Original Article

Association between Marginal Bone Loss and Bone Quality at Dental Implant Sites Based on Evidence from Cone Beam Computed Tomography and Periapical Radiographs

Abstract

Objective: The aim of this study was to assess bone quality in patient's preoperative cone beam computed tomography (CBCT) and their relation with marginal bone loss at implant placement sites over follow-up periods. **Materials and Methods:** In this retrospective cross-sectional study, 100 implants were evaluated. The implants had been placed in the maxillary and mandibular edentulous areas. Bone quality at implant placement sites was measured on preoperative CBCTs and then classified by two observers according to Lekholm and Zarb classification. Marginal bone height was then measured on periapical radiographs obtained at baseline and then 6, 12, 18, 24, and 30 months' follow-up periods from a reference point (implant shoulder) to the bone-implant interface. The relation between bone quality and bone loss was assessed. ANOVA was used to compare mean difference among groups and Pearson correlation coefficient to assess the correlation between observers. All statistical analyses were performed at 0.05 significance level using Stata 11 software (StataCorp, College Station, TX, USA). **Results:** Of 100 implants, 48 were placed in the maxilla and 52 in the mandible. There was no significant difference between bone quality and the mean bone loss at follow-up periods. Using Pearson's correlation coefficient, it was shown that with an increase in bone quality, marginal bone loss was decreased at follow-up periods. **Conclusions:** The results confirmed that during the follow-up periods, less bone loss was observed in implant areas with higher bone quality and CBCT is a reliable tool for assessing bone quality at implant placement sites and estimation of subsequent treatment prognosis.

Keywords: *Alveolar bone loss, bone density, cone beam computed tomography, dental implants*

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Introduction

Dental implants are reliable tools for replacement of lost teeth and are increasingly used in modern dentistry.[1,2] Studies have shown that osseointegrated implants have high success rates. This success depends on factors related to patient and surgical technique including overall oral hygiene status, biocompatibility of implant material, and characteristics of the implant surface.[3] However, quality and quantity of bone are two important factors on the strength of the implant-bone interface. Thus, they have a critical effect on surgical technique, healing time, and time of loading during prosthodontic reconstructions.[4-9] Bone quantity is defined as the height and width of the residual alveolar bone. The adequate bone quality is a critical prerequisite for achieving primary stability of dental implants. However, its accurate definition and technique of assessment have yet to be fully specified.[10] Several factors can influence the quality of bone namely the cortical bone thickness, volume of trabecular bone, and overall rate of mineralization. Bone quality is a key factor in achieving successful osseointegration of the implant. Thus, bone quality is important before implant insertion for treatment planning.[11]

Several definitions are suggested for bone quality,[12] but the most acceptable system of classification of bone tissue in the field of dentistry was introduced by Lekholm and Zarb.[13] They categorized bone quality into four types based on the observation of the amount of cortical bone versus spongy bone in a specific area of the alveolar process. It is assumed that implants inserted into areas of poor bone quality have higher odds of failure. However, such estimates are subject to controversy between the observers.[1,14]

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Multislice computed tomography (CT) has been used as a reliable tool to assess bone quantity and quality. However, the cost and the radiation dose absorbed by the patient during a CT scan are higher than that in other imaging modalities.[15-18] This limits its application for routine diagnostic workup or periodic examinations.[19]

In recent years, cone beam CT (CBCT) has been used as a specific tool for head and neck imaging.[20,21] The advantages of CBCT include high resolution, lower radiation dose, and lower cost compared to CT.[22] CBCT is also a valuable diagnostic tool for preoperative evaluation of implant treatment planning.[23] In addition to the subjective assessment of morphological bone characteristics, it is capable for quantitative measurement of bone at the possible implant site.[11]

This study was aimed to assess bone quality subjectively in edentulous areas using CBCT. The effect of this factor on the marginal bone loss was also evaluated in the follow-up periods using periapical radiographs.

