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內文：

Introduction

A. Osteoporosis is a skeletal disorder characterized by **low bone mass** and **micro-architectural deterioration**, with a resulting increase in bone fragility and susceptibility to fracture

B. Because 70% of bone strength is determined by skeletal **bone mineral density** (BMD) and the remaining 30% by factors determining **bone quality**, such as bone turnover rate, *BMD measurement of the general skeletonis an important indicator of risk of fractures for individuals*

C. **Menopause** is a major risk factor for osteoporosis, and most postmenopausal women are at risk of osteoporosis and consequent fractures

D. Bisphosphonates decreased the rate of fracture (USA food and drug Administrattion)

E. **Early detection** of individuals at risk of osteoporotic fractures and **early intervention** can help reduce the incidence of these fractures, especially hip fractures

F. Measuring the **mandibular inferior cortical width** (MCW) below the mental foramen of the mandible on dental panoramic radiographs might be a useful method for identifying postmenopausal women with low-skeletal BMD or at risk of osteoporotic fractures

G. Computer-aided technique was developed, in which the MCW was semiautomatically measured, and **manual assistance** was needed during some parts of the measurement. Furthermore, the MCW was measured at only one point (**below the mental foramen**) in most previous studies. In addition, the hyoid bone image might overlap the cortex below the mental foramen and influence the MCW measurement and accuracy

H. The objectives of this study, therefore, were to develop a computer-aided (CAD) system that continuously measures the MCW between the upper and lower boundaries of the cortical bone in the region of interest (ROI), and to evaluate the diagnostic efficacy of this system in identifying postmenopausal women with low-skeletal BMD

Materials and methods

Patients

A. 531 women underwent a skeletal BMD examination at an oral radiology clinic at Hiroshima University Hospital (Hiroshima, Japan) between 1996 and 2001

B. The inclusion criteria: 100 postmenopausal women, aged 50 years and older, with no previous diagnosis of osteoporosis

C. The exclusion criteria were:

(a) women who had menstruated less than 1 year prior to the study, or had undergone hysterectomy or oophorectomy

(b) women with a history of a metabolic bone disease: (hyperparathyroidism,

hypoparathyroidism, Paget's disease,osteomalacia, renal osteodystrophy, or osteogenesisimperfecta), cancer with bone metastasis, significant renal
Impairment, bone destructive lesion (e.g., malignanttumors or osteomyelitis) of the mandible, and spinal fracture(confirmed semiquantitatively on lateral radiographs);
(c) women on medication that affects bonemetabolism (e.g., estrogen)
(d) smokers

Bone densitometry

A. All 100 women underwent BMD of the lumbar spine(L2–L4) and femoral neck by dual-energy X-ray absorptiometry (DXA) (DPX-alpha; Lunar, Madison, WI, USA)
B. The patients were classified as normal ,osteopenic or osteoporotic (SD) at each skeletalsite according to the WHO

Dental panoramic radiography

All the panoramic radiographs were obtained :

a) using AZ-3000 (Asahi, Kyoto, Japan) at 12 mA at 15 sec
b) kVp values varied between 70 and 80
c) digitized at a resolution of 300 dpi using a flat-bed scanner (ES-8000; Epson, Tokyo, Japan).
d) Screens of speed group 200(HG-M; Fuji Photo Film, Tokyo, Japan) and film (UR-2;Fuji Photo Film) were used.

Digital panoramic radiography for a pilot study

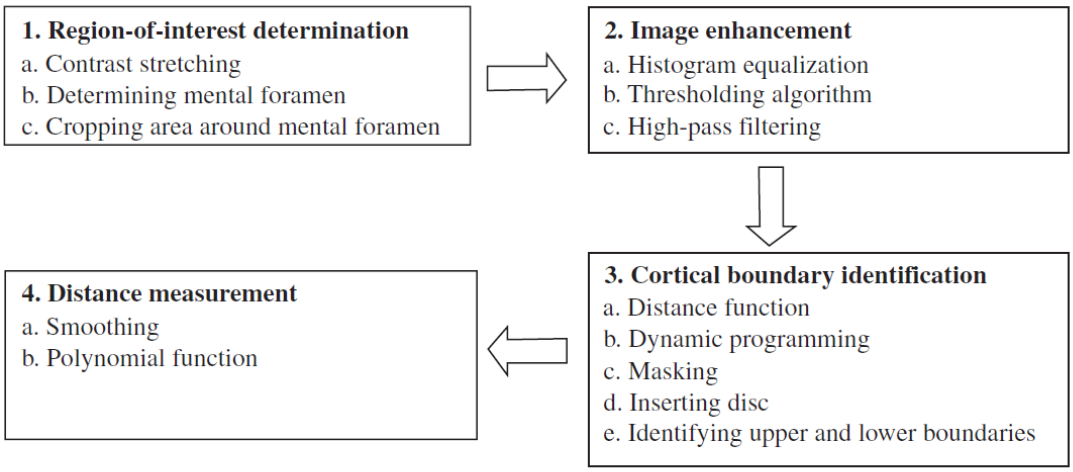
a) This study also included digital panoramic radiographs by randomly selected 40 participants as for the pilot study
b) Applied CAD to pairs of a digital dental panoramic radiograph to evaluate the diagnostic vdidity.

