and 61.8 ± 24.9% in the P group. The difference between the 2 groups was statistically significant ($P = 0.011$; Fig. 4). Right bending was 116.0 ± 57.3% in the NP group and 82.2 ± 23.5% in the P group. Left bending was 112.9 ± 55.6% in the NP group and 65.5 ± 18.9% in the P group. Both side-bending strengths were significantly higher in the NP group than in the P group ($P = 0.039$ and $P = 0.004$, respectively).

At 12 Months Postoperation

The flexion strengths did not differ between the NP and P groups. The extension muscle strength was 124.3 ± 38.5% in the NP group and 62.2 ± 6.0% in the P group, and the difference was statistically significant ($P = 0.007$). Right bending was 126.9 ± 49.3% in the NP group and 82.0 ± 13.3% in the P group. Left bending was 122.9 ± 49.0% in the NP group and 60.6 ± 6.7% in the P group. Thus, the side-bending strengths were significantly higher in the NP group than in the P group ($P = 0.007$ and $P = 0.007$, respectively). The preoperative muscle strengths for all directions did not differ between the NP and P groups at both 3 months and 12 months. The data are summarized in Tables 2 and 3. VAS and neck muscle strength in extension were weakly correlated ($r_s = -0.366$, $P = 0.0066$). VAS and the reduction in neck muscle strength (n-MMT) in extension were strongly correlated ($r_s = -0.609$, $P = 0.0002$; Fig. 5).

DISCUSSION

No previous study has evaluated the sequential changes in subjective muscle strength before and after cervical surgery. In this study, neck muscle strength was measured successfully before and after the operation, and was evaluated in relation to axial symptoms. Statistical analysis indicated that the neck pain VAS and neck muscle strength were significantly correlated.

The source of axial symptoms is thought to be multifactorial and to include deep extensor muscle denervation, facet joint injury, C2 or C7 muscle invasion, neural element compression, and prolonged postoperative external immobilization.[7–10] Several modifications have recently been applied to reduce the axial symptoms. In accordance with evidence, the C2 and C7 muscles have been preserved, facet joint invasion has been reduced as much as possible, and postoperative immobilization is brief, as in our procedure.[12]

We hypothesized that muscle strength might be reduced by surgical invasion to the deep extensor muscles, which might be related to axial symptoms. However, interestingly, muscle strength was recovered by 3 months and had increased to 120% of the preoperative value by 12 months after the operation in most patients. These findings indicate that although a temporary reduction in muscle strength occurred during the early postoperative period, caused by operative invasion or wound pain, operative invasion to the deep extensor muscles was not a crucial factor in maintaining neck muscle strength. Surgical decompression of the spinal cord or nerve root will reduce neck pain, and will also contribute to the subsequent increase in muscle strength. Our findings actually demonstrated that all patients who complained of severe preoperative neck pain reported a reduction in neck pain postoperatively.

The results of this study showed that axial symptoms occurred more in women than in men. The causes of sex difference for axial symptoms were not well

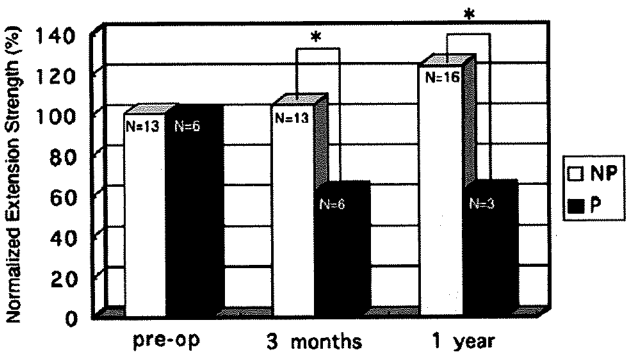

FIGURE 4. Normalized muscle strength in extension. The extension strength was significantly higher in the NP group than in the P group at 3 months. At 12 months, the extension strength was 124.3% in the NP. Preoperative values are intrinsic strengths (Newtons). *Statistically significant. NP indicates no pain group; P, pain group.

TABLE 2. Relationship Between Clinical Data and Axial Symptoms at Three Months

	NP Group[13]	P Group[6]	P
JOA recovery rate (%)	58.8 ± 27.5	36.7 ± 31.8	NS
C2-C7 lordosis (degrees)	15.7 ± 9.2	5.0 ± 9.6	0.002*
ROM (degrees)	35.8 ± 8.2	29.0 ± 10.9	NS
Flexion (%)	103.9 ± 28.7	87.1 ± 13.6	NS
Extension (%)	104.9 ± 40.8	61.8 ± 24.9	0.011*
Right bending (%)	116.0 ± 57.3	82.2 ± 23.5	0.039*
Left bending (%)	112.9 ± 55.6	65.5 ± 18.9	0.004*

Values are means ± SD.
*Statistically significant: $P < 0.05$.
NP indicates no pain (VAS < 3); NS, not significant; P, pain (VAS ≥ 3).

TABLE 3. Relationship Between Clinical Data and Axial Symptoms at 12 Months

	NP Group[14]	P Group[3]	P
JOA recovery rate (%)	61.0 ± 25.5	36.1 ± 37.6	NS
C2-C7 lordosis (degrees)	13.1 ± 10.5	15.4 ± 11.8	NS
ROM (degrees)	40.0 ± 11.1	51.8 ± 16.5	NS
Flexion (%)	113.2 ± 28.2	79.6 ± 18.1	NS
Extension (%)	124.3 ± 38.5	62.2 ± 6.0	0.007*
Right bending (%)	126.9 ± 49.3	82.0 ± 13.3	0.007*
Left bending (%)	122.9 ± 49.0	60.6 ± 6.7	0.007*

Values are means ± SD.
*Statistically significant: $P < 0.05$.
NP indicates no pain (VAS < 3); NS, not significant; P, pain (VAS ≥ 3).

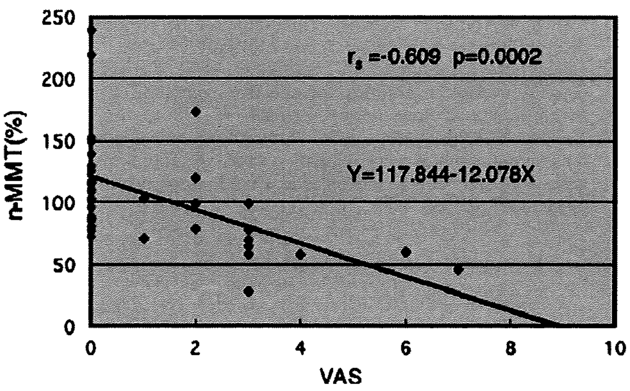

FIGURE 5. Correlation between neck pain VAS and the reduction in muscle strength (n-MMT) at extension using Spearman rank correlation coefficient. n-MMT = postoperative MMT/preoperative MMT × 100 (%). MMT indicates manual muscle testing; VAS, visual analogue scale.

discussed, we wondered about the correlation of muscle strength and symptoms. These findings are similar to those of previous reports, in which the muscle strengths of normal volunteers were 2 times stronger in men than in women.[15] The same trends were also observed in our study. Although in the current study preoperative muscle strength was not identified statistically as a risk factor for axial symptoms, surgeons should keep in mind the sex difference of the incidence of axial symptoms.

The results of current study raise a query as to whether weakness causes pain or pain causes weakness. Our study demonstrated the correlation between axial symptom and neck muscle strength, but could not clarify as to whether weakness caused pain or pain caused weakness. Previous studies have indicated that flexor and extensor muscle strength are reduced in patients with neck pain, which indicated neck pain caused the muscle weakness.[11] If neck pain is the main cause of muscle weakness, sex difference of axial symptom can not explained. In consideration of sex difference and pain relief after neck muscle exercise, axial symptom was liable to occur in patients with weak muscle strength preoperatively, which combined with operative invasion. That is, reduction of the muscle weakness by limited operative invasion, brief postoperative external immobilization, and strengthening of muscle after surgery will contribute to reduce the incidence of axial symptoms.

