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ACCURACY OF QUICKSCAN IMAGING PROTOCOLS OF ICAT FLX CBCT IN ASSESSMENT OF PERI-IMPLANT BONE DEFECTS

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ABSTRACT

Aim of the study: The current study was conducted to determine the accuracy of QuickScan imaging protocols of iCAT Flx CBCT machine in detection and measuring crestal bone defects around dental implants.

Materials and Methods: 20 simulated peri-implant crestal bone defects were created in bovine ribs bone models then were scanned by iCAT FLX CBCT machine with HD Scan 0.25 mm voxel, QuickScan 0.25mm voxel, and QuickScan + 0.3mm voxel sizes. All scans were imported in on-demand 3D App software and produced linear measurements were compared to true measurements done directly with digital caliper on bone models.

Results: All imaging protocols of CBCT showed no statistical significance in detection of shallow peri-implant bone defects while the QuickScan + imaging protocol showed less accuracy in measuring the depth of defects.

Conclusion: QuickScan + can be used as a low dose periodic follow up imaging utility for postoperative implant surgery for detection of any small bone changes but if more details are needed QuickScan technique is required.

KEYWORDS: Peri-implant defect, QuickScan, CBCT, linear accuracy

INTRODUCTION

Tooth loss is normal for deciduous teeth, when they are replaced by permanent teeth. Otherwise, permanent teeth loss is unfavorable and considered one of the major problems in dentistry [(1)]. There are different ways for teeth replacement includes removable dentures, fixed bridges, and implants which are considered the best, longest lasting option for restoring missing teeth especially single tooth replacement [(2)].

Dental implant (Endosseous implant or fixture) is “a surgical component that interfaces with the bone

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of the jaw or skull to support a dental prosthesis such as a crown, bridge, denture, facial prosthesis or to act as an orthodontic anchor". Dental implant success depends mainly on the sustainable long-term health of hard and soft peri-implant tissues[3]. When the tissues are healthy, a well-integrated implant with suitable biomechanical loads can have 5-year plus survival rates from (93 - 98 %) [4].

Ideally, implants should be assessed by standardized success criteria [5] and not only for their survival. Success criteria for different implant systems are: Immobilization of individual unattached implant when tested clinically; no radiographic evidence of peri-implant radiolucency; at the peri-implant surfaces, vertical marginal bone loss should not exceed 1–2 mm at the first year of function and 0.2 mm after that; absence of signs and symptoms such as infection, pain, paraesthesia neuropathies, or involvement of the inferior canal during individual implant performance; and finally a success rate of 85% at the end of a 10-year period is the minimum criteria for success. [6]

So, specific attention has been directed towards postoperative radiographic assessment, which can be carried out immediately after surgery, after the initial 4–6 months healing period, on an annual basis for the first few years and then is done bi-annually [3, 7].

Postoperative radiographic assessment

It should include: the position of the implant fixture in the bone with its relation to surrounding vital structures as mandibular nerve and maxillary sinus; healing and integrity of the implant fixture in the bone; the level of peri-implant bone and any following vertical bone loss; early detection of any related disease, e.g. peri-implantitis*;* fitting of the abutment to the fixture; fitting of the abutment to the crown/prosthesis; and probable fracture of the implant or prosthesis [7].

As for initial bone loss, it was found that it generally starts at the crestal region in successfully osseointegrated endosseous implants, whatever is the surgical approaches (submerged or nonsubmerged) [8]. Crestal bone loss has been considered a common phenomenon that occurred after implant insertion, and studies suggest that after successful implantation, the rate of crestal (marginal) bone loss is approximately 1.2 mm in the first year then subsequently decrease to about 0.1 mm in following years [9].

Nowadays, multiple radiographic techniques can be used to investigate the peri-implant bone morphology [10] including intraoral periapical radiography (film and digital), panoramic radiography, and CBCT [9, 11].

