A study on evaluation of trabecular bone density in partially edentulous maxilla

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Abstract

Evaluation of local bone density before implant placement plays a crucial role in treatment planning so that predictable successful outcome can be achieved. The aim of this study was to evaluate the trabecular bone density of partially edentulous maxilla using Cone Beam Computed Tomography (CBCT) images of patients who seek for implant treatment in the University of Dental Medicine, Mandalay, Myanmar.

Twenty patients (8 males, 12 females; mean age- 43.5 years) with partially edentulous maxilla from the Dental Implant Clinic of Department of Prosthodontics, University of Dental Medicine, Mandalay were included in this study. The trabecular bone density in each implant recipient site of partially edentulous maxilla: anterior maxilla (n=10) and posterior maxilla (n=13) were measured using OnDemand 3D software. Five regions of interest (1mmx1mm each) were determined in each implant recipient site to measure bone density of trabecular bone and the measurements were recorded in Hounsfield units (HU).

Mean bone density (±SD) of maxillary trabecular bone was highest in <40 yrs age group (386 ± 126 HU) followed by 41-60 yrs age group (323 ± 145 HU) and lowest in >61 yrs age group (319 ± 205 HU). There was no statistically significant difference within groups ($p > 0.05$). The mean bone density of male group was 396 ± 185 HU and mean bone density of female group was 321 ± 132 HU respectively. Although bone density seemed to be higher in male than female, the difference was not statistically significant ($p > 0.05$). The mean bone density of anterior maxilla and posterior maxilla were 439 ± 271 HU and 271 ± 143 HU respectively and the difference was statistically significant ($p < 0.01$).

In conclusion, bone density of posterior maxilla in the study population is poor and proper treatment planning for long term success is indicated.

Keywords: bone density, CBCT, implant, maxilla, trabecular bone

Introduction

Recently, the dental implant has become a reliable and predictable treatment option for oral rehabilitation. Although there are many factors influencing the clinical outcome of an implant such as the implant geometry, the surgical technique, skill of surgeon and so on, the key factor for success is the primary stability at the time of implant placement. Some studies have proved that the quality of the alveolar bone (bone density) is the most important factor for achieving good primary stability with subsequently increasing secondary implant

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stability (osseointegration) and the implant success rate [1,2]. Others have indicated that a greater incidence of implant failure occurs in poor quality bone (soft bone) [3,4].

Bone density is variable depending on anatomic location, whether anterior or posterior and maxilla or mandible. Lekholm and Zarb classified jaw bone density into four types based on the amount of cortical bone versus trabecular bone [5]. Moreover, Misch further classified jaw bone into D1 to D4 according to differing resistance during drilling procedures. The densest bone type is found in the anterior mandible (mainly D2, but D1 in about 6% of the population), followed by the posterior mandible (D2 and D3), the anterior maxilla (mainly D3, also D2 in 25% occurrence), and the posterior maxilla made of D3 bone and D4 bone. Therefore, posterior maxilla has the lowest bone density which is characterized by a thin layer of cortical bone enclosing a core of low-density trabecular bone [6].

Cone Beam computed tomography (CBCT) is an advanced imaging modality with several applications in dentomaxillofacial diagnosis and treatment planning. Cone Beam computed tomography (CBCT) is preferred for three-dimensional dental imaging because it has advantages in terms of cost, time, image resolution, and radiation dose over conventional Computed Tomography (CT). The CT numbers are expressed as Hounsfield unit (HU) which represents the relative density of body tissues according to a calibrated gray-level scale.

Evaluation and identification of local bone density before implant placement plays a crucial role in treatment planning so that predictable successful outcome can be achieved by the modification of the implant design and number, and placement procedure in poor bone density region. The quality of bone in the jaw has been studied previously and demonstrated that CBCT is useful for pre- and post-operative evaluation of bone quality [7-11]. The aim of this study was to evaluate the trabecular bone density of partially edentulous maxilla using CBCT images of patients who seek for implant treatment in the University of Dental Medicine, Mandalay, Myanmar.

Materials and methods

Inclusion / Exclusion criteria

Inclusion criteria;

1) Patients who are not having any endocrine diseases such as diabetes mellitus, Addison's disease, Cushing's syndrome and Graves's disease.

