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Value of MDCT data of mandibular condyle cancellous bone to osteoporosis screening

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ABSTRACT

The purpose of this study was the application of age- and gender-related differences in mandibular condyle computed tomography (CT) values on multidetector-row CT (MDCT) imaging to osteoporosis screening.

The mandibular CT images of 321 patients were analyzed retrospectively. The ovoid-shaped region of interest contouring was manually performed on both sides of the mandibular condyle on axial images to determine the mean CT value. The Klemetti index (KI) for each patient was categorized into C1, C2, and C3 based on coronal CT images.

The mean CT values of the mandibular condyle were decreased with age in both males and females. The mean CT values of the mandibular condyle also decreased as the KI progressed.

Our result suggested that the mean CT values of the mandibular condyle may be a novel predictor for screening osteoporosis on MDCT images.

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KEYWORDS

Osteoporosis; MDCT; CT value; mandibular condyle; klemetti index

Introduction

Osteoporosis is a disorder of the skeletal system characterized by a weakened bone tissue, which increases fracture risk [1,2]; it is an emerging medical and socioeconomic threat [1]. A diagnosis of osteoporosis is often based on measurements of bone mineral density (BMD), such as by dual X-ray absorptiometry (DXA) [1,2]. DXA is a well-established method for the diagnosis of osteoporosis and is the recognized diagnostic standard by the World Health Organization (WHO) [2]; however, DXA is a high-cost examination [2]. Conversely, dental panoramic radiography is known to be a low-cost examination [1]. The mandibular cortical width and porosity, known as Klemetti index (KI), seen on dental panoramic radiographs are useful for assessing an individual's risk of osteoporosis [3–7]. Gomes et al. [2] reported that the mandibular index on cone beam computed tomography (CBCT) images can lead to the identification of patients with osteoporosis. Kawashima et al. [8] reported that the body of the mandibular cancellous bone and the mandibular condyle cancellous bone are affected by osteoporosis. We hypothesized that the computed tomography (CT) value of the mandibular condyle cancellous bone may be a novel predictor for screening osteoporosis. This study, therefore, aimed to determine the application of age- and sex-related differences in mandibular condyle CT values on multidetector-row CT (MDCT) imaging to osteoporosis screening.

Materials and Methods

This retrospective study was approved by Ethics Committee on Epidemiological Studies, Kagoshima University (Epi-200282 ver.1).

Patients

Of the 701 patients who underwent CT imaging for the evaluation of mandible, maxilla, and maxillary sinus diseases and trauma of the mandible and/or maxilla as outpatients in Kagoshima University hospital (Kagoshima, Japan), between October 2019

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and May 2020, the mandibular CT images of 321 patients were analyzed retrospectively. The exclusion criteria were cyst and tumor with presentation in the mandibular condyle; mandibular condyle unobservable on MDCT images; osteoarthritis or osteosclerotic changes in the mandibular condyle; metal artifacts precluding accurate imaging of the mandibular condyle by MDCT.

Imaging protocol

CT examinations were performed with an IQon Spectral CT scanner (Philips Healthcare, Amsterdam, the Netherlands). Images of 1.25-mm thickness were reconstructed using soft tissue and bone reconstruction kernels according to our institutional clinical protocol. Axial 1-mm images and coronal 3-mm images with bone kernel reconstruction with 0.675 mm × 0.675-mm in-plane resolution were used for this analysis. The imaging protocol at our hospital is as follows: tube voltage, 120 kV; tube current, auto mA; field of view, 240 × 240 mm; helical pitch, 0.7; rotation time, 0.5 seconds; Dose Right Index, 21; mean mAs, 116; mean CTDIvol value, 7.34 mGy; mean DLP value, 202.2 mGycm. In this study, the *k* factor used is the head-neck factor 0.0031 mSv/ (mGy cm). The reference for the used conversion factor is International Commission on Radiological Protection publication 102 [8].

Image analysis

The ovoid-shaped region of interest (ROI) contouring was manually performed on both sides of the mandibular condyle on axial images (Fig. 1a). The ROI was placed in the condyle including only the cancellous bone and excluding the cortical bone (Fig. 1b). The mean CT value of each ROI was recorded in Microsoft Excel (Microsoft Corp, Redmond, WA). This contouring was performed using a picture archiving and communication system (Synapse viewer Fuji Medical system, Tokyo, Japan). These contours were performed on three consecutive axial images.

