Diagnostic efficacy of computed tomography in oral implant treatment

(口腔インプラント治療における CT 診断の有用性)

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本論文は、

1) Age affects alveolar bone height and width in patients undergoing dental implant treatment: findings from computed tomography imaging

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2) Diagnostic utility of mandibular cortical width using computed tomography for prediction of peri-implantitis

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をまとめたものである。

1. Abstract

Purposes:

The purposes of this study were 1) to assess age-related changes in alveolar bone height and width using computed tomography (CT) of patients in oral implant treatment and 2) to assess the diagnostic utility of mandibular cortical bone width (MCW) using CT for peri-implantitis**.**

Materials and Methods:

This study was a retrospective cohort study, approved by the ethics committee, Nihon University School of Dentistry at Matsudo (EC19 - 010).

1) The present study analyzed CT scans of 1960 sites in 655 cases (225 male, 430 female; age rage, 20 - 85 years; mean age, 60.96 years) obtained from June 2016 to December 2018 at the Nihon University Hospital at Matsudo. The mean alveolar bone height and width were the outcomes of interest. The participants were dichotomized by age into groups of patients under 65 years old and patients 65 years old and older. Alveolar bone height and width were classified into six groups by site; the values were examined by age. Analyses were performed with the Mann-Whitney *U* test and Spearman correlation coefficients. Statistical significance was established at $P < 0.05$.

2) Patients underwent CT at the Nihon University Hospital at Matsudo between April 2014 and October 2020. This study included among the 254 patients (116 male, 138 female; 31 - 88 years of age, mean age 68.42 years) examined peri-implantitis by CT examinations, 179 patients were found to exhibit peri-implantitis. The MCW of patients without peri-implantitis and those with peri-implantitis were evaluated. The predictor variable was presence or absence of peri-implantitis. The primary outcome variable was the MCW. The other variables were age and sex. Data were analyzed using a Mann-Whitney *U* test and Spearman's correlation coefficient. Statistical significance was set at $P < 0.05$.

Results:

1)The height of the maxillary anterior, maxillary premolar, maxillary molar, mandibular anterior, mandibular premolar, and mandibular molar sites, and the width of the maxillary anterior, maxillary premolar, and maxillary molar sites in the alveolar bone were significantly associated with age. 2) The MCW was significantly different between the non-peri-implantitis and peri-implantitis groups. This study found a significant correlation between peri-implantitis and the MCW.

Conclusion:

This study showed that the age-related changes in the alveolar bone indicated insufficient alveolar bone height or width for oral implant and measuring MCW may be used effectively to determine bone quality, implant planning for predicting peri-implantitis. The present study suggested that the diagnostic efficacy of CT in oral implant treatment.

Key words:

Computed tomography, Oral implant treatment, Peri-implantitis, Mandibular cortical width, Alveolar bone

2. Introduction

Developed countries are experiencing growth in the proportion of population aging[1]. Aging is a process associated with chronological age; older adults are defined as those aged over 65 years old[1]. The changing demographics and associated tooth loss are likely to affect the future demand for dental care services. Tooth loss and oral disease in older adults are public health challenges, and oral implant treatment is becoming increasingly common worldwide for patients with tooth loss[2,3].

Oral implants help reduce the risk of dysfunction in people who have lost their teeth and may improve their overall health and quality of life[3,4]. Oral implant treatment requires that the dentist knows the exact height, width, and contour of the alveolar bone and the relationship between the maxillary sinus and the mandibular canal. Failure to accurately assess these parameters may lead to complications, including inferior alveolar nerve injury and maxillary sinus membrane perforation. Previous studies have shown that oral implant treatment without suitable alveolar bone height and width is unlikely to be effective. In addition, previous studies have shown that older age may increase the risk of implant failure. In fact, older patients are more likely than their younger counterparts to experience implant failure[5,6], highlighting the importance of accurate radiographic assessment of alveolar bone morphology ahead of any implant treatment. long-term success of implants comprises the basic continued assessment of peri-implant tissues and diagnosis of peri-implantitis[7)].

Peri-implantitis including periodontal disease is a chronic destructive disease caused by periodontal pathogen, such as *Porphyromonas gingivalis* and *Tannerella forsythia*. Osteoporosis is a skeletal disease characterized by reduction in bone mass and micro architectural changes in the bone, which lead to increased bone fragility. Thus, osteoporosis is suspected to be a risk factor for the progression of periodontal disease; many studies have reported evidence that change in mandibular cortical width (MCW) thickness caused by osteoporosis is associated with periodontal disease and tooth loss[8-10)]. Moreover, reported significant association between MCW and bone mineral density on panoramic radiographs[11,12)]. The stability of oral implants during placement depends on the condition of the bone and is often difficult to achieve the stability, with low density bone. Therefore, measuring MCW is consider useful in diagnosing bone status including alveolar bone. These complications could be declined chewing ability and quality of life. Computed tomography (CT) has been shown to be an excellent tool for the preoperative evaluation of the mandible and maxilla for oral implant surgery. It is also excellent in evaluating post-implant peri-implantitis. However, few studies have assessed the alveolar bone height, alveolar bone width, and MCW using CT in implant treatment.

The purposes of this study were 1) to assess age-related changes in alveolar bone height and width using CT of patients in oral implant treatment. and 2) to assess the diagnostic utility of MCW using CT for peri-implantitis**.**

3. Materials and Methods

3-1) Age affects alveolar bone height and width in patients undergoing dental implant treatment: Findings from computed tomography imaging

The present study examined CT findings from 1960 clinical sites underwent oral implant treatment at the Nihon University Hospital at Matsudo between June 2014 and December 2018 (Table 1). The exclusion criteria were tooth sockets due to extraction procedures (n=331) and severe metal artifacts in imaging (n=154).

Ethics approval and consent to participate

The study had the approval of Nihon University School of Dentistry at Matsudo ethics committee (EC19 - 010) and the need for informed consent was waived.

Data acquisition

CT were acquired with an Aquilion 64 system (Canon Medical Systems Corp. Otawara, Japan), which is a multi-detector row CT (MDCT) unit, with Ziostation (Ziosoft, Newark, CA) as the workstation. Imaging parameters included tube voltage of 120 kV, tube current of 100 mA, and helical pitch of 41 s/rotation; bone display images were used. The MDCT images were displayed on the workstation, and the height and width of the alveolar bone were measured on the screen, using the distance measurement function, on the cross sectional CT. The distance was measured twice by two radiology specialists (S.I.

4 years of experience; H.M. 9 years of experience) blinded to the age of the patients; the average value was used in subsequent analyses. Alveolar bone height was a line tangential to the floor of the maxillary sinus, nasal cavity, mandibular canal, or superior border of the mandible were drawn, and line parallel to this tangent was drawn on the crest of the alveolar bone, A line perpendicular to this tangent intersecting the crest of the alveolar bone was constructed, along which the height was measured (Fig. 1). Alveolar width was measured at the distance between the buccal and lingual or palatal sides of the cortical bone in the high of border between cortical bone and cancellous bone (Fig. 2) [13].

Statistical analysis

In this study, patients were dichotomized into two age groups (patients under 65 years old and patients 65 years old and older) based on the World Health Organization Elderly Classification[1]. The alveolar bone height and width were examined at the maxillary anterior (patients under 65 years old;132 sites and patients 65 years old and older;154 sites), maxillary premolar (patients under 65 years old;167 sites and patients 65 years old and older;199 sites), maxillary molar (patients under 65 years old;145 sites and patients 65 years old and older;272 sites), mandibular anterior (patients under 65 years old;102 sites and patients 65 years old and older;104 sites), mandibular premolar (patients under 65 years old;134 sites and patients 65 years old and older;132 sites), and mandibular molar sites (patients under 65 years old;203 sites and patients 65 years old and older;216 sites). Between group comparisons of the alveolar bone height and width were performed using the Mann-Whitney *U* test. Spearman's correlation coefficients were calculated using bone height and width as independent variables and age as the explanatory variable. Intraclass correlation coefficient (ICC) values were interpreted as follows: 0 - 0.2, 0.21 - 0.39, 0.40 - 0.59, 0.60 - 0.79, 0.80 - 0.90, and > 0.90 indicated slight, minimal, weak, moderate, strong, and perfect agreement, respectively[14)]. These analyses were performed with SPSS (IBM Japan Inc., Tokyo, Japan). *P*-values of < 0.05 were considered statistically significant.

