Association between number of teeth present and mandibular cortical erosion in Japanese men and women aged 40 years and older: A cross-sectional study

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Abstract

Mandibular cortical erosion detected on dental panoramic radiographs is associated with increased risk of osteoporosis in older adults. Additionally, many reports have demonstrated an association between decreased number of teeth present and osteoporosis. However, whether mandibular cortical erosion is associated with a decreased number of teeth remains unclear. The purpose of this study, therefore, was to clarify the association between mandibular cortical erosion and number of teeth present in Japanese men and women aged 40 years and older. Among patients who visited our university hospital and underwent dental panoramic radiography for the diagnosis of dental diseases, 839 patients (293 men and 546 women) aged 40–89 years (mean [SD], 63.7 [10.6] years) participated in this study. Multiple regression analysis revealed that mildly to moderately eroded cortex (p = 0.007) and severe eroded cortex (p < 0.001) were significantly associated with a decreased number of teeth present. Analysis of covariance adjusted for covariates revealed a significant association between mandibular cortical erosion category and number of teeth present (p < 0.001). Subjects with a severely eroded cortex had significantly fewer teeth present than those with a normal cortex (mean [SE], 20.7 [0.5] vs. 23.4 [0.3], p < 0.0001) or mildly to moderately eroded cortex (22.2 [0.4], p = 0.04). Subjects with a mildly to moderately eroded cortex had significantly fewer teeth present than those with a normal cortex (p = 0.033). Our results suggest the significant association between mandibular cortical erosion and number of teeth present in Japanese men and women aged 40 years and older.

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1. Introduction

Osteoporotic fractures are a crucial burden worldwide and can result in an increased risk of subsequent fractures, morbidity, and mortality [1]. The global incidence of fractures has gradually decreased except in Asia [2]. In particular, the incidence rate of osteoporotic fractures in Japan continues to increase; there are approximately 13 million patients with osteoporosis and 170,000 femoral neck fractures occur annually [3]. One potential explanation may be insufficient identification of patients at risk of osteoporotic fractures. In fact, only 30% of patients with osteoporosis receive some type of therapy for osteoporosis in Japan [4].
Since 1994, we have investigated the usefulness of mandibular cortical shape, namely the mandibular cortical index (MCI), detected on dental panoramic radiographs, which are widely used in general dental practice for the diagnosis of dental diseases [5]. We have demonstrated associations between the MCI and osteoporosis diagnosis determined by bone mineral density (BMD) measured by dual energy X-ray absorptiometry [6,7]; the MCI and biochemical markers of bone turnover [8]; and the MCI and risk of osteoporotic fractures [9]. Additionally, a recent meta-analysis indicated the usefulness of the MCI for identification of asymptomatic individuals at risk of osteoporosis [10].

Daniell demonstrated the association between osteoporosis and increased risk of tooth loss in postmenopausal women [11]. Since then, many investigators have confirmed the association between osteoporosis and tooth loss in the elderly worldwide, including Japan and Korea [12–14]. Furthermore, Wactawski-Wende suggested a potential mechanism by which systemic bone density loss during osteoporosis may provide a host system that is increasingly susceptible to destruction of periodontal tissue by infection, resulting in tooth loss [15]. Nevertheless, if a positive association between osteoporosis and tooth loss exists, then it is likely that the MCI detected on dental panoramic radiographs may be associated with number of teeth present in the elderly. The purpose of this study, therefore, is to clarify the association between the MCI and number of teeth present in Japanese men and women aged 40 years and older.

2. Materials and methods

2.1. Subjects and panoramic radiography measure

Among patients who visited our university hospital and underwent dental panoramic radiography for the diagnosis of dental diseases between January 2007 and December 2013, 2187 men and women aged ≥40 years were invited to complete a structured questionnaire. Patients who refused to provide written informed consent, had destructive jaw lesions such as osteomyelitis and malignant tumors, or were receiving cancer medications were excluded from the study. The subjects completed the structured questionnaire, which collected information regarding body height (cm), body weight (kg), age, gender, body height (cm), body weight (kg), history of smoking (yes or no) and alcohol consumption (yes or no), history of hypertension (yes or no), diabetes mellitus (yes or no), and rheumatoid arthritis (yes or no), daily number of tooth brushings, use of inter-dental brush or floss (yes or no), and use of osteoporosis medications (yes or no) among the three MCI categories. Multiple regression analysis in a step-wise manner, adjusted for the abovementioned variables, was used to clarify the association between number of teeth present and MCI category. Dummy variables were used for categorical data in this multiple regression analysis.

