Alveolar bones density assessment of dental implant sites using cone-beam computed tomography

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ABSTRACT

Introduction: a preoperative assessment of bone density plays a vital role in the success of dental implant treatment. the maxilla and mandibular alveolar bone had a variety of bone densities. Therefore, dental imaging is an important step before placing a dental implant. Recently, Cone beam computed tomography (CBCT) is widely used in dental medicine and also recommended by AAOMR for preoperative implant placement. The aims of this study is to analyzed the alveolar bone density of the dental implant sites for dental implant planning using CBCT. **Methods:** ninety-three CBCT data were retrieved from the database of the department of oral and maxillofacial radiology at Dental Hospital Faculty of Dentistry Universitas Trisakti and examined. The recipient sites for dental implant placement were determined based on CBCT data using implant planning software (i-Dixel). The alveolar bones value is recorded in grayscale value (GV). **Results**: a great variety of alveolar bone density was observed ranging from 134-891 GV. One-way ANOVA was conducted, and statistically significant was only shown at the anterior mandibular region and molar mandibular region. However, no statistical differences were observed when comparing the male and female groups using the T-test. **Conclusion:** Critical evaluation through dental CBCT can be made before dental implant placement in the alveolar bones. the lowest alveolar bone density was observed in maxillary molar dental implant sites with mean 322 GV and highest alveolar bone density was shown in mandibular anterior dental implant sites with mean 558.8 GV. Determining the bone density at the dental implant site before dental implant placement is crucial. Primary stability and secondary stability is determined by bone density. Therefore, higher value of alveolar bone density is needed for dental implant placement.

Keywords: alveolar bone density assessment; dental implant; cone-beam computed tomography.

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INTRODUCTION

Tooth loss has been a problem for humans over the centuries. Since the 19th century, Dental implant has been used to replace missing teeth.[1] To date, the dental implant has been widely used because of its advantages, such as more protection for the surrounding teeth and the alveolar bone. On the other hand, rehabilitation treatment using dental implants has been reported to increase mastication function and quality of life.[2] Therefore, a dental implant can be an essential treatment option for replacing missing teeth.[3]

Dental implants have a wide variety of success rates in dentistry. The quantity and quality of bone availability are the primary determinants in predicting the success rate of the dental implant. However, different sites in the jaw have different success rates.[4] The functional quality of alveolar bones is determined by bone density. Bone density has a critical effect on surgical technique, healing time, and time of loading during prosthodontic reconstructions.[5,6] The golden site for dental implant placement is in the site with high bone density. Otherwise, the success rate decreases when the bone has a lower density or is porous.[4] Assessing the bone tissue has two objectives: first, is the bone tissue sufficient for dental implant placement (as a diagnostic tool), and second, to predict the success rate of the dental implant (prognostic tool).[7]

Poor bone density is considered a risk factor for biological complications of the implant, associated with lack of primary stability and impaired healing or osseointegration, which can lead to early implant loss.[7] There are two strategies to evaluate bone quality and quantity. The direct estimation strategy incorporates ex vivo examinations (i.e., dry skulls or corpses) or sample/biopsy recovered for examination from creatures or human subjects and in vivo examinations done on living subjects.

The indirect estimation strategy depends on radiographic imaging, like registered tomography (CT) or cone-beam computed tomography (CBCT). These estimation methods give a three-dimensional depiction of bony structures. They are viewed as a precise diagnostic instrument that enables the assessment of the morphology, bone quality, and volume of the leftover alveolar ridge.[8] The American Academy of Oral and Maxillofacial Radiology (AAOMR) currently advocates using sectional imaging for all dental implant treatment.[9] CBCT provided volumetric data of the jaw with relatively low radiation doses and costs with high resolution.[6,10] Overall dental implant placement (implant size, angle, and type) can directly influence the alveolar bone quantity. On the other hand, the stability of dental implants is associated with bone quality. Therefore, a comprehensive assessment of both factors is essential.[11] Ivanova et al.[12] Concluded primary stability and secondary stability is determined by bone density.[12] Baltayan et al[7]. found a strong correlation between alveolar bone density and primary stability.[13]

Poor bone quality associated with lack of primary stability.[7] Therefore, to better understand the alveolar bone density of the edentulous area for dental implant planning using CBCT, we studied the edentulous area of the implant site on 93 patients who underwent preoperative evaluation using CBCT in our department in January 2018 – December 2021. The aims of this study is to analyzed the alveolar bone density of the dental implant sites for dental implant planning using CBCT.