3-2) Diagnostic utility of mandibular cortical bone width using computed tomography for prediction of peri-implantitis

Study design

This study included patients (116 male; age range: 33 - 85 years; mean age: 70.01 years, and 138 female; age range: 31 - 88 years; mean age: 67.01 years) who underwent basic periodontal examination, pantomography, and CT simultaneously between April 2014 and March 2020. The exclusion criteria included severe metal artifacts (n=156) and tumor and cyst in the jaw (n=5). The patients were divided into non-peri-implantitis and peri-implantitis groups. The non-peri-implantitis group (34 male, 41 female; mean age, 67.88 years) included outpatients without findings such as bleeding on probing (BOP), probing-pocket depth (PD) < 4 mm, suppuration (SUPP) around the teeth, and ≥ 2.0 mm of radiographical alveolar bone loss. The peri-implantitis group (82 male, 97 female; mean age, 68.66 years) had pain on implant function, implant mobility, PD ≥ 4 mm, radiographic alveolar bone loss ≥ 2.0 mm, and a history of exudate around the implant[15)].

Ethics approval and consent to participate

The study had the approval of Nihon University School of Dentistry at Matsudo ethics committee (EC19 - 010) and the need for informed consent was waived.

Data acquisition

Pantomography was performed using digital pantomography (Veraviewepocs; J. Morita Ltd., Kyoto, Japan) at 10 mA and a peak kV of 60-80. CT images were acquired with AquilionTM64 (Toshiba Medical Systems Corporation), used as the multi-detector row CT unit, and ZIOSTATION (ZIOSOFT), used as the workstation. Imaging parameters included tube voltage of 120 kV, tube current of 100 mA, and helical pitch of 41; bone display images were used. The bilateral MCW was measured bilaterally on the coronal CT slice corresponding to the mental foramen. A line tangential to the inferior border of the mandible was drawn, and line parallel to this tangent was drawn on the superior border of the mandible. A line perpendicular to this tangent intersecting the inferior border of the mental foramen was constructed, along which the MCW was measured (Fig. 3)[16). Bilateral mean MCW was independently measured by two radiology specialists (S.I. 4 years of experience; H.M. 9 years of experience). Furthermore, the individually measured MCWs by these two observers were averaged. The study participants were divided into a peri-implantitis and non-peri-implantitis group.

Statistical analysis

The two groups were compared using a Mann-Whitney *U* test. This test was performed with the presence or absence of peri-implantitis as a predictor variable and

MCW as an outcome variable. Spearman's correlation coefficients were calculated using mean MCW as the criterion variable and age and sex as explanatory variables. The weight kappa coefficients and ICC results were interpreted as follows: 0 - 0.2, 0.21 - 0.39, 0.40 - 0.59, 0.60 - 0.79, 0.80 - 0.90, and > 0.90 indicating slight, minimal, weak, moderate, strong, and perfect agreement, respectively[14,17)]. Statistical analyses were performed using SPSS version 21.0 (IBM Japan Inc., Tokyo, Japan). Values of $P < 0.05$ were considered statistically significant.

4. Results

4-1) Age affects alveolar bone height and width in patients undergoing dental implant treatment: Findings from computed tomography imaging

The ICC value was 0.79, indicating moderate agreement between the two observers regarding all height and width measurements of the alveolar bone. Fig. 4, 5 presents the alveolar bone height and width values by site per group. There were significant differences between groups in height estimates of the maxillary anterior, maxillary premolar, mandibular molar sites, the maxillary molar, mandibular anterior, and mandibular premolar sites ($P < 0.05$). Moreover, there were also significant differences between groups in width estimates of the maxillary anterior, maxillary premolar site, and molar sites ($P < 0.05$). There was no significant difference in mandibular alveolar bone width between groups ($P > 0.05$). Correlations between age and alveolar bone height and width per site are presented in Fig 8 - 11. Age was negatively correlated with the height of the maxillary anterior, maxillary premolar, maxillary molar, mandibular anterior, mandibular premolar, and mandibular molar sites. Age was positively correlated with maxillary molar site width. No correlation was found between age and mandibular molar width.

4-2) Diagnostic utility of mandibular cortical bone width using computed tomography for prediction of peri-implantitis

The kappa coefficients and ICC for the presence or absence of peri-implantitis and MCW showed strong (0.88 and 0.81, respectively) agreement. These indicated the fluctuation tendency of the measurement values showed similar between the two measurers, and reliability of measurement values were high. Table 2 presents patient data including the number of patients, mean age, sex, and median MCW (mm) with and without peri-implantitis. The patients' mean age was 67.88 (n=75) and 68.88 (n=179) years, corresponding to non-peri-implantitis and peri-implantitis groups, respectively. There were not significant between-group differences in both the mean age (*P*=0.43). The median MCW were 3.20 mm and 2.15 mm, corresponding to non-peri-implantitis and peri-implantitis groups, respectively. The median MCW showed significant differences between the non-peri-implantitis and peri-implantitis groups using the Mann-Whitney *U* test and MCW in peri-implantitis group showed lower than non-peri-implantitis group (P<.01, Fig. 12). The median MCW for all the age groups was 2.46 mm in men and 2.36 mm in female *(P* = 0.10, Fig. 13, Table 3). Correlations between age and MCW per sex are presented in Fig. 14 (male) and Fig. 15 (female). Age was negatively correlated with the MCW.

5. Discussions

5-1) Age affects alveolar bone height and width in patients undergoing dental implant treatment: Findings from computed tomography imaging

The present study examined the alveolar bone height and width in each site of interest, stratified by age; these parameters differed between patients 65 years old and older and those aged patients under 65 years old. The width of the maxillary molar alveolar bone in patients aged patients 65 years old and older was significantly greater than that in those aged patients under 65 years old. Mandibular alveolar bone width was similar in both groups. As life expectancy is increasing worldwide, the duration of periodontal disease is also increasing in older adults[18,19)]. Generally, losing a tooth causes irreversible resorption of the alveolar bone over time. The presence of sufficient alveolar bone in the maxillary and mandibular jaws is essential for the success of dental procedures such as placement of oral implants and dentures. The height and width of the alveolar bone are the most important factors that affect long-term efficacy in oral implant treatment. Failure rates of implants shorter than 9 mm tend to be higher than those of longer implants, regardless of implant manufacturer, design, surface characteristics, or type of application[20,21)]. Root form implants with 4 mm crestal diameter usually require ≥ 6 mm of bone width to ensure sufficient bone thickness and blood supply around the implant, helping achieve long-term retention. Therefore, the baseline alveolar bone height and width should approximate 12 mm and 6 mm, respectively, to accommodate the ideal treatment plan[22,23]. Previous studies have reported alveolar bone height and width deficiencies in many parts of the maxillary and mandibular jaws[13]. Similarly, in this study, there was a decrease in alveolar bone height and width in most areas. In the maxilla and mandible, the alveolar bone height tended to be higher and the width mandibular in the anterior teeth region, where esthetics is more important. The alveolar height of the maxillary and mandibular molars, which were subjected to occlusal pressure, tended to be mandibular. The alveolar width of the mandibular molars not change significantly but tended to increase in the maxillary molar region. These changes might be due to the morphology of the base of the maxillary molars resulting from resorption of the maxillary molars. In cases of inadequate width before implant placement, bone grafting may be used to create an optimal site for restorative implantation[24,25].