2) Patients who are not suffering any bone related diseases such as osteoporosis and Paget’s disease.

3) Patients who have good oral hygiene with healthy periodontium of remaining natural teeth

Exclusion criteria;

1) Patients with uncontrolled medical conditions such as hypertension, heart disease, liver disease and radiation to head and neck.

2) Patients who are currently taking bisphosphonates.

CBCT examinations of recipient implant sites

For this study, Cone Beam computed tomography (CBCT) images of 20 patients (8 males, 12 females; mean age- 43.5 years) with partially edentulous maxilla from the Dental Implant Clinic of Department of Prosthodontics (2019 January to 2020 January), University of Dental Medicine, Mandalay were included. The CBCT was taken with 5 mA, 89 kV for 2.3 s exposure time. A series of axially sliced image data were

exported to a personal computer and saved in DICOM format. All CBCT images were utilized to assess the bone density of partially edentulous maxilla within the two regions: the anterior maxilla (n=10) and the posterior maxilla (n=13). In partially edentulous maxilla, anterior and posterior regions were delimited by the mesial surface of the first premolar. So, anterior maxilla region included incisors and canine areas whereas premolar and molar areas included in the posterior maxilla region.

Measurements of Bone Density

The CBCT images were loaded into professional medical imaging software (OnDemand 3D, Cybermed Inc.) that enabled the construction of a three-dimensional model of each maxilla to measure the bone density of potential implant sites in partially edentulous maxilla. Five regions of interest (ROI) each with an area of 1mm² (1mmx1mm) were determined to measure bone density of trabecular bone. To avoid the cortical bone, the four ROIs (buccal crestal, buccal middle, palatal crestal, palatal middle) were positioned 0.5 mm away from the surrounding inner cortical bone and apical ROI at 10 mm as approximate implant height position (Figure.1). Then bone density measurements given in Hounsfield units (HU) were recorded.

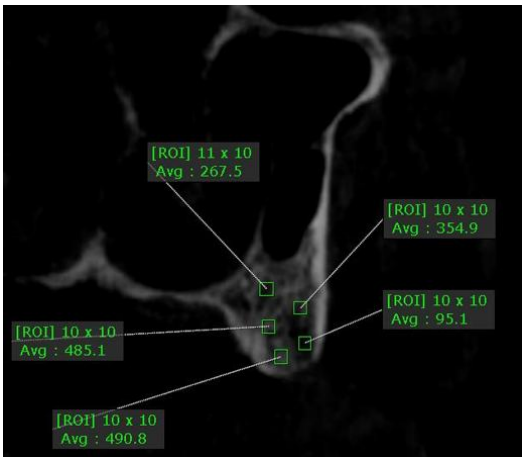

Figure 1. The five ROIs of alveolar bone measured in partially edentulous regions of the alveolar ridge.

The partially edentulous alveolar bone samples were divided into twelve groups according to region- of- interest and anatomical location: 1 – Buccal Crestal(BC) anterior maxilla, 2 – Buccal Crestal(BC) posterior maxilla, 3 – Buccal middle (BM) anterior maxilla, 4 – Buccal middle (BM) posterior maxilla, 5 – Palatal crestal (PC) anterior maxilla, 6 – Palatal crestal (PC) posterior maxilla, 7 – Palatal middle (PM) anterior maxilla, 8 – Palatal middle (PM) posterior maxilla, 9- Apical anterior maxilla, 10- Apical posterior maxilla, 11-Height of anterior maxilla, 12-Height of posterior maxilla. The data were subjected to statistical analysis using the Independent sample t- test and one-way ANOVA. The level of statistical significance was set at $P < 0.05$.

Results

There were 23 implant sites in 20 partially edentulous maxilla patients; 10 in the anterior maxilla and 13 in the posterior maxilla. These sites were divided into twelve groups, as described in the previously. Table 1 presents the descriptive statistics of the mean HU values of the alveolar bones from each group. Bone height was higher in anterior maxilla than posterior maxilla but statistically not significant ($p>0.05$).

Figure 2 showed the comparison of mean bone density between anterior and posterior maxilla regions of each five region of interest (ROI). The alveolar bone density ranged from 194 to 558 HU. The lowest HU value (194 ± 152 HU) was found in apical posterior maxilla region and the highest HU value (558 ± 175 HU) was found in buccal middle of anterior maxilla region. Among five ROIs, three groups (Buccal Crestal, Buccal middle and Palatal crestal) showed statistically significant difference between anterior maxilla and posterior maxilla ($p<0.05$).

