Relationship between Oral Condition and Bone Density as shown by Results of Public Health Screening Examinations using Functional Tooth Evaluation Score

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Key Words : health screening examination, osteoporosis, bone density (%YAM), oral condition, functional tooth evaluation score

ABSTRACT

In our previous study, we examined the relationship between the results on bone density of the calcaneus measured by ultrasonography (echography) and the number of remaining teeth. However, it is difficult to conclude that the number of remaining teeth alone is sufficient for use as a parameter of the oral condition, though this parameter is indispensable for quantifying and expressing the oral condition as a numeric rating. In the present study, the bone density of the calcaneus was compared with the results of a similar parameter known as the Functional Tooth Evaluation Score (FTES), and the following findings were obtained:

1. Both FTES results and the number of remaining teeth demonstrated a positive correlation at the same level with bone density of the calcaneus, though the confidence level was higher for the FTES.
2. FTES reflected changes in the oral condition more closely than the number of remaining teeth. Thus the FTES is a practical parameter for judging long-term changes in the bone density of the calcaneus.

Introduction

Recently, the relationships between medical disease and periodontal disease have been studied, and this field is referred to as periodontal medicine [1~4]. In the present periodontal medicine study, we focussed on osteoporosis. Although others have investigated and analyzed its relationship with periodontal disease [5~11], we know of no reports that compared the results of medical examinations with those of dental examinations obtained from public health screening.

We are currently conducting a series of studies...
on the relationships between the results of an osteoporosis screening examination and those of a dental health checkup carried out in a large population living in the same municipality. In our previous study, we reported the relationship between bone density of the calcaneus (%YAM) and the number of remaining teeth [12]. However, when quantifying and expressing the oral condition by using a numeric rating on the basis of results obtained in a public health screening examination, it is difficult to conclude that the oral condition can be reflected sufficiently only by the number of remaining teeth, though this parameter is a convenient and indispensable one. Previously we found the Functional Tooth Evaluation Score (FTES) to be a parameter that reflects the oral condition in greater detail and can be expressed numerically [13]. In the present study, the relationships among FTES, number of remaining teeth, and bone density of the calcaneus were examined.

SUBJECTS AND METHODS

The subjects were the same residents examined in our previous study. In Mitsu-cho, Ibo-gun (now known as Mitsu-cho, Tatsuno-shi, as of October 1, 2005), located in the southwest part of Hyogo Prefecture, various public health examination screens known as ‘Whole Town Health Checkups’ are performed in May of each year for local residents 20 years old and older. The examinations include a dental health checkup, as well as a basic health checkup and cancer screening. Furthermore, in late May an osteoporosis screening examination is scheduled on a different day for the same residents. For the present study, we selected subjects from those who had participated in the dental health checkup and osteoporosis screening portions of the Whole Town Checkups during the 5-year period from 1997 to 2001. Since osteoporosis is a disease found largely in females, most of the subjects who underwent the osteoporosis screening were women. Thus, a total of 235 women were examined as subjects in the present study.

To analyze the dental health checkup results, we used a detailed chart to record dentition according to a dental formula. The number of remaining teeth and FTES were used as parameters for expressing the oral condition numerically. As for the results of osteoporosis screening, we used echographic data on the calcaneus. Bone density of the calcaneus was expressed as the percent of the young adult mean (%YAM).

We investigated the relationship between the number of remaining teeth and FTES, and that between FTES and bone density in the calcaneus. Forty-three subjects (103 total examinations) underwent the osteoporosis screening examination at least twice during the study period. In those cases, the yearly changes in the number of remaining teeth, FTES, and bone density were compared.

FTES

The number of remaining teeth is a simple means of rating and quantifying the oral condition. In our other study, we used the FTES to reflect oral conditions in greater detail [13]. For calculating the FTES, subject teeth were assigned points as follows: An intact tooth without any caries received 10 points, whereas a tooth with suspicion of caries received 9 points. One with completed restorative treatment using an inlay or resin, was given 8 points; an abutment tooth for a crown or bridge, 7 points; a tooth with secondary caries, 6 points; a tooth with caries, 5 points; a tooth with moderate mobility due to periodontal disease, 4 points; a pontic tooth used for a bridge, 3 points; an artificial tooth in a denture, 2 points; a tooth with only the root remaining, 1 point; and a tooth diagnosed as impossible to preserve due to strong mobility or missing, 0 points (Table 1). The scores were thus a reflection of the degree of tooth destruction corresponding to the advancement of dental disease and of restorative treatment.