These findings suggest that age-related changes in the alveolar bone result in insufficient alveolar bone height or width necessary for oral implants. These findings can be applied in clinical settings.

5-2) Diagnostic utility of mandibular cortical bone width using computed tomography for prediction of peri-implantitis

This study suggested that significant correlation between peri-implantitis and MCW. Moreover, this study found that patients with peri-implantitis had significantly lower MCW than patients without peri-implantitis. MCW and mandibular cortical index (MCI) are significantly related with bone mineral density in the lumbar spine, hip, and foramen, so these measurements are effective for bone quality evaluation[26,27]. MCI is not generally quantified but assessed subjectively. MCW was not measured accurately by pantomograhy. A major reason was that the border between the cortical and trabecular bones was not detected accurately due to an indistinct margin. In some cases, it is very difficult to determine the endocortical margin even manually[28]. Therefore, CT is a more suitable index than pantomograhy for evaluating the border between the cortical and trabecular bones and MCW on CT is a more suitable index than MCI for evaluating bone quality. Oral implants have wide acceptance in prosthetic rehabilitation. As the global number of oral implants increases, their complications and failures rise further. When oral implant treatment is considered, must evaluated on the risk. Peri-implantitis is a common long-term complication oral implantation. It is a pathological condition occurring in tissues around oral implants, characterized by inflammation in the peri-implant mucosa and progressive loss of the supporting bone. This study has expected that ICOI diagnostic criteria appropriate. Because this criterion included that diagnostic parameter inflammation of tissue around oral implants. In the clinical setting, soft tissue inflammation is detected by probing, while progressive bone loss is identified on radiological evaluation[29,30]. Characteristics of this disease include erythema, swelling, and suppuration. The number of patients/implants affected by peri-implant diseases has been increasing. The main goal of treatment of peri-implantitis is to control the infection and prevent disease progression. However, there are no established and predictable concepts for the treatment of peri-implantitis. Progressive peri-implantitis may lead to mobility of the implant and loss of the implant. Infrequently, primary or metastatic peri-implant malignancies that closely resemble peri-implantitis have been reported, making early detection and prediction of peri-implantitis important[31]. Local factors of peri-implantitis are generally excess cement, poor plaque control, and no regular maintenance care after implant therapy, a biomechanical factor resulting from occlusal overload and patients with a prior history of periodontitis. In patients with risk factors for peri-implantitis (local and systematic), careful planning before implant treatment is important to avoid the risk of peri-implantitis[32]. It has been reported that MCW was significantly reduced in patients with periodontitis and osteoporosis[33]. For the radiological evaluation of implant treatment, conventional modality (e.g., dental radiography and pantomography) and CT for the purpose of three-dimensional evaluation of the jaw are used. In particular, CT has become one of the most valuable tools in planning oral implant placement and evaluating prognosis. The CT imaging technology provides cross-sectional of various directions views of the jaws. Many studies have reported the validity of CT in bone quality and morphology assessment in oral implant treatment[34,35)]. Moreover, studies have reported assessment of morphology and severity of peri-implantitis bone defects using CT [36)]. However, the relationship between the peri-implantitis and the MCW remains unclear. In this study, there was no significant difference in sex, age, and mean MCW. The MCW was significantly different between the non-peri-implantitis and peri-implantitis groups (Fig. 16). Therefore, the significant reduction in MCW observed in the peri-implantitis group may be due to peri-implantitis only to the factor in the oral cavity, but also to systematic conditions such as bone quality in these patients.

6. Conclusion

This study showed that the age-related changes in the alveolar bone indicated insufficient alveolar bone height or width for oral implant and measuring MCW may be used effectively to determine bone quality, implant planning for predicting peri-implantitis. The present study suggested that the diagnostic efficacy of CT in oral implant treatment.

7. References

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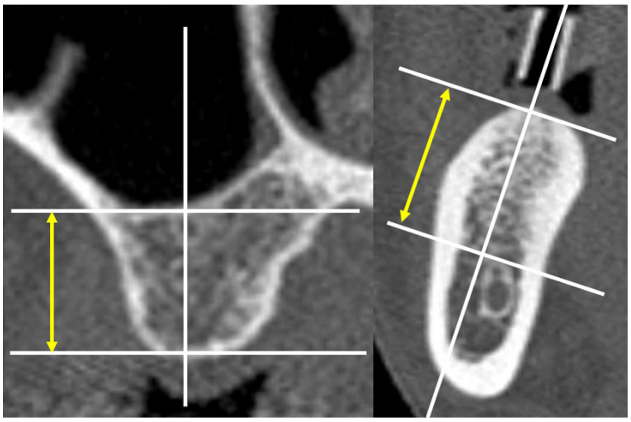
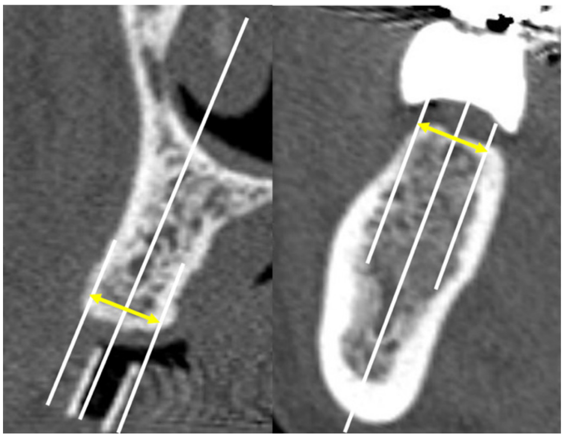
8. Figure and legends

Figure 1. Evaluation method of alveolar bone heigh



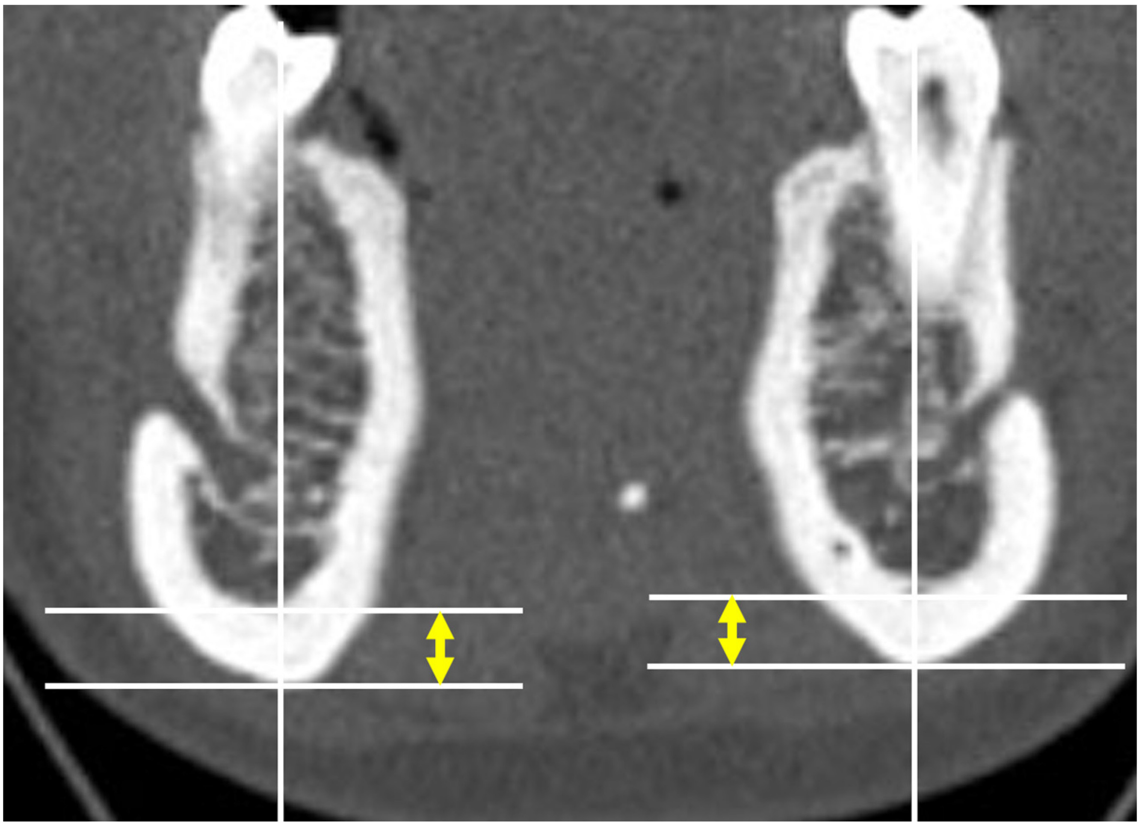
Alveolar bone height (yellow double-headed arrow line) was a line tangential to the floor of the maxillary sinus, nasal cavity, mandibular canal, or superior border of the mandible were drawn, and line parallel to this tangent was drawn on the crest of the alveolar bone, A line perpendicular to this tangent intersecting the crest of the alveolar bone was constructed, along which the height was measured on cross sectional CT images.