Materials and Methods

In this retrospective cross-sectional study, data of patients who referred to private clinic in Hamadan province (Iran) between 2010 and 2011 were evaluated. Among 360 implants inserted in the edentulous areas, 100 implants (48 in the maxilla and 52 in the mandible, 24 were inserted in the anterior segment, 39 at the premolar, and 37 in the molar region) of 22 patients who had preoperative CBCT of the respective area and regular follow-up periapical radiographs were enrolled. The selected patients had all these criteria: Patients with no systemic diseases and no smoking. There had been no problem during their surgical healing. None of the implants had very high or very low insertion torque and also none of them were fresh socket and immediate loaded. The implants were inserted in one stage, and bone augmentation was not used in any of them. All of the implants were of the same brand and also were bone level type) collar of the implants were inserted up to the level of the cortical bone of alveolar crest). The only difference between the patients was the bone quality. According to the Lekholm and Zarb classification, the implant sites were divided into four subgroups. According to the similar studies,[24,25] the sample size was estimated 100 implants using power 0.96.

The implants were placed in both the maxillary and mandibular edentulous areas. The study protocol was approved by the Research Council of Hamadan University of Medical Sciences (Res. Number 16/71/3/1001).

CBCT of patients was obtained by Proma× 3D (Planmeca OY, Helsinki, Finland) at 84 Kvp, 12 mA, and 0.32 mm voxel size exposure setting. Cross-sectional views with 1 mm slice thickness and 1.5 mm step were obtained. The unnecessary radiation dose which should be imposed to patient made it impossible to obtain CBCT after implant placement. Thus, to determine the implant placement site on CBCT, postoperative periapical radiographs were used to obtain the implant sites for making the cross-sectional images and also the inter-implant distances. Then, a rectangle with the dimensions of the respective implant was inserted at the selected cross-section view for all 100 implants using software options. The section specified for each implant along with a mesially and a distally section of it was chosen, and each implant was assigned a specific code. A maxillofacial radiologist and an implantologist were asked to determine the bone quality at each edentulous area according to the Lekholm and Zarb classification[13] as follows using the three sections chosen for each implant:

- Type 1: Almost completely comprised of homogeneous compact bone
- Type 2: A thick layer of compact bone surrounding a central core of dense trabecular bone
- Type 3: A thin layer of compact bone surrounding a central core of dense trabecular bone
- Type 4: A thin layer of compact bone surrounding a central core of low-density trabecular bone.

The assessment condition was similar for both observers.

In order to measure bone density for classification of bone quality on CBCT of patients specified by gray value, region of interest (ROI) was determined in the form of a rectangle with the inserted implant dimensions from the marginal bone level in the respective cross-sectional view. The software expressed ROI density as minimum, maximum, mean, and standard deviation values [Figure 1]. This measurement was made for all 100 implants twice with a 3-week time interval.

Follow-up intraoral radiographs of patients were taken by Minray machine (Soredex, Tuusula, Finland) and the Digora Optime sensor (Soredex, Tuusula, Finland) using parallel technique. All images were available in their actual size and also at ×2 magnification printed on Kodak films.

Available follow-up periapical radiographs which was taken in 6, 12, 18, 24, and 30 months' interval from the time of

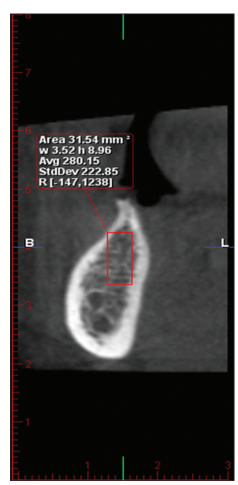

Figure 1: Example of demonstrating bone density measurement in a region of interest corresponding to the site of implant placement

loading assessed to measure the amount of marginal bone loss from a reference point namely implant shoulder to the nearest bone-implant interface [Figure 2]. Measurements were compared with the position of marginal bone level on the radiograph obtained immediately after loading (baseline radiograph). The measurements were repeated in all periapical radiographs 3 weeks later.

We used ANOVA to compare mean difference among groups and used Pearson correlation coefficient to assess the correlation between observers. All statistical analyses were performed at 0.05 significance level using Stata 11 software (StataCorp, College Station, TX, USA).

Results

A total of 22 patients (12 females and 10 males) with a mean age of 42.63 years (range 18–61 years) were enrolled and 100 implants (48 in the maxilla and 52 in the mandible) were evaluated. Of 100 implants, 24 were inserted in the anterior segment, 39 at the premolar, and 37 in the molar region of both jaws.

