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Cone beam CT Versus DXA For Evaluation of Bone Density Around Dental Implant in Vitamin D Deficient Patients

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ABSTRACT

Aim: The present study aimed to assess the accuracy of CBCT for evaluation of maxillary bone density. **Subjects & Methods:** The study was conducted on twelve vitamin D deficient patients indicated for posterior maxillary rehabilitation. Patients were divided into two groups: Group A received vitamin D and calcium supplement while Group B was a control group. First parameter was overall body bone density using Dual-energy X-ray absorptiometry (DXA) while second parameter was maxillary bone density using CBCT. **Results:** Group A showed a significant increase in vitamin D levels from 12.75 to 26.64 ng/ml ($p < 0.05$). this increase in vitamin D was accompanied by increase in bone density of spine from - 1.48 to - 1.08 T-score ($p > 0.05$). On the other hand, group B did not show similar improvements either at vitamin D or bone density of spine. Nevertheless, assessment of maxillary bone density using CBCT showed improvement in group B greater than group A. **Conclusion:** CBCT can be used as a relative rather than a reliable indicator of bone density

KEYWORDS

Dental implant, Vitamin D, Calcium, Bone density, CBCT and DXA.

INTRODUCTION

The achievement of long-term stable functioning of dental implants is ensured by osseointegration[1]. This complex phenomenon depends on many factors including bone density[2]. over the years, many independent clinical groups, following a standardized surgical protocol, documented the indisputable influence of bone density on clinical success [3].

Engquist et al. observed that 78% of all reported implant failures were in soft bone types [4]. Friberg et al. observed that 66% of their group's implant failures occurred in the resorbed maxilla with soft bone[5]. Jaffin and Berman in a 5-year study reported a 44% implant failure rate when poor-density bone was observed in the maxilla [6].

Misch proposed four bone density groups [7,8]. For each bone density type, suggested treatment plans, implant design, surgical protocol, healing, and progressive loading time spans have been described [9, 10].

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Following this regimen, similar implant survival rates have been observed for all bone densities [11, 12].

The bone density may be determined by various techniques including tactile sensation during surgery, general location or radiographic evaluation. Periapical or panoramic radiographs are minimally beneficial in determining bone density, because of their two-dimensional nature and the lateral cortical plates often obscure the trabecular bone density. Bone density may be more precisely determined using computerized tomography [13-16].

With conventional Computed Tomography (CT), each image is comprised of pixels. Each pixel in the CT image is assigned a number, also referred to as a Hounsfield unit (HU) or CT number. In general, the higher the CT number is the denser the tissue. HUs has been correlated with bone density and treatment planning for dental implants [13-16].

Many studies have demonstrated that the grey levels taken from CBCT (Cone Beam Computed Tomography) scans can be used to derive Hounsfield units in a clinical environment. This capability along with the decreased patient radiation exposure, ease of access, greater resolution than medical CT and affordability should solidify CBCT as the imaging modality of choice in dental implant placement [17,18].

For radiographical evaluation of overall body bone density, Dual energy X ray absorptiometry (DXA) was used. DXA is an extremely accurate and precise method for quantifying bone mineral density (BMD) [19]. For bone density, regions with higher contents of cancellous bone, such as the spine and total hip, are scanned because they are more sensitive to osteoporotic and treatment changes [20].

In our study, T score was used as the indicator for assessment of bone density . The T score is calculated as the difference between the patient's BMD and a young reference BMD in units of the population standard deviation [19].

Table (1) *WHO criteria for diagnosing osteoporosis from T-score* [21].

Status	Criteria
Normal	T score at –1.0 and above
Low bone mass (Osteopenia)	T score between –1 and –2.5
Osteoporosis	T score at or below –2.5

With this background in mind, the purpose of this study was to check the reliability of CBCT as an accurate measure of maxillary bone density .

