Bull Yamaguchi Med School 53(3-4):25-36, 2006

Dietary and Physical Activity Effects on Bone Metabolism after Gastrectomy

Rieko Kawamoto

Department of Nursing Science and Arts, School of Health Science, University of Occupational and Environmental Health, Iseigaoka 1-1, Yahatanishi-ku, Kitakyushu 807-8555, Japan
(Received February 10, 2006, accepted Novemver 7, 2006)

Abstract The purpose of this study was to investigate how diet and physical activity affect bone density, assessing bone metabolism changes in patients who underwent gastrectomy. The subjects were 10 patients from among 13. Their progress had been monitored for more than 12 months and all participants provided informed consent for this study to be conducted.

The study parameters consisted of bone density measurement using an ultrasound method, measurement of bone metabolism makers, the level of daily physical activity by the number of steps walked, and dietary assessment via a questionnaire.

As a result, although the OSI (Osteo Sono-Assessment Index) values showed some bone metabolism disorder in the 6th post-operative month, the subjects recovered to the pre-operative condition during and up to the 12th post-operative month.
Both bone formation and bone absorption, as indicated by bone metabolism markers (BAP, NTx, and DPD), improved from the 3rd post-operative week to the 6th post-operative month.

No correlation was observed linking bone metabolism, body weight, BMI, and physical activity. Intakes of milk, Ca, and Vitamin C, which normally affect bone metabolism disorders, tended to decrease in the bone metabolism risk and disorder groups.

Some possible causal factors resulting in bone metabolism disorder include insufficient intakes of calcium and vitamin C and a lack of physical activity.

Key words: gastrectomy, bone metabolism disorder, bone assessment indicators, diet, physical activity

Introduction

Concerning bone metabolism after gastrectomy, starting with a report of cases of osteomalacia after gastrectomy by Sakai, et al.[1] in 1967, it has been reported that bone metabolism disorder develops after distal gastrectomy at a rate of 34%, and following total gastrectomy at a rate of more than 40% at present.[2] It is recognized that, after gastrectomy, bone metabolism disorders advance relatively rapidly within one or two years after the operation because of a reduced food intake, the insolubility and malabsorption of calcium, and the ineffective absorption of vitamin D caused by the operation, after which disorders slowly advance.[2-4] Many previous studies were centered on the effects caused by different operative procedures[2)3)5] and the treatments. But few studies have been focused on life conditions when the effects of the operation still remain. As for studies on the effects of physical activity, it was reported that early walking after an operation[6)7] is effective for the prevention of bone metabolism disorder. An important factor relating

to bone metabolism disorder is that patients are living under conditions where the effects of the operation still remain, so that their dietary intakes have changed because of a poor digestive function less than one year after the operation, and their daily activity levels have not returned to the pre-operative levels.

On the other hand, it has been recently pointed out that patients who commonly undergo gastrectomy are of advanced age.

Given the increased aging of patients who receive the operation and the shortening of the hospital stay, effective lifestyle guidance from the period of hospitalization immediately after the operation should be given in order to prevent bone metabolism disorder, from the view point of nursing care.

For the purpose of obtaining basic data necessary to develop a lifestyle-guidance program for gastrectomy patients in this study, we conducted a follow-up survey on changes in bone metabolism, diet, and the physical activity level, discussed the effects of these conditions on bone density, and reported any intermediate progress.[8)]

As a result, although bone-type alkaline phosphatase (BAP), deoxypyridinoline (DPD), and crosslinked N-telopeptide of type I collagen (NTx) significantly increased three to six months after the operation, the bone density (SOS: Speed of Sound) showed no change.

This means that an increase in bone metabolism did not affect bone density (SOS).

Bone metabolism disorder should be assessed using both characteristics of the speed of sound (SOS) reflecting bone density, and the transmission index (TI) reflecting bone mass.

Consequently, we used a bone density measurement device, which reflects both SOS and TI and is able to measure an osteo sono-assessment index (OSI), which is considered to be a comprehensive index.

We conducted research for two years, during which time the patients' dietary conditions and physical activity would become stable. The report is as follows.

Methods

1. Subjects

The subjects were male patients diagnosed with gastric cancer from December 2001 to March 2004 at a particular university hospital and they submitted informed consent. The cases satisfied the following conditions; the patients were totally or partially gastrectomized and it was considered a radical extirpation at the time of surgery; during the follow-up survey, patients who were diagnosed as having a serious complication or a recurrence or metastasis of cancer, or received treatment of osteopenia with calcium and vitamin D were excluded.

Of the patients who were diagnosed with cancer and from whom informed consent for this study was obtained, 13 patients were subjected to the SOS, TI, and OSI measurements by an ultrasound bone assessment system.

However, during the follow-up survey, the number of subjects decreased due to cancer metastasis, death, or the patient's decision to discontinue cooperation.

Accordingly the subjects of this study were defined as 10 who had been followed up for more than 12 months.

In this study, the breakdown of ages of the ten subjects (64.4 ± 7.7 years old) on whom the survey could continue was four 70 year olds (40.0%), three 60 year olds (30.0%), and three 50 year olds (30.0%). The breakdown according to operative procedures was eight (80.0%) by partial gastrectomy (B-I method) and two (20.0%) by total gastrectomy.