Because the cervical curvature was affected not only by neck pain but also disc degeneration, facet arthrosis, neck muscle strength, and whole spine posture, the relationship between axial pain and cervical curvature was still controversial. Matsumoto et al[16] studied cervical curvature after whiplash injury and the results indicated no association between clinical symptoms and cervical curvature. Yoshida et al[14] reported no correlation between axial pain and cervical curvature at 6 months to 1 year after cervical laminoplasty. Although we could show the correlation between cervical curvature and axial symptom at only 3 months, because the cervical curvature and ROM are affected by wound pain or external immobilization, it is difficult to define the clear correlation between axial symptom and cervical curvature in early postoperative periods.

This study has several limitations. First, although several surgical procedures were used for cervical spondylotic myelopathy, the differences in the surgical procedures used were not evaluated. However, a recent study has demonstrated that clinical results and axial pain are not dependent on the surgical procedure used.[17] Second, the sample size was relatively small. To clarify the risk factors for axial symptoms, another extensive longitudinal study with a large sample of patients is required.

In conclusion, neck muscle strength was measured before and after cervical laminoplasty. Axial symptoms occurred more often in women than in men. Muscle strength recovered to the preoperative level after 3 months and increased to 120% after 12 months in the NP group, whereas in the P group, neck muscle strength remained by 60% and did not recover. These data indicate that neural decompression reduced the patients' neck pain and that the surgical invasion of the C2 and C7 muscles with these surgical techniques was not crucial for, and did not affect the maintenance of, muscle strength. Although no preoperative predictive risk factors were identified, axial symptoms and reduced muscle strength were significantly correlated.

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Clinical Study

The value of palliative surgery for metastatic spinal disease: satisfaction of patients and their families

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Abstract

BACKGROUND CONTEXT: Although there have been several studies in which the surgical outcomes were evaluated by pain reduction or neurological improvement, there have been few studies focused on the quality of life (QOL) of the patients after the surgery. We considered that the most important consideration in palliative surgery was to respect the wishes of patients and their families, which are likely to be influenced by the patients' QOL for their limited life span.

PURPOSE: To evaluate the value of palliative surgery for spinal metastasis and to identify the factors predicting satisfaction of patients and their families after the surgery.

STUDY DESIGN: Questionnaire-based survey of palliative surgery for spinal metastasis.

PATIENT SAMPLE: Seventy-one consecutive patients who had undergone palliative surgery and their families.

OUTCOME MEASURES: Survival period after surgery, neurological status, ambulatory period, pain scale, and satisfaction of patients and their families.

METHODS: The QOL of the patients after surgery was evaluated by analyzing the satisfaction and related parameters of patients and their families. Questionnaires were sent to 71 consecutive patients who had undergone palliative surgery for spinal metastasis. To identify the factors predicting satisfaction of patients and their families, multivariate logistic regression analyses were performed.

RESULTS: Questionnaires were successfully delivered to 71 patients or their families. Full responses were collected from 37 patients, giving an overall response rate of 52.2%. Overall, 80% of patients were satisfied with the results of the surgical treatment. Age (below 65 years) and neurological improvement after surgery were significant predictors of patient's satisfaction. Pain reduction and the continued survival of the patient were significant predictors of family member's satisfaction.

CONCLUSIONS: These results strongly suggested that palliative surgery is a valuable treatment for metastatic spinal disease. Younger patients were more likely to want active treatment and to seek any functional improvement that contributed to an improved QOL in their limited life span. Pain control and the length of patient survival were important factors for people caring for patients.

Keywords: Spinal metastasis; Palliative surgery; Satisfaction; Quality of life

Introduction

The spinal column is the most frequent site of bone metastasis, and between 30% and 70% of patients with cancer will have evidence of spinal metastasis at autopsy [1–3]. Spinal cord compression, the most serious sequela of spinal metastasis, occurs in 20% of patients with such metastasis

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[4]. Spinal column metastasis may cause significant clinical problems, including severe pain and neurological symptoms. Treatment of metastatic disease of the spine involves a fine balance between survival, function, and overall quality of life (QOL). Radiotherapy has been traditionally considered to be the first-line treatment for spinal metastasis. In cases of radioresistant tumors with neurological compromise or mechanical instability, nonsurgical treatment has not proved effective.

Surgery has been performed on occasion for patients with metastatic spinal tumors and has been shown to be an excellent treatment for symptoms of pain and palsy. An improvement in QOL that cannot be achieved by other methods can be immediately apparent in selected patients [5]. Surgery can provide early mobilization, return of useful ambulation or urinary function, pain reduction, and improvement in QOL, as well as prolongation of life [6]. Improvements in spinal surgical techniques and implants now allow for safe and effective decompression of neural elements and provide structural stability by means of a rigid internal fixation [7,8]. The objectives of surgical management for metastatic spinal disease are usually palliative. However, the prognostic factors affecting outcomes after spinal metastasis remain unclear, and the use of surgery is still controversial [9–12].

Because metastatic disease suggests a limited life expectancy, the ability to function and the QOL become profoundly important considerations. Although there have been several studies to objectively evaluate the effects of surgery on survival and functional status, there has been little attempt to subjectively assess the outcomes. Certainly, several physical factors, such as ambulation status, pain reduction, and prolongation of life, may be important to the QOL of the patients. We considered that the most important factors affecting the QOL of the patients with a limited life span were measures of their subjective satisfaction, such as having a stable and positive outlook. Therefore, in the present study, we chose the satisfaction of patients and their families as an indicator for success of surgical intervention for metastatic spinal disease. To establish the value of this treatment, we evaluated satisfaction using a questionnaire.

EVIDENCE & METHODS

Context
Patient and family satisfaction following palliative surgery for metastatic spinal disease has been understudied. This article aims to address this issue.

Contribution
The authors found improved function and decreased pain in many patients following surgery. Eighty percent of patients were satisfied with their results, correlating with younger age and improved neurological status, and 73% of families were satisfied, correlating with survival and pain relief.

Implications
Despite some design limitations recognized in the study, the authors' compassionate shift of focus toward satisfaction as a primary outcome in these terminally ill patients is to be commended and, really, defines the goal of palliation.

—*The Editors*

Material and methods

From April 2000 to November 2005, palliative surgery was performed in our institute and in related hospitals for 71 patients with metastatic spinal disease. Patients had a general medical status good enough to be acceptable surgical candidates and an expected survival of at least 3 months. The objectives of surgical intervention for all patients were palliative. Excisional procedures performed during this period, such as total en bloc spondylectomy [13], were excluded. Questionnaires were sent by mail to 71 patients and to their families in February 2006. Informed consent was obtained from the subjects and/or guardians. Three months later, simultaneous analysis was performed on collected questionnaires combined with the demographic data from the patients' hospital records. The questions included whether patients survived at the time of questionnaire completion, their survival period after surgery, their neurological status before and after surgery, their ambulatory period, the pain scale before and after surgery with or without adjuvant therapy, identification of the key person responsible for decision making, and the satisfaction of patients and their families. Data obtained from patient's records included the patient's age at surgery, their gender, the anatomic site of the primary carcinoma and of the metastatic lesion of the spine, and the nature of the operative procedures. Because of the sensitivity of the situation, it was decided not to undertake an additional telephone survey.

Factors evaluated as predicting variables were age at surgery, gender, anatomic site of the primary carcinoma, survival at the time of questionnaire completion, survival period after surgery, neurological status before and after surgery (Frankel grade), improvement of neurological status, ambulatory period, pain scale before and after surgery, improvement of pain scale with or without adjuvant therapy, key person for decision making, and satisfaction of patients and their families with treatment. The severity of palsy was classified according to Frankel's classification into five grades [14], and neurological status was graded before and after surgery. Patients with Frankel Grade E were neurologically normal; those with Grade D had useful motor function below the level of involvement, with incomplete sensory loss (ambulatory); those with Grade C had some motor function below the level of involvement and incomplete sensory loss (nonambulatory); those with Grade B had complete motor and incomplete sensory loss (nonambulatory); and those with Grade A had complete motor and sensory loss (paraplegia). Pain was categorized as no pain, mild pain, moderate pain, or severe pain. Patients with severe pain routinely used narcotic agents. For subjective assessment of the overall results of surgery, the patients or their families were asked to select from among the following options: 1) very satisfied, 2) satisfied, 3) somewhat satisfied, 4) somewhat dissatisfied, and 5) dissatisfied. In cases where the patients had died, their family members completed the questionnaires.

