# CALIBRATION OF NEW SOFTWARE WITH CONE BEAM C.T FOR EVALUATION OF ITS RELIABILITY IN DENSITOMETRIC ANALYSIS AROUND DENTAL IMPLANTS

* Khaled Atef Elhayes; ** Mahmoud Aly Gamal Eldin

* Ass. Professor Oral & Maxillofacial Surgery, OMFS Department, Faculty of Oral & Dental Medicine, Cairo University #

** Master Degree in Oral Radiology, Oral Radiology Department, Faculty of Oral & Dental Medicine, Cairo University

# Corresponding Author: pdkae@yahoo.com

**Abstract:** ***Aim:*** assessment of the validity and reliability of Idrisi Kilimanjaro software for densitometric analysis around dental implant to evaluate osseointegration by calibration with CBCT. ***Material and Methods*****:** 42 clinically osseointegrated dental implants; 28 immediate (17 mandibular and 11 maxillary) and 14 delayed implants (5 mandibular and 9 maxillary) were inserted in 28 patients of both sex (9 males and 19 females) with average age of 31.7 years. All the implants were radiographed using CBCT 1day and 4 months postsurgically, densitometric analysis was performed around dental implant on CBCT image at these 2 time intervals. Another radiodensitometric analysis was performed on the same radiographic image taken by CBCT and at the same time intervals using new computer software called **"**IDRISI Kilimanjaro". "Microstat 7" for windows statistical package, paired "t" test, Pearson's correlation and Coefficient of variation of both techniques were used for statistical analysis of the results. ***Results****:* There was a very high positive correlation between bone density values measured by CBCT and IDRISI techniques while there was no statistically significant difference between coefficients of variation of both readings in both techniques that indicates the reliability of IDRISI Kilimanjaro software for densitometric analysis around dental implants. There was also a statistically highly significant difference between both readings in each technique indicating a highly significant osseointegration of dental implants involved in this study. ***Conclusions:*** IDRISI Kilimanjaro software is a valid and reliable way in densitometric analysis around dental implants for assessment of osseointegration procedure when it is calibrated with CBCT and it is as accurate as CBCT.

**[**Khaled A. Elhayes; Mahmoud A. Gamal Eldin. **CALIBRATION OF NEW SOFTWARE WITH CONE BEAM C.T FOR EVALUATION OF ITS RELIABILITY IN DENSITOMETRIC ANALYSIS AROUND DENTAL IMPLANTS.** Life Science Journal. 2012;9(2):61-67] (ISSN:1097-8135). http://www.lifesciencesite.com. 12

