ABSTRACT
This Study aims to examine the correlation between the characteristics of trabeculae through structural analysis of femoral bone from radiographic image. With 34 females (average age of 62.1 years) and 6 males (average age of 60.7 years) who received osteoporosis related examination chosen as subjects and were categorized into normal group and osteoporosis group in accordance with the T-score of the average value of the measurement of the bone density of femoral bone measured with DEXA (Dual Energy X-ray Absorptiometry). ROI (Region of interests) was selected and characteristics of trabeculae were analyzed by using the skeletonization of fractal analysis and trabeculae image in order to examine the correlation with osteoporosis. The result of measurement of configuration of the bone displayed statistically significant correlation between Neck cortical thickness, Shaft cortical thickness (Medial) and Shaft cortical thickness (Lateral) with BMD average (T-score). In addition, only the trabeculae area among the 5 structural indices displayed statistically significant correlation with BMD average (T-score). This research shows significant correlation of the morphological characteristics analysis of bone from the femoral radiographic images with BMD.

KEY WORDS
Digital radiograph image, Morphological Analysis, Osteoporosis, skeletonization, Fractal Dimension, Trabeculae

1. Introduction
Osteoporosis is skeletal disorder in which risk of bone fracture increases due to damages to the strength of the bone, and is the state in which the bone density is lowered and the bone becomes fragile against fracture. With recent increase in the lifespan of people, this disorder has been receiving much attention along with increase in the population of aged people. In addition, bone fracture arising from osteoporosis has close relationship with increase in death rate and induces social problems including increase in overall cost of medical care, thereby rapidly increasing medical interest on osteoporosis. Bone strength is the strength of resistance against bone fracture and is categorized by the bone mass and bone quality. Bone mass can be substituted by bone density and the bone quality is a factor different from the bone mass and determines the strength of bone. General methods of measuring bone density include DEXA (Dual Energy X-ray Absorptiometry), QCT (Quantitative Computed Tomography) and QUS (Quantitative Ultrasound) that are used mostly in clinical settings. Among these, determination of osteoporosis by measuring the bone density of lumbar and femoral bone with DEXA (Dual Energy X-ray Absorptiometry) is the most generalized method of measuring the bone density.1-4

According to the recent researches, it is known that not only the bone quality but also the structural characteristics of bone quality is important as factors that determine the bone strength.5-8 In the structural integrity of bone quality, area of the bone, size and arrangement of trabeculae play important role and methods of quantitative analysis of morphological characteristics of trabeculae are being researched actively.9-12 Method of analyzing the bone structure through simple radiographic images that are being propagated widely has the possibility of forecasting the bone strength and osteoporosis of the corresponding area. In addition, researches on evaluation of changes in bone quality or forecasting of bone quality by using fractal analysis are also being carried out. Fractal analysis is a method of obtaining fractal dimension value, which is the value of prescribed range by quantifying complex shapes or structural aspects.13-14 Fractal analyses is used as a method of explaining the complex structure of trabecular bone.
Accordingly, it is anticipated that through correlation between the method of using measurement apparatus for bone density and method of analyzing the bone structure would be able to provide further assistance in diagnosing osteoporosis.

In forecasting bond fracture arising from osteoporosis, the bone density measured at the femoral bone, in comparison to other areas, illustrate the highest correlation\textsuperscript{15,16}. Diagnose with the area with the lowest bone density among the overall area of femoral bone, neck region and trochanter section.\textsuperscript{17}

In this thesis, research on the correlation between the characteristics and configuration of bone, and bone density is carried out by comparing the bone density examination between osteoporosis patient and normal person (T-score) after having morphologically analyzed bone geometry and minute structures of trabeculae of osteoporosis patient and normal person from digitalized radiographic image of femoral bone, and obtained the value of fractal dimension analysis.

2. Study method

2.1 Subjects of research

34 females (average age of 62.1 years) and 6 males (average age of 60.7 years) who received osteoporosis related examination were chosen as subjects, and their height and weight were measured before measuring the bone density of femoral bone area by using DEXA (Dual Energy X-ray Absorptiometry, HOLOGIC, USA), and subjects were categorized into control group and osteoporosis group in accordance with this measurement value by applying WHO categorization\textsuperscript{18} by T-score. The ROI was stored in the computer in the format of digital radiographic image by prescribing the area of femoral neck.
2.2 Image analysis Method

2.2.1 Analysis of digital image

In order to analyze the image, total of 40 images were obtained by selecting ROI of width 40 pixel, height 40 pixel at the femoral bone area by using bone configuration related computer program.