The mandibular cortical shape was obtained by observing the right side of the mandible distally from the mental foramen on coronal MDCT images [2]. We categorized these into one of the three groups according to the method of Gomes et al. [2] and Klemetti et al. [6,7] as follows (KI): the appearance of the inferior cortex of the mandible was classified as C1, the endosteal margin of the cortex was even and sharp; C2, the endosteal margin presented semilunar defects (lacunar resorption) or appeared to form endosteal cortical residues; or C3, the cortical layer formed heavy endosteal cortical residues and was clearly porous [1,6,7]. The KI of the mandible was recorded for each image in Microsoft Excel (Microsoft Corp, Redmond, WA).

Reliability

The KI on MDCT images was assessed by three oral and maxillofacial radiologists with 10, 25, and 30 years of experience. Intra-observer agreements were evaluated by the intraclass correlation coefficient and the interobserver reliability as indicated by Fleiss's Kappa was calculated.

Statistical analyses

The assessment of significance for age-related changes of the mean CT value of the mandibular

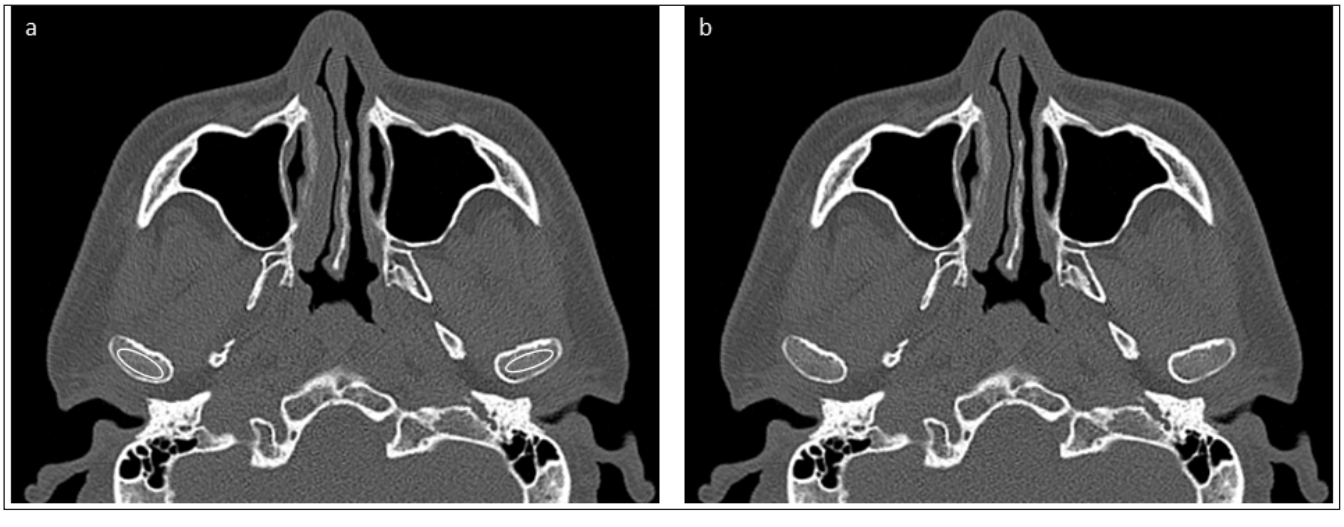


Figure 1. The ovoid-shaped ROI of both sides of the mandibular condyle on a representative axial image (a) and the axial image without ROI (b).

condyle was evaluated by Spearman's rank correlation coefficient.

The differences in mean CT values of the mandibular condyle in each age group between males and females were statistically evaluated using the Mann–Whitney *U* test. The mean CT values of the mandibular condyle were subclassified by KI in both males and females and accordingly were statistically evaluated using the Steel–Dwass test. The differences in the mean CT values between males and females subclassified by KI were also statistically evaluated using the Mann–Whitney *U* test. *p* values less than 0.05 were considered statistically significant. All statistical analyses were carried out using SPSS version 16.0 (SPSS Inc., Chicago, IL) for Windows.

Results

The intraobserver agreements were 0.81, 0.82, and 0.85. The interobserver agreement was 0.828.

