Validity of Hounsfield Units from computed tomographic images of mandibular bone in detection of osteoporosis

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ABSTRACT

Background: The figure for the clinical application of computed tomography have been increased significantly in oral and maxillofacial field that supply the dentists with sufficient data enables them to play a main role in screening osteoporosis, therefore Hounsfield units of mandibular computed tomography view used as a main indicator to predict general skeleton osteoporosis and fracture risk factor.

Material and Methods: Thirty subjects (7 males &23 females) with a mean age of (60.1) years underwent computed tomographic scanning for different diagnostic assessment in head and neck region. The mandibular bone quality of them were determined through Hounsfield units of CT scan images and were correlated with the bone mineral density values obtained from t-scores of lumbar spine using dual x-ray absorptiometry scans (DEXA).

Results: There was a highly significant positive correlation [p-value 0.000 (HS)] of bone mineral density that measured by t-score of dual x-ray absorptiometrical scan and Hounsfield units with very strong relation in measuring the bone density (r test) = 0.969, this close relation lead to predict osteoporosity and the chance of fracture occurrence using a statistical equation that classified the patients as osteoporotic.

Conclusion: Hounsfield units obtained from computed tomography scans that are made for any purposes can provide an alternative clinical parameter to predict osteoporosis at no additional cost to the patient and no additional radiation.

Key words: Hounsfield units, DEXA, Osteoporosis. (J Bagh Coll Dentistry 2014; 26(3):79-83).

الخلاصة

الخلفية : لقد تزايد التطبيق السريري للتصوير المقطعي بشكل كبير في مجال الفم و الوجه والفكين مما قدم لأطباء الأسنان بيانات كافية تمكنهم من لعب الدور الرئيسي في فحص هشاشة العظام ، وبالتالي اصبح استخدام وحدة هاونسفيلد في التصوير المقطعي للفك السفلي يوصف بكونه مؤشرا رئيسيا للتنبؤ بهشاشة العظام الهيكلي العام و معامل خطر لحدوث الكسور.

المواد و الطريقة : ثلاثون شخصا (7 ذكور و 23 إناث) بمتوسط عمر (60.1) سنة تم استخدام المسح الشعاعي الطبقي لهم لغرض التشخيص التقييمي في منطقة الرأس و الرقبة و تحديد نوعية العظم للفك السفلي من خلال وحدات هاونسفيلد لصور الاشعة المقطعية وربطها مع قيم كثافة العظام التي تم الحصول عليها من فحص العمود الفقري القطني باستخدام المسح الامتصاصي المزدوج للأشعة السينية .

النتائج : كان هناك ارتباط ذات دلالة عالية من الإيجابية بين و حدات هاونسفيلد وقيمة كثافة المعادن في العظام (0.000 p value) مع وجود علاقة احصائية قوية جدا في قياس كثافة العظام (r-test) = 0.969 ، وهذا يؤدي إلى علاقة وثيقة التنبؤ وفرصة حدوث الكسر باستخدام المعادلة الإحصائية التي تصنف المرضى على اساس هشاشة العظام .

الاستنتاج : ان استخدام وحدات هاونسفيلد في المسح التصويري المقطعي التي يتم إجراؤه لأي غرض توفر البديل السريري للتنبؤ بمرض هشاشة العظام دون أي تكلفة إضافية او اي اشعاعات إضافية للمريض

INTRODUCTION

Osteoporosis "porous bones" is a generalized systemic skeletal disease affects the entire skeleton characterized by low bone mass and microarchitectural deterioration of bony tissue, with a resultant increase in bone fragility and susceptibility to fracture (minimal trauma fractures), [(1)] the bone mass loss usually occurs silently and progressively often, there are no symptoms until the first fracture occurs [(2)].

Osteoporosis is usually associated with oral bone loss furthermore; it shows that osteoporosis results in lower bone mineral density (BMD) of mandibles, [(3,4)] it affects the craniofacial and oral structures with the same rate as the total body [(5,6)]

Considerable work has been carried out on developing a method to detect individuals with low bone mass at an early stage, so that therapeutic intervention may limit the disease process [(3)]. Most clinicians were taught directly or indirectly that bone density is the gauge for assessing bone strength. In recent years, however, the concept has moved beyond density alone and has expanded to include number of characteristics of bone that collectively are called "quality" [(7)]. The assessment of bone density and quality can be determined by using a variety of techniques: quantitative computed tomography (QCT), quantitative ultrasound (QUS), single or dual photon absorptiometry (SPA&DPA), and by dual X-ray absorptiometry (DXA) or called dual energy X-ray absorptiometry (DEXA) [(2,8)] which considered the golden method for measurement of low bone mineral density (BMD) that associated with osteoporosis and it allows detailed visualization of osseous structures [(9)].