Each tooth was given a score, with a possible total of 280 points when all 28 teeth excluding the third molar were present and intact. The ratio to full health was calculated to determine the FTES by use of the following formula:

\[ \text{FTES} = \frac{\text{points accumulated}}{280} \times 100. \]

The results for 750 women, including those who had undergone only the dental health checkup, were used to analyze the relationship between the FTES and number of remaining teeth.

Statistical Analysis

Statistical analyses were performed using SPSS for Windows v. 11.0 (SPSS Inc., Chicago, IL). A result was considered statistically significant when \( p < 0.05 \).
RESULTS

1. The age distribution of the 750 women used as subjects for examining the relationship between FTES and number of remaining teeth is shown in Figure 1.

2. The relationship between the FTES and the number of remaining teeth and that between bone density of the calcaneus and the number of remaining teeth are shown in Figure 2-1 and 2-2, respectively, which depict scatter diagrams and correlation coefficients.

3. The relationship between the number of remaining teeth and the FTES obtained from the results of the dental health checkup for the 750 subjects are shown in a scatter diagram and approximated by a quadric curve in Figure 3.

### Table 1. Evaluation score of each tooth.

<table>
<thead>
<tr>
<th>Tooth condition</th>
<th>Score (Point)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intact tooth (Caries Free)</td>
<td>10</td>
</tr>
<tr>
<td>Questionable Caries</td>
<td>9</td>
</tr>
<tr>
<td>Filling with Resin or Inlay etc</td>
<td>8</td>
</tr>
<tr>
<td>Crown or Abutment of Bridge</td>
<td>7</td>
</tr>
<tr>
<td>Secondary Caries</td>
<td>6</td>
</tr>
<tr>
<td>Caries</td>
<td>5</td>
</tr>
<tr>
<td>Mobility Tooth (Medium)</td>
<td>4</td>
</tr>
<tr>
<td>Pontic of Bridge</td>
<td>3</td>
</tr>
<tr>
<td>Artificial Tooth of Denture</td>
<td>2</td>
</tr>
<tr>
<td>Remaining Root</td>
<td>1</td>
</tr>
<tr>
<td>Missing Tooth or Mobility Tooth (Severe)</td>
<td>0</td>
</tr>
</tbody>
</table>

Fig.1 As for the age distribution of the 750 subjects, those from 40 to 70 years old accounted for 80% of the total.

Bulletin of the Osaka Medical College 52 (2) : 91-99, 2006
4. The relationship between FTES and bone density of the calcaneus is seen in Figure 4-1 and 4-2 as scatter plots. In these plots, the FTES is divided into 2 groups, namely, one group under 60 points and the other 60 points or higher (line A). Bone density in the calcaneus was also divided into 2 groups, one with a density up to 79% and the other with a density of 80% or greater. The results for each group, numbered Group 1 - 4, are shown in Figure 4-1.

On the basis of the results for these 4 groups, odds ratios were calculated. The odds ratio between the FTES and bone density of the calcaneus is seen in Figure 4-1 and 4-2 as scatter plots. In these plots, the FTES is divided into 2 groups, namely, one group under 60 points and the other 60 points or higher (line A). Bone density in the calcaneus was also divided into 2 groups, one with a density up to 79% and the other with a density of 80% or greater. The results for each group, numbered Group 1 - 4, are shown in Figure 4-1.

Fig.2-1 A positive correlation (r=0.2421, p<0.05) is observed between the number of remaining teeth and bone density of the calcaneus.

Fig.2-2 A positive correlation (r=0.2711, p<0.01) is seen between the FTES and bone density of the calcaneus.

Fig.3 A strong correlation (correlation ratio r²=0.9564) between the number of remaining teeth and the FTES is found by using this approximated quadratic curve.
Fig. 4-1 Line A divides the FTES into "less than 60 points" and "more than 60 points."

The respective number of subjects, mean FTES, and mean density (%YAM) for each group were as follows:

- **Group 1**: 120 subjects, 81.98 points, 94.36% YAM
- **Group 2**: 89 subjects, 79.44 points, 70.37% YAM
- **Group 3**: 2 subjects, 49.65 points, 97.5% YAM
- **Group 4**: 24 subjects, 43.66 points, 68.70% YAM

Fig. 4-2 Line B divides the FTES into "less than 70 points" and "more than 70 points."

The respective number of subjects, mean FTES, and mean density (%YAM) for each group were as follows:

- **Group 1'**: 108 subjects, 83.94 points, 94.43% YAM
- **Group 2'**: 72 subjects, 82.54 points, 70.19% YAM
- **Group 3'**: 14 subjects, 62.51 points, 94.29% YAM
- **Group 4'**: 41 subjects, 53.06 points, 69.76% YAM
calcanecus was 16.18, with a 95% confidence interval of 3.73 for the lower limit and 70.25 for the upper limit, which ratio was considered to be significant.