Table 1. The number of patients in each age group subclassified by gender.

Age group	20's	30's	40's	50's	60's	70's	80's	90's
Male	4	8	23	20	47	51	24	3
Female	8	10	19	20	22	28	32	2

Patients characteristics

The study cohort was composed of 180 males and 141 females; mean age was 64.1 years (SD, 16.6, age range, 20–97 years). The number of patients in each age group subclassified by gender is shown in Table 1.

Age- and gender-related differences of mean CT value of the mandibular condyle

In males, the mean CT values of the mandibular condyle on both left (Fig. 2a) and right (Fig. 2b) decreased with age. The correlation coefficient of mean CT value and age in the left mandibular condyle was −0.44 ($p < 0.01$) and that in the right mandibular condyle was −0.45 ($p < 0.01$).

In females, the mean CT values of the mandibular condyle on both the left (Fig. 2c) and right (Fig. 2d) decreased with age. The correlation coefficient of mean CT value and age in the left mandibular condyle was −0.59 ($p < 0.01$) and that in the right mandibular condyle was −0.58 ($p < 0.01$).

Age-related differences in the CT values in each age group

The CT values of the mandibular condyle in each age group in males are shown in Figure 3 and those in females are shown in Figure 4.

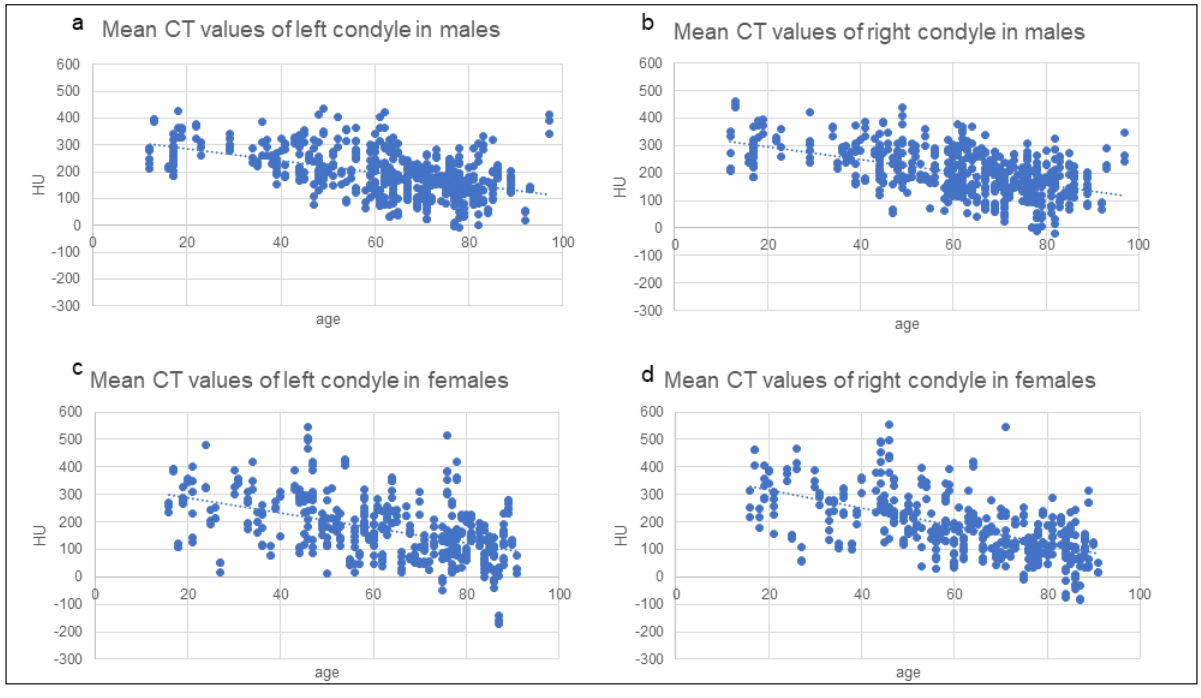


Figure 2. Age-related changes of the mean CT values of the mandibular condyles in males and females. The mean CT values of the mandibular condyle on both the left (a) and right (b) decrease with age. The correlation coefficient of the right mandibular condyle is −0.44 ($p < 0.01$) and that of the left mandibular condyle is −0.45 ($p < 0.01$). The mean CT values of the mandibular condyle on both the left (c) and right (d) decrease with age. The correlation coefficient of the right mandibular condyle is −0.59 ($p < 0.01$) and that of the left mandibular condyle is −0.58 ($p < 0.01$).

