EVALUATION OF BONE MINERAL DENSITY USING CONE BEAM COMPUTED TOMOGRAPHY

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ABSTRACT

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Introduction: Bone mineral density (BMD) is an important factor in the use of anchorage device. This study assessed the amount of bone density in the areas from 2.5 and 8.11 mm from maxillary alveolar to basal bone in Hounsfield units.

Methodology: The samples included 30 unilateral cleft palate (15 males and 15 females) with the mean age of 14.23±2.5 years and 30 non-clefts (15 males and 15 females) with the mean age of 14±2.59 years. CBCT was used to estimate the values of bone density in Hounsfield units in the cleft and noncleft patients. BMD was measured in 4 heights (2-5-8-11mm) from alveolar bone to basal bone in mesio-distal and bucco-lingual slices in the upper jaw. T-test was used to analyze the bone density values between the cleft and noncleft.

Results: The highest alveolar bone density in the mesio-distal slice was 1004± 6 HU between the right and left centrals in the upper jaw in height of 11 mm in non-cleft patients. The least amount of alveolar bone density in the mesio-distal slice was 259±29 HU in tuberosity in height of 11 mm in cleft patients. In non-cleft patients, the most amount of bone density was found 1639± 11 HU between the centrals in height of 11 mm in the bucco-lingual slice.

Conclusions: Bone density in cleft patients was lower than in non-cleft patients in all areas and maxillary tuberosity showed the lowest bone density in cleft and non-cleft patients.

Keywords: Cone Beam Computed Tomography; Bone Mineral Density; Dental Implants; Single-Tooth; Orthodontics.

1. Introduction

The amount of bone tissue is called bone mineral density (BMD)[1]. Assessment of BMD is necessary in many clinical conditions such as oral systemic diseases, implant planning and it also has an important role for the stability of mini-implants as anchorage [2,3]. Computed tomography (CT) is a diagnostic method before performing dental implant. It allows accurate three-dimensional evaluation of anatomical structures of the bone. It also measures BMD which it expresses in Hounsfield units (HU) [4]. Although CT is a diagnostic tool in medical practice, this method has not been broadly used in dentistry because of its high cost, presence of artifacts in images, high dose of radiation and complexity of examination.