All ROI images were processed as follows by using the method devised by White and Rudolph. Firstly, blurred image was obtained by removing minute or interim sized structures by applying Gaussian filter (sigma=10 pixel) onto each of the ROI images selected at the femoral bone (Fig.2B).

Furthermore, this blurred image was subtraction processed at the original image and 128 grey scale values was added to obtain image with average grey scale value of 128. This binary image was made on the basis of 128 grey scales as the standard by usig bone structure analysis program (Fig.3C). Only the external border line was extracted from this binary image in order to obtain outline image (Fig.3E). In order to remove the noise from such binary image, the image underwent erosion and dilation procedures (Fig.3D). Finally skeletonized image in which only the central line of pixels remained at the end was made (Fig.3F). Periphery measured selecting region length of outline image and trabecilae area measured point number of of outline image. Length of skeletonized trabeculae measured selecting region length of skeletonized image.

Fractal dimension value was computed with box-counting method by using image j program ver 1.42(National Institutes of Health, USA) from the skeletonized image obtained through image processing.

2.2.2 Morphological measurement of radiographic film

Morphological aspect other than the analysis of bone structure was measured together through radiographic analysis of proximity of femoral bone. Firstly, for cortical thickness, cortical thickness of neck region at the mid position of internal aspect of neck region of femoral bone and cortical thickness of internal and external aspect of diaphysis at 3cm lower aspect of lesser trochanter of femoral bone were measured. Secondly, neck width of femoral bone was measured. Thirdly, shaft width of location that is 3cm in the lower portion of the lesser trochanter was measured. Most clear radiographic image was used in order to make maximally accurate measurement. Micrometer was used to measure the distance to the unit of 0.01mm(Fig.3)

3. Result

3.1 Analysis of subjects of research

Firstly, the age distribution and T-score, which is the average value of BMD, was classified normal and osteoporosis (Table1).

<table>
<thead>
<tr>
<th>AGE</th>
<th>Normal(n=18)</th>
<th>Osteoporosis(n=22)</th>
<th>Total(n=40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE</td>
<td>53.3(11.7)</td>
<td>69.2(7.5)</td>
<td>62.5(12.2)</td>
</tr>
<tr>
<td>BMD average(T-score)</td>
<td>-0.5(0.9)</td>
<td>-3.4(0.9)</td>
<td>-2.2(1.7)</td>
</tr>
</tbody>
</table>

Values are mean(SD)

<table>
<thead>
<tr>
<th>Normal</th>
<th>Osteoporosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean gray level</td>
<td>94.25(7.49)</td>
</tr>
<tr>
<td>Trabeculae area</td>
<td>119.52(15.62)</td>
</tr>
<tr>
<td>periphery</td>
<td>137.10(21.39)</td>
</tr>
<tr>
<td>Length of skeletonized trabeculae</td>
<td>144.15(24.29)</td>
</tr>
<tr>
<td>Fractal dimension</td>
<td>1.185(0.011)</td>
</tr>
</tbody>
</table>

Values are mean(SD)
The average age of the osteoporosis group was higher than the control group.

### 3.2 Image analysis indices and fractal analysis

5 indices of image analysis were Mean gray level, Trabeculae area, periphery, Length of skeletonised trabeculae and Fractal dimension value. The values of the 5 indices in the image are given (Table 2). The fractal dimension value of control group was 1.185 (0.011) and that for osteoporosis group was 1.181 (0.009).

Statistically, it can be seen that the fractal dimension value of control group is higher.

The results of analysis of Pearson correlation between BMD average (T-score) and 5 indices showed statistically significant correlation with BMD average (T-score). Correlation between BMD average (T-score) and trabeculae area is indicated through graph (Fig. 4).

### 3.3 Morphological analysis

Analysis of bone from morphological aspect is given (Table 4, Table 5). As seen in the Table 4, the cortical thickness of the control group is definitely larger than that in osteoporosis group (p<0.01).

The result of configuration measurement of the bone in the radiographic image showed statistically significant correlation between Neck cortical thickness, Shaft cortical thickness (Medial) and Shaft cortical thickness (Lateral) with BMD average (T-score).

