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Relationship between bone fragility of the mandibular inferior cortex and tooth loss related to periodontal disease in older people

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Objective**:** The purpose of this study was to evaluate the relationship between bone fragility of the mandibular inferior cortex and tooth loss in older adults by accounting for periodontal disease and bone metabolism markers. ***Research Design*****:** A total of 177 subjects aged 77 years participated in this study. We counted the number of remaining teeth. The mandibular cortex condition was examined using the mandibular inferior cortex classification (MICC) on dental panoramic radiographs. The mandibular inferior cortex was detected on both sides of the mandible, distally from the mental foramen (C1, normal; C2, mild/moderate erosion; C3, severe erosion). Multiple linear regression analysis was performed to assess the relationship between the mandibular cortex condition with the MICC and the number of remaining teeth after controlling for confounding factors such as gender, the percentage of sites with ≥4 mm clinical attachment levels, and serum osteocalcin levels. ***Results*****:** The mean ± SD number of remaining teeth of MICC C1, C2 and C3 were 20.7±7.5, 14.6±8.1 and 4.0±0.0 for males, and MICC C1, C2, and C3 were 21.7±7.6, 17.2±8.0, and 16.2±10.4 for females. The MICC was significantly associated with the number of remaining teeth using multiple linear regression analysis (beta= -0.21, p=0.031). ***Conclusion*****:** This study suggests that there is a relationship between bone fragility of the mandibular inferior cortex and tooth loss related to periodontal disease.

Key words: Dental panoramic radiograph, elderly, epidemiology, mandibular inferior cortex, number of teeth

Introduction

Tooth loss is a social health problem in terms of both insufficient nutrient intake and decreasing quality of life related to eating in the elderly. However, the relationship among the number of remaining teeth, jawbone loss, and skeletal bone mineral density (BMD) remains unclear. Many studies have investigated the association between the number of remaining teeth and BMD (May *et al*., 1995; Krall *et al*., 1996; Mohammad *et al*., 1997; Taguchi *et al*., 2004); between alveolar bone and BMD (Hildebolt *et al*., 2000; Wactawski-Wende *et al*., 2005); and between periodontal status and BMD (VonWowern *et al*., 1994; Klemetti *et al*., 1994a; Tezal *et al*., 2000; Inagaki *et al*., 2001). However, almost all studies have focused on elderly females. Some studies have shown that post-menopausal women with very low BMD have few teeth remaining compared with those with normal BMD (Inagaki *et al*., 2001; Klemetti *et al*., 1994a). In addition, some studies have revealed a relationship between periodontal status, especially periodontal attachment loss, and osteoporosis or BMD (Tezal *et al*., 2000; Yoshihara *et al*.,2005). In contrast, other studies have failed to find a significant association between the number of remaining teeth or periodontal status and BMD (Weyant *et al*., 1999; Lundström *et al*., 2001). Furthermore, although some investigators have demonstrated a significant association between jawbone condition and tooth loss (Taguchi *et al*., 1995; Inagaki *et al*., 2001), others have failed to find this association (Lundström *et al*., 2001). Based on these studies, the ability to determine whether low BMD is causally related to tooth loss appears to be limited.

An important issue when evaluating the condition of the jawbone is standardization of assessment criteria. Several investigations have used the mandibular inferior cortex classification (MICC) to evaluate the condition of the jawbone (Klemetti *et al*., 1994b; Nakamoto *et al*., 2003; Halling *et al*., 2005). This classification is an assessment of the appearance of the inferior cortex of the mandible on dental panoramic radiographs. Several studies have indicated that the mandibular inferior cortex is not affected by alveolar bone resorption caused by tooth loss (Taguchi *et al*., 1995; Giannobile *et al*., 2003). In addition, investigators have reported a satisfactory level of reproducibility of the MICC (Nakamoto *et al*., 2003; Halling *et al*., 2005). However, only a few reports have evaluated the relationship between the number of remaining teeth and mandibular inferior cortical findings on radiographs (Taguchi *et al*., 1995).

The purpose of this study was to evaluate the relationship between bone fragility of the mandibular inferior cortex and tooth loss in older adults by taking periodontal disease and bone metabolism markers into consideration.