MATERIALS AND METHODS

A total of 12 patients were included in this study. Inclusion criteria were as follows: need for implant treatment in the maxillary posterior area, healed edentulous area for at least 6 months after extraction and vitamin D serum level less than 20 ng/ml (vitamin D deficiency level). Patients chosen were non-smokers and healthy without any systemic or metabolic conditions that may contraindicate dental implant placement or affect bone health. Patients were divided randomly into two groups:

Group **A**: Patients received vitamin D in the form of cholecalciferol intramuscular injection (equivalent to 300,000 I.U. once a month for three months) and calcium in the form of Ca carbonate tablet (equivalent to 600 mg elemental calcium once daily for six months). Supplementation started immediately post-operative.

Group **B**: Patients have not received any supplements during the healing period.

CBCT (Orthophos SL, Dentsply, USA) was performed for every patient prior to the surgical intervention to determine the bone height and width at the proposed implant site. For all cases, a dental implant of at least 8.5 mm in length and 4.5 mm in diameter was planned to be placed. A para-crestal incision along with mesial and distal sulcular incisions around the neighboring teeth were made, and a full thickness flap was raised.

The implant osteotomy was initiated using a 2-mm pilot drill at a speed of 1000 rotation per minute (RPM) in a clockwise direction. Then Densah burs (Versah LLC, USA) were used at a speed of 1000 RPM in counter clockwise direction in the sequence recommended by the manufacturer. The implant was installed using surgical handpiece, at speed 20 RPM and torque 35N/cm. Once the implant has been successfully seated, implant stability using Osstell device were recorded. After that, the cover screw was placed and the wound was closed with interrupted sutures.

Assessment of maxillary bone density using CBCT and BMD of spine and total hip using DXA scan was carried out immediately post-operative and at loading time after 6 months.

In addition to implant stability measurement using Osstell device, a second evaluation of vitamin D and calcium serum levels was performed at loading time

Statistical analysis

Data in the current study are presented as mean ± standard deviation. Data were explored for normality using Kolmogorov–Smirnov and Shapiro–Wilk tests. Satisfaction data showed parametric (normal) distribution. Independent sample t test was used to compare between two groups in non-related samples. Pearson test was used to examine correlation between different parameters. The significance level was set at $p \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

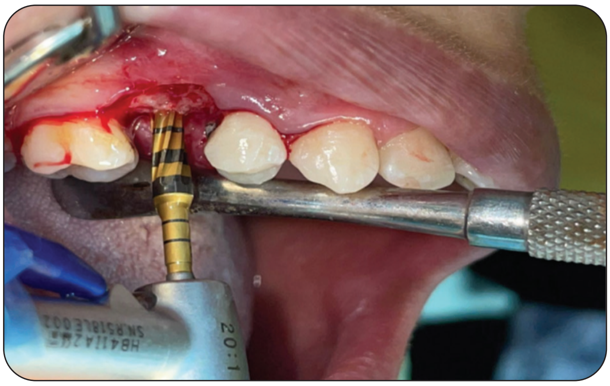

Fig. (1) Clinical photograph showing the use of Densah burs.

Fig. (2) Clinical photograph showing implant placement using surgical handpiece.

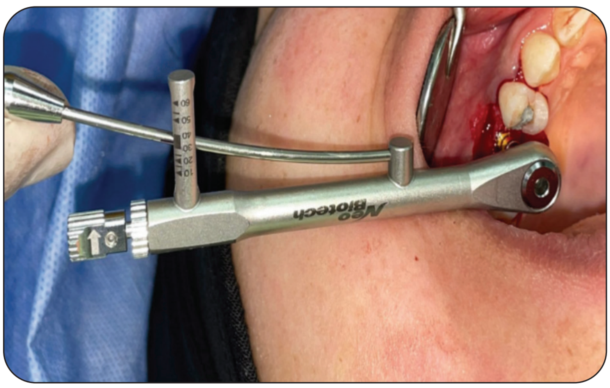

Fig. (3) Clinical photograph showing measurement of insertion torque using torque wrench.

Fig. (4) Clinical photograph showing secondary implant stability measurement.