DEXA scanner produces two X-ray beams, each with different energy levels one beam is high energy while the other is low energy. The bone density can be measured by the difference between the two beams depending on the bone thickness. Although osteoporosis involves the whole body, measurements of BMD at one site can be predictive of fractures at other sites, so DEXA scanning usually focuses on two main obvious areas: the hip, and the spine, but In certain situations if the hip or spine can't be measured, for instance it is measured in the forearm [(10)].

The mandibular bone changes due to osteoporosis can be estimated on the other hand

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by different image analysis of X-ray techniques. [11] Computed tomography (CT) scan is one of the imaging technique that shows bony details in cross sections and provides a three-dimensional dataset that can be used for studying bone tissue attenuation independent of the surrounding soft tissue in which the CT numbers, or x-ray attenuation, in each voxel of a tissue is resembling by direct Hounsfield unit that provides information about the quality of the examined boney tissue including its density referenced to a standard calibration according to a scale, based on values for air (-1000 HU), water (0 HU), and bone (+1000 HU). Many studies have evaluated the use of HU to assess the relative bone density of the jaws in CT, and seem to be a useful method to analyze bone density [12-14].

MATERIALD AND METHODS

The total sample consist of (61) subjects referred to computed tomography unit at X-ray Institute / Medical City to have computed tomography (CT) scanning in head and neck regions as part of their diagnostic assessment for one or more of different clinical problems using (Toshiba 64S, 2012 CT scanning machine).

The bone quality values for all patients were determined from the Two-dimensional phantom-less CT images in the trabecular field of the mandibular bone at different points in the region of interest "ROI" (incisor, premolar, and molar regions), halfway buccolingually between the buccal and lingual cortical plates. approximately (1–1.5cm^2) should be leaved out from any nontrabecular fields such as teeth, bony cortex, mental symphysis and mandibular canal using (Aquilion systems,Vitrea software) that display digital DICOM images from a conventional axial tomographic view of linear beam based on direct measurement for the mean number of Hounsfield unit (HU), so that optical density at a specific area is correlated with its bone density, Fig.(1)

Out of (61) subjects only (30) subjects were included (7 males &23 females) with mean age of (68.7 years) were with low mandibular bone quality <150 HU interpreted according to the Misch [15] classification categories of bones: (D1, 1250 HU; D2, 850-1250 HU; D3, 350-850 HU; D4, 150-350; and D5, < 150 HU), after a Permission was sought from those patients to perform bone densitometry, they were referred to DEXA unit at the same institute (X-ray Institute / Medical City), to do scanning for the lumbar spine (L1-L4) which is considered the gold standard method for the diagnosis of osteoporosis in which the bone mineral density was performed using (DEXXUM 3, OSTEOSYS Spine Alg: 2 Scanner using Ver. 2.0 Software analysis), Fig. (2). The bone density was measured in absolute terms (g/cm^2) and compared to a known standard of the device manufacturer which is typically the t-score that refers to the number of standard deviations above or below the mean for a healthy young adult of the same sex and ethnicity as the patient**.** DEXA findings were classified according to the World Health Organization (WHO) establishment diagnostic guidelines: t-score ≥ −1.0 is considered normal, a score −2.5 < t-score < −1.0 is classified as osteopenia, and a t-score ≤ −2.5 is defined as osteoporosis.[16] Both recorded data from CT and DEXA were analyzed statistically.