Statistical analysis

Cross-tables were analyzed with the Student *t* test or the Fisher exact test. p Values less than 5% were considered significant. To confirm that the 37 patients included in the study group were an appropriate sample, demographic data, including age, gender, anatomic site of the primary carcinoma and of the metastatic lesion of the spine, and neurological status, were compared with those of the 34 patients not included. To identify the influence of response difference between actual patient and family members, subgroup analysis was performed. Univariate and multivariate analyses used the Cox proportional hazards model for the variables. To identify factors predicting satisfaction of patients and their families, univariate and multivariate logistic regression analyses were performed. Satisfaction of patients or that of their families was used as the dependent variable. Binary data (very satisfied vs. others) obtained from a five-point Likert scale were analyzed. Age (65 years as the cutoff point), gender, improvement of neurological status, improvement of pain scale, and survival of patients (dead or alive) were selected as independent variables.

Surgical procedures

The standard surgical procedure was posterior decompression and stabilization using instrumentation. Preoperative selective embolizations were not routinely performed. In the case of involvement of the thoracic spine, laminectomy was performed one segment above and one segment below the metastatic lesion. Circumferential decompression

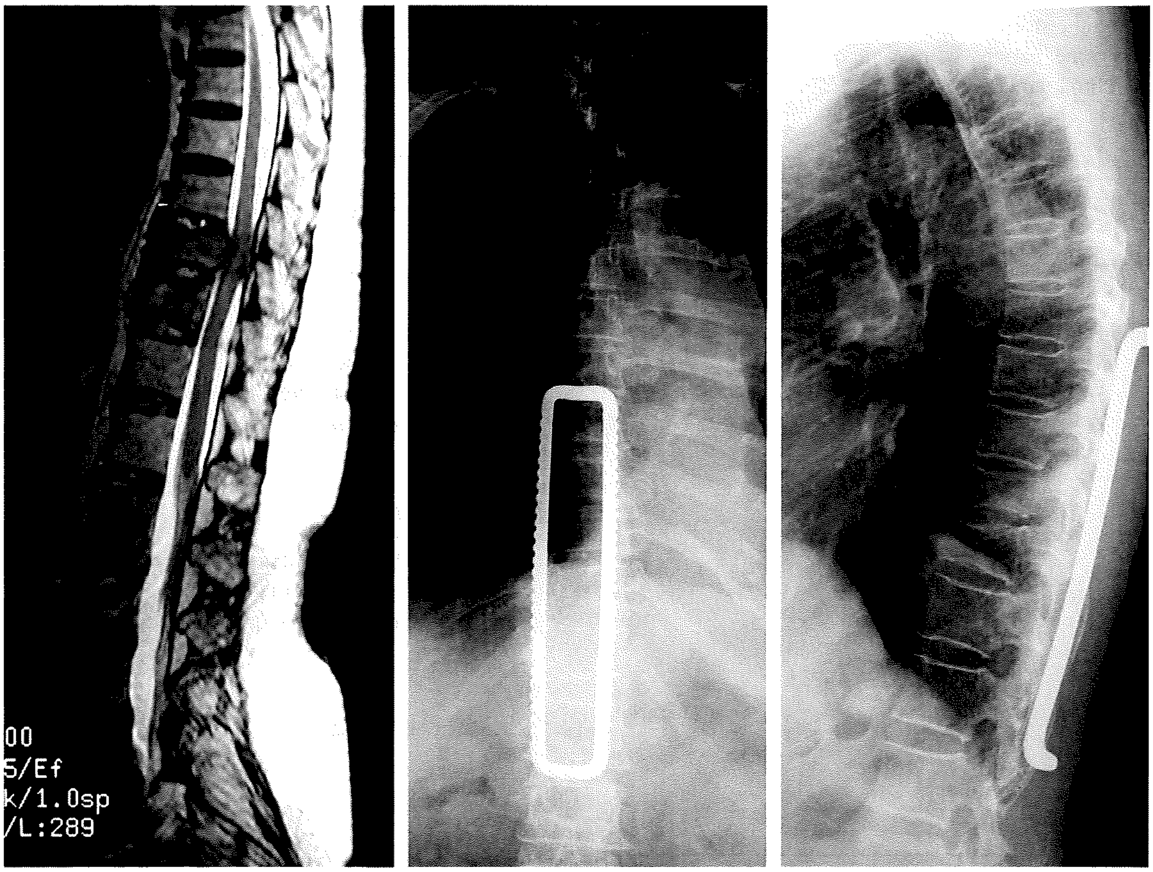

Figure. Seventy-three-year-old female with Frankel C paraparesis from lung cancer metastasis. (Left) Preoperative magnetic resonance T2WI-sagittal image demonstrates severe thoracic spinal cord compression at Th10 level. (Middle) Postoperative anteroposterior and (Right) lateral X-ray images. Circumferential decompression was performed via the posterolateral route by laminectomy at Th9 to Th11 combined with posterior stabilization using a rectangular rod.

was performed through the posterolateral route with bilateral pedicle excision. Tumor and bony fragments ventral to the dural tube, which caused the neural compression, were excised as completely as possible. Hemostasis was attempted by packing an atelocollagen sponge into the metastatic vertebrae. Bilateral thoracic nerve roots that ran into the tumor were routinely cut. An anatomically bent rectangular titanium rod was secured to the laminae using radiolucent polyethylene wire by a sublaminar wiring technique [15]. In cases of involvement of the lumbar spine or extending thoracolumbar spine, stabilizations were performed using the more rigid pedicle screw system. No autologous bone grafting was performed. A typical case of thoracic spine metastasis from lung cancer is shown in Figure.

Results

Complete responses were collected from 37 patients, giving an overall response rate of 52.1% (37 of 71 patients).

The mean age of the 37 patients (21 males and 16 females) at the time of surgery was 60.1 years. The primary carcinoma occurred in the breast in 11 patients (29.7%), the lung in 8 (21.6%), the prostate in 4 (10.8%), the kidney in 3 (8.1%), and the stomach and liver each in 2 patients (5.4%). There was one patient with each of bladder, lymphoma, ovary, sarcoma, and thyroid cancer (2.7%), and the primary carcinoma site was unknown in two patients (5.4%). Neurological status before surgery was Frankel A in 3 patients (8.1%), B in 5 (13.5%), C in 13 (35.1%), D in 9 (24.3%), and E in 7 (18.9%). The metastatic lesion of the spine, as located from the symptoms, was located in the cervical spine in 5 patients (13.5%), in the thoracic spine in 24 (64.9%), and in the lumbosacral spine in 8 (21.6%). The period between surgery and completion of the questionnaire was an average of 32.7 months (range, 3–69 months). Twenty-one patients were alive and 16 patients were dead at the time of questionnaire completion, that is, 16 responses were made by family members. Twenty-eight patients (75.8%) survived more than 6 months after the surgery. Twenty-three patients received adjuvant chemotherapy, and 28 patients received radiotherapy to the metastatic vertebrae before or after the surgical intervention. Statistical analysis, comparing the 37 patients of the study group and the 34 patients in the nonresponding group, showed no significant differences in age (p=.914), gender composition (p=.826), anatomic site of the primary carcinoma (p=.061), site of the metastatic lesion of the spine (p=1.000), or neurological status (p=.155). Thus, these demographic data were an acceptable representation of the overall data for the 71 patients. Mortality and surgically related neural tissue injury were not observed during the perioperative period. Preoperative demographic data are summarized in Table 1.

Table 1
Patients' demographic data

Factor	Overall patients (n=71)	Study group (n=37)	p Value*
Age (y)	59.3 (31–85)	60.3 (31–85)	.914 (NS)
Gender	M=41, F=30	M=21, F=16	.826 (NS)
Metastatic origin			.061 (NS)
Breast	18	11	
Lung	13	8	
Liver	11	2	
Kidney	6	3	
Prostate	5	4	
Colon	3	0	
Stomach	2	2	
Pancreas	1	0	
Others	12	7	
Metastatic lesion			1.000 (NS)
Cervical	8	5	
Thoracic	46	24	
Lumbar	17	8	
Neurological status (Frankel)			.155 (NS)
A	3	3	
B	6	5	
C	24	13	
D	25	9	
E	13	7	

M, male; F, female; NS, not significant.