Figure 2. Evaluation method of alveolar bone width



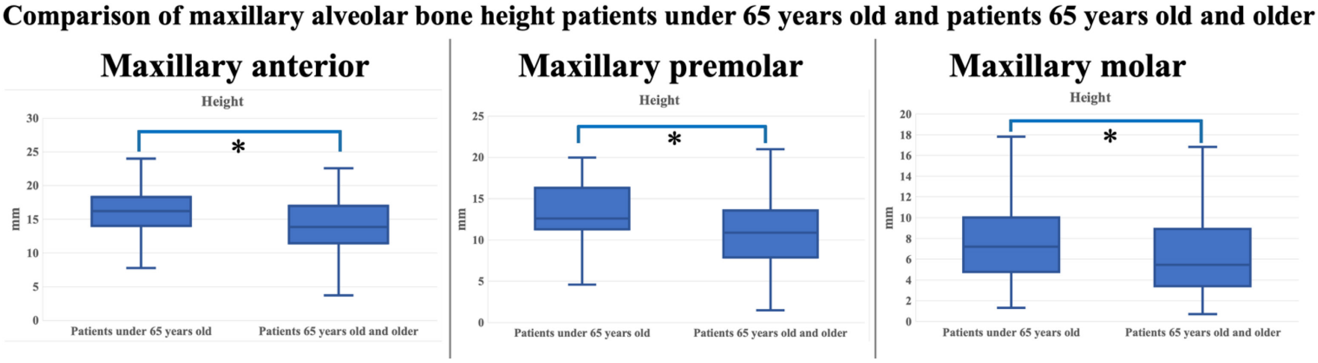
Alveolar width (yellow double-headed arrow line) was measured at the distance between the buccal and lingual or palatal sides of the cortical bone in the high of border between cortical bone and cancellous bone on cross sectional CT images.

Figure 3. Mandibular cortical width (MCW) evaluated under the mental foramen on computed tomography



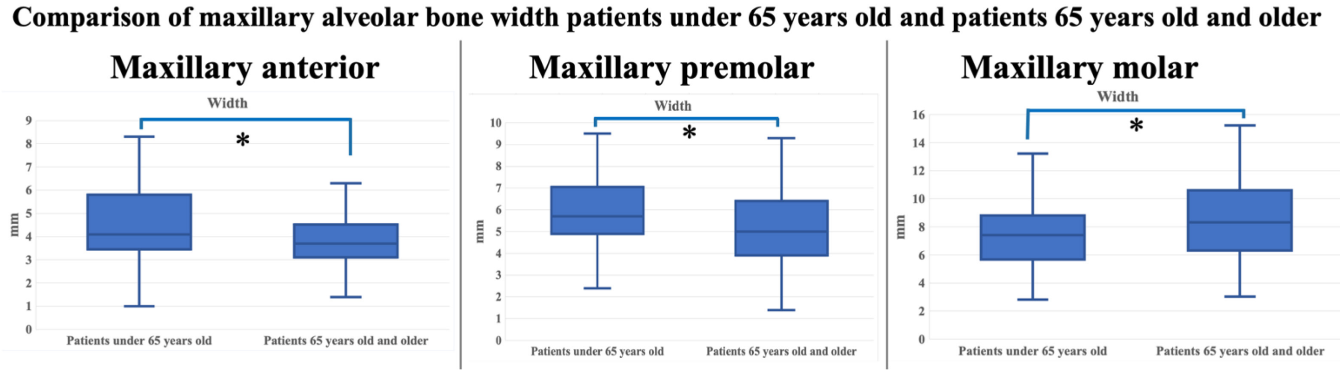
The bilateral MCW (yellow double-headed arrow line) was measured bilaterally on the coronal CT slice corresponding to the mental foramen. A line tangential to the inferior border of the mandible was drawn, and line parallel to this tangent was drawn on the superior border of the mandible. A line perpendicular to this tangent intersecting the inferior border of the mental foramen was constructed, along which the MCW was measured.

Fig 4. Comparison of maxillary alveolar bone height patients under 65 years old and patients 65 years old and older



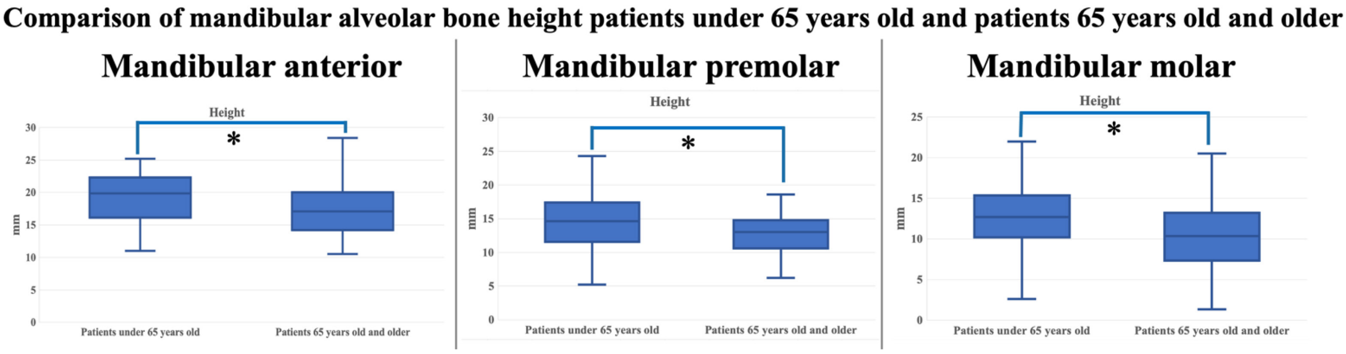
The rectangular box represents the interquartile range, and the line across the box indicates the median value. From the two ends of the box, lines extending outward to the upper end represent the maximum value, and the lower end represents the minimum value.

Fig 5. Comparison of maxillary alveolar bone width patients under 65 years old and patients 65 years old and older



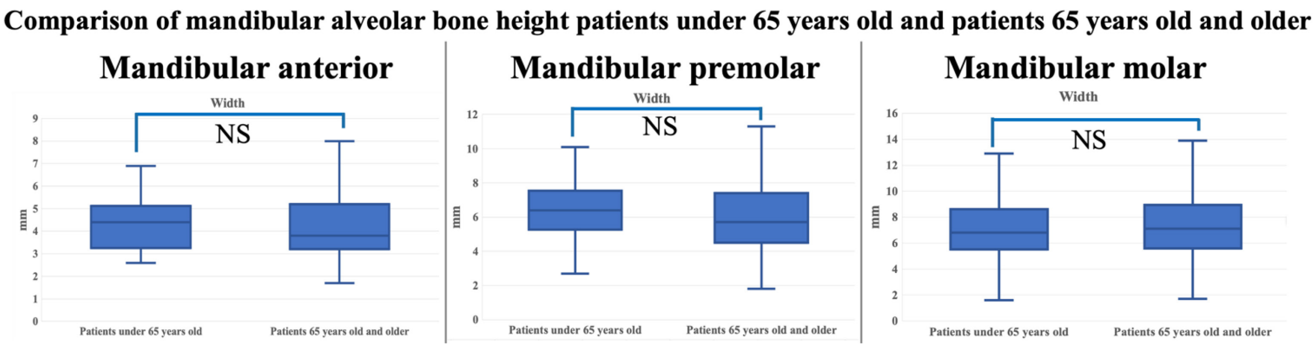
The rectangular box represents the interquartile range, and the line across the box indicates the median value. From the two ends of the box, lines extending outward to the upper end represent the maximum value, and the lower end represents the minimum value.