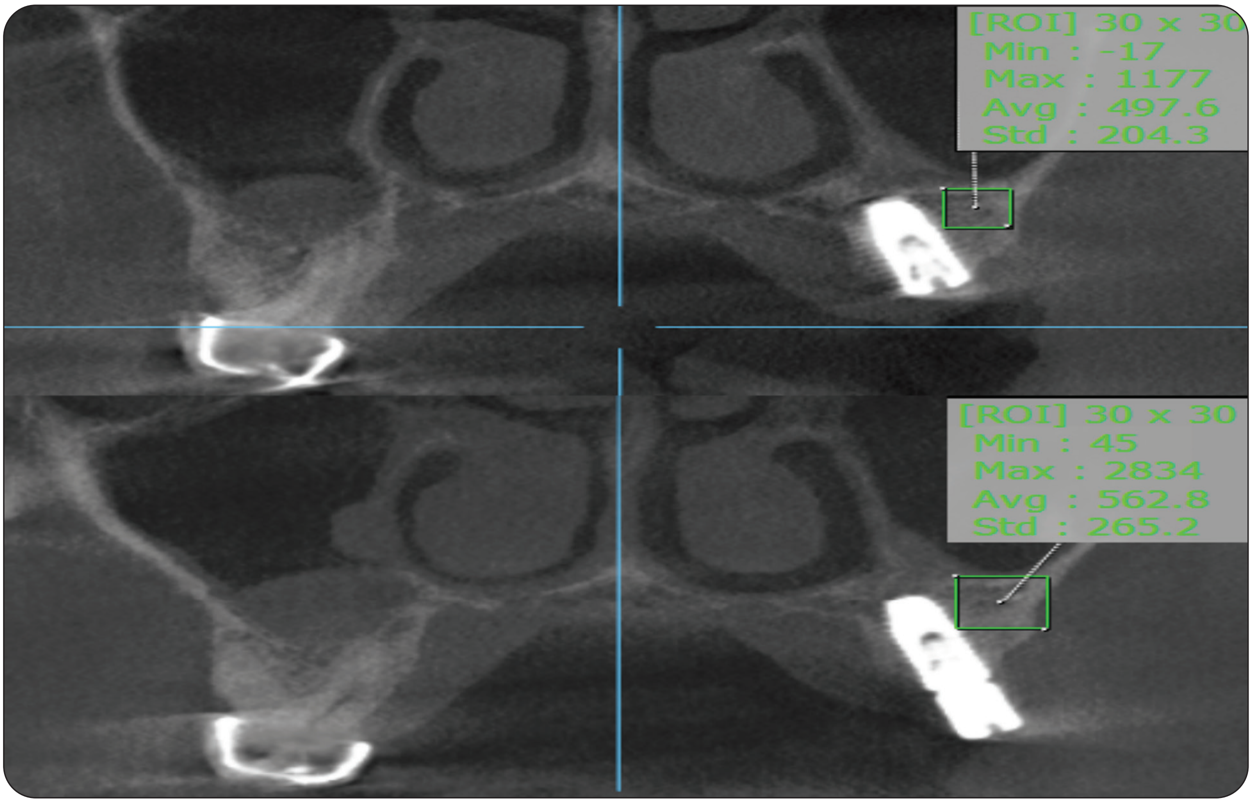

Fig. (5) This figure showing changes in bone density (using CBCT) pre-treatment and post-treatment (Group B).

RESULTS

A total of 12 patients (6 males and 6 females) with an age range of 27–62 years were treated in this study. The mean age of study group was 42.5±3.5 and the mean age of control group was 41.8±4.9. there was no significant difference between the two groups according to age.

The pre-operative vitamin D levels were deficient for all patients without a statistically significant difference between the two groups. After 6 months, vitamin D levels showed a significant increase in group A (from 12.7 to 26.6 ng/ml) while group B was nearly stable (from 11.8 to 13 ng/ml). Total calcium serum levels were within the normal range (from 8.5 to 10.5 mg/dl) for all patients during the hole study period.

Regarding overall body bone density, group A showed improvement in BMD of spine (T-score increased from -1.48 to -1.08) and total hip (T-score increased from -0.3 to -0.06) while group B showed almost no change in BMD. However, the difference between the two groups was insignificant.

There was no significant difference between both groups at primary stability. At loading time after 6 months, group A showed improvement in implant stability (from 44 to 74 ISQ) greater than group B (from 58 to 69 ISQ). Nevertheless, the difference was statistically insignificant.