Conventional periapical radiography:

The advantages of periapical radiography for implant assessment: [9, 12] are that they have high image definition, showing the mesial and distal aspects of the alveolar bone/fixture interface and marginal alveolar bone tangential to the X-ray beam, with minimal distortion and the least cost and radiation dose. On the other hand, it has some limitations such as: limited imaging area, limited reproducibility, can't give faciolingual dimensions, image foreshortening and elongation, and underestimation of the actual size of peri-implant defect with no volumetric information about it [13].

Cone Beam CT:

Cone-beam CT scanners use a 2D detector and, which allows entire volume scan with just single gantry rotation, with comparison to medical CT machines whose multiple "slices" must be fused to form a complete volumetric image. When conventional fan beam or spiral CT compared with cone-beam CT, the CBCT shows greater efficiency in X-ray use, faster volumetric data acquisition, and low cost.

CBCT have many advantages such as variable field of view (FOV); sub-millimeter resolution accuracy; high speed scanning; dramatic dose reduction;

real time analysis and manipulation; the unique implant analysis tools such as virtual simulation at all possible implant sites; no superimposition; and uniform magnification with accurate measurement within 0.1mm. However, the main disadvantages of using CBCT in implant dentistry are limited availability, sensitivity to technical errors, metallic artifacts, image interpretation needs special training, and relative bone density measurements (HU) are not calibrated.

Metallic artifacts around the dental implants provide severe limitation in using CBCT as a primary tool in post-operative assessment. Some authors recommend using conventional periapical radiography to overcome this error.

With the development of new imaging protocols in CBCT machine using low dose techniques, iCAT FLX machine provides new QuickScan + imaging protocol which is nearly equivalent to panoramic radiograph in exposure dose [14]. Also, they develop QuickScan protocol which uses low dose of x-ray when compared to other CBCT machines in the market.

Therefore, this study is carried out to evaluate the accuracy of low dose imaging protocols (QuicScan, and QuickScan +) of new iCAT FLX CBCT machine in detection and measuring peri-implant bone defects.

MATERIALS AND METHODS

Bovine rib preparation

Fresh young bovine ribs [15-17] were collected from anatomy and embryology department, faculty of veterinary medicine, Mansoura University, then transferred to oral medicine, periodontology, diagnosis and oral radiology department, faculty of dentistry, Mansoura University, then they were prepared by removing of any remaining soft tissues after that cutting them gently (to avoid creation of cracks) into ten blocks measuring approximately 80 x 20 x 12 mm (length/height/thickness) to simulate human mandibular posterior region (Fig.1). The buccal surface represented by the convex side of the block and the lingual surface represented by the opposite side [15].

The ten rib blocks were divided into five simulation models, each model consisted of two bone blocks, which simultaneously stabilized by acrylic resin supports and simulate the perimeter and positioning of the mandible body (Fig.1).

All blocks were placed in a plastic container of water (to stimulate soft tissue)[18, 19], and scanned with a CBCT unit (iCAT FLX v17 Machine, Imaging Science International, Hatfield, PA, USA) to detect any possible pre-existence cracks or bone defect that may be mistaken for the simulated defects. Defective ribs were excluded from the study.

After that, the bone samples were stored in a freezer at temp (0° F) to keep bone marrow integrity [20].

Implant site preparation and placement

Two implant sites (at least 2mm apart) were selected on the superior border of each bone block. Twenty titanium dental implants (IHDE Dental, Switzerland, size 3.3x13mm) were placed in the planned sites of rib blocks. Sequential drilling was then performed by an oral and maxillofacial surgeon to place the dental implants.

Simulated defect creation

After implant placement, twenty shallow mechanical cavities (~1-2mm) simulating peri-implant bone defects were created mesially and distally around each implant using fissure carbide dental burs (Fig. 1)

The depth of each individual defect was monitored with a digital caliper. Each implant inside rib block was numbered properly for easy retrieving of the data during the data analysis.