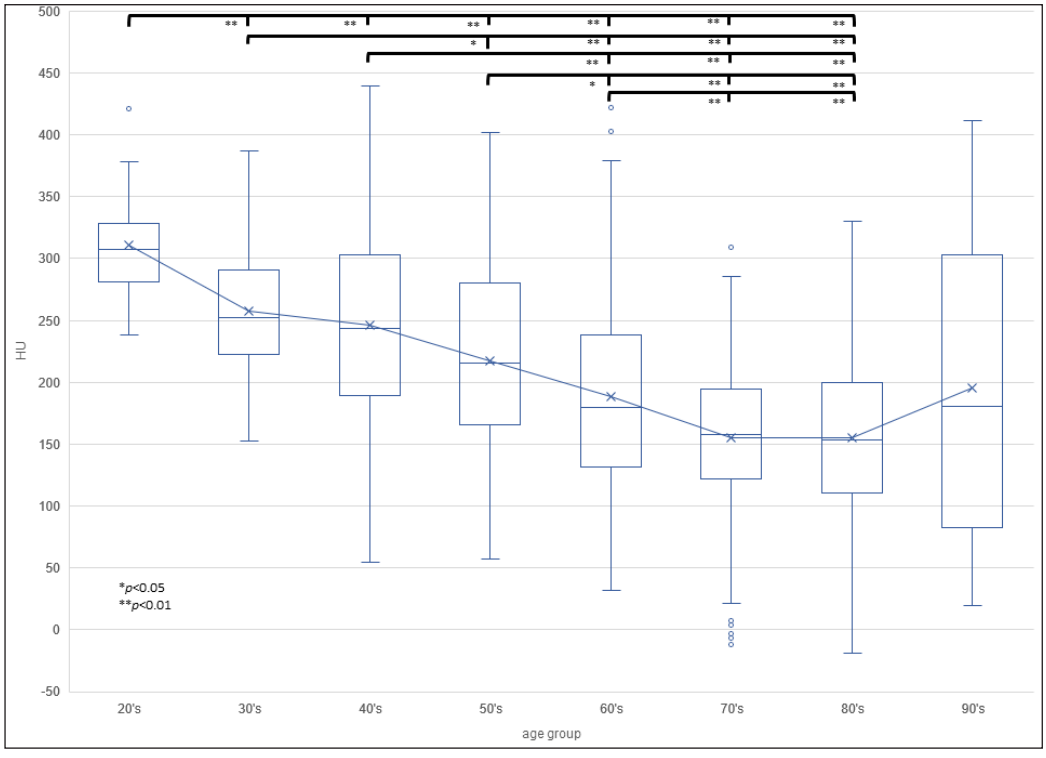


Figure 3. The CT values of the mandibular condyle in each age group in males. The mean CT values of the mandibular condyle decrease with age. The mean CT values of the mandibular condyle in younger groups are higher than those in older age groups.

