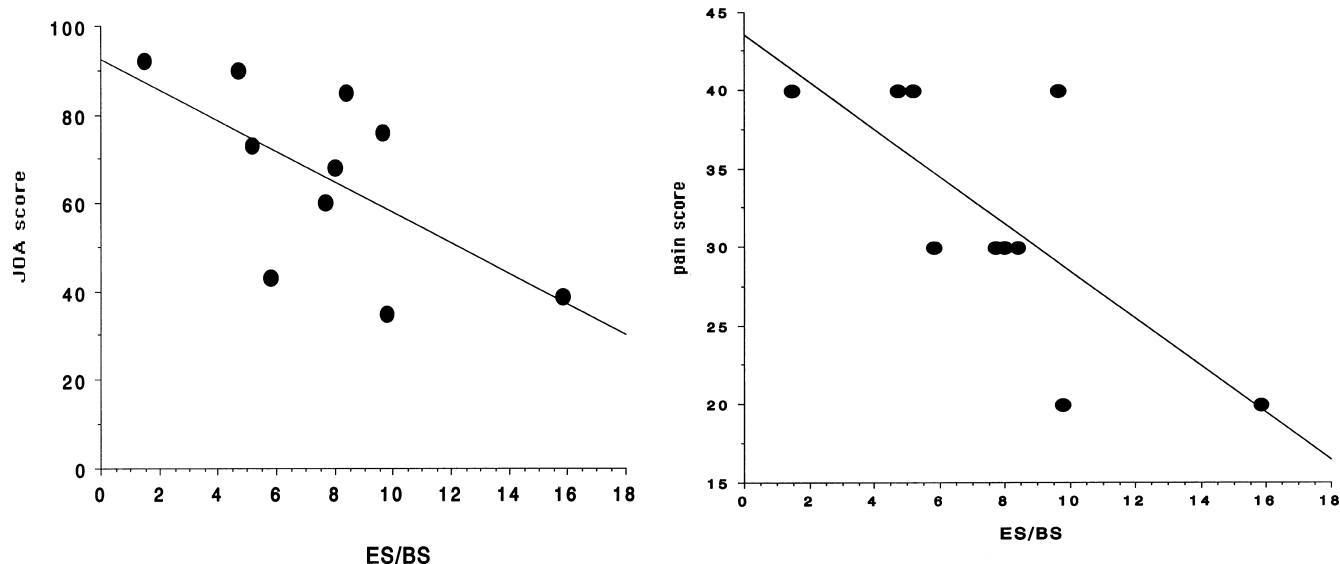
score were negatively correlated with ES/BS (Spearman's rank correlation, Fig. 4). However, the JOA score and the pain score did not correlate with the remaining histomorphometric parameters or with N-RLL or D-RLL.

## Discussion

### Bone volume and bone dynamics in RA patients

There have been a number of studies showing that the bone mineral volume in RA patients is smaller than that in con-

trols. A number of studies using biochemical markers found enhancement of bone absorption, but evaluation of bone formation varies. Based on the measurement of DXA in several regions in patients with RA in the early stage, Gough et al.<sup>11</sup> suggested that biochemical markers are related to osteoporosis because it shows systemic progression. In MUD patients with more severe RA, a higher turnover of bone dynamics and more severe osteoporosis were noted in the present study. The differences in bone volume and bone dynamics in RA between these studies may be because we did not take into consideration the disease type and severity.



**Fig. 4.** Correlation between clinical results and ES/BS. *Left:*  $\rho = -0.648$ ,  $n = 10$ ,  $P < 0.05$ . *Right:*  $\rho = -0.727$ ,  $n = 10$ ,  $P < 0.05$

Bone volume and bone dynamics at the time of surgery and radiographs after surgery

RLL after TKA is thought to be caused by implant designs, micromotion, stress shielding, osteolysis, and wear particles, and its incidence varies between 4% and 85%.<sup>12-14</sup> In our hospital, RLL was observed in 71% of the 42 RA patients (61 knees) in whom Ortholoc II had been implanted after the mean follow-up period of 4 years 1 month. This incidence was slightly higher than that in other studies.

In this study, a correlation was noted between N-RLL and BFR/BS<sup>''</sup>, and RLL was more often associated with higher bone metabolism. There was higher correlation between N-RLL on the weight-bearing surfaces and BFR/BS<sup>''</sup> than N-RLL. Therefore, under the uncoupling conditions of high-turnover bone metabolism, bone dynamics appeared to be involved in the fixation of the implant and the bone on the weight-bearing surface. Since D-RLL did not correlate with the parameters examined, we considered that bone dynamics are involved only in the occurrence of RLL, but not in its progression, which may be caused by various other factors.

Bone volume and bone dynamics at the time of surgery and clinical results

The postoperative JOA score and pain score showed a negative correlation with bone absorption surface, and the patients with enhanced bone absorption had slightly less favorable postoperative results. However, postoperative JOA score did not correlate with bone volume, BFR, N-RLL, or D-RLL at the time of surgery. The reasons for these relationships are unclear, but disease activity, synovial proliferation, micromotion, and loosening are generally considered to cause pain in RA after TKA. In the patients in this study, synovial proliferation and micromotion are

likely to be the cause of postoperative pain, since loosening was not observed. Bone ingrowth onto the Co-Cr surface may be impaired in patients who showed high disease activity and enhanced bone absorption. This suggested that bone dynamics, rather than the bone volume at the time of TKA, are involved in RLL and pain after surgery for RA.

## Conclusion

Histomorphometric measurement of the iliac bone in RA patients was performed at the time of TKA, and postoperative condition were evaluated.

1. Osteoporosis in which thinning of trabecular thickness is the main symptom was observed in the RA patients, and significant uncoupling conditions of high-turnover bone metabolism were observed in the severe RA patients.
2. From postoperative observation of 10 patients, most of whom were classified as having MES, for a mean period of 7 years 2 months, a positive correlation between BFR/BS<sup>''</sup> and N-RLL was noted. The JOA score and the pain score showed negative correlations with ES/BS.
3. There was correlation between BFR/BS<sup>''</sup> and N-RLL on the weight-bearing surface, and we concluded that bone dynamics were involved in the fixation of the implant and the bone on the weight-bearing surface.

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