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ORIGINAL ARTICLE

Application of telemedicine to assess mandibular cortical width on panoramic images of dental patients in the Lao People's Democratic Republic

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Abstract
Objectives Mandibular cortical width (MCW) reference standards for osteoporosis screening have not yet been established in Laos, where panoramic radiography has recently been introduced. The present study was designed to determine the average MCW in Laotian people using panoramic radiography via telemedicine.
Methods MCW was measured in 519 patients who underwent diagnostic panoramic radiography at a Laos university. Images were transferred to a Japanese university using a telemedicine system. MCW was measured with a computer-aided diagnostic system and was classified by gender, age, and thickness according to OSTEODENT reference standards.
Results The overall average MCW was 3.70–3.83 mm in men and 3.54 mm in females. The Mann–Whitney U test showed a statistically significant difference ($P = 0.\ 04$). MCW increased with age: 2.89 mm at age 0–19 years and 4.25 mm at >60 years. The rate by gender for ≤3 mm cortical thickness of MCW was 34.1 % in men and 48.6 % in females. The average MCW was 3.50 mm in the 20–44 year age group and 3.88 mm in the 45–70 year age group. The connection for teleconferencing and data transmission went smoothly.

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Conclusion This study used panoramic radiography to determine average MCW in Laotian people for the first time. MCW was thicker in males than in females and increased with age. Use of the telemedicine system will contribute to further developments in oral and maxillofacial radiology in Laos.

Keywords Mandibular cortical width · Osteoporosis · Laos · OSTEODENT · Telemedicine system

Introduction

Osteoporosis is a recognized major public health problem in both developed and developing countries [1, 2]. Dual-energy X-ray absorptiometry (DXA) is the most reliable way to determine bone mineral density (BMD) for the diagnosis of osteoporosis [3]. In recent years, radiographic mandibular cortical width (MCW), as detected on dental panoramic radiographs, has been effectively used for the diagnosis of osteoporosis [4, 5]. Decreased MCW has been suggested as a predictor for calcified internal carotid arteries and heart disease [6]. Osteoporosis risk can be evaluated based on MCW [7–9], and the use of panoramic radiography to measure MCW as a tool for osteoporosis diagnosis has been internationally recognized [3–5]. However, these methods are not widely applied in developing countries because of the lack of expertise and equipment.

The Lao People's Democratic Republic (Laos) is a landlocked country located on the Indochina Peninsula in Southeast Asia. Laos has maintained an economic growth rate of slightly below 8 % in recent years. Economic development in Laos has lagged behind neighboring countries, and public health care has suffered as a consequence. The incidence of low birth weight (LBW) babies in Laos stands at 11 %, and neonatal mortality is higher than in the surrounding countries [10]. Birth weight is thought to be related to bone health in childhood [11]. LBW babies tend to have low bone mineral content and develop low BMD and osteoporosis in adulthood, and the bone health of mothers of LBW babies may also be affected. Therefore, it is important to survey BMD and osteoporosis disease in Laotian people; however, DXA has not yet been introduced in Laos.

In 2000, the Nihon University School of Dentistry began collaborating with the Faculty of Dentistry at the Laos University of Health Sciences and provided a single panoramic radiography unit for diagnostic use in dentistry. In 2013, a telemedicine system was set up at the university because there were no specialists in oral and maxillofacial radiology at the Laos University of Health Sciences.

MCW can be measured using panoramic radiography, but no such system had been established in Laos. Therefore, the aim of this study was to calculate average MCW, average MCW according to gender, a rate by gender for MCW classification based on OSTEODENT reference standards for osteoporosis, and an MCW average for perimenopausal females using panoramic radiography in Laotian people. The average values of MCW in Laotians may be useful as a screening tool for low bone density in the Laotian population. A further aim of the study was to evaluate the efficacy of the telemedicine system.

Materials and methods

Subjects

The study population consisted of a total of 519 Laotian patients (age 7–79 years; mean 38.21 years; 296 males and 223 females) who underwent panoramic radiography at the Department of Dental Radiology, Faculty of Dentistry, Laos University of Health Sciences, for the diagnosis of caries, third molar pericoronitis, and periodontitis. Patients diagnosed with osteomyelitis and tumors were excluded (Tables 1, 2).