2. Survey period

The survey period was from December 2001 to March 2004. The surveys were conducted once before the operation and five times after the operation (six times in total). The survey time before the operation was when a patient was admitted to hospital and those after the operation were at the 3rd week, 3rd, 6th, 12th, and 24th month after the operation.

3. Survey contents

Fig. 1 outlines the protocol showing follow-up survey periods and survey items for each survey period.

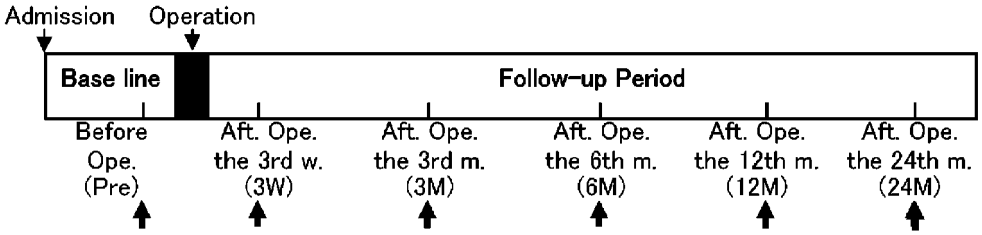

Fig. 1 Bone density measurement, blood test, urine test, survey through a questionnaire, and protocol for the physical activity survey.

↑ { Bone density measurement (SOS, TI, OSI)
Blood test (BAP, Ca, Phosphorus)
Urine test (DPD, NTx)
Survey through a questionnaire }

Ope. : Operation
W : Week, M : Month

1) Attributes of the subjects

Subjects were surveyed based on age, gender, occupation, diagnosed disease, previous disease, operative procedure, reconstruction method, treatment and course after the operation, complications, being dosed with anticancer drugs and vitamins or not, and being dosed with steroids or not.

2) Bone density measurement and bone metabolism disorder assessment methods

(1) Bone density measurement method

Bone density was measured by placing a probe at both heel bones three times each using an ultrasound bone density measurement system (Ultrasound Bone Evaluating Equipment AOS-100. ALOKA). Measurement parameters of bone density are the speed of sound (SOS), osteo sono assessment index (OSI), and transmission index (TI).

The accuracy of AOS-100 has been compared with that of bone mass measurement equipment by the DXA method, and the correlation coefficient with OSI in the calcaneus was extremely high at 0.896 ($p<0.001$).[9)]

(2) Bone metabolism disorder assessment method

Standard values for OSI were formulated in accordance with age based on the measurement results.

According to the criteria based on these standard values, if it is within the standard value -1SD (SD=standard deviation), the measured value is determined to be normal (within the standard range), if it is between less than -1SD and more than -2SD, the measured value is determined to be slightly lower than normal and there is a threat of bone density decrease, and if it is -2SD lower than the standard value, bone density is decreasing.

In this way, the levels of bone metabolism disorder can be assessed using these criteria. The subjects with OSI values within a standard value of -1SD were assigned to the normal group, those with OSI values between a standard value of -1SD and -2SD were assigned to the risk group, and those with OSI values less than a standard value of -2SD were assigned to the disorder group.

3) Bone metabolism makers

Bone alkaline phosphatase (BAP), deoxypyridinoline (DPD), crosslinked N-telopeptide of type I collagen (NTx), corrected calcium (corrected Ca = 4 + serum calcium-serum albumin), and inorganic phosphorus were measured.

Because NTx fluctuates throughout the day, urine sampling was performed between 9～12 AM, and the sampling method was randomized.

4) Dietary survey

As for the survey on dietary intake, the number of meals and kinds of food ingested at each survey time were assessed through a questionnaire. The kinds of foods surveyed were categorized as meat, egg, fish, small

fish, seaweed, milk, dairy products other than milk, soybean products, vegetables, fruit, and instant food, and it was recorded how many days each food was consumed during one week for the period of one month before the day the survey was conducted.

Everyday intake (7 day/week) was defined as 7, 6 days intake (6 days/week) was 6, and zero intake was 0.

The results of the survey on foods were classified and organized according to nutrients. Nutrients which enhance bone formation are calcium, protein, vitamins C, D, and K, and magnesium, etc. In order to classify these foods according to nutrients, foods high in each nutrient were selected, as shown in Table 1.

Table 1 Nutrients and foods that affect bone metabolism

Nutrients	Main foods
Protein	Meal
	Egg
	Fish
	Small fish
	Milk
	Dairy products
	Soybean products
Calcium	Milk
	Dairy products
	Soybean products
	Small fish
	Seaweed
Vitamin C	Green and yellow vegetables
	Fruits
Vitamin D	Fish
Phosphate	Instant foods

Because lactose in milk promotes the absorption of calcium and a higher calcium absorption rate than other foods,[10] milk was included as an item although it is not a nutrient. Conversely, excess intakes of phosphate and dietary fiber possibly reduce the absorption of calcium.