* Statistical analysis was performed between 37 patients of study group and 34 patients of nonresponding group using the Student *t* test or the Fisher exact test.

Table 2
Comparison of neurological status between before and after the operation

	Postoperative Frankel					
Preoperative Frankel	A	B	C	D	E	Total
A			1	1	1	3
B	1		1	2	1	5
C			2	5	6	13
D				3	6	9
E					7	7
Total	1	0	4	11	21	37

Neurological status

The number of ambulatory patients increased from 16 (43.2%) to 32 (86.4%) after surgery. Twenty-two patients (59.4%) maintained a useful ambulatory status for more

Table 3
Comparison of pain score between before and after the operation

	Postoperative pain score				
Preoperative pain score	1	2	3	4	Total
1	2	3	2	3	10
2		4	11	7	22
3			1	1	2
4				3	3
Total	2	7	14	14	37

Table 4
Patient's satisfaction and responses

Patient satisfaction grade	Responses		Total
	Patient	Family member	
1	8	8	16
2	5	9	14
3	3	4	7
4	0	0	0
5	0	0	0
Total	16	21	37

Satisfaction grade: (1) very satisfied, (2) satisfied, (3) somewhat satisfied, (4) somewhat dissatisfied, and (5) dissatisfied.
p=.832 (Fisher exact test).

than 6 months. The improvement of neurological status was four grades in 1 patient, three grades in 1, two grades in 9, and one grade in 13. Twelve patients showed no improvement, and the condition of one patient gradually deteriorated. The average degree of neurological improvement was one grade (Table 2).

Pain status

Twenty-seven patients (73.0%) showed improved pain status after the surgery. The improvement on the pain scale was three grades in 3 patients, two grades in 8, and one grade in 16. Ten patients showed no improvement in pain scale, including three patients with no pain before the surgery, and no patient showed deterioration. The average degree of pain improvement was 1.1 grades (Table 3).

Satisfaction and other variables

The subjective assessment showed that 16 patients (43.2%) were very satisfied with the results of the surgical intervention, 14 (37.8%) were satisfied, and 7 (18.9%) were somewhat satisfied. No patient responded as somewhat dissatisfied or dissatisfied. Overall, 30 patients (81.1%) were satisfied or very satisfied. Of the responding families, 18 (48.6%) were very satisfied, 9 (24.3%) were satisfied, 7 (18.9%) were somewhat satisfied, and 2 (5.4%) were somewhat dissatisfied. Overall, 27 (73.0%) families were very satisfied or satisfied. The decision for surgery was made by the patient in 23 cases (62.1%), by the family alone in 1 case (2.7%), by both patients and families in 12 cases (32.4%), and by the physicians in 1 case (2.7%). As such, the decision for surgery was made by the patient in more than 90% of the cases. There was no difference between the results of patient's response and family member's response for patient's satisfaction (p=.832) (Table 4). There was also no difference between the results of patient's response and family member's response for family member's satisfaction (p=.153) (Table 5). The correlation between patient's satisfaction and family member's satisfaction was statistically significant in the patient's response group (p=.003) (Table 6). The correlation between patient's satisfaction and family member's satisfaction was also statistically significant in the family member's response group (p<.001) (Table 7). These results indicated that there was no response bias between the actual patient and family members.

Table 5
Family member's satisfaction and responses

Satisfaction grade	Responses		Total
	Patient	Family member	
1	11	7	18
2	2	7	9
3	3	5	8
4	0	2	2
5	0	0	0
Total	16	21	37

Satisfaction grade: (1) very satisfied, (2) satisfied, (3) somewhat satisfied, (4) somewhat dissatisfied, and (5) dissatisfied.
p=.153 (Fisher exact test).

Table 6
Correlation between patient's satisfaction and family member's satisfaction in patient's responding group

Patient satisfaction grade	Family member's satisfaction					Total
	1	2	3	4	5	
1	7	1	0	0	0	8
2	4	1	0	0	0	5
3	0	0	3	0	0	3
4	0	0	0	0	0	0
5	0	0	0	0	0	0
Total	11	2	3	0	0	16

Satisfaction grade: (1) very satisfied, (2) satisfied, (3) somewhat satisfied, (4) somewhat dissatisfied, and (5) dissatisfied.
p=.003 (Fisher exact test).

Results of statistical analysis

The results of univariate logistic regression analysis are shown in Table 8. Among the variables examined, only age (crude odds ratio [OR]: 0.17, p=.024) was significantly associated with patient's satisfaction, although improvement of neurological status (crude OR: 2.03, p=.064) was close to being significantly associated. In contrast,

Table 7
Correlation between patient's satisfaction and family member's satisfaction in family member's responding group

Patient satisfaction grade	Family member's satisfaction					Total
	1	2	3	4	5	
1	6	0	2	0	0	8
2	1	7	0	1	0	9
3	0	0	3	1	0	4
4	0	0	0	0	0	0
5	0	0	0	0	0	0
Total	7	7	5	2	0	21

Satisfaction grade: (1) very satisfied, (2) satisfied, (3) somewhat satisfied, (4) somewhat dissatisfied, and (5) dissatisfied.
p<.001 (Fisher exact test).

Table 8
Patient's satisfaction and related factors

Factor	Crude OR	95% CI	p Value	Adjusted OR	95% CI	p Value
Gender	0.62	0.17–2.30	.470	6.26	0.63–62.2	.117
Age (y)	0.17	0.04–0.80	.024*	0.88	0.79–0.98	.016*
Neurological improvement	2.03	0.96–4.31	.064	2.77	1.01–7.63	.049*
Pain improvement	1.37	0.66–2.87	.403	1.33	0.47–3.70	.591
Survival	0.62	0.17–2.30	.470	0.78	0.15–4.09	.772

OR, odds ratio; CI, confidence interval.
*p<.05 (statistically significant).

improvement of the pain scale (crude OR: 2.52, p=.036) and the patient's survival at the time of survey (crude OR: 0.23, p=.037) were significantly associated with family member's satisfaction. The results of multivariate logistic regression analysis are shown in Table 9. Among the variables examined, age (adjusted OR: 0.88, p=.016) and improvement of neurological status (adjusted OR: 2.77, p=.049) were significantly associated with patient's satisfaction. In contrast, improvement of the pain scale (adjusted OR: 4.01, p=.036) and the patient's survival (adjusted OR: 0.15, p=.036) were significantly associated with family member's satisfaction. These results indicate that age below 65 years and neurological improvement were the most important variables for patient's satisfaction after surgery. Pain improvement and the patient's survival at the time of survey were the most important variables for family member's satisfaction.

Discussion

The results of this study clearly demonstrate that surgical intervention in patients with spinal metastasis had a positive impact on the patient's overall health and function. Overall, 80% of the patients in this study were satisfied or very satisfied with the surgical procedure. These results strongly suggest that during their remaining life span, both the patients and their families had a good mental state and were able to maintain hope, which might be a consequence of a good QOL.

Because the nature of a "good death" is still unclear and depends on the individual, it is difficult to determine the primary goal of palliative care [16]. Important goals of palliative care include not only symptom control but also a "good death" or "good process of dying." Physicians must take into consideration the patient's spirits and attitudes, such as "fighting against cancer" or "maintaining hope" when undertaking palliative treatment. That is, the objectives of palliative surgery should be not only functional improvement or pain reduction but also respect for the patient's wishes.

In the literature, the satisfaction rate for surgery has been reported as 82% in lumbar disc herniation [17,18], 78% in lumbar spinal canal stenosis [19,20], 75% in cervical spondylotic myelopathy [21], and 94% in scoliosis [22]. The degree of patient's satisfaction in the present study was almost equal to that of spinal surgeries for degenerative conditions. Although surgery for metastatic disease is massively invasive and has high neurological risk, an emergent nature, and variable patient postoperative status, the satisfaction rate of 80% was a high level of acceptance. In general, Japanese patients would not necessarily consider that autonomy in decision making was essential. There is a tendency for Japanese patients to prefer to entrust the decision to their physicians. However, the patients enrolled in this study were likely to have a positive attitude toward their surgical treatment, and 94.5% patients made the decision for surgery themselves. This might also contribute to the high satisfaction rate observed in this study.