Fig 6. Comparison of mandibular alveolar bone height patients under 65 years old and patients 65 years old and older



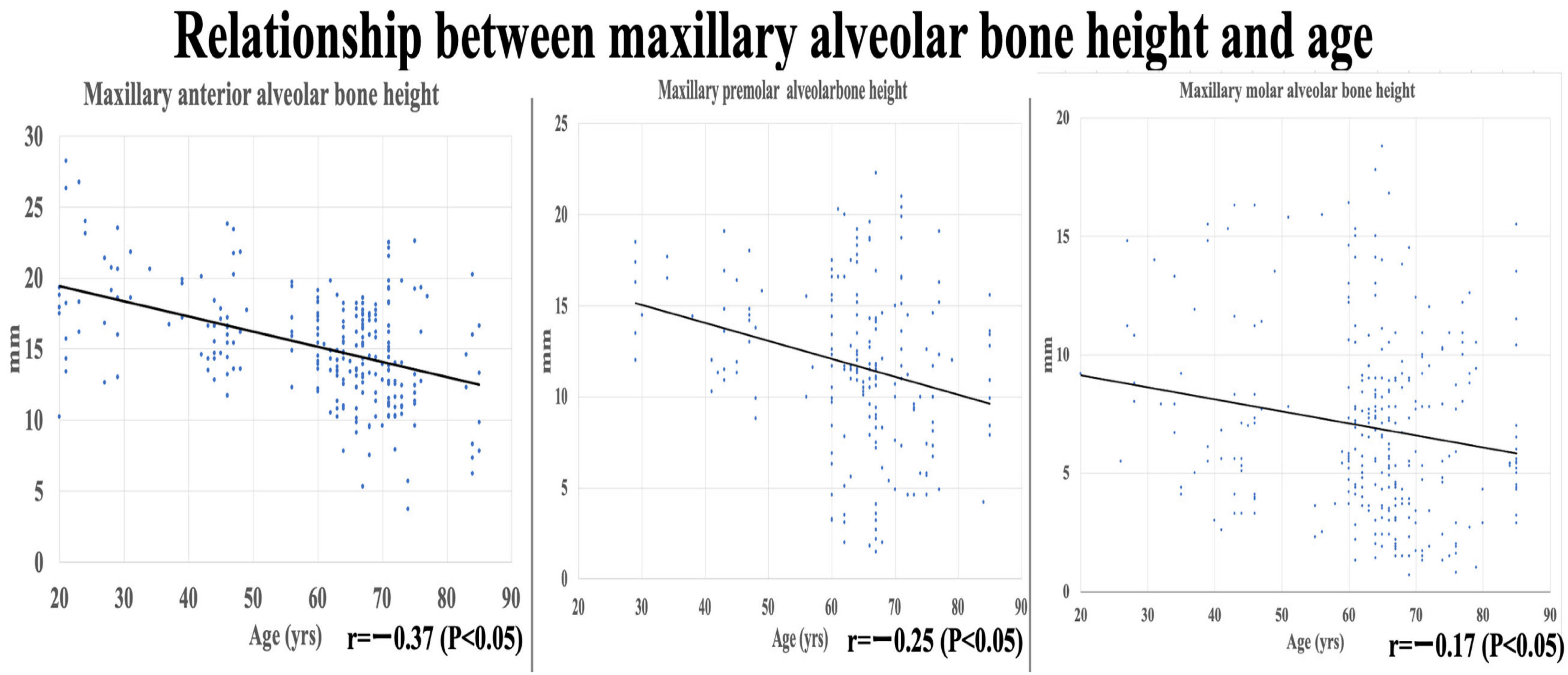
The rectangular box represents the interquartile range, and the line across the box indicates the median value. From the two ends of the box, lines extending outward to the upper end represent the maximum value, and the lower end represents the minimum value.

Fig 7. Comparison of mandibular alveolar bone width patients under 65 years old and patients 65 years old and older



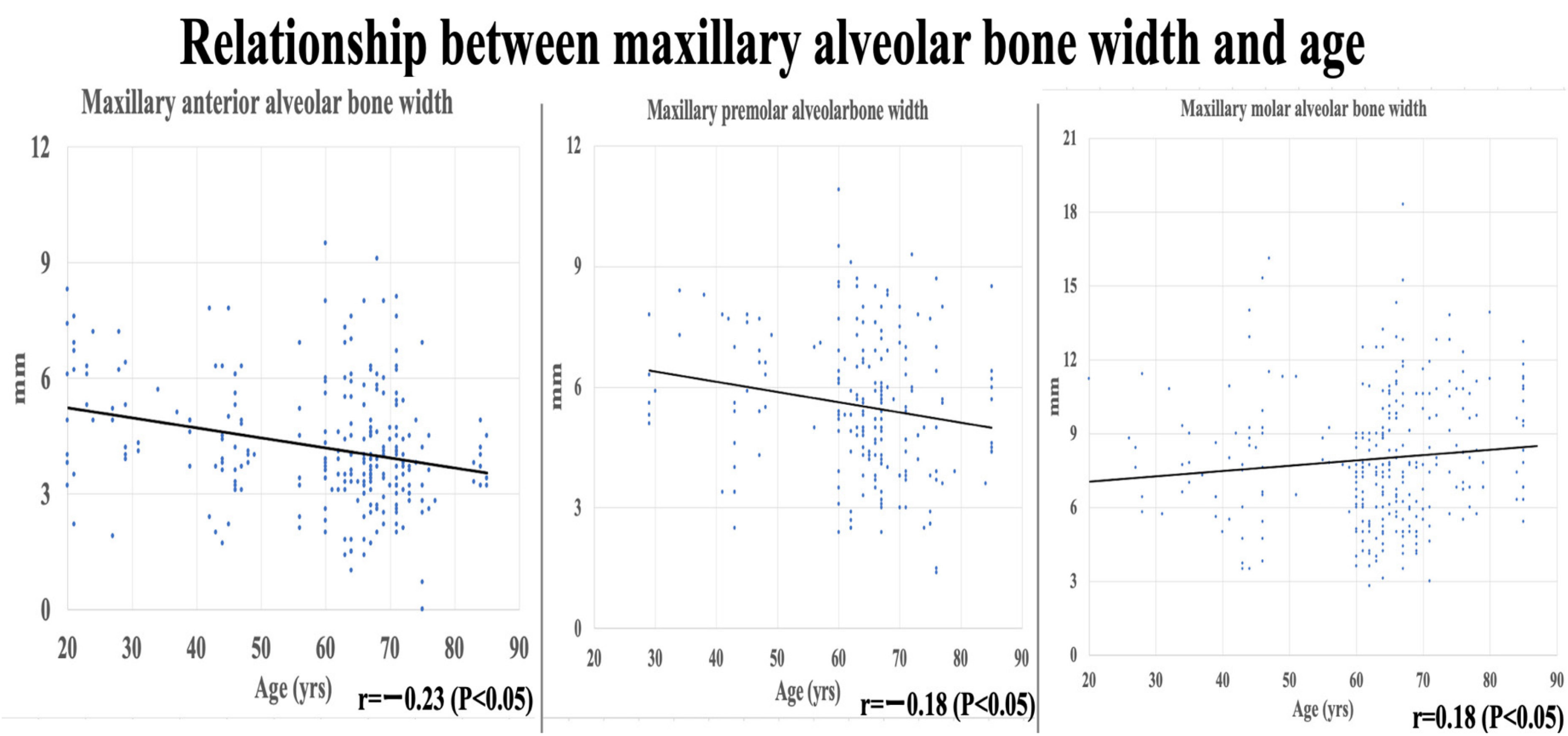
The rectangular box represents the interquartile range, and the line across the box indicates the median value. From the two ends of the box, lines extending outward to the upper end represent the maximum value, and the lower end represents the minimum value.