METHODS

In a cross-sectional study, ninety-three CBCT data of patients randomly selected from the department of oral and maxillofacial radiology database at Dental Hospital Faculty of Dentistry Universitas trisakti (RSGMP-FKG Usakti) between January 2018 – December 2021 was evaluated. The CBCT data must meet the following inclusion criteria: CBCT data in patients aged a minimum of 20 years old and the radiograph taken between January 2018-December 2021, edentulous areas with the potential for dental implant placement in the jaw and the exclusion criteria is CBCT radiographs with poor quality.

Measurements Morita 3D Cone-Beam Computed Tomography (3D Accuitomo 170, J. Morita Co., Japan) was used to obtain patient 3D scan data at 90 KvP, 5 mA, and 80 μm voxel size exposure setting. Cross sectional view with 1.00 mm slice thickness was obtained. All CBCT data were evaluated by two calibrated oral and maxillofacial radiologists.

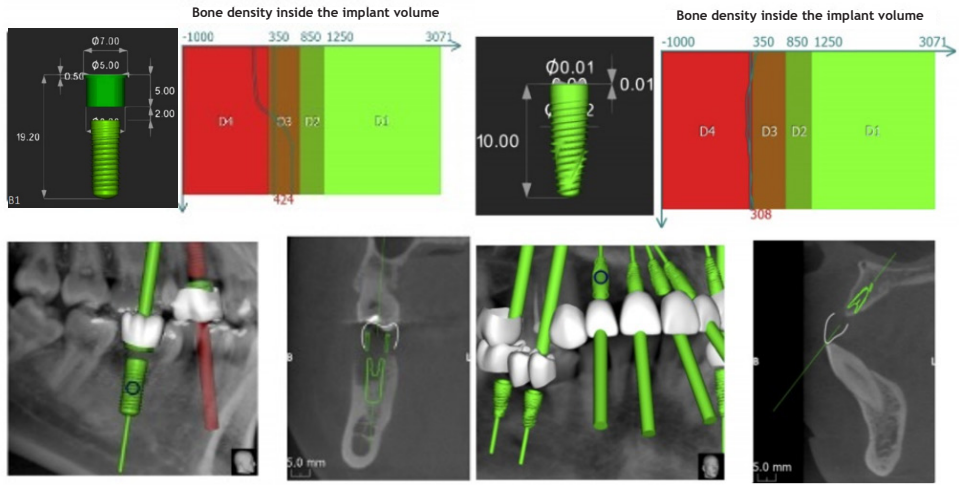

Figure 1. Bone density measurement. (A1) fixture simulation lower molar region (A2) bone density assessment lower molar region (A3) Sagital view showing implant fixture simulation at lower molar region (A4) Coronal view lower molar region (B1) fixture simulation upper incisive region (B2) bone density assessment upper incisive region (B3) Sagital view showing implant fixture simulation at upper incisive region (B4) Coronal view of upper incisive region.

Inter-observer agreement was calculated to verify the reliability of measurements. Bone density Head reorientation on CBCT images was undergone prior to bone density measurement. Bone density was measured using the software AIS-3D App by choosing an implant planning feature build on the software. The next step was to determine the region of interest or tooth area to be measured (incisive, premolar, molar in both jaws) followed by implant insertion in the selected region, and the bone density mean value inside the implant volume will be calculated (Figure 1).

Table 1. Interpretation of Cohen's Kappa (κ)

Cohen's Kappa (κ)	Strength of Agreement
<0.00	*Poor*
0.01-0.20	*Slight*
0.21-0.40	*Fair*
0.41-0.60	*Moderate*
0.61-0.80	*Substantial*
0.81-1.00	*Almost perfect*

Data analysis

We recorded the alveolar bone density data in Microsoft Excel then all statistical analyses conducted using SPSS Statistics for Windows V22 (IBM, USA). First, inter-observer reliability was observed using Cohen's Kappa (k) statistical analysis. The interpretation of Cohen's Kappa (k) can be seen in table 1.[14] Independent sample T-test was used to compare the mean difference between the male and female groups.

One-way ANOVA was used to compare the mean difference among age groups. Tukey post hoc analysis was used to compare all possible age group pairing when One-way ANOVA showed a significant difference. The study protocol was approved by the Komisi Etik Penelitian Kesehatan Fakultas Kedokteran Gigi Universitas Trisakti (Ethical clearance committee, No 024/S3/KEPK/FKG/7/2022)

RESULTS

Two observers evaluated the collected CBCT image data of 93 subjects. First, we divided the alveolar bones into maxillary and mandibular and then differentiated them into three regions: anterior, premolar, and molar.