Analysis of covariance (ANCOVA), adjusted for age, gender, body height (cm), body weight (kg), history of smoking (yes or no) and alcohol consumption (yes or no), history of hypertension (yes or no), diabetes mellitus (yes or no), and rheumatoid arthritis (yes or no), daily number of tooth brushings, use of inter-dental brush or floss (yes or no), and use of osteoporosis medications (yes or no), was used to evaluate differences in the number of teeth present among the three MCI categories. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, version 19.0; IBM Inc., Armonk, NY, USA). P values <0.05 were considered to indicate statistical significance.
3. Results

Of 2187 patients aged ≥40 years initially invited to participate, 1021 patients (371 men and 650 women) aged 40–89 years gave informed consent to participate in our study. After excluding patients based on exclusion criteria, 839 patients (293 men and 546 women) aged 40–89 years (mean [SD], 63.7 [10.6] years) were finally enrolled in this study. The characteristics of the study subjects are shown in Table 1. Four hundred and ninety-five subjects had a normal mandibular cortex, 234 had a mildly to moderately eroded cortex, and 100 had a severe eroded cortex. Weighted kappa for intra- and inter-observer agreement for determining MCI was 0.87 (95% confidence interval [CI], 0.80–0.93) and 0.71 (95% CI, 0.61–0.80), respectively. Thirty subjects used oral bisphosphonate (BP), 10 used selective estrogen receptor modulator, and 6 used vitamin D for osteoporosis treatment. Table 2 shows the differences in subject characteristics according to MCI category. Significant differences were observed in number of teeth present (p < 0.001), gender (p < 0.001), age (p < 0.001), body height (p < 0.001), body weight (p < 0.001), history of hypertension (p = 0.037), alcohol consumption (p = 0.002), smoking (p < 0.001), and use of osteoporosis medications (p < 0.001).

Multiple regression analysis revealed that mildly to moderately eroded cortex (p = 0.007), severe eroded cortex (p < 0.001), advancing age (p < 0.001), and history of smoking (p = 0.001) were significantly associated with a decreased number of teeth present (Table 3). Conversely, increased number of tooth brushings (p < 0.001), use of inter-dental brush or floss (p < 0.001), history of alcohol consumption (yes) (p = 0.009), and use of osteoporosis medications (p = 0.033) were significantly associated with an increased number of teeth present.

Additionally, ANCOVA revealed a significant association between MCI category and number of teeth present (p < 0.001) (Fig. 2). Subjects with a severely eroded cortex had significantly fewer teeth present than those with a normal cortex (mean [SE], 20.7 [0.5] vs. 23.4 [0.3], p < 0.001) or mildly to moderately eroded cortex (20.7 [0.5] vs. 22.2 [0.4], p = 0.04). Subjects with a mildly to moderately eroded cortex had significantly fewer teeth present than those with a normal cortex (22.2 [0.4] vs. 23.4 [0.3], p = 0.033).

4. Discussion

To our knowledge, this is the first study demonstrating the association between MCI category and number of teeth present in Japanese men and women aged 40 years and older, although the association between MCI category and osteoporosis diagnosis has been reported [10]. We previously demonstrated an association between mandibular cortical width measured on dental panoramic radiographs and number of teeth present, without adjusting for covariates that may

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**Table 1** Characteristics of 839 study subjects.

|                        | Men     | Women   |
|------------------------|---------|---------|
| Number of subjects     | 293     | 546     |
| Age (years)            | 67.7 (8.1) | 61.5 (11.2) |
| Height (cm)            | 167.1 (6.6) | 155.3 (5.6) |
| Weight (kg)            | 64.2 (9.4) | 52.7 (8.8) |
| Number of teeth present| 22.0 (6.0) | 23.1 (5.6) |
| Diabetes mellitus (yes)| 39 (13.3) | 24 (4.4) |
| Rheumatoid arthritis (yes)| 5 (1.7) | 10 (1.8) |
| Hypertension (yes)     | 105 (35.8) | 126 (23.1) |
| Daily number of tooth brushing (≥2) | 212 (72.4) | 504 (92.3) |
| Use of inter-dental brush or floss | 169 (57.7) | 405 (74.2) |
| Alcohol consumption (yes) | 179 (61.1) | 148 (27.1) |
| Smoking history (yes)  | 141 (48.1) | 57 (10.4) |
| Use of osteoporosis medications | 3 (1.0) | 43 (7.9) |

Data are expressed as mean (SD) or number of subjects (%).
We recently reported a significant association between increased self-reported kyphosis and increased risk of spine fractures in 407 Japanese women aged 60 years and older [19]. Additionally, we also demonstrated a significant association among increased self-reported kyphosis, number of teeth present, and number of teeth lost within 1 year in 307 Japanese men and women aged 50 years and older [20]. Our findings suggest that individuals who have osteoporosis may lose more teeth than those who do not have osteoporosis. Our current study supports this hypothesis. However, since this is the cross-sectional study, it remains unclear whether osteoporotic change of the mandible contributes to increased risk of tooth loss. It is possible that tooth loss may accelerate the progression of mandibular cortical erosion.