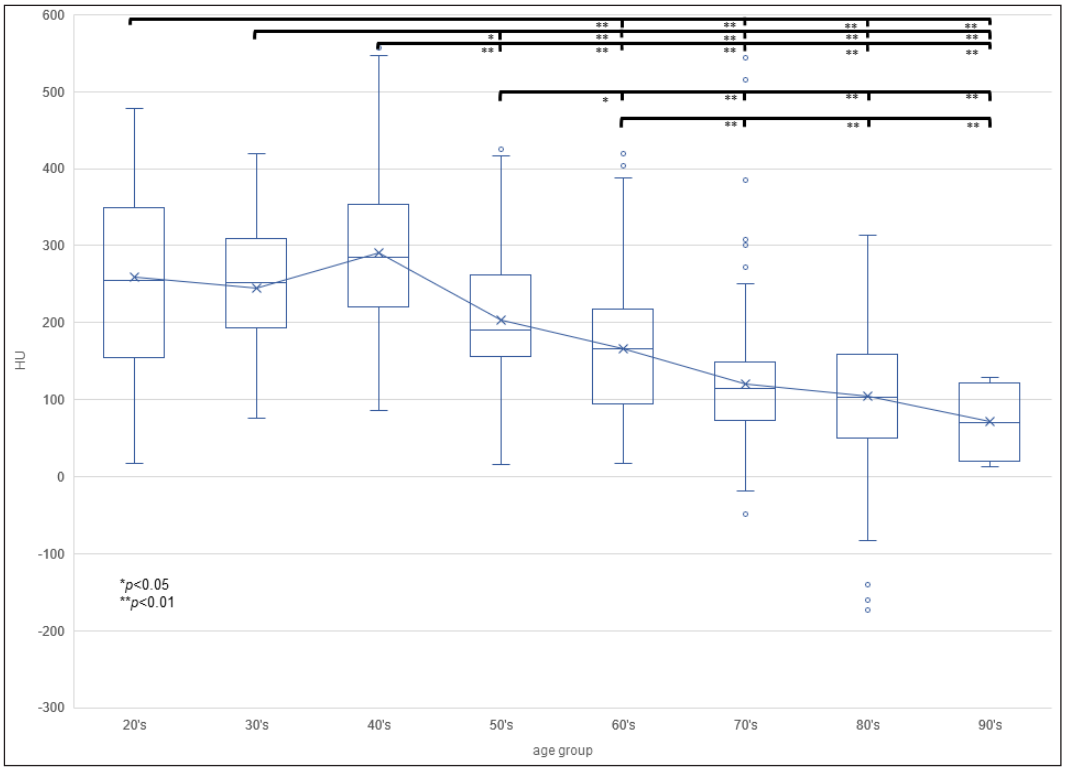


Figure 4. The CT values of the mandibular condyle in each age group in females. The mean CT values of the mandibular condyle decrease with age. The mean CT values of the mandibular condyle in younger groups are higher than those in older age groups.

Comparison of the gender-related differences of the mean CT values in each age group

The statistically significant differences in the mean CT values of the mandibular condyle between males and females for each age group are shown in Figure 5.

Comparison of the mean CT values between males and females subclassified by KI

The results of the mean CT values of the mandibular condyle in males subclassified by KI are as follows: C1 mean CT value 230 HU; SD 77, C2 mean CT value 174 HU; SD 72, C3 mean CT value 161 HU; SD 80. The results of the mean CT values of the mandibular condyle in females subclassified by KI are as follows: C1 mean CT value 252 HU; SD 113; C2 mean CT value 162 HU, SD 83; C3 mean CT value 114 HU, SD 90.

In males, statistically significant differences were observed in the mean CT values of the mandibular condyle between C1 and C2 and between C1 and C3 ($p < 0.01$, Fig. 6). In females, statistically significant differences were observed in the mean CT values of the mandibular condyle between C1, C2, and C3 ($p < 0.01$). Statistically significant differences were also observed in the mean CT values of the mandibular condyle between males and females in between C1, C2, and C3 ($p < 0.01$, Fig. 6).

Discussion

Our study revealed that the mean CT values of the mandibular condyle decreased with age in both males and females.

Marar et al. [9] reported that CBCT images of the mandible can be useful for early detection of osteoporosis. However, they used CBCT images, which have inaccurate HU compared with MDCT [10]. Yamada et al. [11] reported that the BMD of the mandibular condyle in pre-menopausal women did not show a significant decrease with age, though a significant decrease with age was observed in post-menopausal women. The result of our study showed that the mean CT values of the mandibular condyle decrease with age in both males and females on both sides of the mandible. The correlation coefficient showed a moderate negative correlation between age and mean CT values of the mandibular condyle in both males and females. However, values