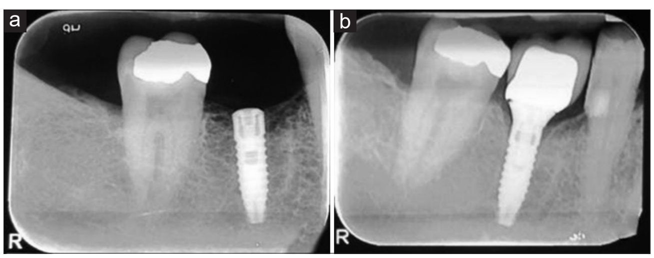

Figure 2: Periapical radiographs: (a) base line, (b) follow-up after 30 months

At the completion of given follow-up periods, all implants were completely osseointegrated and showed 100% success rate.

The mean bone loss during the follow-up periods and bone quality is demonstrated in Table 1. There was no significant difference between bone quality and marginal bone loss.

The mean bone density across different bone quality levels is shown in Table 2. Accordingly, the mean bone density was 724.1 in D1, 489.1 in D2, 344.6 in D3, and 245.2 in D4.

The correlation between mean bone loss and bone density (mean gray value) obtained from CBCT at different follow-up times is shown in Figure 3. Table 3 indicates the Pearson's correlation coefficient between these two variables. Except for the 1st 6 months, by increasing bone quality, bone loss decreased at later follow-up periods.

The interobserver agreement for bone quality was found to be 52% using Kappa statistic [Table 4]. The highest disagreement between the two observers was in bone quality of D2 and D3. Furthermore, the intraclass correlation coefficient for mean bone density and bone loss measurements is shown in Table 5.

Discussion

Preoperative evaluation of bone is critical for implant treatment planning. This may assist the surgeon in determining the appropriate site of implant placement and can reveal the need for bone grafting or application of specific surgical techniques. Such assessment improves the accurate determination of prognosis and increases the implant success rate.[1]

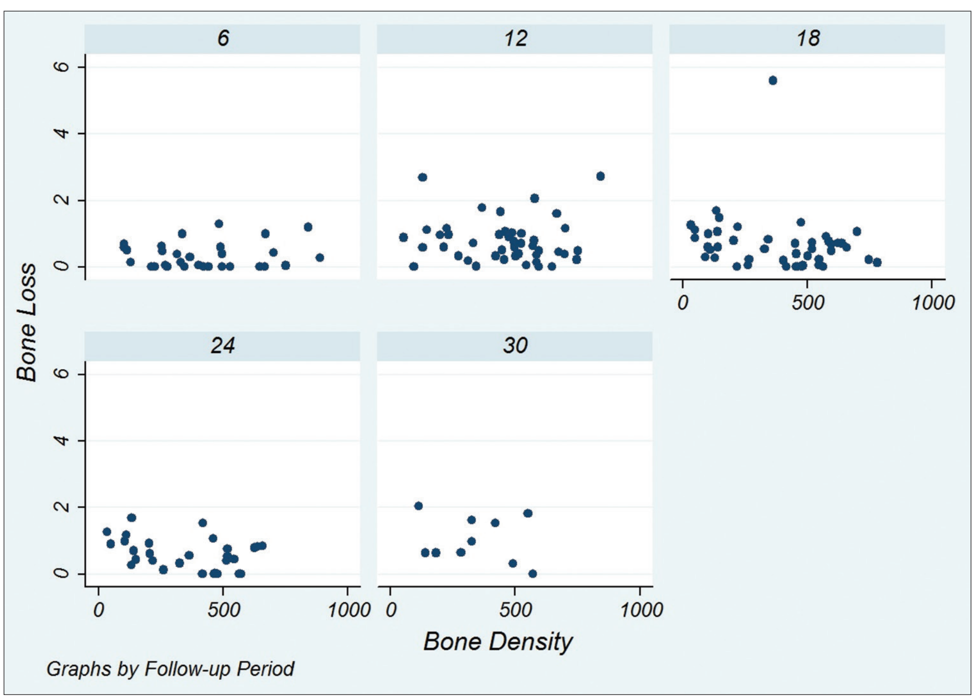

Figure 3: The correlation between mean bone loss and bone density during different follow-up periods

Table 1: The effect of bone quality on marginal bone loss by duration of time and observer using ANOVA test