***Keywords:*** CBCT, IDRISI Kilimanjaro, Osseointegration, Dental implant.

## 1. Introduction:

There are two ways of achieving connection between an endosteal implant and the host tissue. Anchorage may be achieved through a non-mineralized zone or connective tissue, which is claimed to be a pseudo-periodontium. The fibro-integration was attributed to the surgical technique and early over loading, *Garetta et al., (1995)*. The other way of direct contact between bone and implant is called osseointegration, *Albrektsson et al., (1981) and Skalak (1983).* Osseointegration was defined as the apparent direct attachment or connection of osseous tissue to an inert alloplastic material without intervening has been demonstrated as biochemical bonding of living bone to the surface of a hydroxyapatite coated implant, *Rieger et al., (1989).* In implants dentistry, this phenomenon called osseointegration has become the accepted standard for success in dental implants. Yet, Failure of these devices associated with impaired healing, infection, and over load are well recognized, *Ratner (2001).* Because osseointegration is essentially a wound healing process, factors that interfere with healing may contribute to implant failure. Hence, conditions shown to adversely affect wound healing may decrease the potential for successful osseointegration, *Elsubeihi and Zarb (2002).* Cone Beam Computed Tomography (CBCT) is a relatively new medium for maxillofacial conditions, it was developed in 1998 and has been commonly used commercially since 2000, and it offers less radiation than computed tomography (CT) in 3D image construction, *Benninger et al., (2012).* CBCT was introduced into the U.S. market in 2001; it has been shown to be a precise imaging modality and is a valuable tool for use in dental applications, *Hatcher (2010).* It was also used to measure bone density with dental implants, *Lai et al., (2010).* This imaging technique is now used worldwide; it is a reliable and credible alternative to CT scan for dentomaxillofacial imaging; radiation exposure may vary from one machine to another, but it remains definitely lower than CT dose levels; this technique is compatible with dental implant software. The major diagnostic advantage is the exquisite spatial resolution while the main pitfall is the poor contrast of face and neck soft tissues, due to a lower density resolution compared to CT scan, *Hauret and Hodez (2009).* CBCT can provide identical information to multislice computed tomography (MSCT), with a considerable dose reduction when panoramic radiography is not sufficient in the study of the teeth and jaw bones, *Carrafiello et al., (2010).* It was suggested that voxel values of mandibular cancellous bone in CBCT could be used to estimate bone density, *Naitoh et al., (2009).* This bone density assessment was performed by measurement of Hounsfield Units (HU) using cone beam computed tomography (CBCT), *Aranyarachkul et al., (2005) and Marquezan et al., (2011).*In a clinical investigation for measuring bone density in healing periapical lesions by using CBCT; the results of this study supported the use of this CBCT to measure bone density, *Kaya et al., (2012).* Furthermore, a linear relationship can be used to determine the density of materials (in the density range of bone) from the HU values of a CBCT scan. This relationship is not affected by the object's location within the scanner itself, *Lagravère et al., (2008).* Preoperative CBCT for bone density measurements may be helpful as an objective diagnostic tool, *Fuster-Torres et al., (2011).* It is important in presurgical imaging for dental implant treatment, *Naitoh et al., (2009).* It allows accurate assessment of the entire volume of a proposed implant site, *King et al., (2007).* In a study of bone mineral density (BMD) measurement, it was concluded that there was a positive correlation between BMD of total bone block measured by Dual-Energy X-ray Absorptiometry (DEXA) and that measured by (CBCT), *Marquezan et al., (2011).* Radiographic bone density (RBD) assessed by CBCT has also a strong positive correlation with bone volumetric fraction (BV/TV) assessed by micro-CT at the site of dental implants in the maxillary bones and so, pre-operative estimation of density values by CBCT is a reliable tool to objectively determine bone density, *González-García and Monje (2012).* It was suggested that the trabecular bone volume per total tissue volume BV/TV obtained using CBCT images can be used to evaluate the density of mandibular cancellous bone in dental implant treatment, *Naitoh et al., (2010).* The bone quality was objectively assessed with density values obtained from CBCT to determine the correlations between bone density and primary stability of dental implants, *Isoda et al., (2011).* CBCT was also used to evaluate bone quality changes surrounding the apical portion of immediate implants placed under higher insertion torque utilizing an undersized drilling technique, *González-Martín et al., (2011).* Furthermore, CBCT is a useful approach for evaluating bone density changes around teeth induced by orthodontic treatment, *Chang et al., (2011) and Hsu et al., (2011).* It is a good choice for analyzing bone mass, *Hohlweg-Majert et al., (2011).* In recently introduced CBCT, magnification of images did not occur, allowing it being used for accurate clinical procedures, *Yim et al., (2011).* CBCT imaging allows remarkably lower radiation doses and thinner acquisition slices compared with medical computed tomography, *Kim et al., (2007).* IDRISI Kilimanjaro software facilitated image restoration, enhancement, and densitometric analysis and so it was used for image analysis. This software provided a unique facility in comparison to other densitometric measuring software programs, as it facilitated monitoring the changes in bone density at two zones around implant images. The first zone represented the osseointegration zone which was located just adjacent to the implant borders, along the bone-implant interface. On the other hand, the second zone was located just around the first zone and represented the bone surrounding the interface, *Becker (1999) and Radwan (2005).*

**Aim** of this study was to assess the validity and reliability of Idrisi Kilimanjaro software for densitometric analysis around dental implant to evaluate osseointegration; by calibration of this software with CBCT.

## 2. Material and Methods:

### 2.1. Material:

#### 2.1.1. Sample of the study:

42 clinically osseointegrated dental implants were selected to be involved in this study, all of them were performed by the same operator, they were inserted in 28 patients of both sex (9 males and 19 females) aged 23 – 47 years old with average age of 31.7 years; according to the technique of implant insertion, they were 28 immediate dental implants (17 mandibular and 11 maxillary) and 14 delayed implants (5 mandibular and 9 maxillary).