Panoramic radiographs were taken with a Veraviewepocs CCD digital panoramic imaging device (J. Morita Corporation, Kyoto, Japan) with the exposure parameter controlled in the automatic mode.

Verbal informed consent was obtained from all patients. This study was approved by the Ethics Committee in the Faculty of Dentistry, Laos University of Health Sciences (consent number 010/14).

Table 1 Gender and age

Gender	Number	Mean age	Range	SD
M	296	40.4	7–86	16.6
F	223	35.1	10–83	15.1
Total	519	38.1	7–86	16.2

Table 2 Distribution of age and gender

Age bracket	Number of measurements (male/female)
0–19	48 (23/25)
20–29	156 (72/84)
30–39	91 (53/38)
40–49	84 (54/30)
50–59	90 (61/29)
60+	50 (33/17)
Total	519 (296/223)

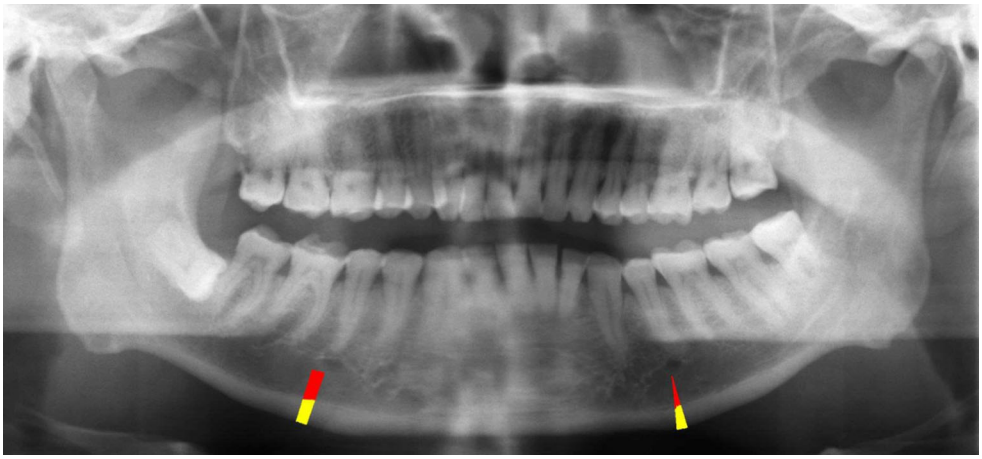

Fig. 1 Panoramic radiograph of a 55-year-old man. MCW (yellow) was 4.5 mm on the right side and 4.2 mm on the left side. *Red line,* the line used to measure MCW is perpendicular to the inferior border of the mandible at the mental foramen and is set automatically. *Yellow line,* the software automatically selects MCW from the *red line*

Telemedicine system

Images were exported as DICOM image stacks and transferred to the Department of Oral and Maxillofacial Radiology, Nihon University School of Dentistry, by a telemedicine system (ViewSend, Tokyo, Japan) with functions for image viewing, image transfer, DICOM storage, real-time video conferencing, and application sharing.

Image analysis and measurements

MCW was measured using a computer-aided diagnostic system (CAD; Fig. 1) [12, 13], which is able to detect MCW automatically using a modified Canny edge detector. The lower and posterior mandibular edges were evaluated under multiple conditions, and the mandibular outline was estimated in a dynamic contour model. A gray-value profile was generated from a straight line perpendicular to the line extending from the mental foramen to the mandibular contour; the cortical bone thickness was measured from the resulting profile data. Data were analyzed according to the gender and age of the patients, and the MCW threshold for osteoporosis was based on reference values obtained from the OSTEODENT project ($\leq$3 and >3 mm) [7–9, 13]. Finally, MCW was compared between patients in the 20–44 and 45–70 year age groups.

Statistical analysis

Study groups were compared using the Mann–Whitney *U* test, and statistical analyses were conducted using SPSS version 21 (IBM Corporation, Armonk, NY, USA).