Bone loss (mm)	6 months		12 months		18 months		24 months		30 months	
Bone quality	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Observer A										
D1	0.62	0.81	1.34	1.15	ND	ND	ND	ND	ND	ND
D2	0.26	0.34	1.00	0.81	0.46	0.39	0.48	0.48	1.28	0.79
D3	0.41	0.50	0.69	0.36	0.84	1.12	0.72	0.46	0.64	0.27
D4	0.32	0.27	0.53	0.38	0.62	0.50	ND	ND	ND	ND
P	0.655		0.106		0.431		0.184		0.165	
Observer B										
D1	0.04	-	1.28	1.11	ND	ND	ND	ND	ND	ND
D2	0.56	0.53	1.12	0.99	0.26	0.30	0.49	0.34	1.73	0.14
D3	0.24	0.36	0.78	0.58	0.82	1.03	0.62	0.51	1.04	0.79
D4	0.30	0.26	0.48	0.34	0.62	0.44	0.92	-	0.53	0.19
P	0.272		0.127		0.313		0.704		0.168	

SD: Standard deviation

Table 2: The relation between subjective bone quality assessment using Lekholm and Zarb classification versus objective bone density assessment using cone beam computed tomography

Bone quality	Bone density				
	n	Mean	SD	Minimum	Maximum
D1	3	724.1	134.1	578.4	842.4
D2	35	489.1	188.4	112.7	887.7
D3	44	344.6	189.2	35.1	780.2
D4	18	245.2	150.4	52.2	585.4

SD: Standard deviation

Table 3: Pierson correlation coefficient (ρ) between bone density and bone loss by duration of time

Duration of time (m)	ρ
6	+0.0926
12	−0.3009
18	−0.1857
24	−0.3462
30	−0.2036
Total	−0.1209

Table 4: Reliability of the 1st and 2nd observers using Kappa statistics (*n*=0.52%)

Observer A	Observer B			
	D1	D2	D3	D4
D1	2	1	0	0
D2	0	15	20	0
D3	0	3	34	7
D4	0	0	0	18

CBCT is a valuable tool for assessing bone quality and quantity and is vastly used before implant surgery. In this study, the correlation of implant success and bone quality and density at implant sites was evaluated using CBCT.

Limitation of this study was that because of the high exposure dose and expense of CBCT, we could not take the CBCT images postoperatively to control the marginal bone loss. Hence, we used intraoral periapical radiographs for this mean which is a standard protocol for assessing the success of implants postoperatively.[26]

To the best of our knowledge, no study has evaluated the correlation of bone density obtained from preimplant CBCT with marginal bone loss and the treatment outcome in follow-up periods.

The study results did not reveal a statistically significant difference in marginal bone loss between implants inserted in bones of different qualities during follow-up periods.

Shapurian *et al*. evaluated the correlation of Hounsfield units values with the Lekholm and Zarb classification.[13] and assessed the inter-observer agreement that was low in the evaluation of bone quality based on this classification ($r = 0.65$, $P < 0.001$).[14] In our study, Kappa value was 52% indicating low interobserver agreement in the determination of bone quality. Furthermore, the highest disagreement was seen for determination of Type 2 and Type 3 bones. This finding can be attributed to the subjective nature of the Lekholm and Zarb classification.

Bone quality at implant site is an important factor for long-term success of osseointegrated implants.[4,27-29] In routine follow-up examinations, there is no need for obtaining CBCT. Benson reported periapical and panoramic radiographies as the imaging techniques of choice for implant remodeling in maintenance periods.[26] Thus, it seems logical that none of the patients had postimplant CBCT. Therefore, periapical radiographs obtained after implant placement were used to select the implant insertion sites for assessment bone quality in initial CBCTs.