5) Survey on physical activity

As for physical activity, the number of steps walked per day was defined as an indicator. For the measurement of steps walked, the subjects used a pedometer (Life Coder; Suzuken Co. Ltd.) continuously for three days for each survey period, and an average value was used.

A survey on whether they continuously worked, and the kind, frequency, and duration of physical activity performed was conducted through a questionnaire.

6) Body measurements

Body height and weight were measured when the bone density was measured.

4. Statistical analysis

Basic statistical values were obtained as a result of the investigation of average time-related changes according to bone mass indexes and the surveyed items. Subsequently, repeated-measures analysis of variance was conducted on the time-related changes of bone metabolism parameters, and, when a significant difference was observed, a multiple comparison test (Tukey HSD) was conducted. Partial correlation analysis was conducted for the relationship between bone density parameters and biochemical markers of bone metabolism. A comparison between groups based on the nutritional status, physical activity, and the level of differences in bone metabolism was conducted by nonparametric statistics and the Mann-Whitney U test because the number of subjects was small. Differences of 1% or 5% were regarded as significant.

Statistical analysis was performed using the statistical package SPSS for Windows 11.5J.

5. Ethical considerations

Approval from the Ethical Committee of the University of Occupational Environmental Health was obtained for this study.

Results

1. Bone assessment indicators

1) Bone density parameters (SOS, TI, and OSI values)

Average time-related changes in SOS

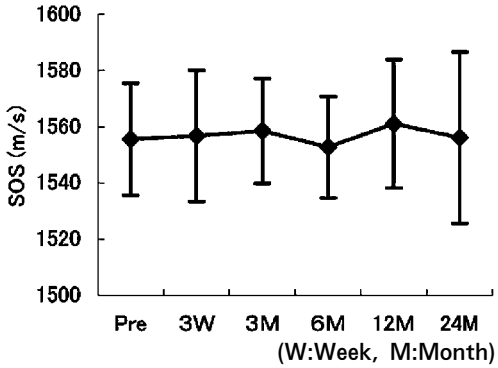

Fig. 2a Time-related SOS value changes

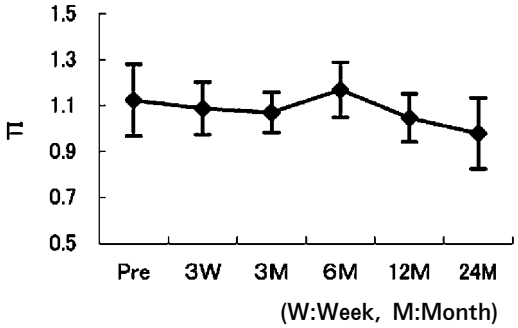

Fig. 2b Time-related TI value changes

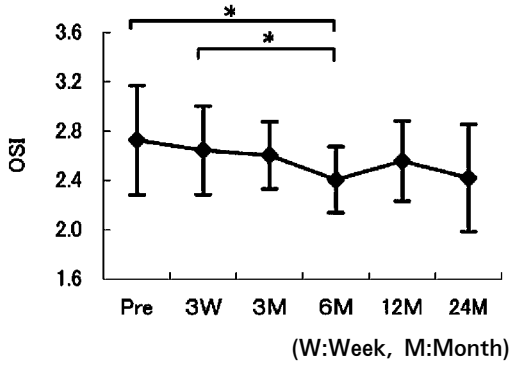

Fig. 2c Time-related OSI value changes

Fig. 2 Time-related changes of bone density parameters.

values from before the operation are shown in Fig. 2a, TI values in Fig. 2b, and OSI values in Fig. 2c.

Although the OSI values significantly decreased at the 6th month after the operation compared with the levels before and at the 3rd week after the operation ($P<0.05$), the values tended to gradually recover after the 12th post-operative month.

A partial correlation matrix among bone metabolism indicators of SOS, TI, and OSI was obtained and is shown in Table 2. Correlations between SOS and TI, and SOS and OSI were observed.

2) Post-operative assessment results by OSI criteria

Table 3 shows the changes in bone metabolism disorder levels by group and OSI criteria. We conducted a comparative investigation based on this table.

Table 2 Partial correlation between bone density parameters and bone metabolism markers

	SOS	TI	OSI	BAP	NTx	DPD	Corrected Ca	Phosphorus
SOS	1	0.47**	0.77**	-0.14	-0.54**	-0.37*	0.14	0.18
TI		1	0.41*	0.14	-0.08	-0.11	0.35*	0.13
OSI			1	-0.08	-0.53**	-0.28	0.32*	-0.02
BAP				1	0.31*	-0.05	-0.27	-0.37*
NTx					1	0.48**	-0.10	-0.13
DPD						1	-0.05	0.17
Corrected Ca							1	0.01
Phosphorus								1

*:P<0.05 **:P<0.01

SOS : Speed of Sound
TI : Transmission Index
OSI : Osteo Sono Assessment
BAP : Bone Alkaline Phosphatase
NTx : N-telopeptide of type I collagen
DPD : deoxypyridinoline
Corrected Ca : corrected calcium