Automated system development for MCW measurements

The schematic diagram of the proposed automated system:

a) describes how to determine the ROI, enhance the original image
b) detect the inner and outer boundaries of the cortex
c) measure the distance between the boundaries of the cortex

Dental radiographs and osteoporosis



ROI determination

A .The mental foramen is an opening on the lateral part of the mandible, inferior to the second premolar

B. The area involved in the lower border of the mandibular cortex below the mental foramen cropped manually on the right and left sides was considered as the **ROI**

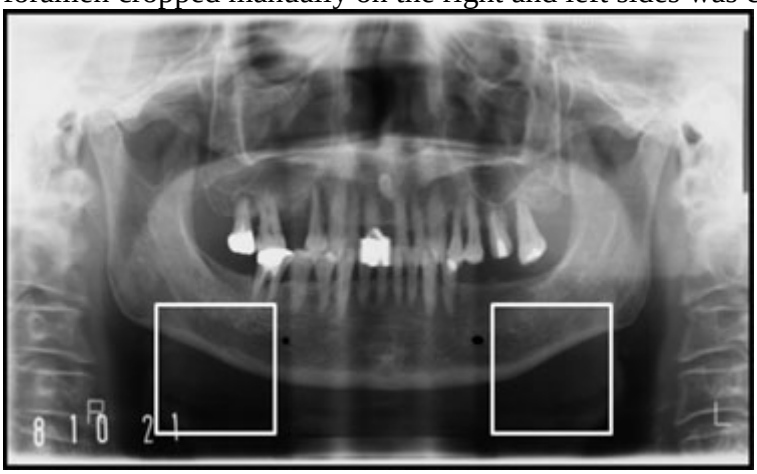


Image enhancement

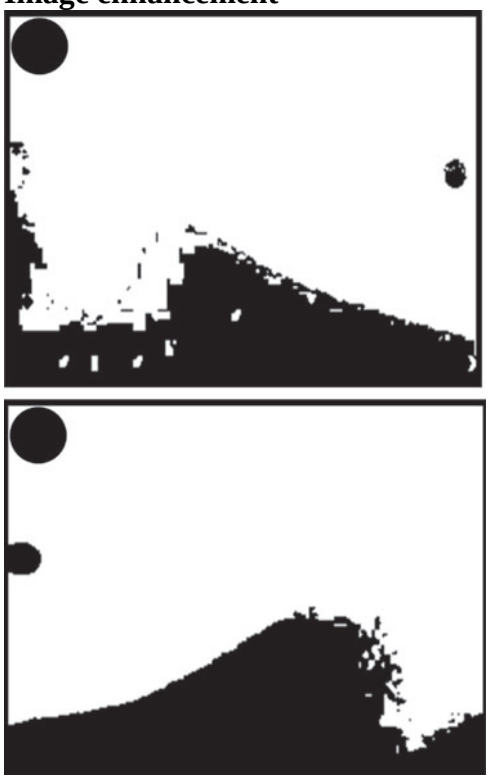


Figure 3. Binary images of the right (a) and left (b) cortices.