Accurate determination of the region for measuring bone density is challenging. In 2008, de Oliveira *et al*. conducted a study and reported that trabecular bone density as an important factor in achieving adequate osseointegration.[30] The reason was that the trabecular bone is responsible for

Table 5: Pierson correlation coefficient for within observer

2nd observation	1st observation					
	Baseline	6 months	12 months	18 months	24 months	30 months
Baseline	0.9393	-	-	-	-	-
6 months	-	0.9890	-	-	-	-
12 months	-	-	0.9902	-	-	-
18 months	-	-	-	0.8937	-	-
24 months	-	-	-	-	0.8375	-
30 months	-	-	-	-	-	0.7770

biologic response and mechanical support of implants. Aranyarachkul *et al*. calculated the upper 1 mm of the coronal one-third of ROI separately and reported that in many cases the upper part of crestal bone is resected during osteotomy.[19] Bergkvist included the cortical bone present in alveolar ridge crest into ROI because he believed that this part of alveolar crest included implant placement site.[10] Other studies stated different opinions regarding the inclusion of cortical bone in ROI.[2,9,31] In our study, implants length and diameter were used for determining ROI and also marginal bone was included in it. Intraexaminer correlation for bone density measurement was 0.99 indicating its high reproducibility.

The mean bone density had a wide range in D2 and D3, and the highest superimposition of bone density values was between these two bone types. However, it seems that this superimposition has no effect on treatment planning.

Our study showed that during the 30-month follow-up period, bone loss decreased by increasing bone quality. Considering the retrospective nature of this study, it can be concluded that aside from the applications of pretreatment CBCT namely the evaluation of distance from critical anatomic landmarks such as inferior alveolar canal and maxillary sinus and also measurement of buccolingual cortex dimensions, determination of bone quality in preoperative CBCT is a great help to implant treatment planning due to its high reproducibility and objective nature.

Our study results suggested that CBCT may be considered as a reliable tool for determining the appropriate site for implant placement and the treatment prognosis.

Clinically, the operator can aware the patients with the bone Types 1 and 4 that the prognosis of implants is not good as for the patients by the bone Types 2 and 3.

Future prospective studies with matched perioperative conditions and more regular follow-up as well as the comparison of bone density on different CBCT machines are recommended to eliminate the existing ambiguities on the effect of bone density on implant success rate.

Conclusions

This study confirmed that CBCT is a reliable tool for determination of bone quality at the implant placement sites preoperatively and consequently determining the treatment prognosis. The results showed that during a 30-month follow-up, increasing bone quality at the implant site was associated with less bone loss.

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Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Fuh LJ, Huang HL, Chen CS, Fu KL, Shen YW, Tu MG, *et al.* Variations in bone density at dental implant sites in different regions of the jawbone. J Oral Rehabil 2010;37:346-51.
2. Turkyilmaz I, Tözüm TF, Tumer C. Bone density assessments of oral implant sites using computerized tomography. J Oral Rehabil 2007;34:267-72.
3. Beer A, Gahleitner A, Holm A, Tschabitscher M, Homolka P. Correlation of insertion torques with bone mineral density from dental quantitative CT in the mandible. Clin Oral Implants Res 2003;14:616-20.
4. Jaffin RA, Berman CL. The excessive loss of branemark fixtures in type IV bone: A 5-year analysis. J Periodontol 1991;62:2-4.
5. Esposito M, Hirsch JM, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. (I). Success criteria and epidemiology. Eur J Oral Sci 1998;106:527-51.
6. Friberg B, Jemt T, Lekholm U. Early failures in 4,641 consecutively placed brånemark dental implants: A study from stage 1 surgery to the connection of completed prostheses. Int J Oral Maxillofac Implants 1991;6:142-6.
7. Herrmann I, Lekholm U, Holm S, Kultje C. Evaluation of patient and implant characteristics as potential prognostic factors for oral implant failures. Int J Oral Maxillofac Implants 2005;20:220-30.
8. Jemt T, Lekholm U. Implant treatment in edentulous maxillae: A 5-year follow-up report on patients with different degrees of jaw resorption. Int J Oral Maxillofac Implants 1995;10:303-11.
9. Shahlaie M, Gantes B, Schulz E, Riggs M, Crigger M. Bone density assessments of dental implant sites: 1. Quantitative computed tomography. Int J Oral Maxillofac Implants 2003;18:224-31.
10. Bergkvist G, Koh KJ, Sahlholm S, Klintström E, Lindh C. Bone density at implant sites and its relationship to assessment of bone quality and treatment outcome. Int J Oral Maxillofac Implants 2010;25:321-8.
11. Valiyaparambil JV, Yamany I, Ortiz D, Shafer DM, Pendrys D, Freilich M, *et al.* Bone quality evaluation: Comparison of cone beam computed tomography and subjective surgical assessment.