The statistical analysis demonstrated that age below 65 years and neurological improvement both correlated with increased patient's satisfaction. These results indicate that younger patients were more inclined to take a positive attitude to treatment and to seek a functional improvement to give a good QOL for their limited life span. The finding of a correlation between functional improvement and QOL is consistent with previous reports [23–25]. Patients with end-stage disease often hope "not to be a burden to

Table 9
Family member's satisfaction and related factors

Factor	Crude OR	95% CI	p Value	Adjusted OR	95% CI	p Value
Gender	0.58	0.16–2.17	.421	3.01	0.29–31.8	.360
Age (y)	0.35	0.09–1.36	.129	0.93	0.84–1.03	.147
Neurological improvement	1.56	0.78–3.09	.206	2.09	0.85–5.11	.107
Pain improvement	2.52	1.06–5.97	.036*	4.01	1.10–14.6	.036*
Survival	0.23	0.06–0.92	.037*	0.15	0.025–0.89	.036*

OR, odds ratio; CI, confidence interval.
*p<.05 (statistically significant).

others.'' The close correlation between patient's satisfaction and neurological improvement is easily explained by such patient attitudes.

Interestingly, factors related to satisfaction in patients were different from those among their families. Statistical analysis demonstrated that improvement of pain status and of patient's survival increased the family member's satisfaction. In the case of terminal care, pain control was an important factor not only for patients but also for their families. Severe pain for a patient may also be a burden to their family members who are undertaking daily care. Moreover, although the patient's neurological condition or pain improved after surgery, the patient's survival was the most important factor for his/her family. The present results strongly suggest that mental satisfaction is crucial for people taking part in the care of the patients with terminal incurable cancer.

There were several limitations in the present study, including a small sample size and an objective bias. In cases where the patients had died, their family responded to the questionnaire, and the period between the surgery and the completion of questionnaire differed between patients (range, 3–69 months). The possibility exists that some patients or their families depended on unreliable memories when responding to the questionnaire. There was also a significant loss of follow-up in part because of the mortality and morbidity associated with cancer and because of the complex psychosocial issues that can affect patients. In the best of circumstances and with the most tactful and sensitive investigators, it can still be very difficult to obtain complete follow-up on patients who may be physically ill, emotionally upset, and in recovery after major surgery. The conclusions were dependent on the interpretation of 34 nonresponding patients. If the worst scenario for these remaining 34 patients without response was assumed, patient's satisfaction rate and family member's satisfaction rate were 42.2% and 38%, respectively. In contrast, if the best scenario for the remaining 34 patients was assumed, patient's satisfaction rate and family member's satisfaction rate were 90.1% and 85.9%, respectively. There were huge differences between these extreme hypotheses. To overcome the possible differences of interpretation, further prospective study should be undertaken. Despite these recognized limitations, this study clearly showed that, in cases of cancer metastasis to the spinal column, surgical intervention had a low rate of surgical complications and offered the patient definite benefits in terms of improved mental status, symptom relief, improved QOL, and improved daily functional status.

Conclusions

The satisfaction of patients and their families after palliative surgery for metastatic spinal disease was analyzed. Patient's satisfaction was affected by age and neurological improvement. Satisfaction of families was affected by pain improvement and patient's survival. The overall satisfaction rate of 80% indicated a high level of acceptance of this treatment. Palliative surgical treatment was a valuable procedure for the patients with metastatic spinal disease and limited life expectancy. Physicians must take into consideration the QOL of patients and their families when undertaking treatment for metastatic spinal disease.

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Clinical Results of the Wear Performance of Cross-Linked Polyethylene in Total Hip Arthroplasty

Prospective Randomized Trial

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Abstract: To investigate the clinical results of cross-linked polyethylene (CLPE) and to compare the CLPE wear against zirconia and stainless steel heads, we studied the radiographic wear after a minimum 3-year follow-up in total hip arthroplasty (THA). Ninety-four hips were randomly implanted with a 22.225-mm head cemented THA—the group of non-CLPE against zirconia and CLPE against 2 different zirconias and stainless steel. The linear wear rate was significantly lower in the group of CLPE against zirconia (0.067, 0.059 mm/y) and against stainless steel (0.068 mm/y) compared with non-CLPE against zirconia (0.170 mm/y). In the short-term results, the wear performance of CLPE against zirconia was superior to that of non-CLPE; however, it did not show a better wear rate than CLPE against stainless steel. Furthermore, long-term investigations will be necessary for understanding CLPE wear in vivo. **Keywords:** wear, cross-linked polyethylene, total hip arthroplasty, clinical result, prospective randomized trial.

Long-term results of total hip arthroplasty (THA) have been improving year by year [1-3], but many problems still need to be resolved. Among them, the major problem that influences the long-term results of THA is periprosthetic osteolysis and subsequent loosening of the prosthesis [4-5].

One of the possible causes of aseptic loosening is considered to be induced by an immunologic response [6-8]. Some literature suggests that the more the acetabular polyethylene (PE) liner is worn, the more frequent the occurrence of periprosthetic osteolysis in THA [9-11].

To resolve the excessive wear of PEs, cross-linked polyethylene (CLPE) has been developed, and CLPEs are now produced by several manufacturers. The clinical use of sockets made of CLPE has become widespread in recent years. Some of the CLPEs have shown excellent wear resistance in vitro [12] and in vivo [13]. However, not all CLPEs are equal because they are produced by various methods. For such reasons, the wear performance of CLPE is still unclear.

In this study, we investigated the clinical results of CLPE and compared the wear performance of it against zirconia and stainless steel heads by analyzing radiographic wear after a minimum 3-year follow-up in THA.

Patients and Methods

From November 1999 to December 2001, 94 hips were implanted with a 22.225-mm head, primary, cemented THA in our hospital. The patients were randomly divided into 4 groups using a sealed envelope technique. All the sockets were all PE cemented acetabular components without a modular metal shell. Twenty-six hips in 23 patients (1 male and 22 females) of group A were implanted with conventional non-CLPE sockets against zirconia heads (BC socket and PHS head, Kyocera Corp, Kyoto, Japan) as control. All the other sockets were made of CLPE (Aeonian socket, Kyocera). The other femoral prostheses were divided into the following 3 groups: 25 hips in 17 patients (1 male and 16 females) of group B were implanted with Kyocera zirconia heads (PHS head, Kyocera), 23 hips in 20 patients (all females) of group C were implanted with Kobelco zirconia heads (HHZ head, Kobelco, Kobe Steel Ltd, Kobe, Japan), and 20 hips in

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17 patients (2 males and 15 females) of group D were implanted with stainless steel (Ortron-90) heads (Elite head, DePuy Inc, Warsaw, Ind). The surface finish of the heads are similar (Ra, <0.02 μm; Ry, <0. 2 μm; the data were provided by its manufacturers).

A preoperative diagnosis was as follows. In group A, 21 hips were secondary osteoarthritis as a result of developmental hip dysplasia, 3 hips were rheumatoid arthritis, and 1 hip was idiopathic avascular necrosis of femoral head (ANF) and postseptic arthritis of one hip. In group B, 24 hips were secondary osteoarthritis as a result of developmental hip dysplasia, and 1 hip was steroid-induced ANF. In group C, 22 hips were secondary osteoarthritis as a result of developmental hip dysplasia, and 1 hip was arthrodesis. In group D, 17 hips were secondary osteoarthritis as a result of developmental hip dysplasia, 2 hips were systemic lupus erythematosus, and 1 hip was steroid-induced ANF. The preoperative and postoperative activity level of the patients was classified by using the UCLA activity level index [14].

Among these groups, patients' demographics such as mean age at operation, follow-up period, the body weight before surgery, the preoperative and postoperative activity level index, and socket abduction angles were not statistically different as shown in Table 1.