Table 2

Differences in subject characteristics according to mandibular cortical shape detected on dental panoramic radiographs.

| Cortical shape                        | Normal cortex | Mildly to moderately eroded cortex | Severely eroded cortex | P-value |
|---------------------------------------|---------------|-----------------------------------|------------------------|---------|
| Number of subjects                    | 495           | 234                               | 110                    | <0.001  |
| Gender (women)                        | 273           | 173                               | 100                    | <0.001  |
| Age (years)                           | 60.8 (11.4)   | 67.3 (8.1)                        | 69.0 (6.8)             | <0.001  |
| Height (cm)                           | 161.4 (7.9)   | 157.3 (8.2)                       | 155.3 (6.8)            | <0.001  |
| Weight (kg)                           | 58.4 (10.4)   | 55.0 (10.3)                       | 52.6 (10.2)            | <0.001  |
| Number of teeth present               | 23.7 (5.1)    | 21.7 (6.2)                        | 20.2 (6.3)             | <0.001  |
| Diabetes mellitus (yes)               | 34            | 21                                | 8                      | 0.599   |
| Rheumatoid arthritis (yes)            | 7             | 5                                 | 3                      | 0.574   |
| Hypertension (yes)                    | 120           | 76                                | 35                     | 0.037   |
| Daily number of tooth brushings (≥2)  | 424           | 199                               | 82                     | 0.946   |
| Use of inter-dental brush or floss    | 330           | 162                               | 82                     | 0.261   |
| Alcohol consumption (yes)             | 217           | 79                                | 31                     | 0.002   |
| Smoking history (yes)                 | 141           | 43                                | 14                     | <0.001  |
| Use of osteoporosis medications       | 13            | 14                                | 19                     | <0.001  |

Data are expressed as mean (SD) or number of subjects.

Table 3

Associations between number of teeth present and mandibular cortical shape detected on dental panoramic radiographs determined by multiple regression analysis.

| Parameter                              | Parameter estimate | SE     | P-value |
|----------------------------------------|--------------------|--------|---------|
| Mildly to moderately eroded cortex     | -1.186             | 0.438  | 0.007   |
| Severely eroded cortex                 | -2.723             | 0.590  | <0.001  |
| Age (year)                             | -0.147             | 0.018  | <0.001  |
| Use of inter-dental brush or floss     | 1.398              | 0.397  | <0.001  |
| Smoking history (yes)                  | -1.570             | 0.454  | 0.001   |
| Alcohol consumption (yes)              | 1.008              | 0.387  | 0.009   |
| Daily number of tooth brushings (≥2)   | 1.186              | 0.534  | 0.027   |
| Use of osteoporosis medications        | 1.767              | 0.825  | 0.033   |

SE: standard error of the mean.

Fig. 2. Association between mandibular cortical shape on panoramic radiographs and number of teeth present. *p < 0.001; †, ‡, †† p < 0.05.

Fig. 3. Dental panoramic radiographs of a 56-year-old female patient who had severe atrophic edentulous mandible and normal cortex.

Fig. 4. Dental panoramic radiographs of a 57-year-old female patient who had a severely eroded cortex. This patient had lost only one tooth because of dental caries. If a
dentate status prevents mandibular cortical erosion, then this patient should have a normal cortex. However, T-scores of both the spine and femoral neck in this patient were less than −2.5. Thus, this case suggests that the presence of teeth does not protect against the progression of mandibular cortical erosion.