Region- of-interest (ROI)	Anatomical location	Number of potential implant sites	Mean (HU)	Std. Deviation
Buccal Crestal BC	Anterior maxilla	10	479.83	228.66
	Posterior maxilla	13	248.03	166.47
Buccal middle BM	Anterior maxilla	10	558.38	175.99
	Posterior maxilla	13	284.40	208.34
Palatal crestal PC	Anterior maxilla	10	453.28	170.44
	Posterior maxilla	13	259.96	190.73
Palatal middle PM	Anterior maxilla	10	408.11	137.32
	Posterior maxilla	13	368.96	169.20
Apical	Anterior maxilla	10	299.46	155.13
	Posterior maxilla	13	194.38	152.59
Height	Anterior maxilla	10	13.84	4.00
	Posterior maxilla	13	10.99	2.89

Table 1. Descriptive statistics of the bone density values of the investigated alveolar bone areas

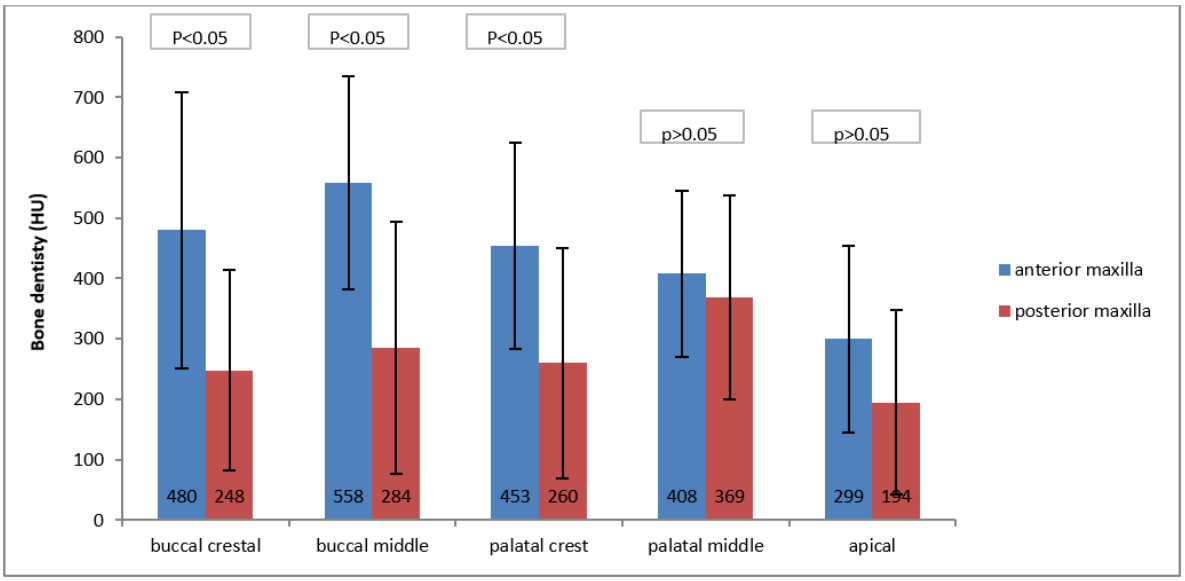

Figure 2.Mean bone density by Region- of- Interest and anatomical locations

The remaining two groups (Palatal Middle and Apical) did not show significant difference between anterior maxilla and posterior maxilla (p>0.05).

Figure 3 showed comparison of the mean bone density by anatomic location (between anterior and posterior maxilla). The mean bone density of anterior maxilla was 439 ± 271 HU and mean bone density of posterior maxilla was 271 ± 143 HU respectively and the difference was statistically significant (p<0.01).