Int J Oral Maxillofac Implants 2012;27:1271-7.
12. Fyhrie DP. Summary – Measuring "bone quality". J Musculoskelet Neuronal Interact 2005;5:318-20.
13. Lekholm U, Zarb G. Patient selection and preparation. In: Branemark PI, Zarb G, Alberktsson T, editors. Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence; 1985. p. 199-209.
14. Shapurian T, Damoulis PD, Reiser GM, Griffin TJ, Rand WM. Quantitative evaluation of bone density using the hounsfield index. Int J Oral Maxillofac Implants 2006;21:290-7.
15. Ekestubbe A, Thilander A, Gröndahl K, Gröndahl HG. Absorbed doses from computed tomography for dental implant surgery: Comparison with conventional tomography. Dentomaxillofac Radiol 1993;22:13-7.
16. Ekestubbe A, Thilander A, Gröndahl HG. Absorbed doses and energy imparted from tomography for dental implant installation. Spiral tomography using the scanora technique compared with hypocycloidal tomography. Dentomaxillofac Radiol 1992;21:65-9.
17. Frederiksen NL, Benson BW, Sokolowski TW. Effective dose and risk assessment from computed tomography of the maxillofacial complex. Dentomaxillofac Radiol 1995;24:55-8.
18. Dula K, Mini R, van der Stelt PF, Lambrecht JT, Schneeberger P, Buser D, *et al.* Hypothetical mortality risk associated with spiral computed tomography of the maxilla and mandible. Eur J Oral Sci 1996;104:503-10.
19. Aranyarachkul P, Caruso J, Gantes B, Schulz E, Riggs M, Dus I, *et al.* Bone density assessments of dental implant sites: 2. Quantitative cone-beam computerized tomography. Int J Oral Maxillofac Implants 2005;20:416-24.
20. Eskandarloo A, Mirshekari A, Poorolajal J, Mohammadi Z, Shokri A. Comparison of cone-beam computed tomography with intraoral photostimulable phosphor imaging plate for diagnosis of endodontic complications: A simulation study. Oral Surg Oral Med Oral Pathol Oral Radiol 2012;114:e54-61.
21. Shokri A, Eskandarloo A, Noruzi-Gangachin M, Khajeh S. Detection of root perforations using conventional and digital intraoral radiography, multidetector computed tomography and cone beam computed tomography. Restor Dent Endod 2015;40:58-67.
22. Isoda K, Ayukawa Y, Tsukiyama Y, Sogo M, Matsushita Y, Koyano K, *et al.* Relationship between the bone density estimated by cone-beam computed tomography and the primary stability of dental implants. Clin Oral Implants Res 2012;23:832-6.
23. Angelopoulos C, Aghaloo T. Imaging technology in implant diagnosis. Dent Clin North Am 2011;55:141-58.
24. Turkyilmaz I, McGlumphy EA. Influence of bone density on implant stability parameters and implant success: A retrospective clinical study. BMC Oral Health 2008;8:32.
25. Turkyilmaz I, Tumer C, Ozbek EN, Tözüm TF. Relations between the bone density values from computerized tomography, and implant stability parameters: A clinical study of 230 regular platform implants. J Clin Periodontol 2007;34:716-22.
26. Benson BW, Shetty V. Implants. In: White SC, Pharoah MJ, editors. Oral Radiology: Principles and Interpretation. St. Louis: Mosby; 2014. p. 630-45.
27. Becker W, Hujoel PP, Becker BE, Willingham H. Osteoporosis and implant failure: An exploratory case-control study. J Periodontol 2000;71:625-31.
28. Wactawski-Wende J, Grossi SG, Trevisan M, Genco RJ, Tezal M, Dunford RG, *et al.* The role of osteopenia in oral bone loss and periodontal disease. J Periodontol 1996;67 Suppl 10S: 1076-84.
29. Hounsfield GN. Computerized transverse axial scanning (tomography). 1. Description of system. Br J Radiol 1973;46:1016-22.
30. de Oliveira RC, Leles CR, Normanha LM, Lindh C, Ribeiro-Rotta RF. Assessments of trabecular bone density at implant sites on CT images. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105:231-8.
31. Norton MR, Gamble C. Bone classification: An objective scale of bone density using the computerized tomography scan. Clin Oral Implants Res 2001;12:79-84.