Recently CT has been replaced by cone-beam computed tomography (CBCT) to evaluate anatomic structures and the direct measurement of mineralized tissue [5,6]. CBCT provides suitable image quality concomitant with a lower exposure dose. Fast scanning time, low cost and a lower number of image artifacts are the other advantages of CBCT when compared to CT [7-9]. CBCT scanning is associated with some drawbacks, such as poor soft tissue contrast, motion
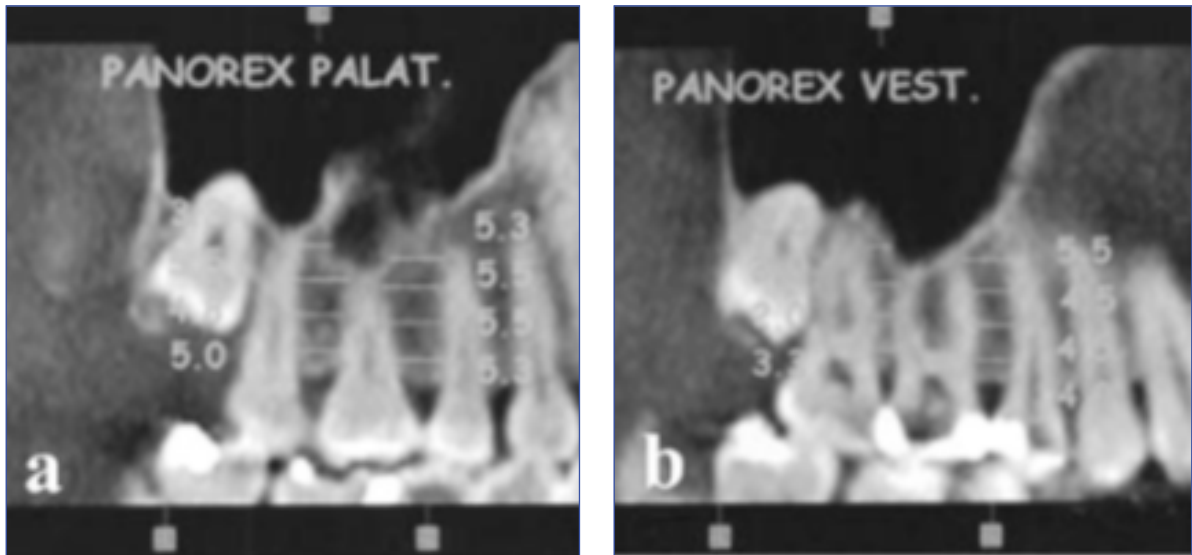
Figure 1. (a) Mesio-distal measurement on the palatal side; (b) Mesio-distal measurement on the buccal side.
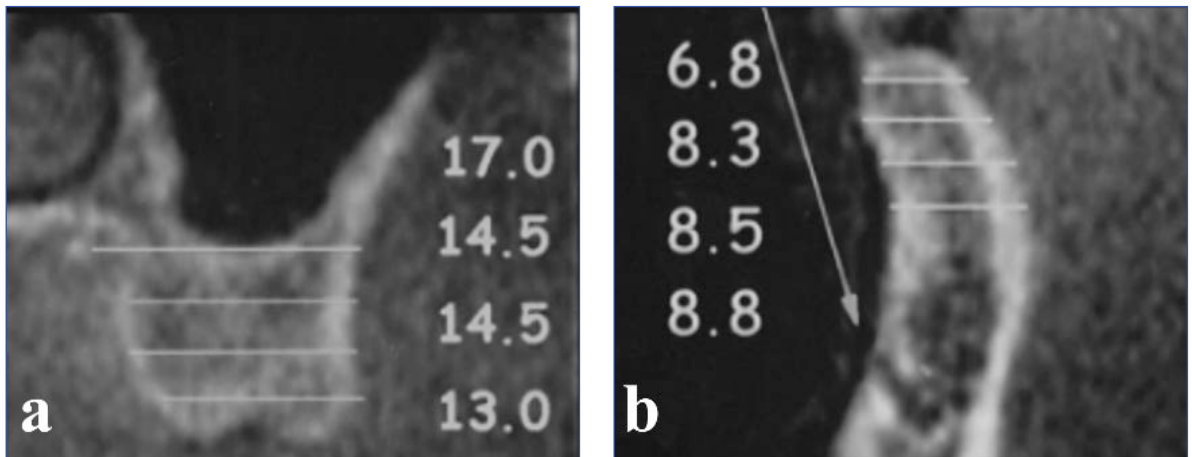

Figure 2. (a) Bucco-lingual measurement on the maxilla; (b) Bucco-lingual measurement on the mandible.

artifacts and image noise. Conventional CT may distinguish 70% of root fractures, but the higher cost and high dose of radiation limit the use of this technique [10].

BMD can be recognized by Gray values acquired with CBCT as the HU values [11]. CBCT provides a three-dimensional analysis with the quantification of the mineral density of jaws in Hounsfield units (HU) [3].

CBCT is a valuable method for diagnosis and treatment planning especially in cleft lip and palate patients because it offers better data about the size and appearance of the anatomic structures affected by the cleft, the position of missing teeth, the amount of BMD, as well as the position of mini screw, dental implants and so on. To our knowledge no study compared the BMD of cleft patients with non-cleft samples.

Therefore, due to the lack of research in this area the aim of this study was to compare the BMD of inter-radicular distances at heights of 2, 5, 8 and 11 mm measured from the alveolar bone crest to basal bone in HU obtained by CBCT in unilateral cleft palate and non-cleft patients.