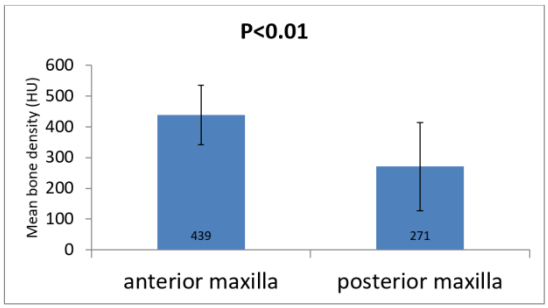

Figure 3. Mean bone density by anatomic location

Figure 4 showed the comparison of mean bone density by age and gender. Mean bone density was highest in <40 yrs age group (386 ± 126 HU) followed by 41-60 yrs age group (323 ± 145 HU) and lowest in >61 yrs age group (319 ± 205 HU). There was no statistically significant difference within groups (p> 0.05).

The mean bone density of male group was 396 ± 185 HU and mean bone density of female group was 321 ± 132 HU respectively. Although bone density seemed to be higher in male than female, the difference was not statistically significant (p> 0.05).

Discussion

Many studies have demonstrated that the success and survival rates of dental implants are significantly affected by the host bone quality [1,3]. Quantitative pre-

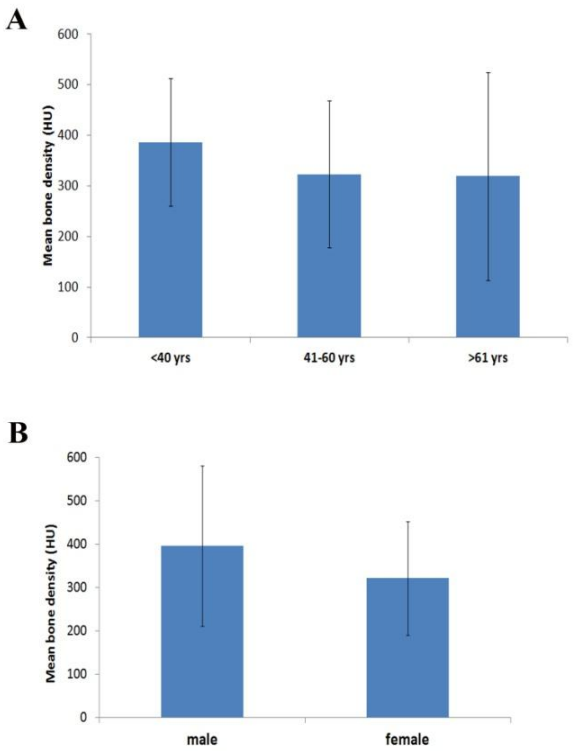

Figure 4. Mean Bone Density by (A) age and (B) gender

operative evaluation of bone density can provide the clinician diagnostic predictor of expected outcome as well as proper treatment planning such as choice of implant surface and design, diameter and length, modification of drilling protocol and subcrestal implant placement etc. Therefore, bone density assessment is crucial prior to every implant case to ensure the success of the treatment.

The acquisition of this pre-operative knowledge requires a reliable and suitable method of radiographic examination. In this study, alveolar bone density was assessed in implant sites of partially edentulous maxilla from CBCT images. CT numbers (HU) recorded with CBCT images represent an objective scale for bone density, which strongly correlates with subjective bone quality scores. The results showed that mean bone density of anterior maxilla was 439 ± 271 HU and mean bone density of posterior maxilla was 271 ± 143 HU showing significant difference between two regions (p<0.05).

According to subjective bone density classification of Misch's HU values, the bone density type observed in this study can be categorized as D3 bone type for anterior maxilla and D4 bone type for posterior maxilla (Table 2). This density scales would act as a prognostic indicator of expected outcome and help clinicians to modify the treatment plan including loading protocols.

It may be interesting to compare the bone density values of this study to others. Norton and Gamble recorded the mean CT numbers of 139 implant sites by using Computerized Tomography (CT) and reported that the average values of CT numbers were 970 HU for the anterior mandible, 696 HU for the anterior maxilla, 669 HU for the posterior mandible, and 417 HU for the posterior maxilla. They concluded that mean CT numbers (HU) of implant sites strongly correlate also with their anatomical location [7]. A study by De Oliveira et al., assessed 75 potential implant sites for trabecular bone density in terms of HU to establish a quantitative scale for each bone quality class. Mean voxel values for the anterior mandible was 383 HU, 370 HU for the anterior maxilla, 306 HU for the posterior mandible and 256 HU for the posterior maxilla. Dental CT measurements of quantitative parameters ranged from type 4 bone (<200 HU), types 2 bone and 3 (>200 to <400 HU), and bone type 1 (>400 HU) [12]. In this study, however, higher mean bone density values were observed than did de Oliveira et al., which might be due to the use of different types of software and method in the two studies.