The conventional BC sockets used were made of non-CLPE. They were made from GUR415, with stearic acid by ram extrusion and sterilized by ethylene oxide gas. Their average molecular weight was 7.3×10^6. The CLPE, Aeonian socket was made from GUR1050 without the use of stearic acid by compression molding. Their average molecular weight is 7.3×10^6. Cross-linking was accomplished by annealing the material at 110°C after irradiation (3.5 Mrad). These sockets were sterilized by γ irradiation (2.5 Mrad) in nitrogen.

All operations were performed by using a direct lateral approach with a trochanteric osteotomy (Dall's approach) [15]. In dysplastic hips, the femoral head was used for the graft [16]. The grafts were screwed to the superolateral aspect of the acetabular roof with poly-L-lactic acid (PLLA) screws (Fixsorb, Takiron Co Ltd, Osaka, Japan). The acetabular sockets were fixed with vacuum-mixed bone cement (Endurance, DePuy), and the femoral stems were also inserted with bone cement and a cement gun, the so-called third-generation technique [17].

Radiologic Analysis of PE Wear

Polyethylene wear was measured radiologically by determining the penetration of the center of the head relative to the center of the acetabular socket, based on the computer-aided technique described by Sychterz et al [18] and modified by Tanaka et al [19]. The analytical methods used in this study, including the digitization of radiographs and the use of software, are the same as those previously reported and verified by retrieved specimens [19].

Table 1. Patients' Demographics

Group	Acetabular Socket (Manufacturer)	Inner Head (Manufacturer)	Femoral Stem (Manufacturer)	n	Age at Operation, y (±SD)	Follow-Up years, y (±SD)	Body Weight, kg (±SD)	Activity Level Index (Preoperative/Postoperative) (Points ± SD)	Socket Abduction Angle, Degrees (±SD)
A	BC socket, non-CLPE (Kyocera Corp)	PHS head, zirconia (Kyocera Corp)	KC stem (Kyocera Corp)	26	60.0 ± 9.4	4.04 ± 0.99	52.3 ± 6.2	3.6 ± 0.9/5.2 ± 0.8	44.3 ± 4.6
B	Aeonian socket, CLPE (Kyocera Corp)	PHS head, zirconia (Kyocera Corp)	KC stem (Kyocera Corp)	25	61.6 ± 7.9	3.80 ± 0.68	50.7 ± 6.7	3.6 ± 0.7/5.2 ± 0.9	43.5 ± 4.7
C	Aeonian socket, CLPE (Kyocera Corp)	HHZ head, zirconia (Kobelco, Kobe Steel Ltd)	K-max stem (Kobelco, Kobe Steel Ltd)	23	62.7 ± 9.6	3.73 ± 0.54	51.0 ± 9.4	3.7 ± 0.6/5.3 ± 0.7	43.7 ± 3.9
D	Aeonian socket, CLPE (Kyocera Corp)	Elite head, stainless-steel (DePuy Inc)	C stem (DePuy Inc)	20	60.9 ± 7.9	4.07 ± 0.43	54.7 ± 12.6	3.7 ± 0.8/5.2 ± 0.9	44.0 ± 4.7
	P				.76	.27	.34	.86/.94	.94

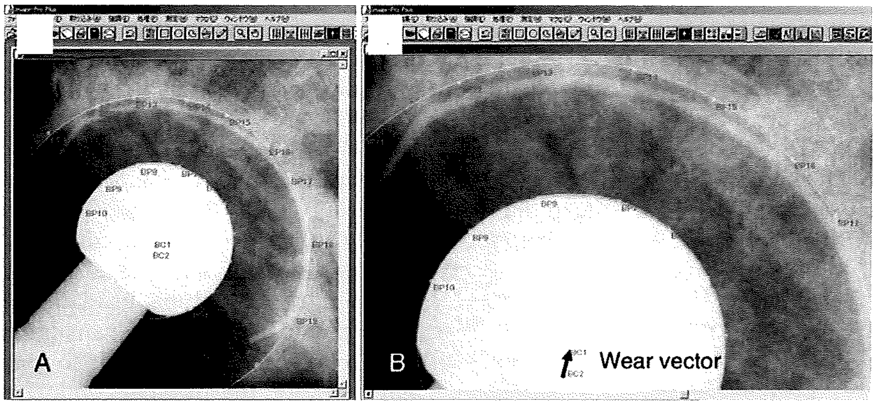

Fig. 1. Radiologic measurements of PE wear. (A) After 10 points around the periphery of the head and the cement-PE interface of the acetabular socket had been identified. (B) The image analysis software provided best-fit circles and their centers. By comparing the coordinates of the centers, the amount and the direction of penetration of the head into the acetabular PE was measured (black arrow).

For each patient, the initial postoperative and most recent radiographs of the pelvis in the weight-bearing positions were selected. First, these radiographs were digitized by using an image scanner (GT-9500, Seiko Epson Corp, Nagano, Japan). After 10 points around the periphery of the head and the cement-PE interface of the acetabular socket had been identified, the image analysis software (Image-Pro Plus version 4.0, Media Cybernetics Inc, Silver Spring, Md) provided the best-fit circles and their centers. By comparing the coordinates of the centers on the initial postoperative and the most recent radiographs, the amount and the direction of penetration of the head into the acetabular PE [20] was measured after the correction of magnification and pelvic tilting, as shown in Fig. 1. Volumetric wear was calculated by using the equation described by Hashimoto et al [21], as shown in Equation 1.

Equation 1. Hashimoto's equation of radiologic PE wear.

$$\text{Volumetric wear} = \frac{r^2 h}{2}(\pi + 2\beta + \sin 2\beta),$$

where r indicates radius of the head; h, linear wear; and β, direction of wear.

Reliability of Measurements

To validate this measurement, the author (KI) measured the PE wear in blind fashion. For 10 randomly selected cases, the measurements were repeated 3 times with 1-week intervals to assess the intraobserver repeatability.

Statistical Analysis

The differences between the groups were compared with analysis of variance, followed by Fisher post hoc test. Statistical significance was set at $P < .05$.

Results

Reliability of Measurements

The intraobserver repeatability coefficients ranged from 0.990 to 0.998 in the measurement of PE wear. The mean error in measurement of PE wear was 0.081 ± 0.062 mm.

Radiologic Analysis of PE Wear

The linear wear rate was significantly lower in the CLPE Aeonian sockets of group B (CLPE sockets against Kyocera zirconia heads, 0.067 ± 0.044 mm/y), group C (CLPE sockets against Kobelco zirconia heads, 0.059 ± 0.027 mm/y), and group D (CLPE sockets against stainless steel heads, 0.068 ± 0.039 mm/y) compared with group A (non-CLPE sockets against Kyocera zirconia heads, 0.170 ± 0.098 mm/y). The volumetric wear rate was also significantly lower in the CLPE Aeonian sockets of

Table 2. Results of Polyethylene Wear

Group	Acetabular Socket (Manufacturer)	Inner Head (Manufacturer)	n	Linear Wear Rate, mm/y (±SD)	Volumetric Wear Rate, mm^3/y (±SD)	Direction of Wear, Degrees (±SD)
A	BC socket, non-CLPE (Kyocera Corp)	PHS head, zirconia (Kyocera Corp)	26	0.170 ± 0.098	49.19 ± 29.09	−7.80 ± 34.90
B	Aeonian socket, CLPE (Kyocera Corp)	PHS head, zirconia (Kyocera Corp)	25	0.067 ± 0.044	19.82 ± 13.10	−7.61 ± 41.90
C	Aeonian socket, CLPE (Kyocera Corp)	HHZ head, zirconia (Kobelco, Kobe Steel Ltd)	23	0.059 ± 0.027	17.23 ± 7.79	−5.44 ± 35.91
D	Aeonian socket, CLPE (Kyocera Corp)	Elite head, stainless steel (DePuy Inc)	20	0.068 ± 0.039	20.00 ± 11.70	−8.26 ± 40.40
	P			<.0001	<.0001	.99

group B (19.82 ± 13.10 mm^3/y), group C (17.23 ± 7.79 mm^3/y), and group D (20.00 ± 11.70 mm^3/y) compared with group A (49.19 ± 29.09 mm^3/y), as shown in Table 1. The direction of wear was not statistically different as follows: −7.80° ± 34.90° in group A, −7.61° ± 41.90° in group B, −5.44° ± 35.91° in group C, and −8.26° ± 40.40° in group D. The material property of the head did not significantly affect wear on the CLPE socket (Table 2).