Correlation between BMD average (T-score) and Neck cortical thickness is indicated through graph (Fig. 5). Correlation coefficient (0.780) is clear positive linear distribution in the graph.

Correlation between BMD average (T-score) and Shaft cortical thickness (Medial) is indicated through graph (Fig. 6). Correlation coefficient (0.865) is clear positive linear distribution in the graph.

Correlation between BMD average (T-score) and Shaft cortical thickness (Lateral) is indicated through graph (Fig. 7). Correlation coefficient (0.807) is clear positive linear distribution in the graph.

### 4. Discussion

In general, method of measuring bone density has been used widely in order to evaluate the bone quality. As one
of the most common vestibular disorders that occur to adults, osteoporosis can be categorized into osteoporosis occurring in women during menopause, senile osteoporosis due to aging, and idiopathic osteoporosis induced by chemicals. Measurement principles and areas are different according to the bone density measurement methods that are currently being used along with differences in their strength and weaknesses including economic value. Accordingly, one needs to apply each measurement method to clinical setting after having familiarized oneself with the characteristics of each measurement method. For lumbar and femoral bone areas, DEXA (Dual Energy X-ray Absorptiometry) and QCT(Quantitative computed tomography) are used, while DEXA and pQCT(peripheral Quantitative Computed Tomography) are used for radial bone, RA (Radiographic Absorptiometry) for hand, and QUS(Quantitative Ultrasound), pQCT(peripheral Quantitative Computed Tomography) and DEXA can be used for calcaneos. Although measurement of bone density can be carried out selectively for each corresponding area, in many cases, bone density is measure for the lumbar and femoral bone area and presence of osteoporosis of entire body is determined on the basis of such measurement.

When measuring the bone density by using DEXA (Dual Energy X-ray Absorptiometry), T-score, which is the variation in average bone density of healthy adult, or Z-score, which is the standard deviation of same age group, is used. However, T-score is preferred in most cases, and in general categorization into 3 groups, namely T≥-1.0 (normal), -1.0≤T≤-2.5 (osteopenia) and T≤-2.5 (osteoporosis). However, this categorization method does not present absolute standard, and it is known that there is possibility of slight error due to racial differences or measurement apparatus.

Not only the bone density but also the structural characteristics of bond quality are also important factors in determining the bone strength. When analyzing the structure of bone quality, trabeculae characteristics of cancellous bone rather than cortical is analyzed in general because it has been reported that the trabeculae area has the tendency of sensitively expressing the extent of bone loss due to faster bone replacement rate. The fact that the bone density reduction rate differs at various areas of femoral bone is perhaps related to the bone replacement rate of the trabeculae area. Recently, method of observing and quantifying the bone structure is being researched actively. In particular, MO(Morphology Operation)
method or fractal analysis method are used as means of quantitatively analyzing trabeculae.

In this research, it was attempted to quantitatively analyze trabeculae by using fractal analysis method. Although the fractal dimension value illustrates diverse range of changes in accordance with the method of computation, it has been reported that the fractal dimension value significantly reflects the pathological changes of bone quality or bone.\textsuperscript{25}

However, the fractal dimension value analyzed from the actual images did not display significant correlation with BMD average (T-score). This could be due to problem in reproduction of black scale of the radiographic image or problem in setting of critical value in the binary procedure. However, it was able to observe that in the statistical average value, the fractal dimension value of the control group is slightly higher than the osteoporosis group.

Outline image was extracted in the process of image processing in order to measure the length of the outline. The length of bone outline and fractal dimension value signifies the complexity of trabeculae pattern. However, no major significance was confirmed in this research.

Although measurement of thickness of cortical and width of neck of femoral bone are factors that are analyzed when determining bone fracture arising from osteoporosis. In this research, on the contrary, study was conducted to find out the extent of flexibility when determining osteoporosis. The thickness of cortical measured from the radiographic image displayed significant correlation with BMD average (T-score). This indicates that, in addition to analysis of trabeculae, the thickness of cortical measured from the radiographic image could be used as an important analytical method when determining osteoporosis.

5. Conclusion

This research shows significant correlation of the morphological characteristics analysis of bone from the femoral radiographic images with BMD. If measurement of bone density is made simultaneously in the future, it is anticipated that it will make contribution towards more precise diagnosis of osteoporosis.

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