Bone Classes	Description	Bone Density (HU)	Localization
D1	Dense cortical bone	>1250	Anterior mandible
D2	Porous cortical bone and dense trabecular bone	850-1250	Anterior and posterior mandible; Anterior maxilla
D3	Thin and porous cortical bone and thin trabecular bone	350-850	Anterior and posterior maxilla; Mandible
D4	Thin trabecular bone	150-350	Posterior maxilla
D5	Non mineralized bone (unsuitable for implant)	<150	-

Table 2. Misch's Classification of Bone Density (HU values)

The mean values of HU obtained in the present study (439 HU for the anterior maxilla and 271 HU for the posterior maxilla) are nearly comparable to the ones inferred by Fuh et al., and Hao et al., [8,9]. Fuh et al., analyzed CT scans of 35 women and 27 men, with a total of 154 potential implant sites from the Chinese jawbone using computed tomography (CT) images. The trabecular bone density was found to be the highest in the anterior mandible (530 HU), followed by the anterior maxilla

(516 HU), the posterior mandible (359 HU) and the posterior maxilla (332 HU). Hao et al., also examined CBCT recordings of 128 patients of 236 potential implant sites from the Chinese jawbone by using ProMax 3D CBCT. The mean bone density for anterior mandible was (679.6 ± 141.67HU), anterior maxilla (460.25 ± 136.42HU) and posterior mandible (394.4 ± 128.37HU) and posterior maxilla (229.62 ± 144.48HU) respectively. Their mean bone densities of anterior maxilla and posterior maxilla were round about 450 HU and 250 HU which were nearly consistent with the present study. This may be due to similar population (Asian) and using similar assessment method (CBCT) although sample sizes in the present study were lesser.

Using the same model ProMax 3D CBCT, David et al., analyzed CBCT images of 46 patients, recorded in identical conditions from 400 potential implant sites. They classified the sites in eight groups, according to gender and location (anterior and posterior regions of the mandible and the maxilla). Among the groups, the mean CT number of trabecular bones from the anterior maxilla of men was (473 HU), posterior maxilla of men was (250 HU), anterior maxilla of women was (354 HU) and posterior maxilla of women was (193 HU) and they concluded that the mean CT number is larger for men than for women for each anatomical region, but their difference is not significant from the statistical point of view [10]. This finding was consistent with our study (Figure.5). They also suggested that CBCT is able to detect differences in bone density and microstructure under identical conditions. Elkhidir et al., also studied feasibility of CBCT by evaluating density changes of bone before and after implant placement. In their study, CBCT detected a postoperative increase in bone density after every implant placement suggesting bone compression, which contributes to the implant stability. Therefore, they concluded that CBCT is reliable to perform pre- and post-operative evaluation of bone quality during dental implant procedures [11].

The posterior maxilla has always been the most challenging site to achieve success due to the softer bone type (D4 bone type according to present study) which makes initial stabilization difficult to achieve and due to a combination of periodontal bone loss and sinus proximity which limits available bone height for implants. Implication of encountering soft bone in maxilla includes modifying the treatment plan to improve the surgical options requires the following; modification of the drilling protocol to underprepare the osteotomy site, using the Osteotome technique which help initial stabilization by compressing the available soft bone [13], using tapered implants due to the wedging effect at the time of placement, bi-cortical fixation with engaging the sinus floor in the posterior maxilla helps anchor the fixture and placement of the platform of the implant at the crest or supra-crestal rather than countersinking into the crestal bone.

The limitations of this study were establishing the bone density measurement only in partially edentulous maxilla and a small sample size. Future studies should include larger samples and measure the bone density values before and after implant placement to evaluate the implant stability quotient, and survival rate of the dental implant with suitable loading protocol.

Conclusion

According to Misch's classification of the HU values, the bone density type observed in this study population can be categorized as D3 bone type for anterior maxilla and D4 bone type for posterior maxilla. Since bone density influences the

amount of bone in contact with implant surface, the information about the density of bone before the implant placement helps the clinician plan the implants and surgical protocol as well as monitor the healing period after the surgery and decide appropriate loading protocol.

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