Materials and methods

The population for this study was drawn from the Niigata study. Briefly, the Niigata study was a prospective community-based study conducted in 1998 that was initiated to

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evaluate the relationship between an individual's general health status and his/her history of dental disease. Initially, questionnaires were sent to all inhabitants (n=4,542) aged 70 years based on a registry of residents in Niigata City in Japan. All recipients were informed of the purpose of the survey. Among those who were randomly selected to participate in the Niigata study (n=600), 436 subjects (230 males and 206 females) who turned 70 in 1998 and were aged 77 years in 2005 underwent annual dental examinations. We randomly selected 200 of these subjects. All subjects were Japanese, in good general health, and did not require special care for their daily activities. To exclude the influence of race and age, selected subjects were homogenous in terms of race and had to be 77 years old. Among the 200 subjects, 177 were included in this analysis because they had one or more teeth at the time of the examination, did not take medicine for bone disorders (tamoxifen, anabolic steroids, bisphosphonates, or estrogen), and did not have a diagnosis of fracture based on an X-ray assessment. The protocol was reviewed and approved by the Ethics Committee of the Faculty of Dentistry, Niigata University.

We took dental panoramic radiographs to evaluate the mandibular inferior cortex and the number of remaining teeth. All panoramic radiographs were obtained with SUPER VERAVIEW X-500 (Morita Co., Tokyo, Japan) at 9 mA and 15 sec; the kV varied between 70 and 80. We used screens of speed group 200 (HG-M; Fuji Photo Film Co., Tokyo, Japan) and film (UR-2; Fuji Photo Film Co.). The inferior cortex was scrutinized on both sides of the mandible, distally from the mental foramen (Figure 1). Subjects were classified into three groups (C1-C3) according to the following criteria (Klemetti *et al*., 1994b): C1, the endosteal margin of the cortex was even and sharp on both sides (normal cortex); C2, the endosteal margin showed semilunar defects (lacunar resorption) or seemed to form endosteal cortical residues (one to three layers) on one or both sides (mildly to moderately eroded cortex); and C3, the endosteal margin showed cortical residues and was clearly porous (severely eroded cortex). Dental panoramic radiographic measurements were estimated by a single examiner with 4 years' experience using the MICC.

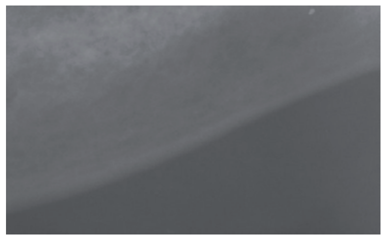
Before we performed this study, we measured the reproducibility of the MICC by two observers, including the examiner in this study. First, two observers (observer A and B) independently read 100 films. Two weeks later, observer A (the examiner in this study) read the 100 films again. The intra- and inter-observer agreements on the MICC were calculated as a percentage and κ value.

The periodontal examination included the assessment of probing pocket depth (PPD) and clinical attachment level (CAL) at six sites around each tooth. Probing was performed using a pressure constant probe (Vivacare TPS Probe®, Schaan, Liechtenstein) and a probing force of 20 g. The periodontal examination was carried out by four trained dentists under sufficient illumination using artificial light. Inter-examiner reliability for the CAL was assessed for the four examiners before the survey using 10 volunteer patients in the University Hospital.

We conducted personal interviews with subjects to obtain information regarding smoking habits. Subjects' blood was taken on the morning of the dental examination. Serum osteocalcin (S-OC, ng/ml), which is considered a valid marker of bone turnover (Giannobile *et al*., 2003, Yoshihara *et al*., 2009), was measured. The laboratory tests were performed at a commercial laboratory (BML, Inc, Tokyo, Japan).

Normal cortex (C1)

Mildly to moderately eroded cortex (C2)



Severely eroded cortex (C3)

Figure 1. *Mandibular inferior cortex classification (MICC) on dental panoramic radiographs.*

After the 177 subjects were divided into three groups according to MICC, we evaluated the relationship between MICC and number of remaining teeth, the percentage of sites with ≥4 mm clinical attachment level (4+CAL), the percentage of sites with ≥4 mm probing pocket depth (4+PPD), smoking habits, and S-OC levels by analysis of covariance (ANCOVA). In addition, a multiple linear regression analysis was performed to assess the relationship between the MICC and the number of remaining teeth after controlling for confounding factors. The number of remaining teeth was used as the dependent variable. The MICC (C1, 0; C2 or C3, 1), gender (male, 0; female, 1), 4+CAL, and S-OC levels were used as independent variables. In this analysis, we used 4+CAL and gender as independent variables because 4+CAL and 4+PPD and gender and smoking habits correlated strongly with each other.