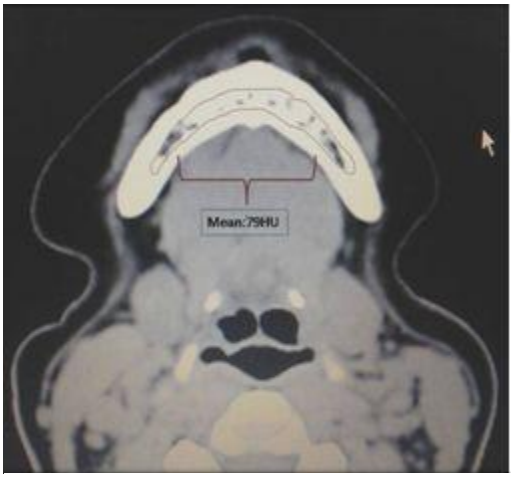

Figure 1: Axial mandible CT of osteoporotic mandibular bone density measurement in Hounsfield Unit (mean: 79 HU).

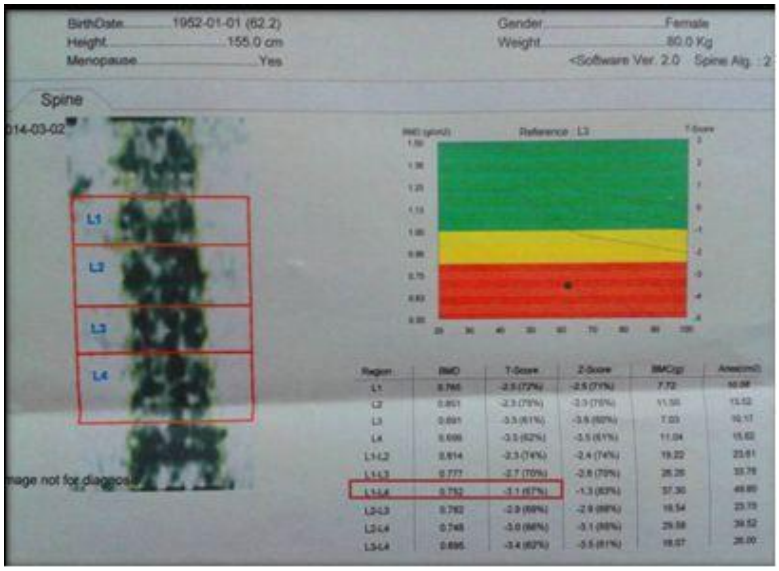

Figure 2: DEXA scan of the lumbar spine with total (t-score -3.1) of L1-L4 in osteoporotic

RESULTS

Out of (30) patients, 7 (23.3 %) were males and 23 (76.7%) were females, representing a female: male ratio of (3.29:1). The age rang was (45–73) years, with mean age of (60.1). The frequency distribution of the study sample among various age groups appears as eight patients in the age group (45-54) years, thirteen patients in the age group (55-64) years, and nine patients in the age group (65-73) years that illustrate the age group (55-64) years was with the highest proportion(43.3%) as shown in table (1).

The diagnosis of osteoporosis by computed tomography in this study depending on the validity of Hounsfield unit. The clinical inclusion criteria was according to Misch[15] classification categories of bones density {any case with low mandibular bone density<150 HU (D5) is considered a suspected case}, out of the 61 patients all the (30) patients whom included in the study sample were recorded as (D5), the mean number of (HU) was (≤ 82 HU) with total average of (68.73 HU).

Regarding to the bone densitometry by DEXA scan the total t-score for lumbar spine from L1 to L4 of all (30) patients ranging between (-2.6) to (-4.4) with mean t-score of (-3.2), so they were identified as cases of osteoporosis according to the WHO criteria for bone mass density at the lumbar spine.

The matching of collected data about bone mass density between the two imaging modalities showed a high statistical correlation in detecting osteoporosis with (r = 0.969) and high significant (p-value = 0.000). To find the relationship between two variables, a special statistical analysis was used for assessing the association between mandibular bone density measured by HU and t-score lumbar spine DEXA. That lead to predict the value of standard t-score for each patient from the mean number of HU, This relationship calculated from [Regression Equation "Y= a +b x"] since y= t-score constant, a= constant/y-intercept, b= HU Coefficients, table (2). This relation was with non significant differences as the p-value=0.206 between the actual and predicted t-score of bone density, table (3).