Discussion

Several CLPE sockets are available from different manufacturers. Some of the CLPEs have shown excellent wear resistance in vitro [12] and in vivo [13]. However, Digas et al [22] showed by 3-dimensional study at 0 to 3 years that the wear resistance of CLPE did not differ from conventional PE in the weight-bearing positions. The results of CLPE sockets, especially in vivo, still seem to be controversial.

The aim of the new PEs is to reduce wear, and this appears to have been achieved by minimizing free radicals. These CLPEs were produced by various methods of irradiation, sterilization, and thermal treatments [23]. The mechanical behaviors of CLPEs are influenced by the choice of PE and the methods for cross-linking. The Aeonian socket is made by compression molding GUR1050, without the use of stearic acid. Their average molecular weight is 7.3×10^6. Cross-linking is accomplished by annealing the material at 110°C after irradiation (3.5 Mrad). It is sterilized by γ irradiation (2.5 Mrad) in nitrogen. However, sterilization with 2.5 Mrad is not analogous to the highly CLPEs in the 5.0 to 10 Mrad range currently being produced by many implant companies.

Our short-term results show that the wear performance of Aeonian sockets against zirconia heads is superior to that of conventional non-CLPE sockets against zirconia heads.

Furthermore, it is unclear whether the material property of the femoral head affects the wear on CLPE sockets. According to the review article by Clarke et al [24], clinical results of zirconia heads have varied. Sakoda et al [25] reported that the wear of CLPE increased dramatically against a scratched counter surface in vitro. To clarify this problem, 2 kinds of zirconia head made by different manufacturers and 1 stainless-steel head were used in this study. The wear of these Aeonian sockets against the zirconia and stainless steel heads showed similar results. Ceramic heads were shown as excellent material for the bearing surface against PE sockets by an in vitro hip simulator wear test [26]. The reasons for such excellent results were considered to be the wettability [27] and the tribological properties [26,28]. Nevertheless, Aeonian sockets did not have a better wear rate against zirconia heads than against stainless steel heads. We speculate that the material properties of these head materials may be inconsequential for the Aeonian sockets because the surface finish of the heads is similar at the time of implantation.

These results included the so-called initial bedding-in period. Digas et al [22] reported that the penetration rate decelerated in the CLPE socket from 6 months after surgery. We therefore expect even better results in the following years. However, the wear rate of CLPE was clearly influenced by the counter surfaces [25]. Some reports have shown that regarding the phase transformation of retrieved zirconia head, the monoclinic phase was more dominantly observed, and it had a relationship with surface roughness in longer follow-up specimens [29,30]. Furthermore, the thermal conductivity of zirconia ceramics is relatively lower than that of other ceramics, especially alumina [31]. These facts suggest a possibility of accelerated phase transformation and subsequent enhanced surface roughness of zirconia head in vivo.

Moreover, Scott et al [32] reported that the size of the particulate debris of CLPE was smaller than that of conventional non-CLPE, and Green [33] reported that smaller particles induce the more active immunologic response to macrophages, which leads to osteolysis. For such reasons, it is clear that more time needs to transpire before the long-term results will be clear. These studies indicate that further long-term investigations will be necessary for understanding CLPE wear in vivo.

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Case Report

Computed Tomography-Based Navigation to Determine the Femoral Neck Osteotomy and Location of the Acetabular Socket of an Arthrodesed Hip

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Abstract: In the conversion of an arthrodesed hip to a total hip arthroplasty, the osteotomy of the femoral neck and the placement of the acetabular socket are difficult procedures as anatomical abnormalities hamper identification of the femoral neck and of the original center of the acetabulum. A 59-year-old woman who had a hip arthrodesis for dysplastic osteoarthritis at 21 years of age underwent total hip arthroplasty for relief of back pain, achievement of good gait function, and improvement of activities of daily living. In this report, we introduce a technical solution, using a computed tomography-based navigation system to determine the site and direction of the femoral neck osteotomy and the positioning of the acetabular socket. **Keywords:** computed tomography–based navigation system, total hip arthroplasty, hip arthrodesis.

Hip arthrodesis is performed in young adult patients with severe osteoarthritis, local infection, and trauma to the hip joint [1]. However, a long-term hip arthrodesis profoundly impairs patients' gait and activities of daily living. In addition, patients may have increased risk for pain in the low back, ipsilateral knee, and contralateral hip [2]. These patients then require a takedown of the arthrodesed hip and conversion to total hip arthroplasty (THA), procedures that include many difficulties, such as identification of the femoral neck and the original center of the acetabulum. To overcome these difficulties, we used a computed tomography (CT)-based navigation system to determine the site and direction of the femoral neck osteotomy and to place the acetabular socket in the correct location.

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Case Report

A 59-year-old woman with an arthrodesed left hip complained of severe low back pain and restriction of her gait and activities of daily living. She underwent arthrodesis of the left hip joint for dysplastic osteoarthritis with severe pain and gait disturbance at 21 years of age. The left hip joint was fused in the arthrodesis position of 20° of flexion, 5° of adduction, 10° of external rotation, and a leg length discrepancy of 1.7 cm (Fig. 1A). Radiographs and computed tomograms showed fusion of the acetabulum with the femoral head, the superior part of the acetabulum with the greater trochanter, and the inferior rim of the acetabulum with the lesser trochanter, and it was difficult to distinguish the border of the pelvis from the femur (Fig. 1B, C, and D). To relieve her low back pain and restore the function of the hip joint, a left THA was planned. After scanning the patient's pelvis and femur, preoperative planning and virtual implantation were performed using a CT-based navigation system software (Vector Vision Hip ver 2.5.1, Brain Lab, Munich, Germany), and the site and direction of the femoral neck osteotomy (Fig. 2A-D), the center of the original acetabulum, and the position of the acetabular socket (Fig. 2E and F) were determined. In planning, we paid attention to retaining greater trochanter as large as possible and to keeping sufficient posterosuperior bone stock in the acetabulum. During the operation, the patient

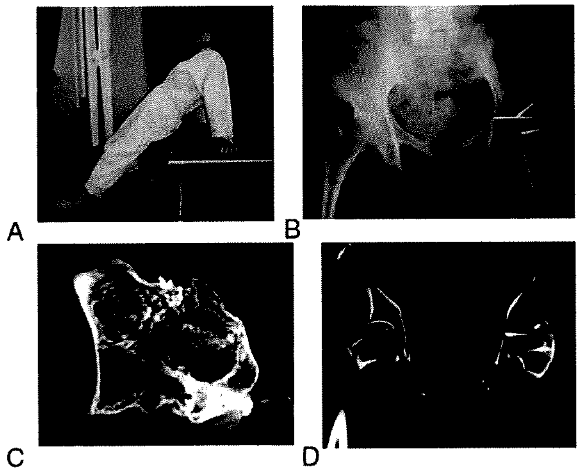

Fig. 1. (A) A preoperative picture of the 59-year-old woman. She could not sit on a chair. (B) A preoperative radiograph and computed tomograms (C, axial section, and D, coronal section) are shown.

was placed in a lateral decubitus position. The left hip joint was exposed using an anterolateral approach. Anterior part of the intertrochanteric region was exposed and then femoral neck osteotomy was performed with oscillation saw in accordance with the preoperative plan using 3 screw heads on the greater trochanter as landmarks. After the entire margin of the acetabular rim was exposed, acetabular reaming was performed in the true acetabulum in accordance with the preoperative plan with the remaining transverse acetabular ligament and the inferior margin of the acetabulum as landmarks. The acetabular socket and the femoral component (PHS type6 straight, JMM Ltd, Osaka, Japan) were implanted with bone cement. The postoperative radiographs and the computed tomograms showed that the femoral neck osteotomy and the location of the acetabular socket corresponded to those in the preoperative plan; the leg length discrepancy was also improved (Fig. 3B, C, and D). Four months after operation, the patient can sit on a chair (Fig. 3A) and walk using a crutch.