Table 3 Categorization of subjects by the levels of bone metabolism 〔Number (%)〕

Group	Time					
	Pre	3W	3M	6M	12M	24M
Normal	6 (60.0)	6 (60.0)	6 (60.0)	5 (50.0)	6 (60.0)	5 (71.4)
Risk and disorder	4 (40.0)	4 (40.0)	4 (40.0)	4 (40.0)	4 (40.0)	2 (28.6)
Risk	4	4	4	3	3	0
Disorder	0	0	0	1	1	2
Missing value	0 (0.0)	0 (0.0)	0 (0.0)	1 (10.0)	0 (0.0)	3* (30.0)

〔Group〕 n=10

Norma : OSI value is standard - 1 SD
Risk : OSI value is lower than standard from -1SD to -2SD
Disorder : OSI value is lower than standard, more than -2SD

〔Missing value〕

Missing value shows the number of subjects who did not visit the hospital and whose data were not available

* : All of the three were in the "Risk" group at 12M

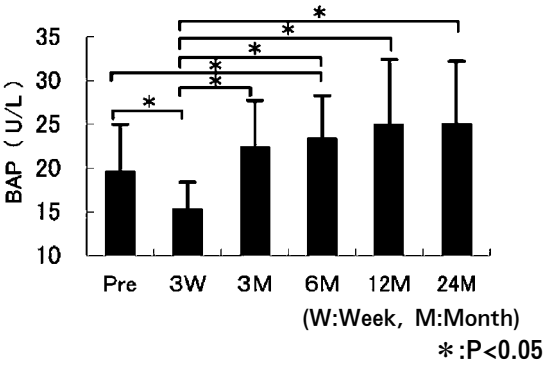

Fig. 3a Time-related BAP changes

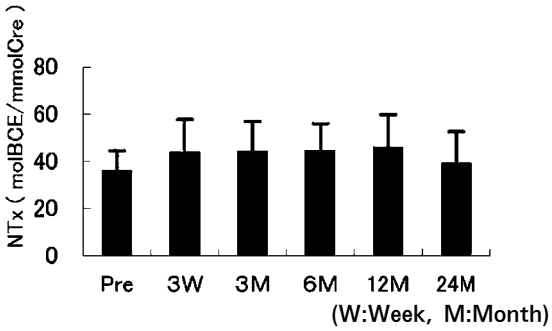

Fig. 3b Time-related NTx changes

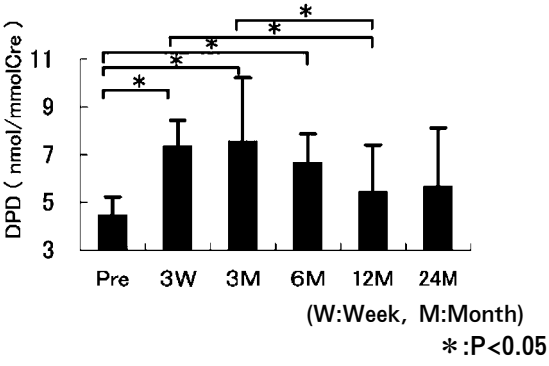

Fig. 3c Time-related DPD changes

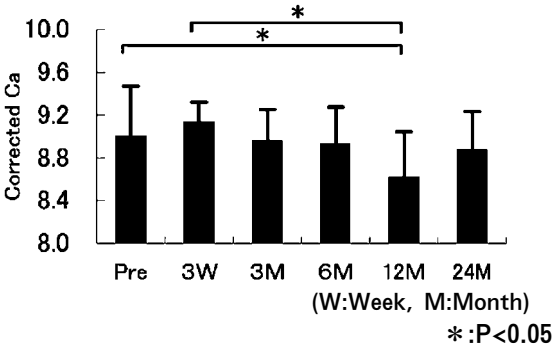

Fig. 3d Time-related corrected Ca changes

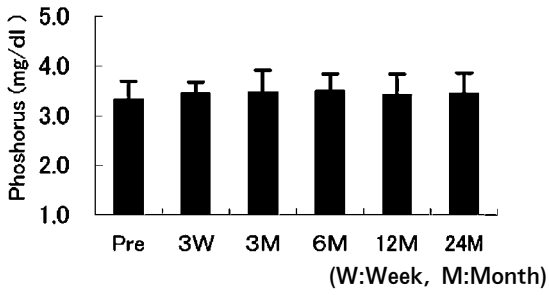

Fig. 3e Time-related phoshorus changes

Fig. 3 Time-related changes of bone metabolism markers.

One out of ten subjects showed bone metabolism disorder at the 6th and 12th post-operative months, and two out of seven subjects showed bone metabolism disorder at the 24th post-operative month.

3) Biochemical markers of bone metabolism

(1) Bone formation markers

Fig. 3a shows the time-related changes of BAP, a bone formation marker, from before the operation. Although it significantly ($P<0.05$) decreased by -5.06 U/L at the 3rd post-operative week, it significantly increased at the 6th month after the operation to higher than the pre-operative level, and remained unchanged after that.

(2) Bone absorption markers

Fig. 3b shows the time-related changes of NTx, a bone absorption marker, from before the operation. No significant difference was observed at any survey time.