### 2.2. Methods:

#### 2.2.1. Clinical procedure for dental implants:

After extraction of the non-restorable tooth that would be replaced by dental implant (in case of immediate implant), adjustment of the extraction socket was performed using the suitable drillers under copious irrigation till reaching the size of proposed dental implant, then, implant was inserted and screwed to its final position in the prepared socket and finally, a non resorpable membrane was placed over the inserted implant to cover it completely over which figure 8 suturing was performed to secure membrane in position. *(Figure 1).*

#### 2.2.2. CBCT procedure for densitometric analysis:

All the implants involved in this study were radiographed by CBCT 1day and 4 months postsurgically. Exposure was performed using “Scanora3D”, Sorredex- Finland, at 15 mA, 85 KV and at a proper field of view. Image reconstruction was performed using special software called

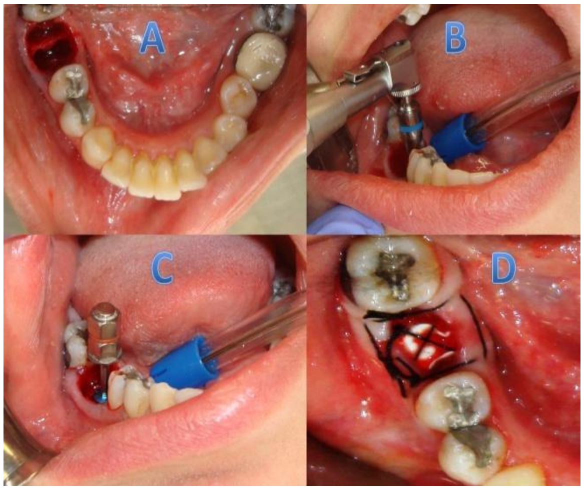



***Fig.1:*** Clinical steps for placement of immediate dental implant

***A:*** *Extraction of non-restorable tooth*
***B:*** *Drilling to widen the socket*
***C:*** *placement and screwing of dental implant*
***D:*** *suturing over the membrane*

"Ondemand3D" version 1.0.9, Cybermed, Korea. Standardization during imaging was achieved through adjusting the patient positioning and lights as follows: The seat height was adjusted to position the region of interest (ROI) vertically within the field of view (FOV). The upper light beam indicated the top of the FOV and the lower light beam indicated the bottom of the FOV. The sagittal light (vertical front light) was positioned in the center of the FOV from sagittal direction so that it is in the center of the ROI. The lateral light (vertical side light) was positioned in the center of the FOV in the lateral direction so that it is in the center of the ROI. The patient was instructed not to move during the duration of exposure. Densitometric analysis was performed around dental implant on CBCT image at these 2 time intervals using this "Ondemand3D" software supplied with the previously mentioned machine. The layer thickness to be analyzed was standardized to 1 cm to be sure that it contains all the implant inside; the reading of men density outside the implant was taken as the final analysis. This analysis gives the actual bone density around the immersed dental implant that proves the process of osseointegration *(Figure 2).*

**2.2.3. IDRISI procedure for densitometric analysis:**

Another radiodensitometric analysis was performed on the same radiographic image taken by CBCT and at the same time intervals using new computer software called IDRISI Kilimanjaro that facilitated image restoration, enhancement, and densitometric measurements. { IDRISI 14.01 (Kilimanjaro) is a software product of Clark Labs, Clark University, Main Street, Worcester, MA.01610-1477, USA}.

***Fig.2:*** Densitometric analysis procedure around dental implant using CBCT

IDRISI assessed the density of the bone surrounding implant in the digitized radiographs by dividing it into two zones with standardized width. First zone (zone 1) was located just adjacent to the implant and represented osseointegration zone (implant-bone interface).The second zone (zone 2) was located just around the first one and represented the bone surrounding implant. The software analyze the images through the following steps; image restoration, image enhancement and density measurements. Image restoration technique allows for both radiometric and geometric correction of images. The procedure is followed by image enhancement technique which allows contrast adjustment regarding all the images, then implant edge enhancement, followed by subtracting the implant from the background image (surrounding bone). Finally, the density measurements are calibrated by quantifying the image on 256 grey-scales. Zero scale are given to the totally black regions, 256 for totally white regions and the values in between represent shades of grey**,** Gonzalez et al., (1992), Bernd (1993) and Dawoud (2009); *(Figure 3).*