Discussion

Hip arthrodesis is a valuable technique in younger patients with an isolated severe arthritic hip condition. However, long-term hip arthrodeses cause back and

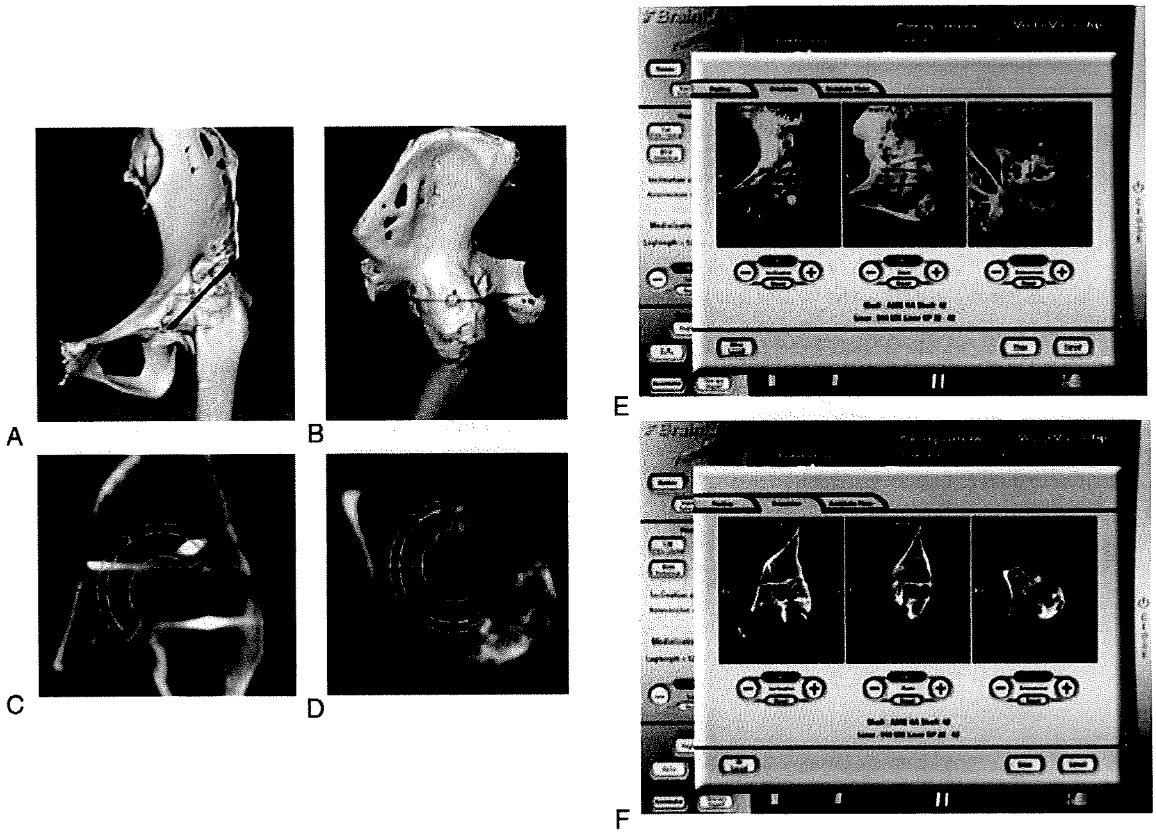

Fig. 2. (A-D) Preoperative planning for the femoral neck osteotomy and (E and F) positioning of the socket during THA using the CT-based navigation system. The putative osteotomy (black plane) is indicated on the 3-dimensional anteroposterior (A) and lateral (B) views. The osteotomy line (purple line) is also shown on the 2-dimensional coronal (C) and horizontal (D) cross-sectional views. (E) Three-dimensional views in the coronal to pelvis plane, the frontal to midsagittal plane, and the frontal to base plane with the targeted socket shaded. (F) The 2-dimensional acetabular coronal, sagittal, and inlet section views are shown with the targeted socket shaded.

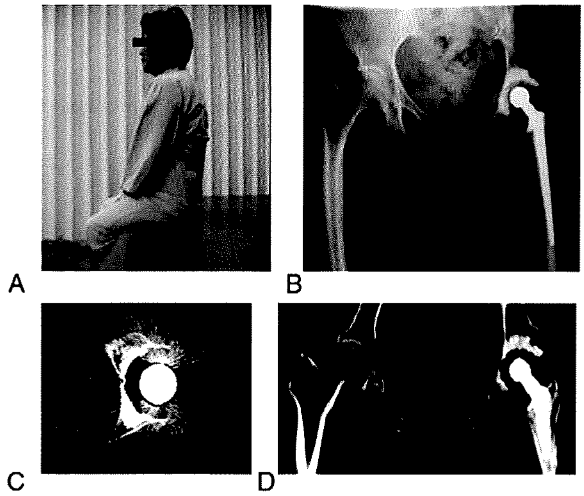

Fig. 3. (A) Postoperative picture of the patient sitting on a chair. (B) A postoperative radiograph and computed tomograms (C, axial section, and D, coronal section) are shown.

ipsilateral knee pain. In addition, activities of daily living and gait are markedly limited. Conversion of hip arthrodesis to THA can restore the functions in the arthrodesed hip joint and relieve pain in other joints. However, the procedure of conversion of hip arthrodesis to THA is technically challenging and has a high risk of postoperative complication and a high failure rate, mainly because of anatomical abnormalities of the fused hip joint [3]. Therefore, precise planning of the procedures based on preoperative evaluation of the position of the arthrodesis as well as review of radiographs is required.

In the conversion of an arthrodesed hip to THA, careful preoperative planning is required to refine operative techniques [3], in particular, precise femoral neck osteotomy, acetabular preparation, and adjustment of leg length. In addition, during the operation, intraoperative x-rays to determine the position of the femoral neck and the acetabulum are needed in most cases, as controlling the orientation of the pelvis and the femoral neck is very difficult. A CT-based navigation system for THA has recently offered a useful method for surgeons to plan and simulate an operation and to perform operative procedures accurately, and it is to be hoped to reduce the incidences of intraoperative and postoperative complications [4-7]. In our case, preoperative CT data of the patient's pelvis and femur were acquired to produce a 3-dimensional model using a CT-based navigation system, and virtual femoral neck osteotomy and implantation of the acetabular socket were done preoperatively. In planning, we focused on preservation of the greater trochanter as large as possible to allow restoration of the abductor mechanism of the hip joint. Furthermore, after the virtual femoral neck osteotomy, retention of sufficient posterosuperior bone stock for adequate containment of the acetabular socket is required. In addition, we estimated the original hip center and the placement of the acetabular socket after the virtual femoral osteotomy.

During the operation, it is quite difficult to visualize the neck-pelvis junction because of the lack of mobility of the arthrodesed hip joint and the coverage of the femoral neck by muscles. In addition, in our case, fusion of the acetabulum with the greater and lesser trochanters prevented us from distinguishing the border between the pelvis and the femur. It is also difficult to determine the original hip center and the acetabular edges with the acetabulum filled with a fused femoral head after a femoral neck osteotomy. To overcome these problems, we referred to 2-dimensional and 3-dimensional preoperative planning views of the pelvis and the femur using a CT-based computer navigation system during the femoral neck osteotomy procedures, reaming of the acetabulum, and placement of the acetabular socket. In our case, we succeeded in performing the femoral neck osteotomy and preparation of the acetabulum without CT-based computer navigation guidance during the operation. There had been 3 screws inserted from the proximal femur to achieve the arthrodesis in this patient, and these screw heads provided good landmarks for the femoral neck osteotomy, as based on the preoperative planning using the CT-based computer navigation system. Moreover, after separation of the acetabular rim from the greater and lesser trochanters, we directly visualized the entire acetabulum, in correspondence with the preoperative planning views. However, intraoperative guidance using a CT-based computer navigation system should be also helpful to monitor the position of the femoral osteotomy and the acetabular socket in most cases. Indeed, although the postoperative position of the acetabular socket is good in our case, the difference between the preoperatively determined inclination and anteversion of the socket with the postoperatively measured position was 3° and 10°, respectively, and the hip center is located 2 mm medially.

The CT-based computer navigation system used here is a powerful tool for preoperative planning and simulation of the femoral neck osteotomy and placement of the acetabular socket in conversion of an arthrodesed hip to a THA.

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