Table 1: Frequency distribution of the study sample by age and gender

Age group (years)	N	%
(45-54)	8	32.1
(55-64)	13	43.3
(65-73)	9	32.1
Range (45–73)		
Mean (60.1)		
Gender	N	%
Female	23	76.7
Male	7	23.3
Total	30	100

Table 2: Relation between the CT and DEXA in measuring the bone density

CT (HU)			DEXA (t-score)	
r			0.969	
p-value			0.000 (HS)	
Model	Un-standardized Coefficients		t-test	p-value
	b	S.D.		
Constant (a)	-6.733	0.172	-39.126	0.000 (HS)
C.T.	0.051	0.002	20.696	0.000 (HS)

Y = - 6.733 + 0.051 X

Where Y= t-score, a= constant, b= coefficients, X= C.T. (HU)

Table 3: Comparison between the actual and predicted bone density DEXA value

DEXA	Descriptive statistics		Differences d.f.=29			
	Mean	S.D.	Mean difference	S.D.	t-test	p-value
Actual	-3.200	0.47	0.027	0.12	1.294	0.206 (NS)
Predicted	-3.227	0.45				

DISCUSSION

Bone density is the most useful measurement tool in estimating osteoporosis and relative risk factor of non-traumatic fractures occurrence due to available possibility for measurement in contrast to the other factors contributing to fractures including the kind of physical activity, and lifestyle factors that are difficult to quantify[2].

Osteoporosis is often referred to age-related disorder that causes the gradual loss of bone density and strength. According to the World Health Organization (WHO) this disease may be classified as primary and secondary osteoporosis, primary type is divided into primary type 1 that is mostly common in old aged women (after menopause) than male, this explain the female: male ratio of (3.29:1) in the current study (76.7 %females and 23.3 % males) due to postmenopausal hormonal disturbance, and primary type 2 that occurs at old aged people and seen in both females and males [16].

The National Osteoporosis Foundation recommends the testing of BMD to confirm the diagnosis and to determine disease severity). [17] The rapid advancement in CT technology in addition to wide range of its application in different maxillofacial and other clinical practice makes the evaluation of bone density very applicable. This study had obtained bone density by the mean Hounsfield unit (HU) values from CT images in which the bone density in each selected voxel measured according to X-ray attenuation coefficient of trabecular field of mandibular bone that is more metabolically active than other compact bone and is the first to change in response to osteoporosis.[18] Because of the unavailable standardized reference data for the value of HU threshold in osteoporosis so any patients with low bone quality (D5) that considered a very soft bone, with incomplete mineralization and large intertrabecular spaces [15] they were included in the study as they considered as suspected to have osteoporosis and all of them were with very low HU values the mean number of (HU) was (≤ 82 HU) with total average of (68.73 HU). Mean HU values decreased consistently with age specially in age group (65-73) years this finding was agreed with Farré et al study [19] which conclude that the older the patient, the greater the decrease in HU values of bone density.

Because most of international guidelines for osteoporosis recommends the application of DEXA scan for spine and hip as a mirror for total skeleton osteoporosis and there is no available specific DEXA software have been designed for the mandible due to superimposition of the mandible by cervical spine[3] all the study sample were referred for spine DEXA. The results of this study revealed that each suspected case with low bone density by HU was with t-score ≤ −2.5 which classified as osteoporotic according to the (WHO) establishment diagnostic guidelines for osteoporosis which presented a high statistical correlation with (r = 0.969) and high significance p-value this agreed with Sungjoon et al. [20] study who found that the bone density by diagnostic CT-based HU value and DXA-based showed strong positive correlation. Schreiber et al. [21] study illustrates significant correlations between Hounsfield unit and dual x-ray absorptiometry scores of lumbar spine. Kribbs et al. [22] study attempted to determine relationships between bone mass in the mandible and skeletal bone mass in a group of postmenopausal women with osteoporosis found Mandibular mass was highly correlated with all skeletal measures. The high statistical correlation of current study will guide to predict osteoporosis resembling by t-score from the correlated value of HU using regression equation since comparison between the actual and predicted t- score using paired sample t-test was with mean differences of only 0.027 between actual test -3.200 (S.D.=0.47) and predicted t-test -3.227(S.D.=0.45) with p-value=0.206(NS) . This data can be applied as a predictor for fracture risk, diagnosis of osteoporosis, and early prescription of necessary treatment. The validity of CT scanning in predicting and monitoring of osteoporosis when compared to that of DEXA has the benefits of giving a true volumetric findings in contrast to the areal findings obtained from DEXA.

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