**2.2.4. Statistical analysis:**

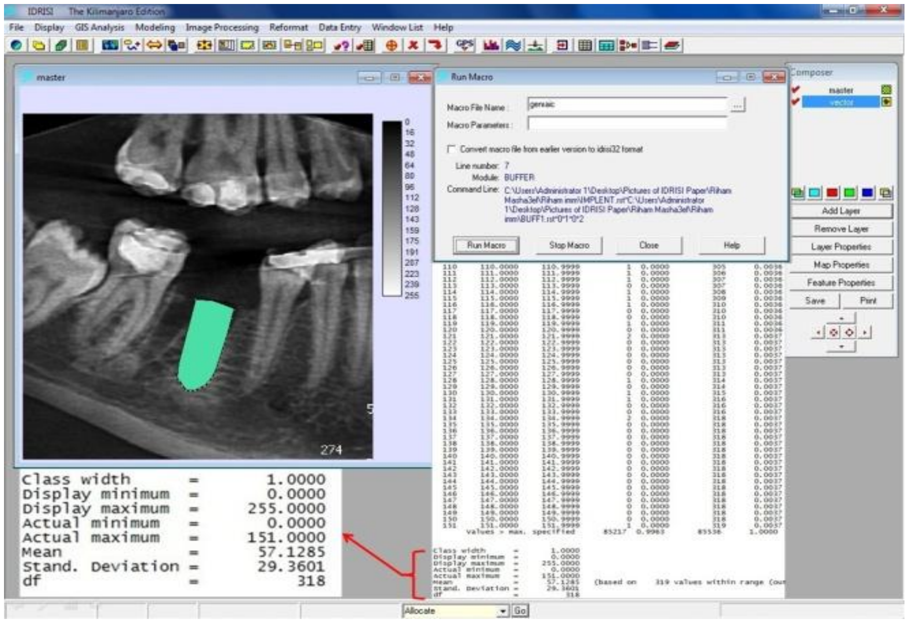
All data were collected and statistically analyzed using "microstat 7" for windows statistical package and Paired "t" test for comparison between both readings in each technique.

"Pearson's correlation" was also used for correlation between reading 1 in both techniques and reading 2 in both techniques too *(r value).*

Coefficients of variation of both techniques were compared using "Z score" test to compare percentages of variations.

*Fig. 3:*

Densitometric analysis procedure around the same dental implant using IDRISI




## 3. Results:

All the statistical results considered to be significant at P value $\leq$ 0.05. There was a very high positive correlation between bone density values measured by CBCT and IDRISI techniques ("r" value = 0.94), indicating that IDRISI Kilimanjaro software is a reliable technique for densitometric analysis around dental implants *(Table 1)*. There was no statistically significant difference between coefficients of variation of both readings in both techniques that also indicates that IDRISI is a reliable technique for bone density measurement around dental implants *(Table 2, Figure 4)*.Using paired "t" test, there was a statistically highly significant difference between both readings in each technique indicating that there was a highly significant formation of bone around dental implants by time that means highly significant osseointegration of these dental implants. *(Table 3 & Figure 5)*. The raw data of densitometric analysis for the 42 dental implants measured by both CBCT and IDRISI Kilimanjaro softwares were tabulated for the previous statistical analysis *(Table 4)*.

***Table 1:*** Correlation between bone density values by CBCT and IDRISI

| BONE DENSITY | " r " value | Prob |
|---|---|---|
| 1 day postoperative | 0.94 | 0.000001 |
| 4 months postoperative | 0.94 | 0.000001 |

***Table 2:*** Coefficient of variation in both techniques

| BONE DENSITY | CBCT | IDRISI | Prob |
|---|---|---|---|
| 1 day postoperative | 22.44% | 22.11% | 0.473 *(NS)* |
| 4 months postoperative | 22.18% | 21.74% | 0.482 *(NS)* |

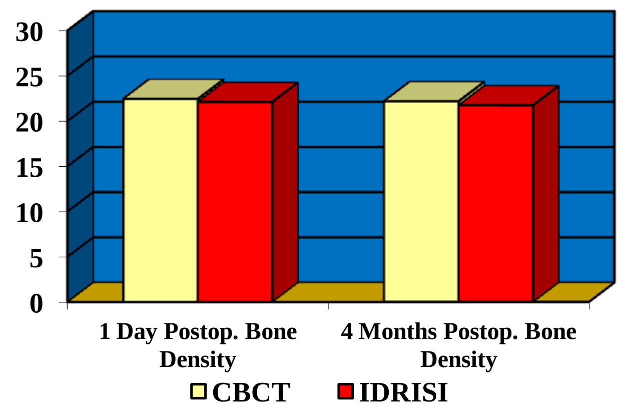



***Figure 4:*** Comparing Coefficient of variation of the same reading in both techniques

***Table 3:*** Paired "t" test comparing both readings in each technique

| Technique | BONE DENSITY | | "t" | Prob. |
|---|---|---|---|---|
| | 1 day postoperative | 4 months postoperative | | |
| CBCT | 639.47 $\pm$ 137.13 | 897.44 $\pm$ 199.02 | 19.605 | 0.000001 |
| IDRISI | 45.21 $\pm$ 10.00 | 63.28 $\pm$ 13.76 | 21.974 | 0.000001 |

