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Original article

# Analysis of correlation between height of residual ridge and bone density of residual ridge crest at edentulous mandible using computed tomography

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ABSTRACT

*Purpose:* The aim of this study was to investigate the correlation between bone density of the edentulous mandibular ridge crest and residual bone height in edentulous subjects using multidetector computed tomography (MDCT) images.

*Methods:* A total of 194 bilateral MDCT images from 97 individuals with an edentulous mandible were selected for analysis. The residual ridge ratio (RRR), the CT values at the residual ridge crest, and the CT values at the lowest point of the mandible measured from MDCT images at molar region. RRR was classified into the three groups (Group 1: >2.0, Group 2: 1.5-2.0, Group 3: <1.5). Bone density at the residual ridge crest was evaluated by calculating the ratio of the CT value at the lowest point of the mandible and the CT value of the residual ridge crest ("ratio of CT values"). The relationship between the height of the residual ridge and the bone density of the residual ridge crest was evaluated by ratio of CT values.

*Results:* Median ratio of CT values was 0.62 in Group 1, 0.70 in Group 2, and 0.84 in Group 3, indicating significant differences between all 3 groups ($p < 0.05$). The correlation coefficient for RRR and residual ridge crest bone density was −0.54 in males and −0.55 in females, implying a moderate correlation for both males and females.

*Conclusions:* The present results suggest a negative correlation between residual bone height and the bone density of the edentulous mandibular ridge crest.

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## 1. Introduction

In complete denture wearers, the residual ridges bear the occlusal forces applied to the denture. As the range of occlusal forces borne by the mandible is less than that of the maxilla, the load per unit area is greater. After the lower teeth are lost, the shape of the residual ridge changes due to various factors [1–5]. Atwood reported that bone resorption of the maxillary residual ridge after tooth loss continued for approximately 3 years before ceasing almost completely, and resorption of the mandibular residual ridge reportedly continues for more than 3 years after tooth loss [1]. On the other hand, although some studies have identified dentures as a cause of this mandibular residual ridge resorption [1,6,7], the mechanism of resorption of the mandibular residual ridge is not fully understood.

In computed tomography (CT) studies, Ozan et al. compared the levels of mandibular residual ridge resorption in removable partial denture (RPD) wearers and non-wearers using cone-beam computed tomography (CBCT), and found that RPD wearers had greater bone resorption than their non-wearer counterparts [6]. Several studies have also investigated mandibular bone density based on CT images [8–11]. For instance, a study by Matsuura et al. using single-slice CT images to assess cortical and trabecular bone quantities at the base of the mandibular molar region found that cortical bone tended to decrease with age in females [8]. Bassi et al. used multislice CT (multidetector CT; MDCT) to examine bone density in human dentate and edentulous mandibles based on horizontal sections [9]. Naitoh et al. used MDCT to measure the CT values of cortical bone at the inferior border of the mandible, and their findings suggested that these values may be applicable in the evaluation of general bone condition [10]. However, no studies have addressed cortical bone density in the part of the mandibular residual ridge crest corresponding to the molar region using MDCT. The purpose of this study is to investigate the cortical bone of the mandibular residual ridge crest corresponding to the region would help to shed light on the mechanism involved in mandibular residual ridge resorption and on the conservation of the residual ridge. The present study applied CT values obtained from MDCT images of participants with an edentulous mandible, and investigated cortical bone density in the residual ridge crest corresponding to the molar region. We also examined the relationship between the bone density of cortical bone tissue of the mandibular alveolar ridge crest and residual ridge height corresponding to the molar region.

## 2. Materials and methods

### 2.1. Analyzed CT images

A total of 206 bilateral MDCT images from 103 individuals with an edentulous mandible (49 males and 54 females; mean age, 76.2 years; range, 65–93 years) who underwent a MDCT scan at Nihon University School of Dentistry at Matsudo Dental Hospital from April 2006 to April 2014 were initially selected for retrospective analysis. MDCT images were obtained using an Aquilion 64 MDCT unit (Toshiba Medical Systems Corporation, Otawara, Japan) with a tube voltage of 120kV, tube current of 100mA, and slice thickness of 0.3mm. Exclusion criteria were history of jaw bone trauma in the stomatognathic region, significant asymmetry due to jaw deformity, and CT images in which the mandibular canal reached the superior border of the mandible due to significant bone resorption. Images that were clearly misaligned were also excluded from analysis. The final analysis set consisted of 194 bilateral CT images obtained from 97 individuals consisting of 47 males (75.2±6.2years) and 50 females (76.7 ±7.1years). The Institutional Ethics Committee approved the study (EC13-017), and the guidelines set out by the Declaration of Helsinki were followed.

### 2.2. Image analysis

MDCT images were analyzed using Ziostation (Ziosoft Inc., Tokyo, Japan). CT values were measured at the residual ridge crest and the lowest point of the mandible, corresponding to the first molar 10mm distal to the bilateral mental foramina (Fig. 1). The residual ridge crest and the lowest point of the mandible were determined from the MDCT images by five prosthodontists. Region of interest (ROI) was set 1mm$^2$ at both the residual ridge crest and the lowest point of the mandible determined from the MDCT images, and the CT values and respective means of each ROI were calculated from MDCT images. If variability of ROI determined from five prosthodontists was over 5mm radius, the MDCT images removed from data analysis. Because bone resorption has a low impact on the distance between the mental foramina and the inferior border of the mandible [12], the present study used the "residual ridge ratio" as an indicator of mandible height based on the reference points proposed by Sofat et al. [13]. The residual ridge ratio (RRR) is the ratio of the distance between the inferior border of the mental foramen and the inferior border of the mandible, and the distance between the inferior and superior borders of the mandible determined from MDCT images. The correlation coefficient between RRR and residual ridge crest bone density calculated in each gender. In addition, the correlation coefficients for aging and RRR, and ratio of CT values calculated in each gender.

Condition of residual ridge at each measurement site was calculated based on the RRR and then classified into 3 groups for descriptive purposes (Group 1: >2.0, Group 2: 1.5–2.0, Group 3: <1.5) (Fig. 2). Bone density at the residual ridge crest was evaluated by calculating the ratio of the CT value at the lowest point of the mandible and the CT value of the residual ridge crest ("ratio of CT values"). In addition, RRR, CT values at the residual ridge crest, CT values at the lowest point of the mandible, and ratio of CT values were compared for male and female participants.

### 2.3. Statistical analyses

Comparison of CT values at the lowest point of the mandible, and ratio of CT values in the 3 groups was performed using Bonferroni's multiple comparison test. Gender differences in RRR, CT values at the lowest point of the mandible, and ratio of CT values were assessed by the Mann–Whitney *U* test. Correlations between RRR and ratio of CT values, aging and

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