Figure 8. Relationship between maxillary alveolar bone height and age



Age was negatively correlated with the height of the maxillary anterior, maxillary premolar, maxillary molar sites.

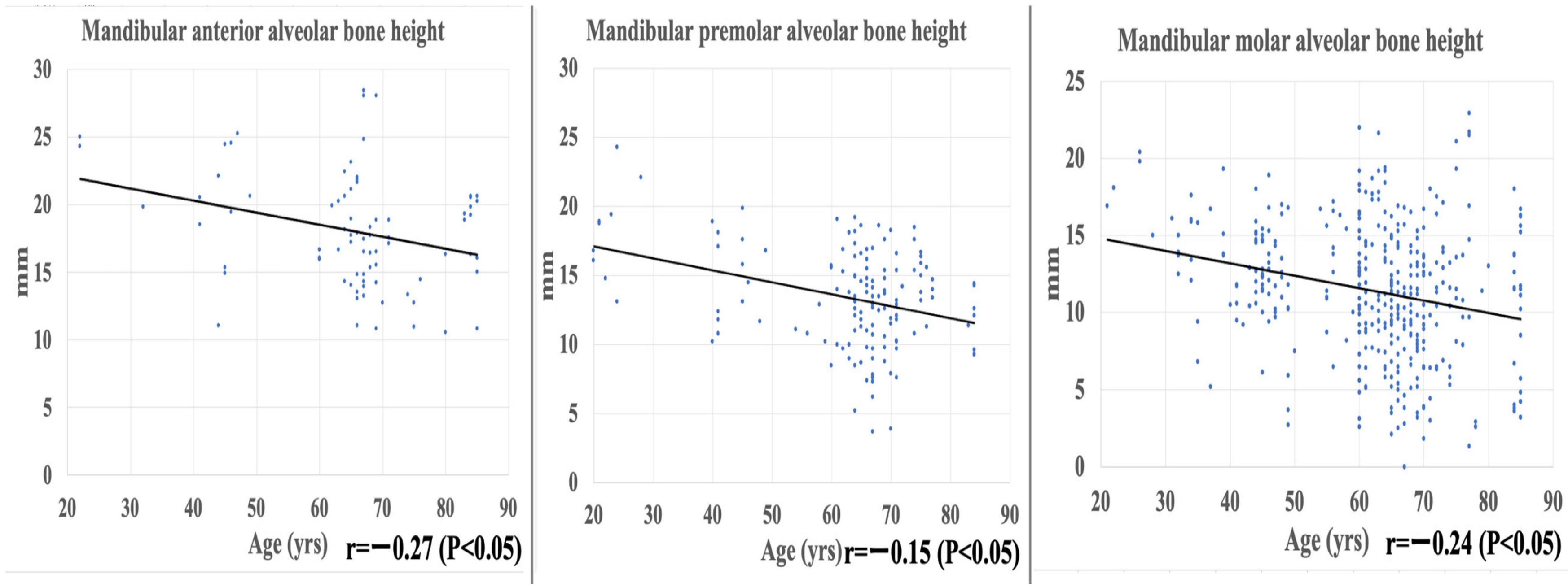
Figure 9. Relationship between maxillary alveolar bone width and age



Age was negatively correlated with the height of the maxillary anterior and maxillary premolar sites. Age was positively correlated with maxillary molar site width.

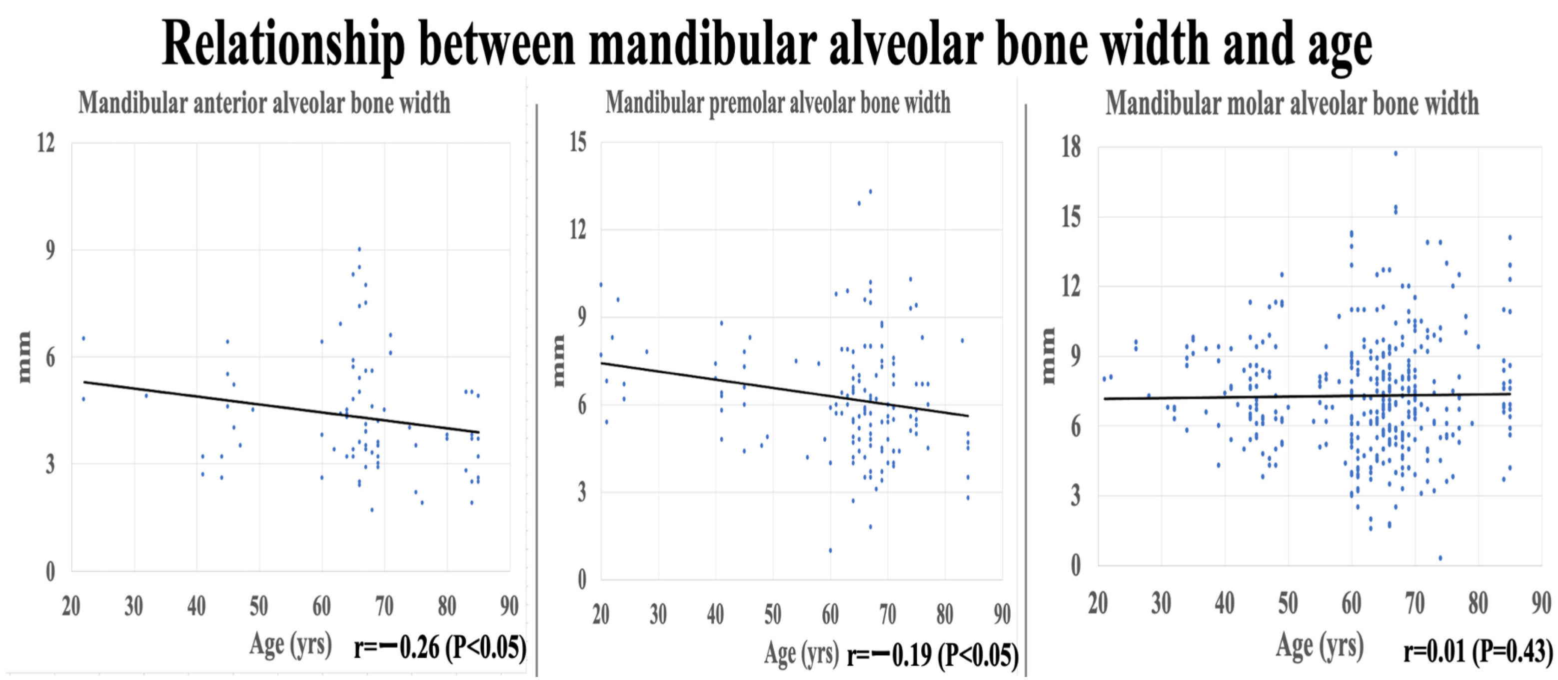
Figure 10. Relationship between mandibular alveolar bone height and age