The kappa coefficients of inter-observer A and B were 0.92, 0.91, and 0.87, respectively, for the maxillary anterior region, maxillary premolar region, and maxillary molar region, indicating almost perfect agreement. However, the kappa coefficients for the mandibular anterior region region bone density

Table 2. Inter-observer kappa coefficients

The Alveolar bones regions	Observer A to B
Maxillary Anterior Region	0.92
Maxillary Premolar Region	0.91
Maxillary Molar Region	0.87
Mandibular Anterior Region	0.70
Mandibular Premolar Region	0.95
Mandibular Molar Region	0.90

The result showed that mean maxillary anterior region bone density was 362.4±107.35 GV, maxillary premolar region bone density was 326.6±77.12 GV, maxillary molar region bone density was 322.0±103.21 GV, mandibular anterior, premolar, and molar region density were 557.8±160.29 GV, 402.8±111.06 GV, and 408.6±95.87 GV respectively (Table 3).

Table 3. The alveolar bones density

The Alveolar bones regions	Min	Max	Mean	Std. Deviation
Maxillary Anterior Region	195	587	362.4	107.35
Maxillary Premolar Region	172	582	326.6	77.12
Maxillary Molar Region	134	745	322.0	103.21
Mandibular Anterior Region	319	891	557.8	160.29
Mandibular Premolar Region	257	848	402.8	111.06
Mandibular Molar Region	173	681	408.6	95.87

Note: all result value describes in grayscale value (GV)

The distribution of male and female patients was 42 and 51 people. The mean maxillary anterior region bone density was 348.5 GV, 377.6 GV for males and females, and maxillary premolar region bone density was 313.8 GV, and 341.6 GV for males and females, maxillary molar region bone density was 296 GV and 342,4 GV. Therefore, the mandibular anterior region bone density was 518.5 and 656.2 for males and females, the mandibular premolar region bone density was 373.1 GV and 428.8 GV for males and females, and the mandibular molar region bone density was 407.6 GV and 409.5 GV for male and female. However, no statistically significant difference was observed when comparing the male and female group bone density (Table 4).

Table 4. Bone density analysis based on gender and age group.

The Alveolar bones Region	Mean±SD (GV) based on gender		p	Mean±SD (GV) based on Age Group			p
	Male	Female		21-45	46-60	>61	
Maxillary anterior region	348.5±117.4	377.6±98.4	0.52	314.5±69.1	366.2±122.4	440.6±35.5	0.25
Maxillary premolar region	313.8±79.2	341.6±73.9	0.26	294.2±73.4	329.6±84.5	356±53.6	0.21
Maxillary molar region	296±62.8	324.4±124.9	0.27	302.7±31	343.1±175.5	318.6±55.7	0.76
Mandibular anterior region	515.5±139.6	656.2±186.4	0.15	324.5±7.7	570.2±150.5	649.7±102.3	0.04*
Mandibular premolar region	373.1±90.4	428.8±123.3	0.17	389.7±55.7	412.2±154.9	399.5±54.8	0.90
Mandibular molar region	407.6±94.4	409.5±98.9	0.94	451.8±66	412.8±105.1	350.3±80	0.01*

Note : Grayscale Value (a number that represents the amount of attenuation of the X-ray beam by the material contained in each voxel or structural unit of the tomographic volume)
***p<0.05 = statistically significant difference**

The median age was 50.34, ranging from 21 to 82 years old. We divided the age group into three groups, ranging from 21-45 (young adult), 46-60 (middle adult), and>61 (elderly) according to WHO age group classification in 2015. The one-way ANOVA test was carried out.

Table 5. Multiple comparison using Tukey post hoc test

The Alveolar bones Region	Age Group	Age Group	*p*	95% Confidence Interval	
				Lower bound	Upper bound
	21-45	46-60	0.581	-181.54	78.11
Maxillary Anterior Region	21-45	>61	0.231	-314.31	61.98
	46-60	>61	0.518	-243.73	94.83
	21-45	46-60	0.458	-197.33	36.43
Maxillary Premolar Region	21-45	>61	0.194	-147.08	23.48
	46-60	>61	0.666	-100.85	48.15
	21-45	46-60	0.747	-178.83	98.01
Maxillary Molar Region	21-45	>61	0.951	-147.69	115.91
	46-60	>61	0.879	-102.34	151.39
	21-45	46-60	0.088	-526.46	34.96
Mandibular Anterior Region	21-45	>61	0.038*	-632.76	-17.73
	46-60	>61	0.599	-296.94	137.94
	21-45	46-60	0.898	-148.47	103.54
Mandibular Premolar Region	21-45	>61	0.984	-151.90	132.40
	46-60	>61	0.966	-113.29	138.72
	21-45	46-60	0.384	-31.61	109.51
Mandibular Molar Region	21-45	>61	0.012*	19.02	183.96
	46-60	>61	0.113	-11.38	136.46

***p<0.05 statistically significant difference**

No significant differences were found between the maxillary anterior region, maxillary premolar region, maxillary molar region, and mandibular premolar region (p=0.255, p=0.216, p=0.760, and p=0.903, respectively) compared to age groups (Table 4). However, the mandibular anterior and mandibular molar regions showed significant differences compared to age groups with p=0.45 and p=0.16. The multiple comparisons using Tukey post hoc clarify the differences only seen in the young adult group compared to elderly groups in the mandibular anterior and molar region (Table 5).