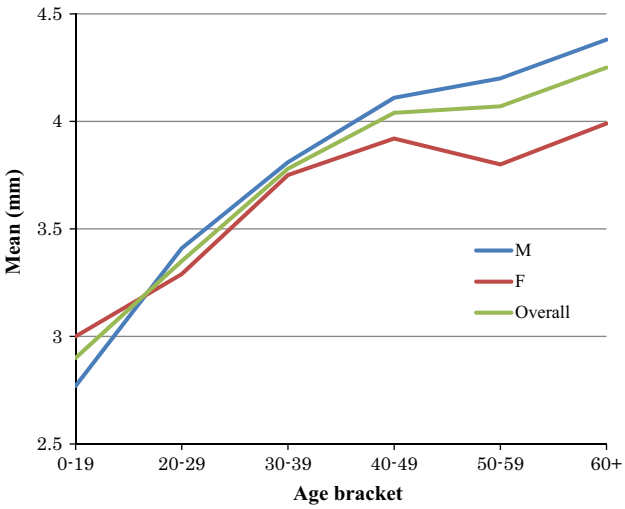

Fig. 2 MCW distribution according to patients' age bracket and gender

Results

1. Age and gender
   Average MCW increased with age as follows: 2.90 ± 0.81 mm (range 1.5–5.8) at age 0–19 years; 3.35 ± 0.82 mm (range 1.5–5.8) at 20–29 years; 3.78 ± 0.99 mm (range 1.9–7.4) at 30–39 years; 4.04 ± 1.18 mm (range 1.8–7.7) at 40–49 years; 4.07 ± 0.98 mm (range 2.6–7.4) at 50–59 years; and 4.25 ± 1.05 mm (range 1.8–6.8) at > 60 years (Fig. 2). There was no significant difference among groups according to the Tukey HSD multiple comparison test.

Table 3 Classification of MCW by gender

Gender	Number	Range (mm)	Mean	SD
M	296	1.7–7.65	3.83*	1.08
F	223	1.45–7.35	3.54*	0.98
Total	519	1.45–7.65	3.7	1

* Mann–Whitney *U* test showed a statistically significant difference ($P = 0.04$)

The overall average MCW was 3.70 ± 1.00 mm (range 1.45–7.65). The average MCW in males was 3.83 ± 1.08 mm (range 1.7–7.65) and in females, 3.54 ± 0.98 mm (range 1.45–7.35), indicating that the cortical bone was thicker in males than in females (Table 3; Fig. 2).

2. Rate by gender for MCW classification for osteoporosis based on OSTEODENT reference standards
   The following data were calculated on the basis of the average MCW according to age group. The rate by gender for ≤ 3 mm MCW was 34.1 % in males and 48.6 % in females. The female average MCW was 3.50 mm in the 20–44 year age group and 3.88 mm in the 45–70 year age group.
3. Telemedicine system
   All panoramic radiographs were transferred from Laos University of Health Sciences to Nihon University School of Dentistry. We also communicated seven times via teleconference. The connection for teleconferencing and the transmission of data went smoothly.

Discussion

As the world's population ages, osteoporosis has emerged as a serious public concern in the developed countries. Decreased MCW and the classification of mandibular cortical shape serve as indicators of osteoporosis risks, and the validity of these associations has been internationally recognized [7–9, 14]. Measures to combat osteoporosis are urgently required in both developed and developing countries, but at present, there are no reports investigating the condition in Laos. The results of the present study have the potential to not only affect international cooperation among developing countries, but also affect worldwide public health strategies focused on diagnostic MCW measurement using dental radiography. The CAD system has a low failure rate in defining the mandibular contour and high accuracy for measuring cortical bone thickness (sensitivity 92.6 %; specificity 100 %) [13].

The telemedicine system comprises both teleradiology and teleconference functions, enabling radiographs to be shared and lesions to be labeled in real time. OPG cases can also be discussed among colleagues through real-time teleconference functions. These features demonstrate how a telemedicine system can contribute to the oral and maxillofacial radiology field in Laos. The MCW data examined in the present study originated from an OPG database of Laotian people constructed using the telemedicine system.