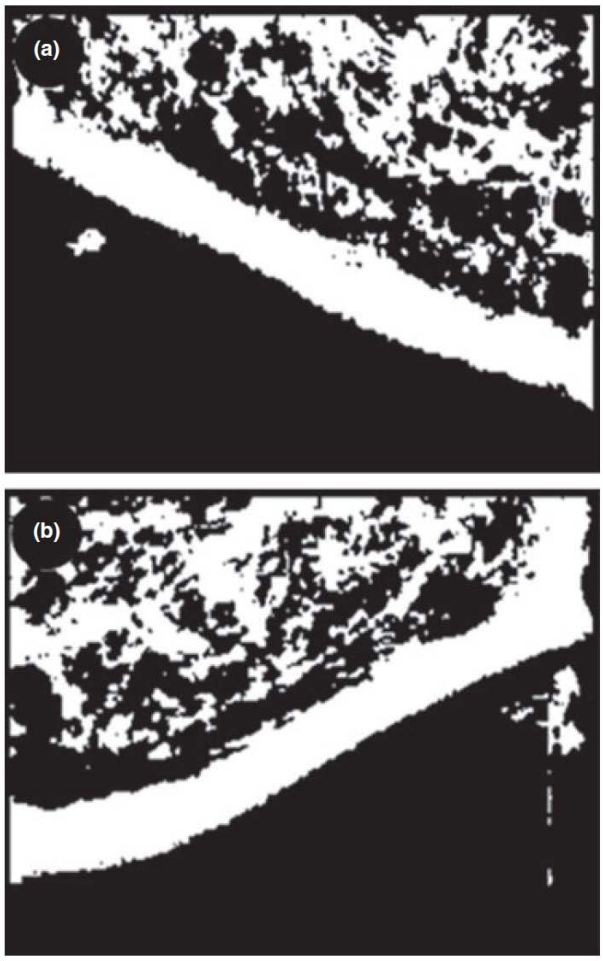
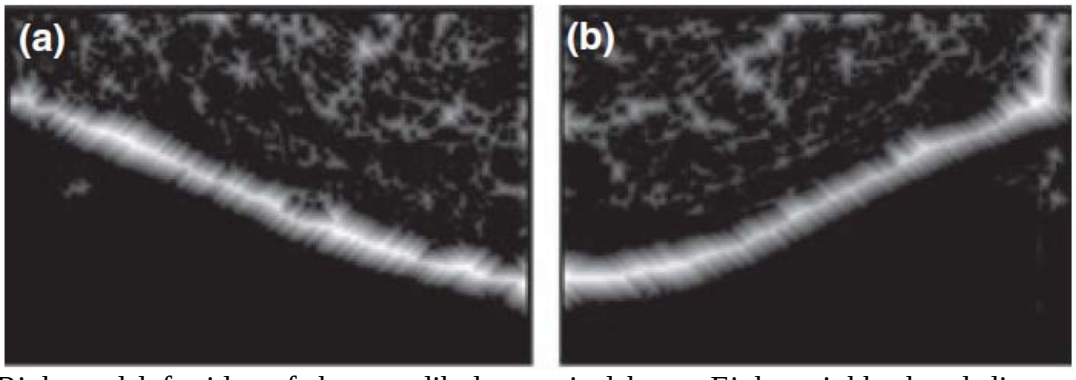


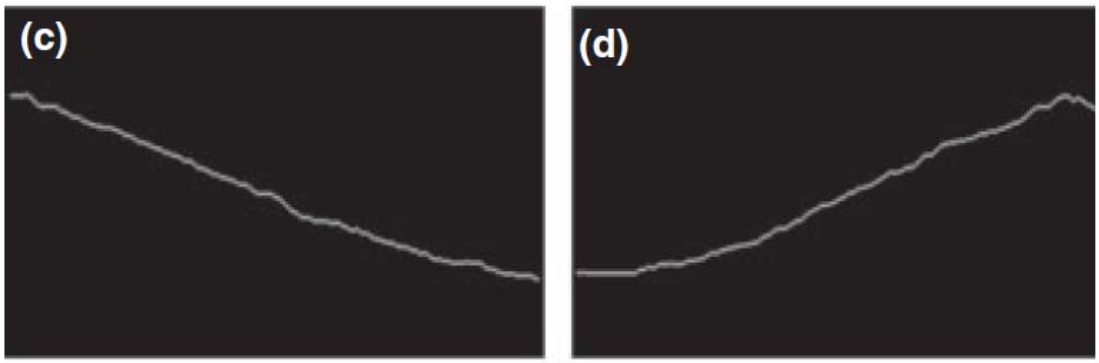
Figure 4. High-pass filter images of the right (a) and left (b) cortices.