All calculations and statistical analyses were performed using the STATA™ software package (StataCorp., College Station, TX, USA). The level of significance was set at $p<0.05$.

Results

Overall agreements for intra- and inter-observer performance were 91.0% and 86.0%, respectively. The κ values for intra- and inter-observer agreement were 0.85 and 0.77, respectively. In addition, as determined by replicate examinations on PPD and CAL, the percentage agreement (±1 mm) ranged from 87.5% to 100% for PPD and from 83.3% to 100% for CAL. The κ ranged from 0.81 to 1.00 for PPD and from 0.74 to 1.00 for CAL.

MICC C1, C2, and C3 were seen in 66.7%, 32.3% and 1.0% of men, and 9.0%, 62.8% and 28.2% of women, respectively. The percentage of subjects with MICC C2 and C3 was significantly higher for females than for males (Fisher's exact probability test, $p<0.001$). The mean ± SD number of remaining teeth for subjects with MICC C1, C2, and C3 was 20.7±7.5, 14.6±8.1, and 4.0±0.0 for males, and 21.7±7.6, 17.2±8.0, and 16.2±10.4 for females (Figure 2). A significantly negative relationship was found between the MICC and the number of remaining teeth (ANCOVA, $p<0.001$). In addition, both 4+CAL and S-OC levels were higher in subjects with MICC C2 or C3 than in subjects with MICC C1 (ANCOVA, $p=0.048$ for 4+CAL, ANCOVA, $p<0.001$ for S-OC levels). There were no significant differences in 4+PPD and smoking habits among the MICC C1, C2, and C3 groups (Table 1). Table 2 shows the results of multiple linear regression analysis. The number of remaining teeth was significantly associated with the MICC (beta=-0.21, $p=0.031$) and 4+CAL (beta=-0.46, $p<0.001$). However, there was no significant relationship between S-OC and the number of remaining teeth.

Discussion

This study showed a positive relationship between MICC and S-OC levels. Because higher S-OC levels indicate higher bone turnover (Iki *et al.*, 2004), we suggest that there is an association between the mandibular inferior cortex and general bone metabolism. These findings are supported by another study that suggested that mandibular inferior cortical findings on dental panoramic radiographs was associated with BMD of the mandibular cortex (Klemetti and Kolmakov, 1997).

Subjects with MICC C1 had more teeth, a lower level of 4+CAL, and a lower level of S-OC than subjects with MICC C2 or C3. However, although there was a significant association between the number of remaining teeth and 4+CAL, and between the number of remaining teeth and the MICC, the relationship between the number of remaining teeth and S-OC levels was less clear. There might be an indirect association between tooth loss and MICC. Generally, periodontal disease, which is the primary reason for tooth loss, is characterized by the absorption of the alveolar bone as well as by the loss of the soft tissue attachment to the tooth. Tooth loss is influenced more by local factors, such as periodontal disease, than by general bone metabolism, which was evaluated by S-OC.

A significantly higher percentage of women than men had MICC C2 and MICC C3. It has been speculated that estrogen deficiency and osteopenia/osteoporosis play a role in the progression of oral bone loss following menopause. Some reports have also linked estrogen deficiency and osteopenia/osteoporosis to increased oral bone resorption, attachment loss, and tooth loss (Paganini-Hill, 1995; Grodstein *et al*., 1996). These results suggest that BMD reduces with advanced periodontal disease, osteoporosis in a high percentage of postmenopausal women.

The standardized site used in this investigation was distal from the mental foramen, which is not associated with attachment sites of the major masticatory muscles (McMinn and Hutchings, 1977). Therefore, mandibular cortical findings might not be influenced by decreased mechanical stresses in occlusion caused by tooth loss.