In this study, use of osteoporosis medications was significantly associated with an increased number of teeth present. This result is in accordance with that of previous studies [23–26]. Furthermore, many investigators have reported the improvement of periodontal disease by oral BP therapy for osteoporosis treatment [27–29]. It is reasonable that advancing age and history of smoking had negative effects on tooth retention. It also is likely that increased number of tooth brushings and use of inter-dental brush or floss may be effective for tooth retention in men and women aged 40 years and older. However, whether history of alcohol consumption has a positive effect on tooth retention remains unclear. Morita et al. reported that factors significantly associated with tooth loss in both males and females included alcohol consumption (odds ratio [OR] = 11.96, males; OR = 3.83, females) in 777 Japanese people aged 20 years and older (390 men and 387 women) [30]. Conversely, Hanioka et al. reported that current alcohol drinking was significantly associated with decreased risk of tooth loss (adjusted OR [95% confidence interval], 0.28 [0.07–0.84]) in 1219 Japanese women aged 60 years or older [31]. However, there was no significant association between former alcohol drinking and tooth loss in 903 men and 1291 women or between current alcohol drinking and tooth loss in men. Significant associations were not observed in these subjects; however, all adjusted ORs were less than 1, suggesting that alcohol consumption may have a positive effect on tooth retention in Japanese men and women aged 60 years and older.

There are some limitations associated with this study. First, the study population consisted of patients who visited our university hospital. Thus, our cohort may not be representative of Japanese men and women aged 40 years and older. Second, the study had a cross-sectional, rather than longitudinal, design. Therefore, it is necessary to evaluate the association between number of teeth lost after baseline and the MCI after adjusting for covariates to clarify whether the number of teeth lost after baseline can be predicted by the MCI. Third, osteoporosis medications might contribute to the MCI detected on dental panoramic radiographs. However, a significant association between MCI category and number of teeth present remained after adjusting for use of osteoporosis medications. Lastly, the reason for tooth should be evaluated to determine whether periodontal disease actually contributes to tooth loss in patients who have mandibular cortical erosion detected on dental panoramic radiographs.

5. Conclusions

Our results suggested the significant association between mandibular cortical erosion and number of teeth present in Japanese men and women aged 40 years and older. A longitudinal study is necessary to clarify whether future tooth loss can be predicted by MCI category on dental panoramic radiographs.

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Conflicts of interest

None.

References

[1] Nojiri S, Burge RT, Flynn JA, Foster SA, Sowa H. Osteoporosis and treatments in Japan: management for preventing subsequent fractures. J Bone Miner Metab 2013;31:367–80.
[2] Ballane G, Cauley JA, Luckey MM, Fuleihan GE. Secular trends in hip fractures worldwide: opposing trends East versus West. J Bone Miner Res 2014;29:1745–55.
[3] Orimo H, Yaegashi Y, Hosoi T, Fukushima Y, Onoda T, Hashimoto T, et al. Hip fracture incidence in Japan: estimates of new patients in 2012 and 25-year trends. Osteoporos Int 2016;27:1777–84.
[4] Iki M. Epidemiology of bone and joint disease - the present and future -. Epidemiology of osteoporosis and osteoporotic fracture in Japan. Clin Calcium 2014;24:657–64 [in Japanese].
[5] Taguchi A. Triage screening for osteoporosis in dental clinics using panoramic radiographs. Oral Dis 2010;16:316–27.
[6] Taguchi A, Suel Y, Sanada M, Ohtsuka M, Nakamoto T, Sumida H, et al. Validation of dental panoramic radiography measures for identifying postmenopausal women with spinal osteoporosis. AJR Am J Roentgenol 2004;183:1755–60.
[7] Taguchi A, Tsuda M, Ohtsuka M, Kodama I, Sanada M, Nakamoto T, et al. Use of dental panoramic radiographs in identifying younger postmenopausal women with osteoporosis. Osteoporos Int 2006;17:387–94.
[8] Taguchi A, Sanada M, Krall E, Nakamoto T, Ohtsuka M, Suel Y, et al. Relationship between dental panoramic radiographic findings and biochemical markers of bone turnover. J Bone Miner Res 2003;18:1689–94.
[9] Bollen AM, Taguchi A, Hujoel PP, Hollender LG. Case-control study on self-reported osteoporotic fractures and mandibular cortical bone. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;90:518–24.
[10] Calciodori E, Donos N, Park JC, Petrie A, Mardas N. Panoramic measures for oral bone mass in detecting osteoporosis: a systematic review and meta-analysis. J Dent Res 2015;94:175–83.
[11] Daniell HW. Postmenopausal tooth loss. Contributions to edentulism by osteoporosis and cigarette smoking. Arch Intern Med 1983;143:1678–82.
Taguchi A, Fujiwara S, Masunari N, Suzuki G. Self-reported number of remaining teeth is associated with bone mineral density of the femoral neck, but not of the spine, in Japanese men and women. Osteoporos Int 2004;15:842–6.