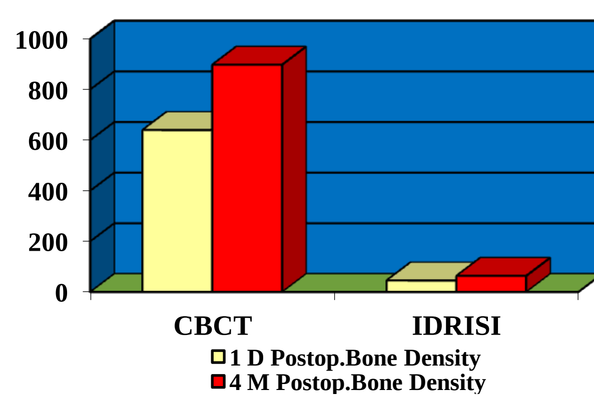



***Figure 5:*** Comparing mean values of bone density measured by each technique in two time intervals

***Table 4:*** Bone density readings for all implants by both techniques

| PATIENTS | | CBCT | IDRISI | PATIENTS | | CBCT | IDRISI |
|---|---|---|---|---|---|---|---|
| **Implant 1** | Read 1 | 465.94 | 32.6677 | **Implant 22** | Read 1 | 593.75 | 46.0271 |
| | Read 2 | 667.17 | 46.7801 | | Read 2 | 829.18 | 64.2438 |
| **Implant 2** | Read 1 | 721.33 | 48.3572 | **Implant 23** | Read 1 | 681.39 | 50.8517 |
| | Read 2 | 1089.20 | 74.3733 | | Read 2 | 992.32 | 71.1838 |
| **Implant 3** | Read 1 | 389.99 | 25.7098 | **Implant 24** | Read 1 | 726.76 | 53.0559 |
| | Read 2 | 617.39 | 40.0044 | | Read 2 | 1034.65 | 75.6557 |
| **Implant 4** | Read 1 | 584.43 | 41.7491 | **Implant 25** | Read 1 | 498.66 | 36.2398 |
| | Read 2 | 857.94 | 58.4487 | | Read 2 | 744.57 | 53.8600 |
| **Implant 5** | Read 1 | 687.49 | 43.8665 | **Implant 26** | Read 1 | 398.98 | 30.8092 |
| | Read 2 | 958.70 | 61.2288 | | Read 2 | 580.99 | 44.0465 |
| **Implant 6** | Read 1 | 812.36 | 48.6959 | **Implant 27** | Read 1 | 728.64 | 55.5564 |
| | Read 2 | 1153.55 | 70.0490 | | Read 2 | 946.32 | 73.1488 |
| **Implant 7** | Read 1 | 514.86 | 36.0041 | **Implant 28** | Read 1 | 691.46 | 50.6415 |
| | Read 2 | 720.80 | 51.8062 | | Read 2 | 951.23 | 68.6810 |
| **Implant 8** | Read 1 | 632.59 | 42.4557 | **Implant 29** | Read 1 | 709.23 | 54.5565 |
| | Read 2 | 988.80 | 64.7364 | | Read 2 | 984.15 | 76.1524 |
| **Implant 9** | Read 1 | 823.66 | 49.9187 | **Implant 30** | Read 1 | 826.41 | 63.0318 |
| | Read 2 | 1234.17 | 74.2390 | | Read 2 | 1187.09 | 88.9460 |
| **Implant 10** | Read 1 | 437.56 | 29.1706 | **Implant 31** | Read 1 | 693.45 | 50.7977 |
| | Read 2 | 611.97 | 41.1305 | | Read 2 | 920.13 | 67.5514 |
| **Implant 11** | Read 1 | 558.04 | 29.6092 | **Implant 32** | Read 1 | 741.36 | 54.7585 |
| | Read 2 | 653.73 | 43.2205 | | Read 2 | 999.83 | 75.7121 |
| **Implant 12** | Read 1 | 526.90 | 45.8630 | **Implant 33** | Read 1 | 456.32 | 32.3104 |
| | Read 2 | 709.03 | 53.6445 | | Read 2 | 634.10 | 44.4387 |
| **Implant 13** | Read 1 | 375.80 | 52.1134 | **Implant 34** | Read 1 | 798.46 | 61.9316 |
| | Read 2 | 465.99 | 63.0572 | | Read 2 | 1126.65 | 86.7043 |
| **Implant 14** | Read 1 | 619.87 | 57.1285 | **Implant 35** | Read 1 | 357.15 | 29.7657 |
| | Read 2 | 737.64 | 67.9829 | | Read 2 | 705.49 | 38.3844 |
| **Implant 15** | Read 1 | 497.21 | 27.1044 | **Implant 36** | Read 1 | 951.35 | 63.9821 |
| | Read 2 | 565.98 | 28.2222 | | Read 2 | 1318.19 | 88.4434 |
| **Implant 16** | Read 1 | 485.34 | 33.1811 | **Implant 37** | Read 1 | 645.91 | 45.2676 |
| | Read 2 | 650.35 | 46.4535 | | Read 2 | 905.07 | 63.3580 |
| **Implant 17** | Read 1 | 538.76 | 36.4786 | **Implant 38** | Read 1 | 831.64 | 58.0713 |
| | Read 2 | 795.20 | 52.2081 | | Read 2 | 1273.45 | 86.9213 |
| **Implant 18** | Read 1 | 533.99 | 35.3252 | **Implant 39** | Read 1 | 597.31 | 46.3778 |
| | Read 2 | 807.55 | 52.9807 | | Read 2 | 761.79 | 60.2866 |
| **Implant 19** | Read 1 | 624.83 | 39.6334 | **Implant 40** | Read 1 | 671.82 | 49.0550 |
| | Read 2 | 924.74 | 61.5744 | | Read 2 | 887.54 | 64.6009 |
| **Implant 20** | Read 1 | 701.01 | 46.7414 | **Implant 41** | Read 1 | 493.71 | 34.9398 |
| | Read 2 | 908.50 | 60.0486 | | Read 2 | 590.29 | 42.3157 |
| **Implant 21** | Read 1 | 583.69 | 46.0323 | **Implant 42** | Read 1 | 746.36 | 53.4637 |
| | Read 2 | 774.52 | 62.4331 | | Read 2 | 879.67 | 63.2797 |