In a separate analysis, the FTES was divided into 2 groups, namely, one under 70 points and the other with 70 points or more (line B). Bone density of the calcaneus was again divided into the 2 groups indicated above. These 4 groups were numbered Group 1' - Group 4' and the results for them are shown in Figure 4-2.

On the basis of the results for these 4 groups, the odds ratio between FTES and bone density of the calcaneus was calculated to be 4.39, with a 95% confidence interval of 2.23 for the lower limit and 8.64 for the upper limit. This ratio was also considered to be significant.

5. Comparisons among yearly changes in number of remaining teeth, FTES, and bone density of the calcaneus are made in Figure 5. Variations over the 3-year study period were 0.50 teeth for the number of remaining teeth, 1.52 points for FTES, and 3.39% for bone density of the calcaneus.

![Diagram showing reduction in score over years](image)

**Fig.5** Rate of reduction per year in the FTES, bone density, and number of remaining teeth are shown. Each of these parameters decreased in a linear fashion over time.

**DISCUSSION**

1. **Age distribution**

To analyze the relationship between the number of remaining teeth and the FTES, we used the data from dental health checkups of 750 women. As for the age distribution of these subjects, those from 40 to 70 years of age accounted for 80% of the total, which was the same as the age distribution of the subjects who had undergone the osteoporosis screening (with women in their 50s and 60s predominating). The distribution resembled that of a similar public health bone checkup carried out in 16 cities in Saitama Prefecture [14]. We speculate that this kind of age distribution is common in mass screening examinations conducted for local residents living in the same area. Consequently, we considered that the 750 subjects investigated in the present study were a standard group without specific bias.

2. **Relationships among number of remaining teeth, FTES, and bone density of the calcaneus**

As was shown in Figure 2-1 and 2-2, the positive correlation between the FTES and bone density of the calcaneus had a higher confidence level, 99%, than that between tooth number and density. Thus, we concluded the FTES to be a
more useful parameter than the number of remaining teeth for examining the relationship with bone density of the calcaneus. The value of the FTES corresponding to a bone density of the calcaneus of 80% YAM or lower was determined to be 66.9 points, which was calculated by using the same formula used to determine the relationship between the FTES and bone density of the calcaneus shown in Figure 2-2.

3. Relationship between number of remaining teeth and the FTES

Figure 3 showed the relationship between the number of remaining teeth and the FTES. In our previous report, the number of remaining teeth was examined in 2 groups of subjects, those with 19 or fewer teeth and those with 20 or more, in accordance with the 8020 Campaign (20 teeth present at the age of 80) promoted by the Japan Dental Association. The value of FTES corresponding to at least 20 teeth present was calculated to be 58.2 points by using the same formula used to determine the relationship between FTES and number of remaining teeth shown in Figure 3.

4. Relationship between the FTES and bone density of the calcaneus

The relationship between the FTES and bone density of the calcaneus was shown in the scatter diagrams in Figure 4-1 and 4-2. According to the diagnostic criteria for primary osteoporosis compiled by the Japanese Society for Bone and Mineral Research, a bone density under 80% YAM is regarded as osteopenia, with possible osteoporosis as a concern.

At the present time, a specific cut-off level has not been determined for bone density of the calcaneus obtained by echography, though a study on the usefulness of that method made some recommendations [15]. We set the borderline between 79% and 80% for bone density of the calcaneus in the present study. For the FTES, we set the borderline at 60 and 70 points on the basis of the results regarding the relationship between FTES and bone density of the calcaneus, as compared with subjects with an FTES of 60 points or higher. The bone density of the calcaneus in these former subjects was 79% or below the mean value for young adults.

The results of our analysis with the FTES borderline set at 70 points were shown in Figure 4-2 (line B). The odds ratio was calculated on the basis of the results for Groups 1' - 4'. The odds ratio between FTES and bone density of the calcaneus, 4.39, was again significant (95% confidence interval of 2.23 for the lower limit and 8.64 for the upper limit). The results of a chi square test showed that the tested value was 18.78, which was significant, with a rate of risk of 0.1% (p<0.001). Thus, subjects with an FTES of under 70 points had an approximately 4.4-fold greater risk of reduced bone density of the calcaneus, as compared with subjects with an FTES of 70 points or higher. Again the bone density of the calcaneus in these former subjects was 79% or below the mean value for young adults.