Fig. 3c shows the time-related changes of DPD, also a bone absorption marker. Although it showed significantly higher values from the 3rd week to 6th month after the operation, it recovered to about the same as the pre-operative level after the 12th post-operative month.

(3) Influence of bone metabolism markers

The following are the results of the survey on corrected Ca and phosphorus, which are nutrients essential for bone metabolism.

Fig. 3d shows the time-related changes of corrected Ca. Corrected Ca tended to increase at the 3rd post-operative week, after which it was generally maintained at the same level. However, it significantly decreased at the 12th and recovered at the 24th post-operative month.

Fig. 3e shows the time-related changes of phosphorus. There was no significant difference at any survey time.

4) Relationship of bone assessment indicators

(1) Bone metabolism parameters

Table 2 shows the partial correlation matrix among bone density parameters (SOS, TI, and OSI), bone metabolism markers (BAP, NTx, and DPD), and corrected Ca and phosphorus.

SOS showed a correlation with NTx ($P<0.01$) and DPD ($P<0.05$), both bone absorption markers, and OSI showed a correlation with NTx ($P<0.01$).

(2) Body weight

Body weight was regarded as a factor affecting bone formation by its kinetic load.

Fig.4 shows the time-related changes in body weight. Body weight had decreased by more than 5 kg ($P<0.01$) at the 3rd post-operative week.

(3) Nutritional status

The body mass index (BMI) was defined as an indicator of the nutritional status.

Fig. 5 shows the time-related changes of BMI. BMI significantly decreased at the 3rd week after the operation, and did not subsequently recover.

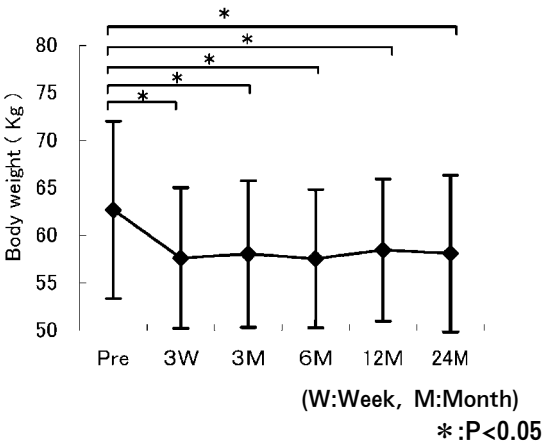

Fig. 4 Body weight changes.

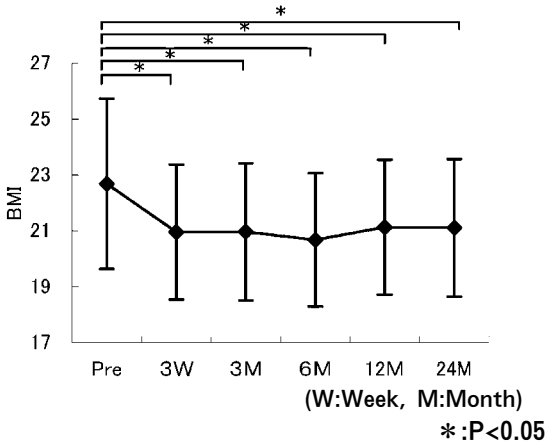

Fig. 5 BMI changes.

(4) Diet

The number of meals per day was generally three before the operation. After the operation, the frequency of meals was increased according to dietary instruction, but returned to the same number as before the operation at the 24th post-operative month.

(5) Physical activity

Fig.6 shows the time-related changes in the daily number of steps walked, an indicator of physical activity.

The number of steps walked decreased at the 3rd post-operative week and significantly increased from the 3rd post-operative month, and, although no significant difference was

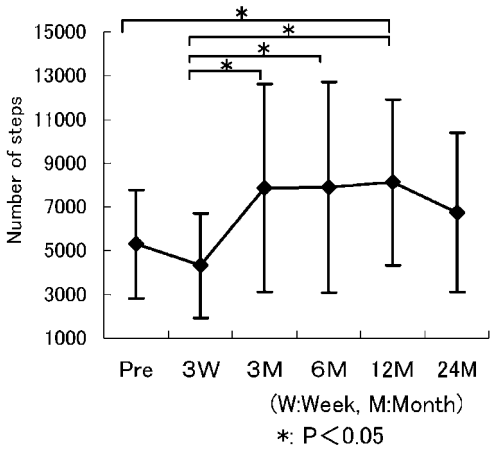

Fig. 6 Changes in physical activity. (Number of steps walked)

Table 4 Relationships between bone metabolism, nutritional status, nutrient intake, and physical activity