Cortical boundary identification

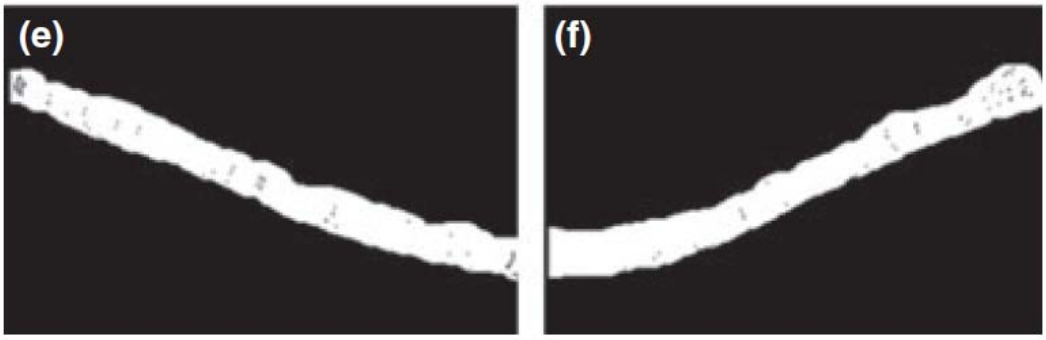
The cortical boundaries of the mandibles are unclear because of multiple connections with the trabecular bone.In this study, we used image-processing techniques based on the eight neighborhood distance functions (ENDF) to estimate the cortical width



Right and left sides of the mandibular cortical bone. Eight neighborhood distance functions (ENDF)

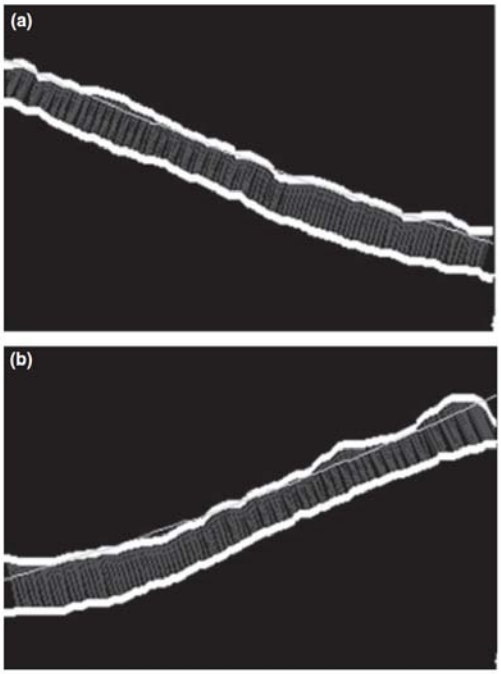


Dynamic programming



Disc insertion

Dental radiographs and osteoporosis



Smoothing and polynomial images of the right (a) and left(b) cortices

∗ In the present study, the results of the continuous measurement were summarized by the trimmed mean, whichexcludes 10% of the highest and lowest data. This mean value is considered to be an estimate of the cortical width

Statistical analyses

A. The mean of the MCW on both sides of the mandible was used in this study

B. Pearson's correlation coefficient was calculated to evaluate the correlations

between the mean MCW measured by this system and the BMD of the lumbar spine and femoral neck for 50 postmenopausal women.

C. A receiver-operating characteristic (ROC)curve analysis was used to determine the optimal cut-off thresholds of the MCW measured by our system for identifying patients with low-skeletal BMD (osteopenia and osteoporosis)

D.The risk –index range corresponding to a sensitivity of approximately 90% was chosen to determine the optimal cut off threshold

E. Two possible errors:

1.inter-and intra-examiner errors caused by manual setting of ROI and were small

2.positioning shift at capturing panoramic radiograph

Results

The optimal cut-off thresholds for the MCW were19.4 pixels for the lumbar spine and 19.6 pixels for the femoral neck in identifying women with low BMD for the development patients (Table 1)

Table 1. Number of patients with normal and low-skeletal bone mineral densities (BMD) of mandibular cortical width among the development and validation patients

Mandibular cortical width	Development patients		Validation patients	
	Normal	Low	Normal	Low
Lumbar spine BMD				
≤Cut-off threshold	10	9	6	14
>Cut-off threshold	30	1	29	1
Femoral neck BMD				
≤Cut-off threshold	12	9	9	12
>Cut-off threshold	27	2	28	1

Cut-off threshold for cortical width at lumbar spine: 19.4 pixels, and at femoral neck: 19.6 pixels.