2. Methodology

This research protocol was approved by the Ethics Committee at the Islamic Azad University, Dental School, Protocol number 25500. The participants in this retrospective research were 30 unilateral cleft palates (15 males and 15 females) with the mean age of 14.23+2.5 years and 30 non-cleft patients (15 males and 15 females) with the mean age of 14+2.59 years. The criteria to select the patients were as follows: no history of serious disease affecting oral bones, no periodontal problems, no previous fracture, no history of bone grafting, no previous orthodontic therapy, none of the patients were on hormone therapy or taking calcium, vitamin D, fluorides, calcitonin, bisphosphonates, no palatal fistula or infection. CBCT of all the patients were taken by the same radiologist for orthodontic treatment. All unilateral cleft palate patients had palatal closure before the age of 2. The CBCT (New Tom 5G; QR, Verona, Italy) was performed to assess BMD in the cleft and noncleft regions in all patients. The images were obtained at 120 kV and 8 mA. 0.2 mm³ voxel, 80 mm field of view BMD was calculated using the Xoran Cat software version 3.1.62 (Xoran Techno-

Table 1. BMD in Hounsfield units (HU) from the mesio-distal slice in the maxillary arch between teeth and tuberosity.

	Mesio-distal slice	2 mm	5mm	8 mm	11 mm
Region	Group	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD
1-1	Non-cleft Cleft	896±17 ** 884±5	935±6 ** 923±7	983±4 ** 973±5	1004±6 ** 994±5
2-1	Non-cleft Cleft	874±7 ** 862±9	916±5 ** 908±8	953±6 ** 941±8	994±5 ** 984±6
3-2	Non-cleft Cleft	851±6 ** 842±19	897±25 * 882±27	935±7 ** 923±9	945±5 ** 932±10
4-3	Non-cleft Cleft	845±25 * 832±26	872±28 860±29	896±27 885±27	915±34 904±34
5-4	Non-cleft Cleft	832±34 831±27	857±26 845±25	886±22 875±23	872±24 857±25
6-5 Palatal side	Non-cleft Cleft	934±61 913±40	980±89 951±37	954±72 927±35	645±50 634±50
7-6 Palatal side	Non-cleft Cleft	899±39 877±59	934±47 919±43	880±37 868±39	542±57 535±50
6-5 Buccal side	Non-cleft Cleft	825±42 814±43	846±38 838±35	870±41 855±42	643±47 626±46
7-6 Buccal side	Non-cleft Cleft	770±82 ** 721±63	671±90 660±88	773±79 759±77	406±81 397±79
Tuber	Non-cleft Cleft	650±125 643±107	566±129 539±105	408±98 407±64	265±55 259±29

** P 01/0>   * P 05/0>

logies, Ann Arbor, MI, USA). This software includes an application to outline the selected bone within a defined area and to provide the average BMD in HU. Using the Xoran Cat software, version 3.1.62 the slices were made in the alveolar bone height in the range of 2-5-8- to 11 mm from the alveolar crest to the basal bone in mesio distal slices and in bucco-lingual slices on the right and left sides of the maxillary arch. In other words, BMD was measured in 4 heights (2-5-8-11mm) from the alveolar bone to the basal bone in mesio distal and bucco-lingual slices in the following areas. Figures 1 and 2 show the mesio-distal and bucco-lingual measurement respectively. Between the right and left centrals (1 and 1); between the central and lateral incisors (1 and 2); between cuspids and first premolars (3 and 4); between the first and second premolars (4 and 5); between the second premolar and first molar (5 and 6); between the first and second molars (6 and 7); the region distal to second molars (7D) and tuberosity for both sides of the upper jaw. These heights were also measured on the palatal and buccal sides in mesio-distal slice only in the posterior region between the second premolar and first molar (5 and 6); between the first and second molars (6 and 7). Mean and standard deviations of BMD were measured for heights of 2-5-8 and 11 mm in cleft and non-cleft patients. T-test was used to analyze the bone density values between the cleft and noncleft. SPSS 18.0 (SPSS, Inc, Chicago, IL, USA) was used for statistical analysis. The differences were considered statistically significant with the p<0.05.