		Time			(M±SD)
	Group	3M	6M	12M	24M
Number (%)	N	6 (60.0)	6 (60.0)	5 (60.0)	5 (50.0)
	R	4 (40.0)	4 (40.0)	4 (40.0)	2 (20.0)
	M	0 (0.0)	0 (0.0)	1 (10.0)	3 (30.0)
Nutritional status					
BMI	N	22.0 ± 1.9	21.4 ± 1.7	22.7 ± 1.9	21.3 ± 1.8
	R	19.5 ± 2.7	18.9 ± 2.3	19.7 ± 2.6	20.8 ± 4.9
Nutrient intake					
Protein (day/week)	N	3.6 ± 0.7	3.6 ± 1.4	3.6 ± 1.4	3.7 ± 1.0
	R	3.3 ± 1.3	3.1 ± 1.2	2.5 ± 0.6	3.3 ± 0.1
Calcium (day/week)	N	1.8 ± 1.5	1.9 ± 1.2	2.1 ± 1.1	2.6 ± 1.2
	R	1.4 ± 0.4	1.3 ± 0.6	1.3 ± 0.6	1.8 ± 0.0
Vitamin C (day/week)	N	3.6 ± 3.0	3.8 ± 2.3	4.2 ± 2.3	5.2 ± 2.4
	R	2.9 ± 0.7	2.6 ± 1.1	2.7 ± 1.1	3.5 ± 0.0
Vitamin D (day/week)	N	2.5 ± 1.1	4.2 ± 2.1	3.3 ± 1.1	3.8 ± 2.0
	R	3.5 ± 1.1	2.5 ± 0.0	3.0 ± 1.0	2.5 ± 0.0
Phosphate (day/week)	N	0.2 ± 0.4	1.8 ± 2.7	0.8 ±1.0	0.6 ± 0.5
	R	0.9 ± 1.2	0.5 ± 0.6	1.4 ± 2.1	1.0 ± 0.0
Milk intake	N	4.8 ± 2.6	4.0 ± 2.8	4.3 ± 3.1	4.1 ± 3.0
(day/Week)	R	3.8 ± 2.6	2.8 ± 2.8	1.7 ± 0.9	4.0 ± 4.2
Physical activity					
Steps walked (number of steps /day)	N	8680.8 ± 5830.4	10799.6 ± 4698.5	8808.0 ± 4899.8	7775.3 ± 3872.3
	R	6655.3 ± 2854.3	5150.1 ± 3493.2	7280.8 ± 2142.8	4186.2 ± 872.3
Working 〔number (%)〕	N	4 (36.4)	4 (36.4)	3 (30.0)	3 (42.9)
	R	2 (18.2)	2 (18.2)	2 (20.0)	0 (0)
Not working 〔number (%)〕	N	3 (27.3)	3 (27.3)	3 (30.0)	2 (28.6)
	R	2 (18.2)	2 (18.2)	2 (20.0)	2 (28.6)

〔Group〕
N : normal (OSI value is standard - 1SD)
R : Risk and disorder
Risk (OSI value is lower than standard from - 1SD to - 2SD)
Disorder (OSI value is lower than standard, more than - 2SD)
M : Missing value
Missing value shows the number of subjects who did not visit the hospital and whose data were not available

observed at the 24th post-operative month, there was a decreasing tendency.

2. Relationship between the levels of bone metabolism disorder and life indicators

1) Relationship between dietary intake and OSI value changes

We discussed the relationship between bone metabolism disorder, dietary intake, and physical activity for more than six months after being operated on.

Assigning the subjects with normal OSI values following the operation to the normal group, and those with OSI values of more than -1SD over the standard following the operation to a risk and disorder group, we conducted a comparative investigation of these two groups.

Table 4 shows the nutrient intakes necessary for body metabolism by group. The intakes of Ca and vitamin C tended to be slightly higher, although not significantly, in the normal group than in the risk and disorder group at the 6th and 12th post-operative months.

As a result of the surveys on body weight, BMI, and the number of steps per day, which is an indicator of physical activity, all indicators showed higher values at all survey times in the normal group. However, there was no significant difference between the two groups.

2) Characteristics of factors affecting bone metabolism disorder at the 24th post-operative month

As shown in Table 3, follow-up was conducted until the 24th post-operative month in seven out of ten subjects, and two subjects among them were observed to have some bone metabolism disorder at the 24th post-operative month.

Because only two subjects showed the onset of bone metabolism disorder, we could not conduct a statistical analysis of bone metabolism parameters.

Therefore, we investigated the characteristics of the subjects individually and investigated the factors affecting bone metabolism in these two individuals.

One subject showed a lower BAP value, an indicator of bone formation, and a 3.5 point lower BMI value than before the operation at the 24th post-operative month.

Another subject had already shown a high value of NTx, an indicator of bone absorption, before the operation. He showed an NTx value as high as 58～70 at any point during the survey time from the 3rd week to 24th month after the operation, indicating an increase in bone absorption.

His body weight and BMI, indicators of the nutritional status, recovered close to their levels before the operation at the 24th post-operative month. However, his BMI was as low as 16.9 even before the operation.

Then, we conducted a comparative investigation concerning diet and physical activity between the subjects whose OSI values showed signs of bone metabolism disorder and those of the normal group.

The intakes of calcium and vitamins C and D, necessary for bone formation, of the subjects suffering from bone metabolism disorder were lower than the subjects of the normal group, although there was no significant difference. Furthermore, as for physical activities, the number of steps taken per day by the subjects suffering from bone metabolism disorder showed low values at the 24th post-operative month.

Discussion

1. Effectiveness of bone assessment indicators

There are various indicators including SOS, TI, OSI, and stiffness for bone metabolism assessment according to measurement instruments.