Evaluation of bone density using CBCT in group A showed slight increase from 229.8±39.7 to 233.3±39.5 while group B showed a greater improvement in bone density from 269.6±53.3 immediate post-operative to 315.2±58.7 after 6 months.

Table (2) *Comparison between group A and group B.*

Variables	Group A		Group B		P value
	Mean	SD	Mean	SD	
Vitamin D pre-treatment	12.7	5.2	11.8	2.1	0.72
Vitamin D post-treatment	26.6	5.9	13	2.7	0.001
Calcium pre-treatment	9.9	0.36	9.6	0.16	0.12
Calcium post-treatment	9.6	0.43	9.3	0.45	0.28
Spine T score pre-treatment	-1.48	1.2	-0.76	1.1	0.33
Spine T score post-treatment	-1.08	1.4	-0.72	1.2	0.66
Total hip T score pre-treatment	-0.3	0.95	-0.02	1.2	0.7
Total hip T score post-treatment	-0.06	1.16	0.02	1.1	0.9
CBCT pre-treatment	229.8	39.7	269.6	53.3	0.29
CBCT post-treatment	233.3	39.5	315.2	58.7	0.17
Primary stability	44	20.5	58.8	4.4	0.15
Secondary stability	74	10.7	69.8	6.4	0.46

Table (3) *Computed Tomography determination of bone density [14].*

Type of bone	Housenfield value
D1	> 1250 HU
D2	850 - 1250 HU
D3	350 - 850 HU
D4	0 - 350 HU

DISCUSSION

Bone density is one of the main factors affecting osseointegration, which is crucial for implant success[1, 2]. Bone density is not uniform but it differs from one arch to the other and even within the same arch. Over the years, many independent clinical groups documented the indisputable influence of bone density on clinical success after following a standardized surgical protocol [3].

To overcome the variations in implant success rate due to different bone densities, Misch proposed four bone density groups [7,8]. For each bone density type, he suggested specific treatment plans, implant design, surgical protocol, healing, and progressive loading time spans [9, 10]. Following this regimen, similar implant survival rates have been observed for all bone densities [11, 12].

The bone density may be determined by various techniques including tactile sensation during surgery, general location or radiographic evaluation. Hounsfield units (HU) or CT numbers obtained from conventional computed tomography (CT) have been correlated with bone density and treatment planning for dental implants [13-16].

Many studies have demonstrated that the grey levels taken from CBCT (Cone Beam Computed Tomography) scans can be used to derive Hounsfield units in a clinical environment. This capability along with the decreased patient radiation exposure, ease of access, greater resolution than medical CT and affordability should solidify CBCT as the imaging modality of choice in dental implant placement [17,18].

In our study, 12 vitamin D deficient patients had implant placement in posterior maxilla. Patients were divided into two groups with no significant difference either at gender distribution or age. Both groups showed increase in vitamin D levels at follow up after 6 months. However, unlike the study group, the change in control group was insignificant.

In alignment with the findings of previous studies (45-48), the increase of vitamin D serum levels in study group led to improvements in BMD of spine and total hip. These improvements of bone density were accompanied by similar improvements in implant secondary stability. On the other hand, control group did not show such improvements as study group either at BMD or implant stability.

In contrast to the results of BMD of spine and total hip using DXA scan and clinical implant stability results, measurement of bone density of maxilla using CBCT showed that mean density in group A has slightly changed. It increased from 229.8 pre-treatment to 233.3 post-treatment. While in group B, mean density increased from 269.6 pre-treatment to 315.2±58 post-treatment. That's why measurement of bone density using CBCT should be regarded as a relative but not as an absolute indicator of bone density.

Our findings are consistent with the findings of Angelopoulos and Aghaloo who reported that density estimates provided by the various CBCT systems demonstrated great variation and inconsistency (sometimes even within the same system). This is mainly due to the high level of noise in the acquired images. In addition, the provided estimates are gray scale values (brightness values) and not true X-ray attenuation values, known as Hounsfield units (HU), such as provided by medical CT scanners [22].