Table 4 Comparison of MCW between female patients aged 20–44 and 45–70 years

Age (years)	Number	Range (mm)	Mean	SD
45–70	49	1.8–6.8	3.88	1.13
20–44	145	1.5–7.4	3.50	0.95

In our findings, the overall average MCW was 3.7 mm in Laotian people, and the mandibular cortex was thicker in males (3.83 mm) than in females (3.54 mm). To date, there have been no studies establishing a normal MCW range in Laotian people. OSTEODENT studies and studies by Taguchi et al. revealed that the mandibular cortical bone was generally thicker in males than in females, suggesting an overall gender-based difference [7–9, 15–19]. Furthermore, in females, mandibular changes ceased after the age of 29 years. In our comparison between the 20–44 and 45–70 year age groups, gender differences were observed only in the 45–70 year age group. Females in the 45–70 age group are generally postmenopausal, and the decreased MCW thickness is believed to be caused by decreased bone density. However, MCW increased in the 45–70 year age group in our study (Table 4), possibly because the sample size of this group was smaller than that of the 20–44 year age group. Jafaripozve et al. investigated postmenopausal Iran women using a sample of 52 cases—slightly more than our sample [20]. According to the WHO, the average life span of Laotian people is 63 years. They have a short life expectancy compared with people in advanced nations, and they contract various diseases after reaching middle age. Accordingly, fewer people in this age group attend the dental clinic, so the sample size was smaller. Therefore, to validate our results, collecting more samples for the 45–70 year age group would be desirable.

In the OSTEODENT project, the diagnostic MCW reference value for osteoporosis in Europeans was 3 mm [6–8]. Based on this standard, our results diagnosed osteoporosis in 34.1 % of males and 48.6 % of females. Taken together, these findings show that MCW increased with age (Fig. 2). In addition, the overall average MCW was lower than that observed in Europeans. This discrepancy may reflect differences in nutrition and climate.

Taguchi and Nakamoto et al. [16, 18] investigated the relationship between BMD and MCW by panoramic radiography and DXA. BMD could not be measured in this

study, because DXA has not yet been introduced in Laos. If a comparison between BMD and MCW could be measured by DXA, consideration could be given to the relationship between MCW and BMD. Regardless of the underlying mechanism, studies with accurate diagnostic criteria tailored to Laotian people are required to evaluate cortical bone roughness in panoramic radiographs comparing osteoporosis data obtained using DXA.

In conclusion, this study is the first to measure average MCW on panoramic radiographs of Laotian people. Our findings suggest that mandibular cortical bone is thicker in males than in females, and its thickness increases with age in Laotian people. Additionally, the average MCW is lower than that observed in the OSTEODENT project conducted in Europe. There are plans to measure more cases in Laotian people to improve the accuracy of the MCW average. Through a study based on this research, the field of oral and maxillofacial radiology in developing countries could be supported by oral and maxillofacial radiology practitioners in Japan.

It is hoped that the field of telemedicine can be further developed in Laos in the future. This will require improvement in practitioners' basic radiographic skills. This could be achieved through lectures using, for example, image traces with the telemedicine system. Future studies evaluating DXA in osteoporosis cases and characterizing the cortical roughness of bone in panoramic radiographs will be conducted using a telemedicine system.

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Conflict of interest Johnny Sisounthone, Ken-ichiro Ejima, Ichiro Nakajima, Kazuya Honda, Shigeharu Hosono, Souksavanh Vongsa, Kunihito Matsumoto, Fumiyuki Kuwata, Hirofumi Aboshi, Bounnhong Sidaphone, Akao Lyvongsa, Sengphouvanh Ngonephady, Aloungnadeth Sitthiphanh, Kichibe Otsuka, Akitoshi Katsumata, and Hiroshi Fujita declare that they have no conflict of interest.

Human rights statements and informed consent All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1964 and later versions. Informed consent was obtained from all patients for being included in the study. Additional informed consent was obtained from all patients for which identifying information is included in this article.

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