Relationship between mandibular alveolar bone height and age



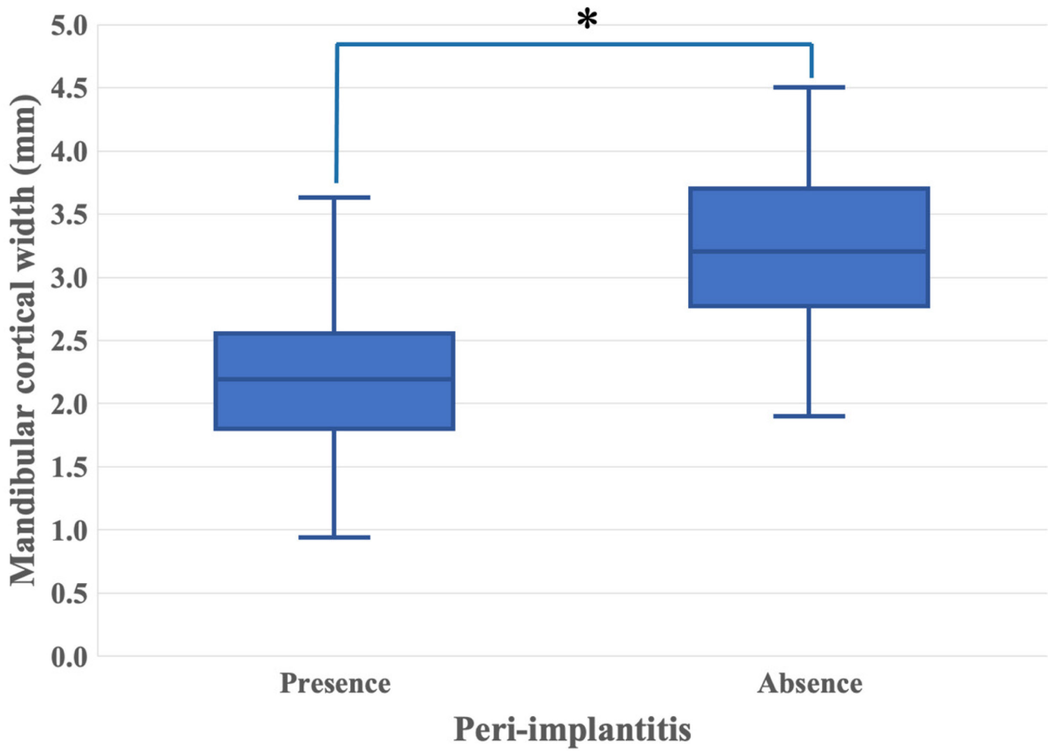
Age was negatively correlated with the height of the mandibular anterior, mandibular premolar, mandibular molar sites.

Figure 11. Relationship between mandibular alveolar bone width and age



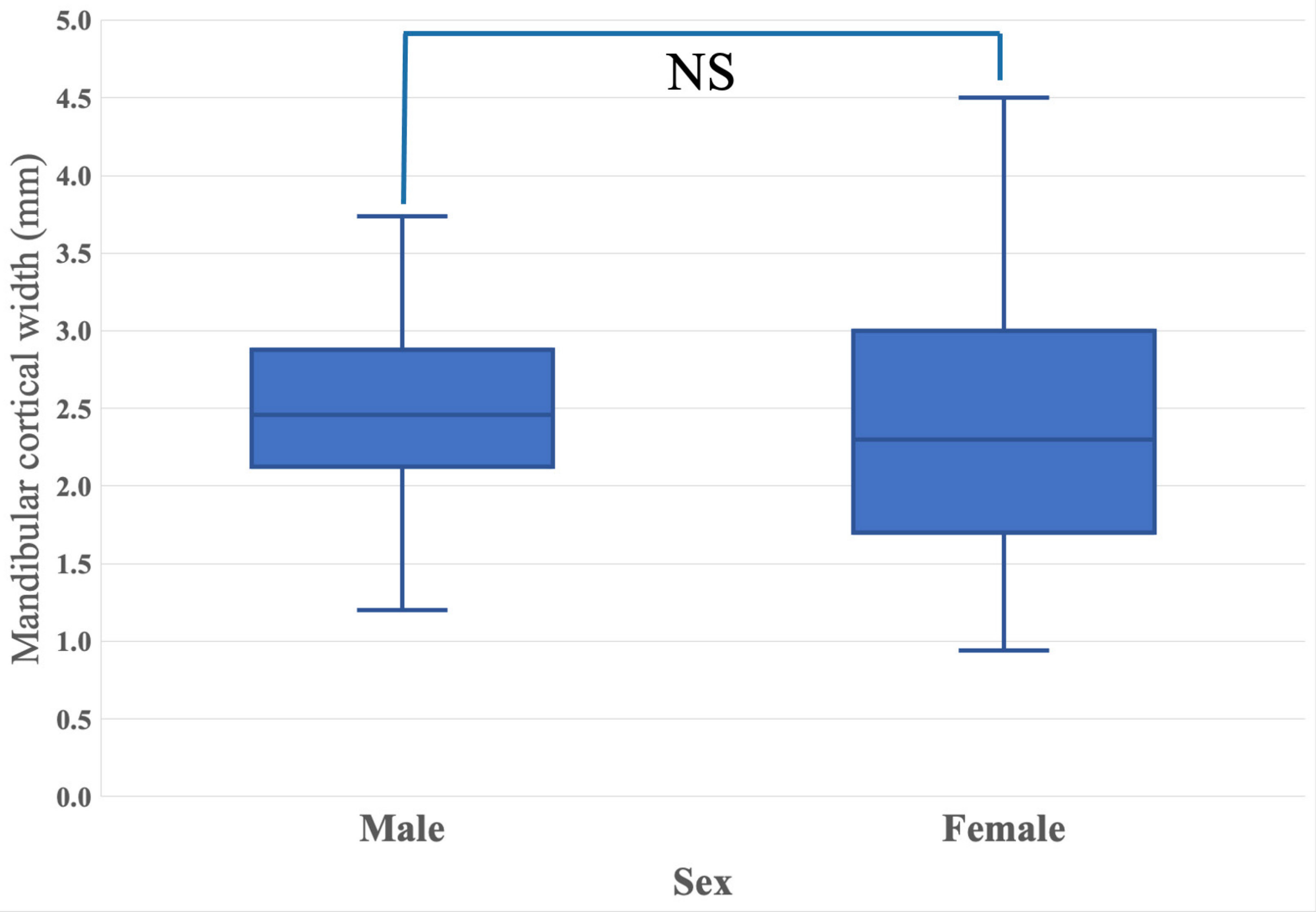
Age was negatively correlated with the height of the mandibular anterior, mandibular premolar sites. No correlation was found between age and mandibular molar width.

Fig 12. Comparison of mandibular cortical width (MCW) between with and without peri-implantitis



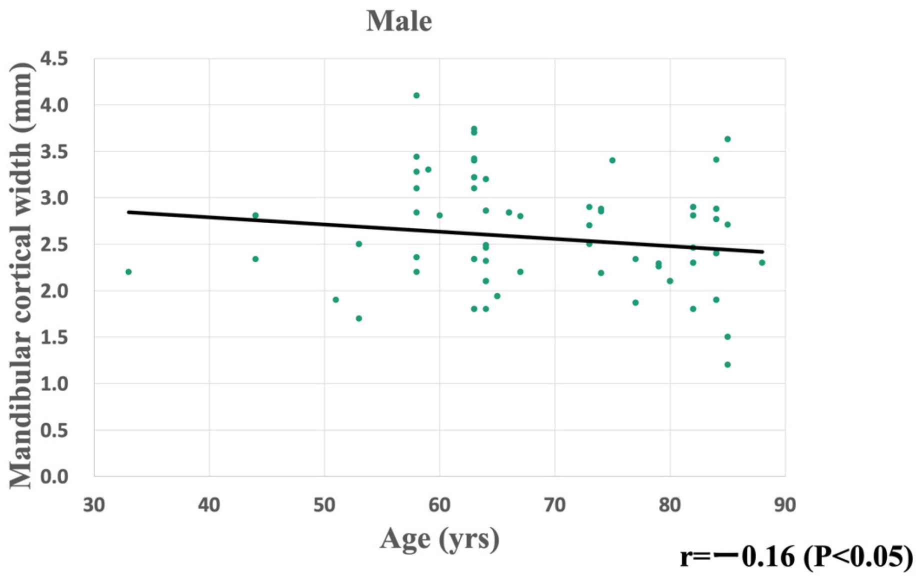
The rectangular box represents the interquartile range, and the line across the box indicates the median value. From the two ends of the box, lines extending outward to the upper end represent the maximum value, and the lower end represents the minimum value.