3. Results
The highest alveolar BMD in the mesio distal slice was 1004± 6 HU between the right and left centrals in the upper jaw in height of 11 mm in non-cleft patients. The least amount of alveolar BMD in the mesio-distal slice was 259±29 HU in the tuberosity in height of 11 mm in cleft patients. The highest amount of BMD in the posterior region found was 980± 89 HU which was between the second premolar and the first molar in a depth of 5 mm from the mesio-distal view in non-cleft patients and it was 927±35 HU in height of 8 mm in the same slice in cleft patients. The highest amount of BMD in the palatal side was 980±89 HU in 5 mm from alveolar crest in non-clefts patients and the lowest one was 626±46 HU in the buccal side in 11 mm from alveolar crest in clefts samples. Table 1

Table 2. BMD in Hounsfield units (HU) from the bucco-palatal slice in the maxillary arch between teeth and tuberosity.

Bucco-palatal slice		2 mm	5mm	8mm	11mm
Region	Group	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD
1-1	Non-cleft Cleft	615±5 ** 607±5	683±4 ** 671±6	783±6 ** 772±6	1639±11** 1582±26
2-1	Non-cleft Cleft	684±4 ** 673±7	764±6 ** 753±9	845±4 ** 836±6	1447±10** 1438±10
3-2	Non-cleft Cleft	756±6 ** 744±7	848±18 ** 837±6	903±6 ** 894±6	1257±10** 1248±10
4-3	Non-cleft Cleft	825±5 ** 819±7	924±5 ** 917±7	963±4 ** 949±8	1064±4 ** 1051±8
5-4	Non-cleft Cleft	934±6 ** 921±7	993±4 ** 981±8	1008±9 ** 1001±9	830±20 822±19
6-5	Non-cleft Cleft	1078±18 ** 1064±19	1159±21 ** 1146±20	1030±9 ** 1018±9	674±105 661±104
7-6	Non-cleft Cleft	1332±43 1331±44	1439±45 1427±45	1254±24 ** 1209±31	643±22 * 631±19
Tuber	Non-cleft Cleft	833±34 822±32	839±26 750±25	365±19 * 354±17	262±19 * 251±19

** P 01/0>   * P 05/0>

shows the means, standard deviations between the assessed areas on cleft and non-cleft patients in mesio-distal slices. The BMD of the anterior region of the maxilla in non-cleft patients was statistically higher than the cleft samples in the bucco-lingual slices in all areas. In non-cleft patients, the highest amount of BMD found was 1639±11 HU between the centrals in height of 11 mm in the bucco-lingual slices in non-cleft patients. The highest amount of BMD in the posterior region was found between the first and second molars in a depth of 5 mm from the bucco-lingual view in both cleft and non-cleft patients which was 1439±45 HU and 1427±45 HU respectively. There was no significant difference between the 2 groups in this area. The least amount of BMD found was 251±19 HU in tuberosity in height of 11mm in the bucco-lingual slice of cleft patients. Table 2 shows the values obtained for the means, standard deviations between the assessed areas on cleft and non-cleft patients in bucco-lingual slices.

4. Discussion

The result of this research can be used as additional information to select the most suitable area for anchorage devices such as mini- implants. These findings suggest that the best quality of alveolar bone density for mini implant installation from the mesio-distal view, may be in the posterior area between the second premolar and first molar in depth of 5 mm

from the crest of the alveolar bone and also in the bucco-lingual slide, may be between the first and second molars in a depth of 5 mm from the crest of alveolar bone in cleft and non-cleft patients. The insertion of mini-implants in this area, considering only the highest BMD as a factor for success, would be more interesting. But one must keep in mind that this does not always occur, because other factors may contribute to loosening the mini-implants. For mini implant installation there must be adequate cortical bone thickness and also high BMD. It is considered that BMD is a key factor for the stability of mini-implants as anchorage. BMD should be such so as to favor the mechanical retention of the mini implant in a predetermined position. There are many factors for losing mini-implants as anchorage and one of these factors is poor bone density [12-15]. BMD has an important role in a successful implant. Areas of lesser bone quality have exhibited weaker stability and higher failure rates of dental implants [16,17]. The data which one obtained from this study will serve as guidelines for choosing the best quality of alveolar BMD for the placement of mini implants or dental implants. There was a progressive increase in BMD from cleft to non-cleft patients in all areas. This study showed that the maxillary tuberosity area had a lower BMD and also showed that BMD was greater on the palatal side than the buccal side between second premolars and the first & second molars in both