Fig. 8:

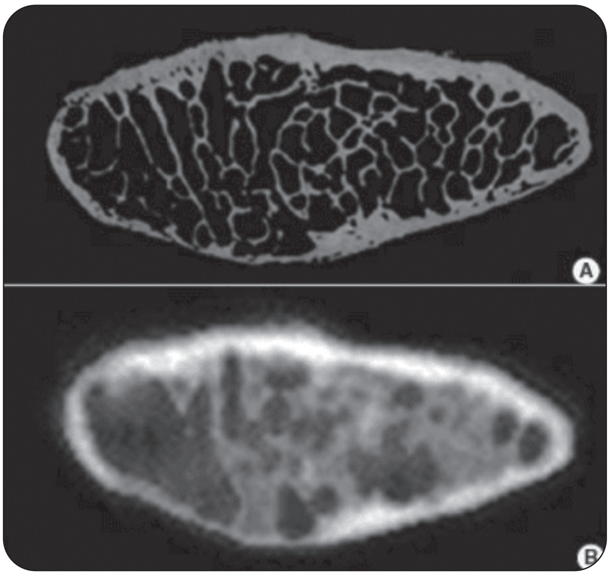

Fig. (6) (A) Micro-computed tomography (CT) image (27×27×27 μm3 voxel size) and (B) Cone beam CT image (200×200×200 μm3 voxel size) of the same human condyle[23].

In addition to Angelopoulos and Aghaloo, Kim also reported that there are some systematic complications to be considered for CBCT based bone density measurement. The most debated aspect is that the HU values of subjects are not consistent between different CBCT systems and between different times scanned even using the same CBCT system. These discrepancies can arise from the non-uniform process of scaling the HU values during reconstruction [23].

To our knowledge, this is the first study to compare between bone density estimates using DXA scan and CBCT. DXA scan is one of the most accurate and reliable methods for assessment of changes in bone density. Another key strength of the study was supplementation with vitamin D and calcium which led to changes in overall body bone density through the study period.

Our study also had some limitations. One limitation is the small sample size. Further studies with larger study samples are recommended.

CONCLUSION

Measurement of bone density using CBCT should be regarded as a relative but not as an absolute indicator of bone density.

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دقة الاشعة المقطعية المخروطية في قياس كثافة عظام الفك العلوي حول الزرعات فى المرضى الذين يعانون من نقص فيتامين د

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الملخص :

الهدف: تقييم دقة الاشعة المقطعية المخروطية في قياس كثافة عظام الفك العلوي.

المواد والاساليب: تم اختيار اثنى عشر مريضا يعانون من نقص في فيتامين د وذلك من المرضى المترددين على العيادات الخارجية التابعة لقسم جراحة الفم والوجه والفكين بكلية طب الفم والاسنان - جامعة الازهر - فرع اسيوط. التدخلات: تم تقسيم المرضى بشكل عشوائي الى مجموعتين. المجموعة الاولى تناولت مكملات غذائية تحتوي على فيتامين د وكالسيوم اما المجموعة الثانية فلم تتناول اي مكملات الغذائية. التقييم الاشعاعي تم عن طريق قياس كثافة العظم باستخدام الاشعة المقطعية المخروطية وجهاز مقياس امتصاص الاشعة السينية ثنائي البواعث.)

النتائج: اظهرت المجموعة أ زيادة ملحوظة في مستويات فيتامين د في الدم حيث ارتفعت من 12.75 الى 26.64 (نانوغرام/ملليلتر) . هذه الزيادة في مستويات فيتامين د كانت مصحوبة بزيادة في كثافة عظام العمود الفقري من 1.48- الى 1.08-. من ناحية اخرى لم تظهر المجموعة ب تحسن مماثل سواء كان في مستويات فيتامين د في الدم او كثافة عظام العمود الفقري. و مع ذلك اظهر تقييم كثافة العظام باستخدام الاشعة المقطعية المخروطية زيادة في كثافة عظام الفك العلوي في المجموعة ب اكثر من المجموعة أ.

الخلاصة: يمكن استخدام الاشعة المقطعية المخروطية كمؤشر تقريبي و ليس قطعي الدلالة في قياس كثافة عظام الفك العلوي.

الكلمات المفتاحية : زرعات سنية؛ فيتامين د؛ كالسيوم، كثافة العظم، اشعة مقطعية مخروطية