Table 2. Diagnostic efficacy of automatic measurements of the mandibular cortical widths for identifying women with low-skeletal bone mineral densities (BMD) in the development and validation patients at the 95% confidence interval

Identification site	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)	Accuracy (%)	Likelihood ratio (+), %
Development patients						
Lumbar spine	90.0 (81.7–98.3)	75.0 (63.0–87.0)	47.4 (33.2–60.8)	96.8 (90.6–100)	78.0 (75.7–88.3)	3.6 (2.3–4.9)
Femoral neck	81.8 (70.1–91.8)	69.2 (56.2–81.8)	42.9 (29.3–56.7)	93.1 (85.9–100)	72.0 (59.6–84.5)	2.7 (1.5–4.6)
Validation patients						
Lumbar spine	93.3 (85.9–100)	82.9 (71.4–92.7)	70.0 (57.3–82.7)	96.7 (90.6–100)	86.0 (76.4–95.6)	5.4 (4.0–6.7)
Femoral neck	92.3 (84.5–99.5)	75.7 (63.0–87.0)	57.1 (43.3–70.7)	96.6 (90.6–100)	80.0 (68.9–91.9)	3.8 (2.5–5.1)

Table 3. Diagnostic efficacy of automatic measurements of the mandibular cortical widths for identifying women with combined skeletal bone mineral densities (BMD) among the development and validation patients at the 95% confidence interval

Patients	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)	Accuracy (%)	Likelihood ratio (+), %
Development	90.5 (83.8–95.1)	70.9 (61.4–79.0)	45.2 (35.6–54.8)	96.6 (92.0–100)	75.0 (65.7–82.4)	3.1 (2.3–4.1)
Validation	92.9 (86.2–96.5)	77.8 (68.9–84.9)	61.9 (52.2–70.9)	96.6 (92.0–100)	82.0 (73.3–88.3)	4.2 (3.3–5.2)

Table 4. Inter and intra-examiner reliability for manual setting of regions of interest for relative technical error measurement (TEM) results (Dahlberg's formula)

Measurement (cortical width)	TEM	*r*
First month		
Inter-examiner	0.052	0.998
Intra-examiner	0.050	0.999
Second month		
Inter-examiner	0.095	0.993
Intra-examiner	0.055	0.999

r, coefficient of reliability.

Discussion

A. The **sensitivity and specificity** of our CAD system were **high** among both the development and validation patients for identifying postmenopausal women with low-skeletal BMD

B. In our previous study, which used data from the same 100 patients, the sensitivity and specificity were approximately 88% and56–59% respectively., clearly indicate that the diagnostic efficacy of our new system is better than that of the old system,especially in terms of specificity

C. MCW below the mental foramen of the mandible has been widely used worldwide from the time investigators simultaneously reported it to be **the most appropriate site for determining MCW**, hyoid bone image sometimes overlaps the cortex

below the mental foramen on dental panoramic radiographs, which can result in measurement errors with CAD systems, continuous measurements of the MCW between the mental foramen and the angle of the mandible with our new CAD system could reduce such measurement errors

D. Osteoporosis Screening Tool (OST), to identify women with low-skeletal BMD or osteoporosis. The **sensitivity** of such decision rules in identifying postmenopausal women with osteoporosis ranged from **92% to 95%**, and the **specificity** ranged from **35% to 46%**

E. The sensitivity of our current CAD system was almost the same, but the specificity was much higher. The difference in these results is reasonable,because the CAD system directly assesses the bones on radiographs. The OST uses parameters, such as age and weight, which might change among the time of the measurement

F. The average time required for the measurements of the MCW was only 9 s

G. The use of digital dental panoramic radiography is expected to spread rapidly worldwide in the near future. It is also proven that our CAD system can also accurately utilize digital dental panoramic radiographs for identifying groups at high risk of osteoporosis

H. The Aichi Dental Association, Nagoya, Japan conducted a large clinical trial in which 95% of women aged 50 years and older who had osteopenia or osteoporosis

I. We compared the MCW measured by our CAD system with the digital dental panoramic radiographs taken, found some differences between the measurements in the average width and SD of the cortical bone, which were less than one and two pixels, this can be due to the positioning error or magnification effect

J. The use of our CAD system by general dental practitioners might allow them to identify many patients with low-skeletal BMD and refer these patients to medical professionals for further examination

K. In conclusion, the sensitivity and specificity of our new CAD system in identifying postmenopausal women with lowskeletal BMD were relatively higher than those obtainedin previous studies. Our new CAD system is a useful tool in screening for osteoporosis