*Read 1 = 1 day postoperative bone density & Read 2 = 4 months postoperative bone density*

**4. Discussion:**

CBCT low sensitivity to metallic artifacts makes it the technique of choice in the follow-up of cochlear implants, *Hodez et al., (2011).* In implant imaging, CT delivers the highest radiation dose to the salivary glands, whereas the CBCT system delivers the lowest dose. Irrespective of imaging modality, during implant imaging, salivary glands receive most radiation, *Chau and Fung (2009).* CBCT imaging has the advantage of allowing thinner acquisition slices compared with medical computed tomography, *Kim et al., (2007).* Furthermore, in recently introduced CBCT, magnification of images did not occur, allowing it being used for accurate clinical procedures, *Yim et al., (2011).* CBCT has also the potential to reduce the size and cost of CT scanners, this emerging technology produces images with isotropic sub-millimeter spatial resolution with high diagnostic quality, short scanning times of about 10-30 seconds, and radiation dosages of up to 15 times lower than those of conventional CT scans, *Bamgbose et al., (2008).* For all these previous reasons, CBCT was the radiographic technique of choice to be used in our study of dental implants for densitometric analysis and assessment of osseointegration. In our study, CBCT was selected as a standard measure for calibration of other ways of densitometric analysis as there was a positive correlation between total bone mineral density measured by CBCT and by dual-energy x-ray absorptiometry (DEXA) which is the most accurate technique for measuring real bone density as stated by *Marquezan et al., (2012).* IDRISI Kilimanjaro software was selected at this study to be calibrated for densitometric analysis and osseointegration assessment around dental implant as it is available cheaper way than CBCT and more accurate tool than DIGORA for that purpose, it gives the mean bone density around dental implant with the standard deviation and the degree of freedom in an accurate way. This was in agreement with Radwan who designed a pilot study that compared the results elaborated by IDRISI Kilimanjaro software with those by DIGORA software and stated that no significant difference was found between the records of both softwares, but IDRISI Kilimanjaro software proved to be more accurate tool for densitometric analysis, *Radwan (2005).* The very high positive correlation seen in our present study between bone density values measured by CBCT and IDRISI techniques at different time intervals; and the insignificant difference between coefficients of variation of both readings in both techniques indicate that IDRISI Kilimanjaro software is as much reliable as CBCT technique for densitometric analysis around dental implants. Furthermore, the highly significant bone density seen at 4 months postoperatively that means a highly significant formation of bone around dental implants by time obviate the highly significant osseointegration of dental implants involved in our study and supposed that IDRISI Kilimanjaro software could be a dependable sole way for assessment of osseointegration of dental implants. This is in agreement with *Dawoud (2009)* who used this software as a sole way for evaluation of osseointegration of immediate dental implants in two groups of patients and stated that “accelerating bone deposition means enhancement of osseointegration and the results of that study revealed sustained increase in bone density throughout the follow-up periods; this increase indicated progressive osseointegration and increase bone density of variable degree within the two groups.”