Iwasaki M, Nakamura K, Yoshihara A, Miyazaki H. Change in bone mineral density and tooth loss in Japanese community-dwelling postmenopausal women: a 5-year cohort study. J Bone Miner Metab 2012;30:447–53.

Jang KM, Cho KH, Lee SH, Han SB, Han KD, Kim YH. Tooth loss and bone mineral density in postmenopausal South Korean women: the 2008-2010 Korea National Health and Nutrition Examination Survey. Maturitas 2015;82:360–4.

Wactawski-Wende J. Periodontal diseases and osteoporosis: association and mechanisms. Ann Periodontol 2001;6:197–208.

Fujiwara S, Nakamura T, Orimo H, Hosoi T, Gorai I, Oden A, et al. Development and application of a Japanese model of the WHO fracture risk assessment tool (FRAX). Osteoporos Int 2008;19:429–35.

Taguchi A, Sanada M, Suei Y, Ohtsuka M, Lee K, Tanimoto K, et al. Tooth loss is associated with an increased risk of hypertension in postmenopausal women. Hypertension 2004;43:1297–300.

Taguchi A, Tanimoto K, Suei Y, Wada T. Tooth loss and mandibular osteopenia. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995;79:127–32.

Taguchi A, Kamimura M, Sugino N, Uchida K, Kitamura Y, Ikegami S, et al. Association of self-reported height loss and kyphosis with vertebral fractures in Japanese women 60 years and older: a cross-sectional survey. Sci Rep 2016;6:29199.

Taguchi A, Kamimura M, Sugino N, Uchida K, Kitamura Y, Ikegami S, et al. Association of self-reported height loss and kyphosis with loss of teeth in Japanese elderly. Oral Health Dent Manag 2016;15:69–74. http://www.omicsonline.com/open-access/association-of-self-reported-height-loss-and-kyphosis-with-loss-of-teeth-in-japanese-elderly-2247-2452-1000874.pdf.

Ishii K, Taguchi A, Nakamoto T, Ohtsuka M, Suthiprapaporn P, Tsuda M, et al. Diagnostic efficacy of alveolar bone loss of the mandible for identifying postmenopausal women with femoral osteoporosis. Dentomaxillofac Radiol 2007;36:28–33.

Bollen AM, Taguchi A, Hujoel PP, Hollender LG. Number of teeth and residual alveolar ridge height in subjects with a history of self-reported osteoporotic fractures. Osteoporos Int 2004;15:970–4.

Paganini-Hill A. The benefits of estrogen replacement therapy on oral health. The Leisure World cohort. Arch Intern Med 1995;155:2325–9.

Grodstein F, Colditz GA, Stampfer MJ. Post-menopausal hormone use and tooth loss: a prospective study. J Am Dent Assoc 1996;127:570–7.

Kraal EA, Wehler C, Garcia RI, Harris SS, Dawson-Hughes B. Calcium and vitamin D supplements reduce tooth loss in the elderly. Am J Med 2001;111:452–6.

Taguchi A, Sanada M, Suei Y, Ohtsuka M, Nakamoto T, Lee K, et al. Effect of estrogen use on tooth retention, oral bone height, and oral bone porosity in Japanese postmenopausal women. Menopause 2004;11:556–62.

Lane N, Armitage GC, Loomer P, Hsieh S, Majumdar S, Wang HY, et al. Bisphosphonate therapy improves the outcome of conventional periodontal treatment: results of a 12-month, randomized, placebo-controlled study. J Periodontol 2005;76:1113–22.

Jeffcoat MK, Cizza G, Shih WJ, Genco R, Lombardi A. Efficacy of bisphosphonates for the control of alveolar bone loss in periodontitis. J Int Acad Periodontol 2007;9:70–6.

Bhavsar NV, Trivedi SR, Dulani K, Brahmbhatt N, Shah S, Chaudhri D. Clinical and radiographic evaluation of effect of risendronate 5 mg as an adjunct to treatment of chronic periodontitis in postmenopausal women (12-month study). Osteoporos Int 2016;27:2611–9.

Morita I, Nakagaki H, Toyama A, Hayashi M, Shimozato M, Watanabe T, et al. Behavioral factors to include in guidelines for lifelong oral healthiness: an observational study in Japanese adults. BMC Oral Health 2006;20:15.

Hanioka T, Ojima M, Tanaka K, Aoyama H. Association of total tooth loss with smoking, drinking alcohol and nutrition in elderly Japanese: analysis of national database. Gerodontology 2007;24:87–92.