Fig 13. Comparison of mandibular cortical width (MCW) between male and female



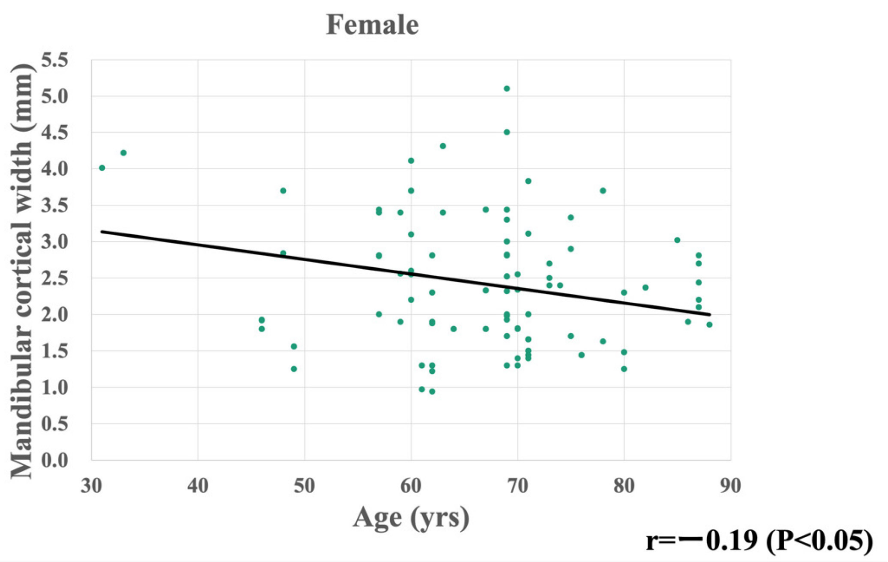
The rectangular box represents the interquartile range, and the line across the box indicates the median value. From the two ends of the box, lines extending outward to the upper end represent the maximum value, and the lower end represents the minimum value.

Fig 14. Relationship between the mandibular cortical width (MCW) and age for male

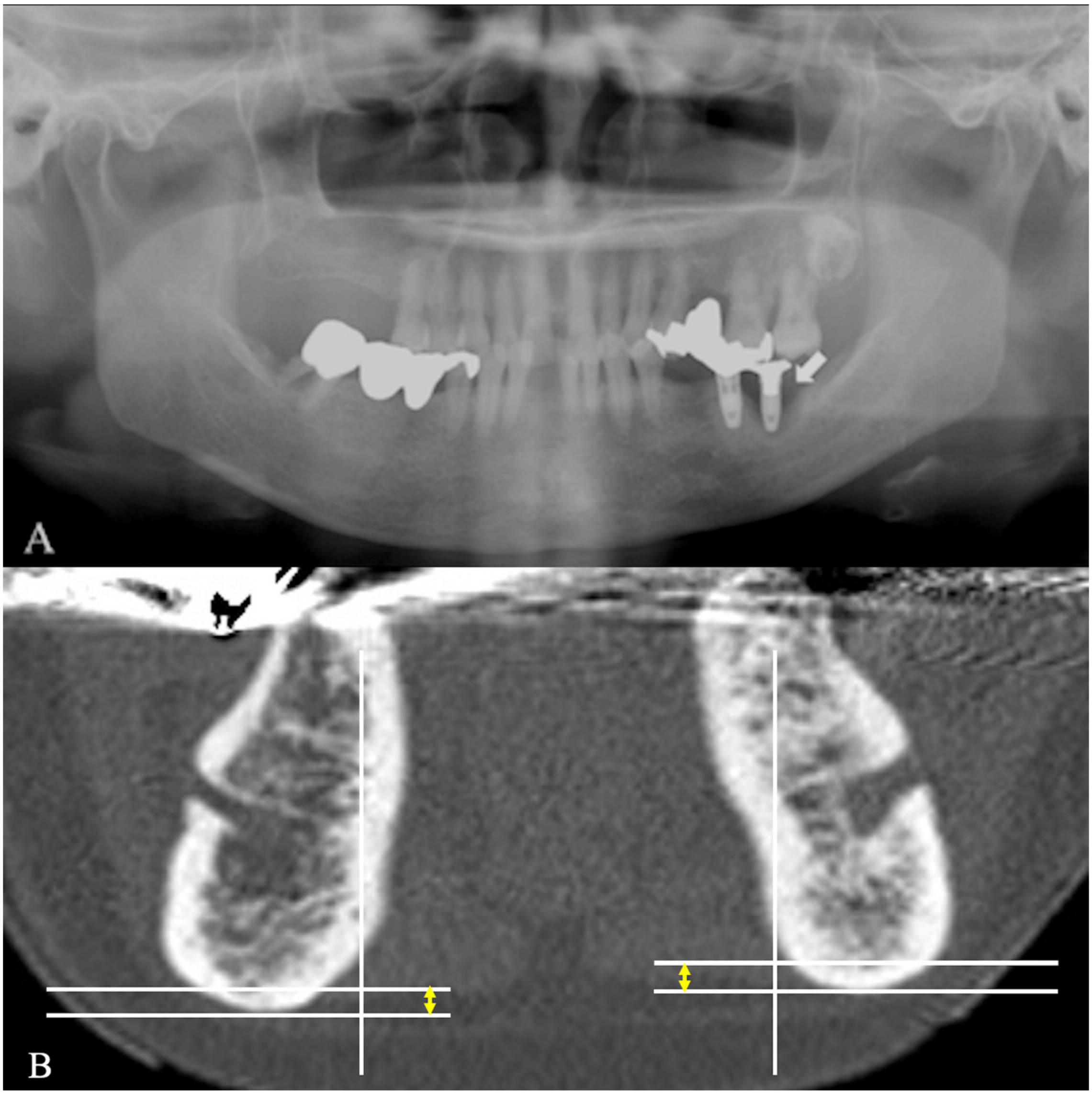


Age was negatively correlated with the MCW in male.

Fig 15. Relationship between the mandibular cortical width (MCW) and age for female



Age was negatively correlated with the MCW in female.



A: Pantomogram shows alveolar bone loss >2.0 mm (arrow). Moreover, this patient had bleeding on probing, suppuration, and probing-pocket depth >4 mm,
B: Computed tomography (CT) shows a thinner mandibular cortical width (MCW) (yellow double-headed arrow line).

9. Tables

Table 1. Number of sites between patients under 65 years old and patients 65 years old and older

			Age groups (yrs.)		
			Patients under 65 years old	Patients 65 years old and older	Total
N	Maxillary	Anterior	132	154	286
		Premolar	167	199	366
		Molar	145	272	417
	Mandibular	Anterior	102	104	206
		Premolar	134	132	266
		Molar	203	206	419

n=Number of sites

Table 2. Median mandibular cortical width, number of patients and mean age in between peri-implantitis and non-peri-implantitis group

	Peri-implantitis		
	Presence (n=179)	Absence (n=75)	*P*-value
Sex			
Male (n)	82	34	
Female (n)	97	41	
Mean age (yrs.)	68.88	67.88	.43

MCW (mm)	2.15	3.20	<. 01

n=Number of patients, MCW= Mandibular cortical width

Table 3. Median mandibular cortical width by sex

	Number of patients (n=Number of patients)		
	Male (n=116)	**Female (n=138)**	***P*-value**
MCW (mm)	2.46	2.36	*P*=.10

n=Number of patients, MCW=Mandibular cortical width