**In conclusion**, IDRISI Kilimanjaro software could prove its validity and reliability in densitometric analysis around dental implants for assessment of osseointegration procedure when it is calibrated with CBCT and it is as accurate as CBCT for this purpose.

## 5. References:


1- **Albrektsson T., Brånemark P. I. and Hansson H. A.:** Osseointegrated titanium implants. Requirements for ensuring a long-lasting direct bone to implant anchorage in man. Acta. Orthop. Scand. 1981, 52: 155.

2- **Aranyarachkul P, Caruso J, Gantes B, Schulz E, Riggs M, Dus I, Yamada JM, Crigger M:** Bone density assessments of dental implant sites: 2. Quantitative cone-beam computerized tomography. Int J Oral Maxillofac Implants. 2005 May-Jun; 20(3)**:**416-24.

3- **Bamgbose BO, Adeyemo WL, Ladeinde AL, Ogunlewe MO:** Cone beam computed tomography (CBCT): the new vista in oral and maxillofacial imaging. Nig Q J Hosp Med. 2008 Jan-Mar; 18(1):32-5.

4- **Becker W.:** Biostimulation of wound healing in rats by low power lasers. Biomed. Tech. Berlin. 1999, 35: 98-101.

5- **Benninger B, Peterson A, Cook V:** Assessing validity of actual tooth height and width from cone beam images of cadavers with subsequent dissection to aid oral surgery. J Oral Maxillofac. Surg. 2012 Feb; 70(2):302-6. Epub 2011 Nov 17.

6- **Bernd, J.:** Digital image processing: Concepts, Algorithms, and Scientific Applications.1993, 2nd ed., Springer-Verlag.

7- **Carrafiello G, Dizonno M, Colli V, Strocchi S, Pozzi Taubert S, Leonardi A, Giorgianni A, Barresi M, Macchi A, Bracchi E, Conte L, Fugazzola C:** Comparative study of jaws with multislice computed tomography and cone-beam computed tomography. Radiol Med. 2010 Jun; 115(4):600-11. Epub 2010 Feb 22.

8- **Chang HW, Huang HL, Yu JH, Hsu JT, Li YF, Wu YF:** Effects of orthodontic tooth movement on alveolar bone density. Clin Oral Investig. 2011 Apr 26. [Epub ahead of print]

9- **Chau AC, Fung K:** Comparison of radiation dose for implant imaging using conventional spiral tomography, computed tomography, and cone-beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009 Apr; 107(4):559-65. Epub 2009 Jan 25.

10- **Dawoud N.M:** Effect of low intensity laser versus bone substitute on osseointegration after immediate implant. Thesis of Master degree. Cairo University. 2009, p: 100.

11- **Elsubeihi E.S., Zarb G.A.:** Implant Prosthodontics in Medically Challenged Patients: The University of Toronto Experience. J Can Dent Assoc. 2002, 68(2): 103-8.

12- **Fuster-Torres MÁ, Peñarrocha-Diago M, Peñarrocha-Oltra D, Peñarrocha-Diago M:** Relationships between bone density values from cone beam computed tomography, maximum insertion torque, and resonance frequency analysis at implant placement: a pilot study.Int J Oral Maxillofac Implants. 2011 Sep-Oct; 26(5):1051-6.

13- **Garetta L.P., Chen J., Parr J.A., and Roberts W.E.:** Remodeling dynamics of bone supporting rigidly fixed titanium implants: A histomorphometric comparison of four species including humans, J. Implants Dent. 1995, 4:235-243.

14- **Gonzalez, A.; Rafel, C.; Woods, A.; and Richard, C.:** Digital image processing, Addison-Wesley, 1992.

15- **González-García R, Monje F:** The reliability of cone-beam computed tomography to assess bone density at dental implant recipient sites: a histomorphometric analysis by micro-CT. Clin Oral Implants Res. 2012 Jan 17. doi: 10.1111/j.1600-0501.2011.02390.x. [Epub ahead of print]

16- **González-Martín O, Lee EA, Veltri M:** CBCT fractal dimension changes at the apex of immediate implants placed using undersized drilling. Clin. Oral Implants Res. 2011 Aug 2. doi: 10.1111/j.1600-0501.2011.02246.x. [Epub ahead of print]

17- **Hatcher DC:** Operational principles for cone-beam computed tomography.J Am Dent Assoc. 2010 Oct; 141 Suppl 3:3S-6S.

18- **Hauret L, Hodez C:** [A new modality for dentomaxillofacial imaging: cone beam CT]. J Radiol. 2009 May; 90 (5 Pt 2): 604-17.