The speed of sound (SOS) is said to reflect bone density, and the transmission index (TI) shows values related to the frequency characteristics when an ultrasound passes through bone, showing bone density. The osteo sonoassesment index (OSI) reflects the characteristics of both SOS and TI, and is a comprehensive index when acoustically diagnosing bone.

In our previous report,[8] in spite of the fact that bone metabolism makers showed abnormal values, no change was shown in SOS values. Then, we began to measure SOS, TI, and OSI at the same time, and analyzed the relationship among the three parameters,

bone metabolism makers, and factors affecting bone metabolism.

As a result of investigating the relationship among the three indexes, a correlation between SOS, TI, and OSI was shown. Of further interest concerning the relationship among these three indexes, bone metabolism markers, and factors affecting metabolism, SOS was shown to have a correlation with NTx and DPD bone absorption markers. Additionally, OSI was shown to have a correlation with NTx.

As described above, a strong correlation was shown to exist between SOS and OSI, and, furthermore, a relationship between the changes occurring in bone metabolism markers before and after the operation and those occurring in SOS and OSI was shown. Moreover, OSI is considered to be useful as an indicator of bone metabolism disorder, because OSI has its judging criteria based upon the standard value.

2. Relationship with changes in bone metabolism parameters

Fig. 2 shows the time-related changes in OSI from pre-operation up to the 24th post-operative month. As shown in this figure, the OSI value decreased significantly at the 6th post-operative month.

As shown in Table 3, some subjects started to show decreases of more than -2SD from the standard value at the 6th post-operative month. In other words, expressing values which indicate bone metabolism disorder.

Discussing the time-related changes of bone metabolism markers, an indicator of bone histological assessment, we examined the relationship with bone metabolism. BAP, a bone formation marker, significantly decreased at the 3rd week, significantly increased at the 6th month to higher than the pre-operative level, and remained unchanged until the 24th month after the operation. Conversely, although NTx, a bone absorption marker, tended to increase until the 12th post-operative month, and DPD showed high values until the 6th post-operative month, both of them tended to decrease after that. In this way, the activities of bone formation and bone absorption tended to increase after the 3rd month until the 6th month following the operation, in particular. As Takafuji, et al.[12] have reported, both bone formation and bone absorption increase after gastrectomy, agreeing with our study results in that bone metabolic turnover is considered to actively occur. In the condition that both bone absorption and bone formation are increasing, that is, a state of high bone metabolism turnover, because normal bone absorption generally exceeds bone formation,[13] bone mass decreases. In this study too, the same trend is considered to have been shown because the OSI values decreased at the 6th post-operative month.

3. Effects of nutritional status, food intake, and physical activity on bone metabolism

1) Relationship between nutritional status and bone metabolism

The body weight after surgery decreased by 5 kg on average at the 3rd month and recovered by only 1 kg by the 24th month after the operation. BMI also decreased by 1.78 at the 3rd post-operative week and did not recover thereafter, suggesting that the nutritional status also remained in a decreased state. Bone formation is affected by the kinetic load, which includes loads induced by body weight, daily life, and physical activity.[6] Accordingly, it is considered important to improve the lifestyle including dietary habits and physical activity, in order to increase bone metabolism. Food intake volume, in particular, decreases when adverse effects caused by chemotherapy and dumping symptoms emerge, the number of meals is reduced, and regular eating behavior is disrupted.[14] This point should be taken into consideration for support and guidance.

2) Relationship between food intake and bone metabolism

Calcium is important for bone formation. We therefore discussed the nutrients affecting calcium absorption.

Protein, a material of collagen and a component of the bone matrix, should be kept in balance with calcium quantitatively. Vitamin C is necessary for osteoblast differentiation, and, if depleted, bones and teeth become fragile.

Although the desirable ratio of calcium to phosphate is 1:2, if phosphate is taken excessively, it impairs the absorption of calcium from the intestine, and, as a result, it causes a shortage of calcium.[10] In this study, although the frequencies of food intake including the nutrient factors shown in Table 4 showed no significant difference, the frequencies of calcium and vitamin C intake tended to be low in the bone metabolism risk and disorder groups. Accordingly, in order to prevent the onset of bone metabolism disorders, it is very important to positively intake calcium and vitamin C, which enhances the absorption of calcium, as well as other nutrient factors affecting bone metabolism in a good balance.

Recently, because the majority of patients who receive gastrectomy are aged persons, it is important to help them improve their volume of food intake and meal contents for the prevention of bone mass loss. Emphasis should be placed on their dietary intakes after the operation because they experience problems which include a reduction of food intake, delayed recovery of digestive functions, and an inability to dietarily adapt.

3) Relationship between physical activity and bone metabolism

Generally speaking, because bones are reconstructed in a way that the bone mass and bone strength are maintained in areas necessary to respond to kinetic loads caused by body weight and physical activity, physical activity is effective for increasing bone mass.[15-17] Although in this study, no significant difference was observed between the normal and risk and disorder groups, the total number of steps walked per day tended to increase in the normal group.

Accordingly, in order to prevent bone metabolism disorder, it is important that walking movement is effective for increasing bone mass.[16] It is therefore recommended to encourage patients to maintain and increase their bone mass by gradually increasing the walking load.