PEMBAHASAN

Bone density assessment is indispensable to achieving the best dental implant treatment planning and the primary stability of the dental implant.[15] Bone density is one predictor of successful dental implant treatment. Therefore, an accurate evaluation of the alveolar bone density is essential. CBCT is three-dimensional dental imaging widely used recently in dental medicine. One of the several advantages of CBCT dental imaging enables the assessment of bone density.[9] This study was conducted to assess the alveolar bone density of dental implant sites using the dental CBCT. A higher value of inter-observer reliability was observed in our study at table 2. Nevertheless, the mandibular anterior region has shown substantial agreement. This study's decrease in inter-observer reliability is thought to be because the available data for the mandibular anterior region is limited.

The result is that a slight difference in the assessment significantly influences the reliability. In line with the previous study, the agreement value of our result ranges from 0.70-0.95, and the previous study was 0.61-0.92.[16] Similar result was seen in a study conducted by Alkhader et al.[17] they showed the Cohen's kappa value was range from 0.77-0.93. The reliability of inter-observer reliability can be improved by practice and training in diagnostic imaging.[14]

The alveolar bone density was greater in females compared to males (Table 4). However, no statistically significant differences between male and female alveolar bone density were found. No data available from the previous study can be compared to our study. This is due to our CBCT data being recorded in grayscale value. Therefore, we try to compare the result with available data recorded in Hounsfield Unit (HU)

using Computed Tomography (CT). This decision was made based on a study that provided a strong correlation between GV of CBCT and HU of CT.[18] In contrast to our study, Cassetta et al.[19] found a statistically significant difference in alveolar bone density between gender, and they concluded that the density of the male alveolar bone was greater than that of females.[19]

A study conducted by Kim et al. was in line with Cassetta result; they found a statistical difference in the alveolar bone density between gender. However, in the study by Kim et al.[20] they showed a greater alveolar bone density was seen in females compared to males. Several risk factors may affect the density of the alveolar bone, such as gender, periodontal disease, osteoporosis,[21] tooth loss, menopause, and age.[22]

Our study showed that a great variety of alveolar bone density was found in the maxilla or mandibular. Statistically significant differences between age and alveolar bone density were observed in young adults compared to the elderly. Based on our result, age seems to affect alveolar bone density (Table 4). Other authors found different results that report that age does not affect the alveolar bone density value.[21]

Previously three-dimensional alveolar bones were evaluated using CT, including the alveolar bones density assessment. Consider the patient who received x-ray exposure. CT is not ideal for some diagnostic purposes in dental medicine due to the high dose of radiation, poor resolution, longer scanning time, difficult interpretation, high-cost charge, and limited availability.[23] To overcome the limitation, Arai et al.[24] (1999) in Japan and Mozzo et al.[25] (1998) in Italy at introduced cone-beam computed tomography (CBCT) for oral and maxillofacial application. The CBCT fulfils the needs, such as reducing unnecessary exposure to the patient, high resolution, rapid scan time, dose reduction, and reduced image artefact.[26]

The alveolar bone density plays a vital role in the mechanical immobilization of the dental implant during healing, distribution, and transition of stresses from the prosthesis to the implant-bone interface after healing. The availability of alveolar bone density determines the dental implant design, surgical approach, healing time, and initial progressive loading during prosthetic construction.[27] With the reason and data provided above, preoperative evaluation of the alveolar bone density prior to dental implant placement at the edentulous area planned to a received dental implant is mandatory.

The limitation of our study is we did not compare the alveolar bone density based on the left and right regions of the jaw and lack of data available from our database for the mandibular anterior region. Hopefully, in the future, a study could be conducted to overcome the limitation.

CONCLUSION

The highest alveolar bone density value was found on the mandibular anterior region, followed by the mandibular molar, mandibular premolar, maxillary anterior, maxillary premolar and maxillary molar regions. These conditions were noted in both gender and age groups. In the age group above 61 years old, the highest density of alveolar bone differences was found in the mandibular anterior region; however, the lowest density was noted in the mandibular molar region. The grayscale value in CBCT can be used to determine the alveolar bone density of dental implant sites.

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