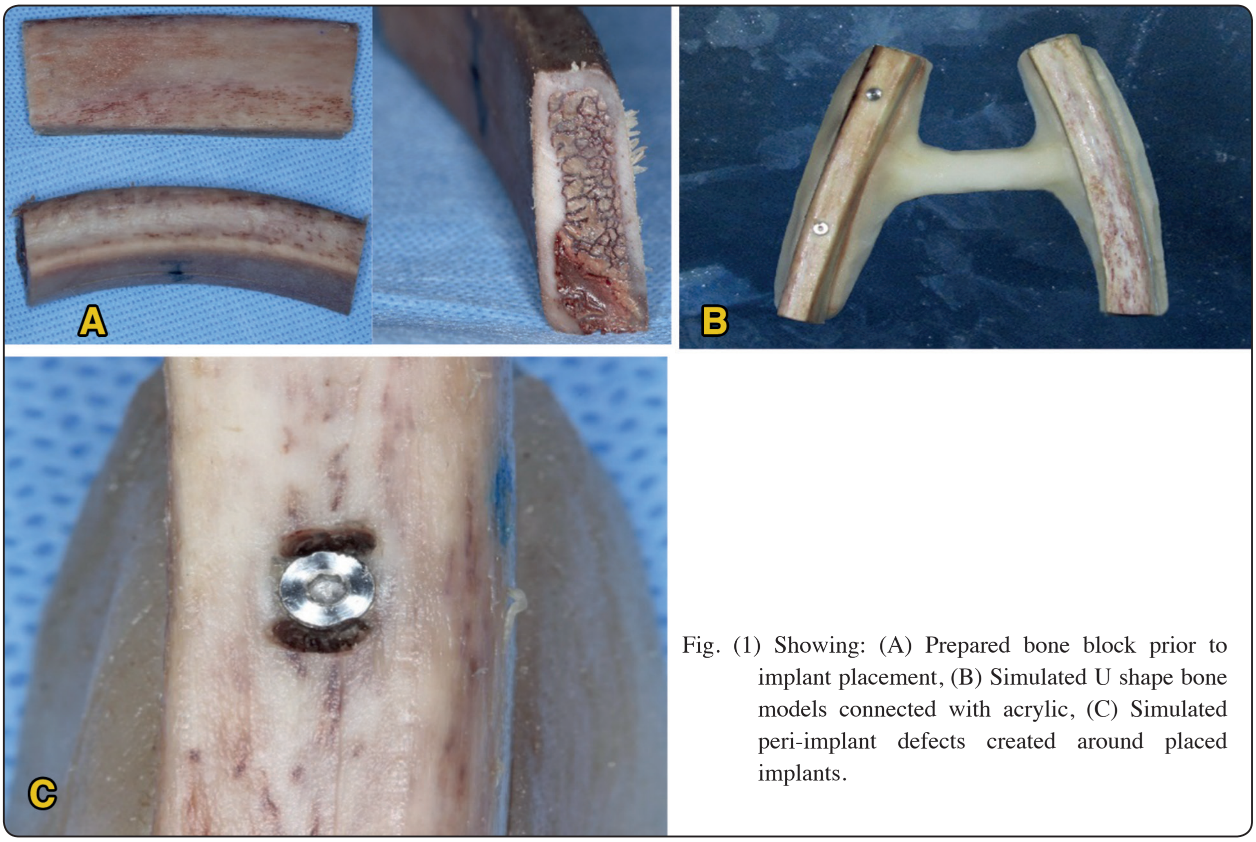

Fig. (1) Showing: (A) Prepared bone block prior to implant placement, (B) Simulated U shape bone models connected with acrylic, (C) Simulated peri-implant defects created around placed implants.

Imaging techniques:

All peri-implant crestal defects were scanned independently by using iCAT FLX v17 CBCT (Imaging Science International, Hatfield, PA, USA) with FOV (16cm diameter x 4cm height) and different imaging protocols HD Scan 0.25mm voxel, QuickScan 0.25mm voxel, and QuickScan + 0.3mm voxel size. All blocks were placed in a plastic container completely submerged in water to mimic soft tissue attenuation.