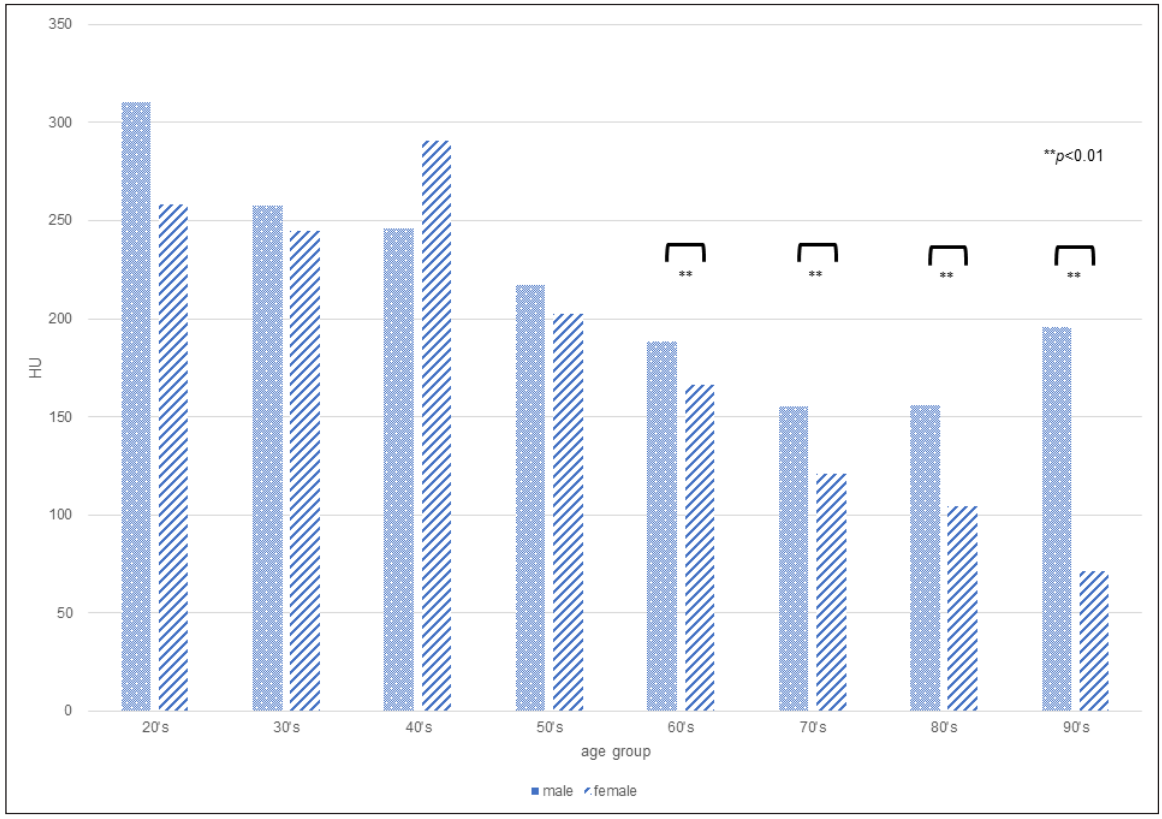


Figure 5. Comparison of the gender differences of the mean CT values of the mandibular condyle in each age group. The mean CT values of the mandibular condyle in younger groups are higher than those in older age groups.