4) Factors associated with bone metabolism disorder

In order to discuss the factors associated with bone metabolism disorder, we compared the nutrient intake status, physical activity, changes in body weight accompanied by the activity, and BMI of the two subjects who showed body metabolism disorder, to those of subjects in the normal group whose bone metabolism was within the normal range, at the 24th post-operative month.

As a result, one of the two subjects who had bone metabolism disorder, as shown by changes in body weight and BMI indicating one's nutritive condition, showed losses of both body weight and BMI, and the other subject, although remarkably thin with low body weight and BMI values even before the operation, recovered after the operation. Furthermore, they were not working or performing exercise, and their levels of physical activity were low, with the numbers of steps walked being only 3500 and 1700 per day, respectively.

These common factors such as insufficient intakes of calcium and vitamin D, lack of physical activity, and weight loss, are considered to be strong factors leading to the onset of metabolism disorder.

Acknowledgements

This study is part of a study conducted with financial support from a Grant-in-Aid for Scientific Research, Basic Research (C), Japan Society for the Promotion of Science, Fiscal year 1999～2002 (Representative: Rieko Kawamoto, Task No. 11672379). We would like to thank all those involved for their cooperation and assistance in our study.

References

1) Sakai, T., Banba, T. and Niwayama, M.: Gastric Lesions after Gastrectomy (in Japanese). *Journal of Clinical Surgery,* **22** : 1711-1720, 1967.
2) Aoki, T.: Management of Disorders after Gastrectomy (in Japanese). *Progress Medicine,* **16** : 3140-3154, 1996.
3) Kitahara, S., Nonaka, K., et al.: Study on Bone Disorder after Gastrectomy (in Japanese). *Japanese Journal of Gastroenterological Surgery,* **26** : 18-25, 1993.

4) Takita, M., Miyake, T., et al.: Relationship between Daily Living Habit and Bone Density (in Japanese). *Nihon University Medical Journal,* **55** : 434-446, 1996.
5) Imamura, M. and Yamauchi, H.: Milk (Lactose) intolerance following gastrectomy - In relation to impairment of bone metabolism (in Japanese). *Gastroenteorology,* **22** : 279-285, 1996.
6) You, K.: II Prevention and Treatment, 4 Exercise Methods (in Japanese). *In* Orimo, H. (ed.), *Saisin-Kotususyousyou,* Life Science, Tokyo, 1999, pp. 452-458.
7) Shigematu, T. and Kawaguchi, Y.: Inactivity (Immobility in Bed, Space Flight) (in Japanese). *In* Orishige, H. (ed.), *Saisin-Kotususyousyou*. Life Science, Tokyo, 1999, pp. 74-78.
8) Kawamoto, R. and Murase, T.: Study on the Relationship between the Changes of Bone Metabolism and Lifestyle after Gastrectomy (in Japanese). *Journal of University of Occupational and Environmental Health,* **27** : 73-87, 2005.
9) Tanizawa, T., Endow, N., Takahasi, E., et al.: Discussion on the Measurement of the Calcaneus and Hipbone by Ultrasound Bone Evaluation Equipment AOS-100 and DX method (in Japanese). *No. 4 Paper Collection by Japan Osteoporosis Association*, 105, 1995.
10) Sawa, J., Fujii, Y., Nisikawa, T., et al.: Daily Activities and Eating Habit affecting Female Students' Bone Density in Whole and Each Part of Body(in Japanese). *The Japanese Society of Nutrition and Dietetics,* **59** : 285-293, 2001.
11) Miura, K.: Medicine for People Who had Received Gastrectomy, with a Focus on Dietary Cure (in Japanese). *Popular Medicine,* **109** : 25-32, 1983.
12) Takafuji, K., Takeda, H., Aoyagi, K., et al.: Study on Bone Disorder after Distal Gastrectomy using DXA Method and Bone Metabolism Marker (in Japanese). *Japanese Journal of Gastroenterological Surgery,* **32** : 2631-2636, 1999.
13) Siraki, M.: Menopause and Bone Metabolism Marker (in Japanese). *In* Orimo, H. (ed.), *Saisin-Kotususyousyou,* Life Science, Tokyo, 1999, pp. 369-375.
14) Arai, H., Futawatari, T., et al.: Gastrectomy Patients' trend of Dietary Life, Intake Volume and Snackining after Discharged from Hospital (in Japanese). *The Japanese Journal of Nursing,* **34** : 40-43, 1993.
15) Sakai, A. and Nakamura, T.: Effects of Physical activity on Bone Metabolism(in Japanese). *Sogo-Rehabilitation,* **27** : 111-115, 1999.
16) You, K.: Assessment of Factors Associ ated with Osteoporosis: Exercise (in Japanese). *Clinical Endocrinology,* **48** : 103-108, 2000.
17) Ueda, A., Yoshimura, N., Morioka, S., et al.: Study on the Factors associated with Bone Density - from the Survey of Bone Density in an area of Wakayama Pref (in Japanese). *Japanese Journal of Public Health,* **43** : 570-577, 1996.