Radiographic findings are affected by many factors, including difficulties in standardizing head position, x-ray projection, radiation dose, and anatomic variability of bony structures. However, it was reported that disagreement caused by positioning error and operator error for the mandibular inferior cortex was negligible (Taguchi *et al*., 1993). The reproducibility of the MICC in our study was high. The percentages of agreement for intra- and inter-observer performances exceeded 80%. The κ values for intra- and inter-observer agreement exceeded 0.70. These findings agree with previous studies (Nakamoto *et al*., 2003; Halling *et al*., 2005).

Limitations of the present study must be taken into consideration. In spite of finding a significant relationship

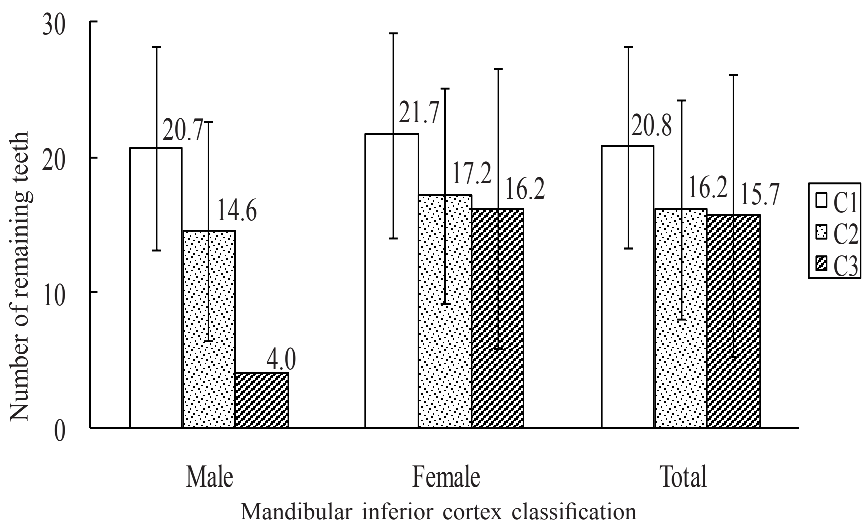


Figure *2. Relationship between mandibular inferior cortex classification and number of remaining teeth. Data are mean ± SD.*

Table 1. Comparison of selected characteristics according to mandibular inferior cortex classification (MICC)

Variables	*Males (n=99) MICC[c]*						*Females (n=78) MICC[c]*						*p value[d]*
	C1 (n=66)		*C2 (n=32)*		*C3 (n=1)*		*C1 (n=7)*		*C2 (n=49)*		*C3 (n=22)*		
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	
4+CAL (%)[a]	42.2	27.7	52.2	27.6	-		19.7	22.7	35.4	30.2	39.2	31.4	0.048
4+PPD (%)[a]	11.2	10.4	12.1	11.0	-		8.6	10.3	11.2	13.1	8.4	9.5	0.452
Smoking habit (%)	22.7		18.8		-		0		0		0		0.828
S-OC[b] (ng/ml)	6.3	2.8	7.4	2.8	-		8.0	1.2	9.4	3.1	10.3	2.8	<0.001

a 4+CAL: % of sites with ≥4 mm clinical attachment level; 4+PPD: % of sites with ≥4 mm probing pocket depth.
b Serum osteocalcin.
c Mandibular inferior cortex classification.
d ANCOVA.

Table 2. Results of multiple linear regression analysis.

	Dependent variable Number of remaining teeth			
Independent variables	*Coef.*	*Std. Err.*	*Beta*	*p value*
MICC[a] (C1:0, C2 or C3:1)	-.351	1.61	-0.21	0.031
Gender (Male, 0; Female,1)	2.02	1.67	0.12	0.227
4+CAL[b] (%)	-0.29	0.05	-0.46	<0.001
S-OC[c] (ng/ml)	-0.11	0.24	-0.05	0.592
Constant	23.17	1.98	-	<0.001

a Mandibular inferior cortex classification.
b % of sites with ≥4 mm clinical attachment level.
c Serum osteocalcin.

between the MICC and the number of remaining teeth, and between the MICC and S-OC or 4+CAL, the ability to address the issue of whether the MICC is causally related to tooth loss is limited because of the cross-sectional design of the study.

In conclusion, our study suggests that there is a relationship between the fragility of the mandibular inferior cortex and tooth loss related to periodontal disease. Longitudinal studies are required to provide stronger evidence before the MICC can be recommended for routine clinical use.

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