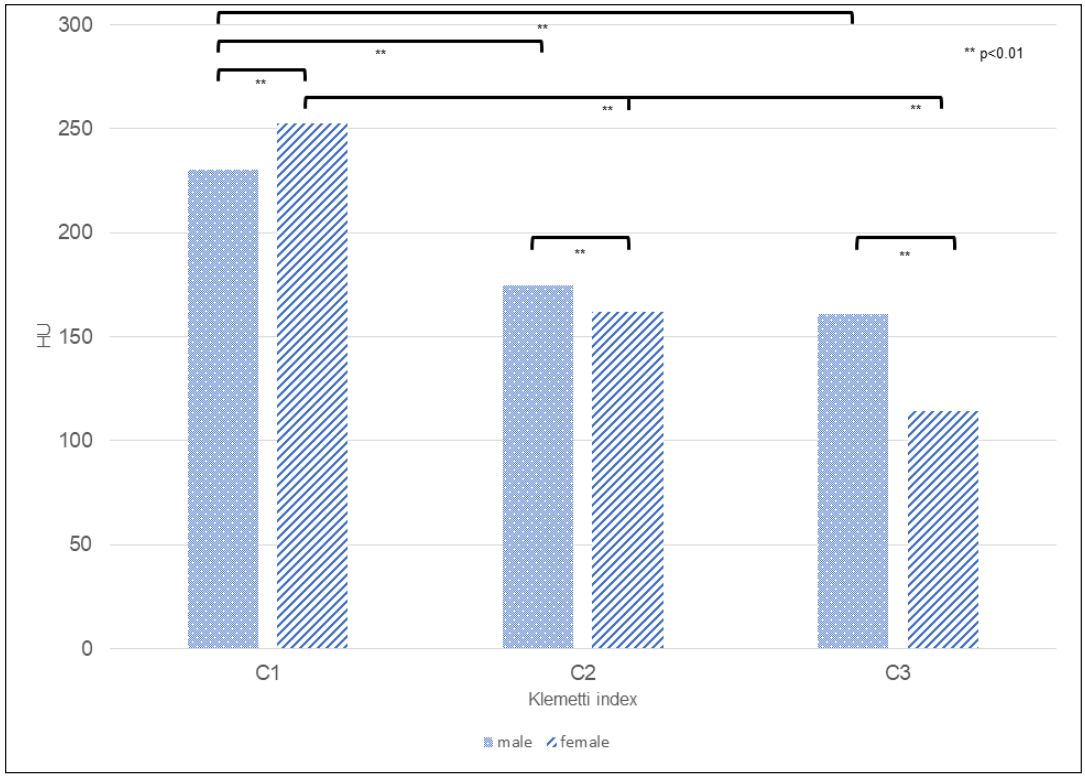


Figure 6. Comparison of the mean CT values between males and females subclassified by KI. In males, statistically significant differences are observed in the mean CT values of the mandibular condyle between C1 and C2 and C1 and C3 ($p < 0.01$). In females, statistically significant differences are observed in the mean CT values of the mandibular condyle between C1, C2, and C3. ($p < 0.01$). Statistically significant differences are also observed in the mean CT values of the mandibular condyle between males and females for C1, C2, and C3 ($p < 0.01$).

from females showed a greater negative correlation coefficient than those from males for both sides of the condyle. This is consistent with the inclusion of postmenopausal female patients in this study, therefore decreasing the mean CT values of the mandibular condyle with age in females to a greater extent than in males.

In both males and females, the mean CT values of the mandibular condyle in each age group were reported. Comparison between age groups showed statistically significant differences in both males and females. Both males and females showed the mean CT values of the mandibular condyle in younger age groups were greater than those of older age groups. We believe that osteoporotic changes occur in mandible with age [12]. In addition, the mandibular condyles are known to contain red bone marrow in individuals aged in their 30's [13]. The mandibular condyle bone marrow changes from red to yellow bone marrow with age [13]. The mean CT values of the mandibular condyle were higher in young age groups than in old age groups, suggesting that the red bone marrow exists in the mandibular condyle of younger individuals or that osteoporotic changes have not yet started in the mandibular condyle or a combination of both factors. Comparison of gender differences of the mean CT values of the mandibular condyle in each age group showed that the values in females were lower than those in males in their 60's, 70's, 80's, and 90's. This suggests that decreasing BMD in the mandibular condyle is likely due to osteoporotic changes that occur after the age of 60 in females.

This was the first study that revealed the mean CT values of the mandibular condyle bone marrow subclassified by KI in both males and females. Assessment of the KI may vary depending on the shape of the mandible. However, the mandibular condyle is a solid and large region. Therefore, the measurement results of the mean CT value would be stable as compared to the KI assessment. The mean CT values of the mandibular condyle decrease as the KI score progresses. According to our results, a mean CT value of the mandibular condyle lower than 174 HU in males and lower than 162 HU in females may fall into C2 or C3, therefore it is considered osteoporosis.

There are some limitations in this study. First, the number of patients in each age group is different. Therefore, we believe that the mean CT values for men in their 80's and 90's are higher than those for men in their 70's, and the mean CT values for women only in their 40's are higher than those for women in their 20's. And other results may be affected. Second, we have not used DXA to diagnose the osteoporosis. Further research that incorporates the use of DXA should be considered. Third, we have not collected the data on osteoporosis treatment intervention status. This may be the focus of the future study.

In conclusion, our data revealed the mean CT values of the mandibular condyle in each age group. The mean CT values of the mandibular condyle were shown to decrease with age in both males and females. Our results suggested that the CT values of the mandibular condyle may be a novel predictor for screening osteoporosis on MDCT images.

Conflict of interest

There is no potential conflict of interest.

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