19- **Hodez C, Griffaton-Taillandier C, Bensimon I:** Cone-beam imaging: applications in ENT. Eur Ann Otorhinolaryngol Head Neck Dis. 2011 Apr; 128(2):65-78. Epub 2011 Apr 2.

20- **Hohlweg-Majert B, Pautke C, Deppe H, Metzger MC, Wagner K, Schulze D:** Qualitative and quantitative evaluation of bony structures based on DICOM dataset.J Oral Maxillofac Surg. 2011 Nov; 69(11):2763-70. Epub 2011 Jun 23.

21- **Hsu JT, Chang HW, Huang HL, Yu JH, Li YF, Tu MG:** Bone density changes around teeth during orthodontic treatment. Clin Oral Investig. 2011 Aug; 15(4):511-9.

22- **Isoda K, Ayukawa Y, Tsukiyama Y, Sogo M, Matsushita Y, Koyano K:** Relationship between the bone density estimated by cone-beam computed tomography and the primary stability of dental implants. Clin. Oral Implants Res. 2011 May 5. doi: 10.1111/j.1600-0501.2011.02203.x. [Epub ahead of print]

23- **Kaya S, Yavuz I, Uysal I, Akkuş Z:** Measuring bone density in healing periapical lesions by using cone beam computed tomography: a clinical investigation. J Endod. 2012 Jan; 38(1):28-31. Epub 2011 Nov 13.

24- **Kim SH, Choi YS, Hwang EH, Chung KR, Kook YA, Nelson G:** Surgical positioning of orthodontic mini-implants with guides fabricated on models replicated with cone-beam computed tomography. Am J Orthod Dentofacial Orthop. 2007 Apr; 131(4 Suppl):S82-9.

25- **King KS, Lam EW, Faulkner MG, Heo G, Major PW:** Vertical bone volume in the paramedian palate of adolescents: a computed tomography study. Am J Orthod Dentofacial Orthop. 2007 Dec; 132(6):783-8.

26- **Lagravère MO, Carey J, Ben-Zvi M, Packota GV, Major PW:** Effect of object location on the density measurement and Hounsfield conversion in a New Tom 3G cone beam computed tomography unit. Dentomaxillofac. Radiol. 2008 Sep; 37(6):305-8.

27- **Lai RF, Zou H, Kong WD, Lin W:** Applied anatomic site study of palatal anchorage implants using cone beam computed tomography. Int J Oral Sci. 2010 Jun; 2(2):98-104.

28- **Marquezan M, Osório A, Sant'Anna E, Souza MM, Maia L:** Does bone mineral density influence the primary stability of dental implants? A systematic review. Clin Oral Implants Res. 2011 Jun 2. doi: 10.1111/j.1600-0501.2011.02228.x. [Epub ahead of print]

29- **Marquezan M, Lau TC, Mattos CT, da Cunha AC, Nojima LI, Sant'anna EF, de Souza MM, de Souza Araújo MT:** Bone mineral density. Angle Orthod. 2012 Jan; 82(1):62-6. Epub 2011 Jul 20.

30- **Naitoh M, Hirukawa A, Katsumata A, Ariji E:** Evaluation of voxel values in mandibular cancellous bone: relationship between cone-beam computed tomography and multislice helical computed tomography. Clin Oral Implants Res. 2009 ay; 20(5):503-6. Epub 2009 Feb 25.

31- **Naitoh M, Aimiya H, Hirukawa A, Ariji E:** Morphometric analysis of mandibular trabecular bone using cone beam computed tomography: an in vitro study. Int J Oral Maxillofac Implants. 2010 Nov-Dec; 25(6):1093-8.

32- **Radwan D.A.:** A clinical study on the effect of diode laser therapy on the osseointegration of delayed immediate implant. Thesis of Doctor degree. Cairo University. 2005, p: 114.

33- **Ratner B.D.:** Replacing and Renewing: Synthetic Materials, Biomimetics, and Tissue Engineering in Implant Dentistry. Journal of Dental Education; 2001, 65 (12): 1340-1347.

34- **Rieger M. R., Fareed K., Adams W. K. and Tanquest R. A.:** Bone stress distribution for three endosseous implant. J. Prosthet. Dent. 1989,61:223-8.

35- **Skalak R.:** Biomechanical consideration in osseointegrated prothesis. J. prosthetic Dent. 1983, 49: 843-848.

36- **Yim JH, Ryu DM, Lee BS, Kwon YD:** Analysis of digitalized panorama and cone beam computed tomographic image distortion for the diagnosis of dental implant surgery. J Craniofac Surg. 2011 Mar; 22(2):669-73.