groups. Due to this fact anchorage devices can be applied on the palatal side. On the other hand, with respect to the aesthetic concerns of the device, and for greater mechanical control, mini implants can be inserted in the lingual side[18]. BMD can be measured in HU by CT and CBCT [8]. With CT, BMD values are presented in Hounsfield Unit (HU) based on density of air (-1,000 HU) and pure water (0 HU).The density of cortical bone ranges from±1,000 to ±1,600 HU values [19]. Turkyilmaz et al [20] determined that BMD ranged from 278 to 1,227 HU in the jaws, with a mean of 751 HU. According to Turkyilmaz et al, the variability of the different amount of DBM in the literature is due to the effect of variables such as age and sex. BMD varies according the regions of the jaws and may be affected by many factors including osteoporosis, existence or absence of cleft [21-22].

Because of the high dosage of CT and lower dose of radiation exposure of CBCT, recently CBCT has been widely used for craniofacial imaging [23].

Pripatnanont et al [24] found that the mean BMD after grafting in the cleft site was 426.1±120.1 HU which was statistically lower than that in the non-cleft site with the mean value of 543.9 ±120.2 HU. Regarding the different types of secondary alveolar bone grafting in patients with cleft lip and palate, Scalzone et al [25] in a systematic review found that the autologous bone and the rh-BMP2 graft showed a similar effectiveness in maxillary alveolar reconstruction assessing bone graft volume and height, although the rh-BMP2 grafta relative shorter shelf life. The use of BMD using CBCT required high stability and reliability of gray values and a consistent correlation between quantitative gray values and density. Various limitations are associated with the use of Hounsfield unit values in CBCT. These issues relate to the limited-field of CBCT geometry, basic radiation physics principles and the assumptions and limitations of currently used reconstruction algorithms [25].

5. Conclusions

BMD in non-cleft patients was higher than in cleft patients in all areas; however, the mean BMD in non-cleft patients was significantly greater than in cleft patients from the upper left to the right canines in all areas in the medio-distal slice. Significantly higher BMD was found in the labial cortical plate between the centrals on the mesio distal direction in depth of 11 mm from the alveolar crest in cleft and non-cleft patients. The highest amount of BMD was found between the first and second molars on the bucco palatal area 5 mm from the alveolar crest in cleft and non-cleft patients and the differences between them were not statistically significant. The maxillary tuberosity showed the lowest BMD.

The amount of BMD was higher in the palatal side than the buccal side both in cleft and non-cleft patients between the second premolar and the first & second molars.

Author Contributions

MSN: responsible for study design, administration, data interpretation, recruitment, statistical analysis, literature review. ART: responsible for data interpretation, critical revision and final approval of the article. AJ: responsible for the study concept, study design, data interpretation, critical revision, writing and revising the report and final approval of the article. LN: responsible for the literature review. AAK: responsible for data gathering, LP: responsible for drafting, data interpretation, critical revision and final approval of the article.

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Questions

1. What is the amount of bone tissue?

❑a. Hounsfield unit;
❑b. Bone mineral density (BMD);
❑c. Bone resorption;
❑d. Bone remodeling.

2. Which one is used to evaluate anatomic structures and thr direct measurement of mineralized tissue before dental implant?

❑a. CBCT;
❑b. HU;
❑c. MRI;
❑d. CT.

3. What is the highest alveolar bone density in the mesio distal between … in the upper jaw in height of … mm in … patient?

❑a. Right and left centrals, 8, non-cleft;
❑b. Central and lateral, 11, non-cleft;
❑c. Right and left centrals, 11, non-cleft;
❑d. Central and lateral, 8, non-cleft.

4. Which is the highest amount of bone density in the posterior region?

❑a. First and second molars;
❑b. Second premolar and first molar;
❑c. First and second premolars;
❑d. Second and third molars.