The average number of remaining teeth in subjects with an FTES of 60 points was 20.67, and that in subjects with an FTES of 70 points was 23.88, based on the formula expressing the relationship between remaining teeth and the FTES shown in Figure 3. The FTES scores were converted into the number of remaining teeth to obtain the odds ratios on the basis of the number of remaining teeth in order to examine the relationship. The results were as follow:

(a) We set the cut-off line for remaining teeth between 20 and 21. The odds ratio between the number of remaining teeth and bone density of the calcaneus was 7.50.
(b) We set the cut-off line for remaining teeth between 20.66 and 20.67, instead of setting borderline for FTES at 60 points. The odds ratio between the number of remaining teeth and bone density of the calcaneus was 16.18.
(c) We set the cut-off line for remaining teeth between 21 and 22. The odds ratio between the number of remaining teeth and bone density of the calcaneus was 5.02.
(d) We set the cut-off line for remaining teeth
between 23 and 24. The odds ratio between the number of remaining teeth and bone density of the calcaneus was 4.03.

(e) We set the cut-off line for remaining teeth between 23.88 and 23.87, instead of setting borderline for FTES at 70 points. The odds ratio between the number of remaining teeth and bone density of the calcaneus was 4.39.

(f) We set the cut-off line for remaining teeth between 24 and 25. The odds ratio between the number of remaining teeth and bone density of the calcaneus was 2.87.

Based on the results shown in (a), (c), (d), and (f), the odds ratio tended to be reduced as the number of remaining teeth increased. Furthermore, when the FTES was converted into the number of remaining teeth, the odds ratio by the FTES was higher than that by the number of remaining teeth.

We concluded that the oral condition could be expressed numerically and quantified in more detail by the FTES than by the number of remaining teeth, as the confidence level of the correlation coefficient between the FTES and bone density of the calcaneus was high. As a result, the odds ratio between the FTES and bone density of the calcaneus was higher than that obtained by using the number of remaining teeth. The number of teeth present was reduced by 1 when an intact tooth was evaluated as missing. Since the range was divided into 11 grades based on evaluation score, a maximum number of 10 cut-off levels could be set for the FTES to represent the decrease in the number of remaining teeth. Therefore, our results suggest that evaluation of the oral condition by the FTES is more useful than that by the number of remaining teeth.

5. Annual variations in the number of remaining teeth, FTES, and bone density of the calcaneus

There was a linear decrease with time in the number of remaining teeth, FTES, and bone density of the calcaneus, as was shown in Figure 5. However, since the decline in the number of remaining teeth was as low as 0.50 teeth over the 3-year study period, it would require 6 years to lose 1 tooth in the present subjects. Accordingly, we consider it difficult to predict long-term changes in the oral condition based only on the number of remaining teeth. The FTES was reduced by 0.41 to 0.66 points per year. When determining the FTES, 1 point in the evaluation of the tooth condition is equivalent to 0.36 points in the FTES system. Accordingly, a decline of 0.41 to 0.66 points in the FTES in 1 year corresponds approximately to a decline of 1 to 2 points in the evaluation of teeth. For example, when determining actual changes in the oral condition of a subject, a tooth treated with an inlay or resin (8 points) might be decreased to the level of a tooth with a crown (7 points) or secondary caries (6 points), and subsequently be reduced by 1 or 2 total points. This suggests that FTES is more reliable for detecting changes in the oral condition over time at an earlier stage than the number of remaining teeth. Thus, we showed that the FTES was able to quantify the oral condition with a numerical rating system and could detect long-term changes in it.

The bone density of the calcaneus in our subjects was reduced by 1.13% to 1.22% YAM per year. It was previously reported that changes in bone quantity in a single year were as low as under 1%. It was also reported that bone quantity showed an approximately 2% reduction per year during menopause [16]. In light of those findings, we consider that the reduction in bone density would be in the range of 1% to 2% per year. The results for bone density of the calcaneus obtained in the present study corresponded approximately to that range.

On the basis of our finding that the bone density of the calcaneus and the FTES were positively correlated, with a confidence level of 99%, we propose that the FTES could be utilized for predicting long-term changes in bone density of the calcaneus.
ACKNOWLEDGEMENTS

A summary of this study was presented at the 12th Conference of the Society of Hard Tissue Biology (September 2003, Takatsuki) and the 17th Kinki Regional Conference of the Japanese Society of Primary Care (Nihon-Primary Care-Gakkai; October 2003, Kobe).

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Received April 17, 2006
Accepted August 8, 2006