Image analysis:

Raw dicom data were imported to On-demand 3DApp software system (Cybermed, Korea) which was our dicom viewer software. All scans were analyzed by oral radiologists for accurate detection and measurement of linear depth of crestal defects in different imaging protocols.

For depth measurement, the initial depth location was determined in the axial reconstructed images, and then the long axis of the implant was adjusted in the coronal reconstructed images. The final produced images were seen on the sagittal reconstructed plane (Fig. 2), which was used to measure the depth linearly along with coronal plane then the mean of both readings was calculated for each defect (Fig. 3,4).

Data collection:

Specific computer software re-arranged the cases to be blindly reported without any known history. Three well experienced oral and maxilla-facial radiologists interpreted the cases in all imaging modalities to detect the presence or absence of the crestal bone defects around the dental implants. The analysis was performed independently and on separate occasions under the same conditions.

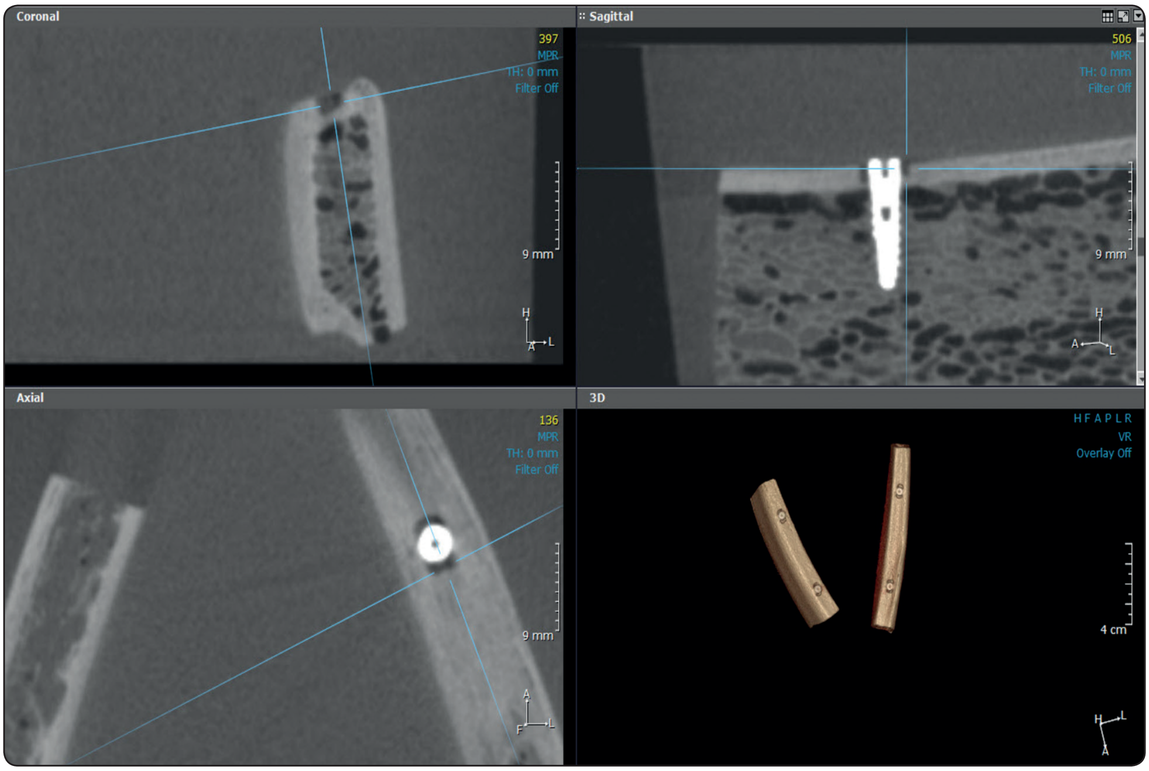

Fig. (2) Showing the simulated peri-implant defect in 3D module of ondemand 3D App Software

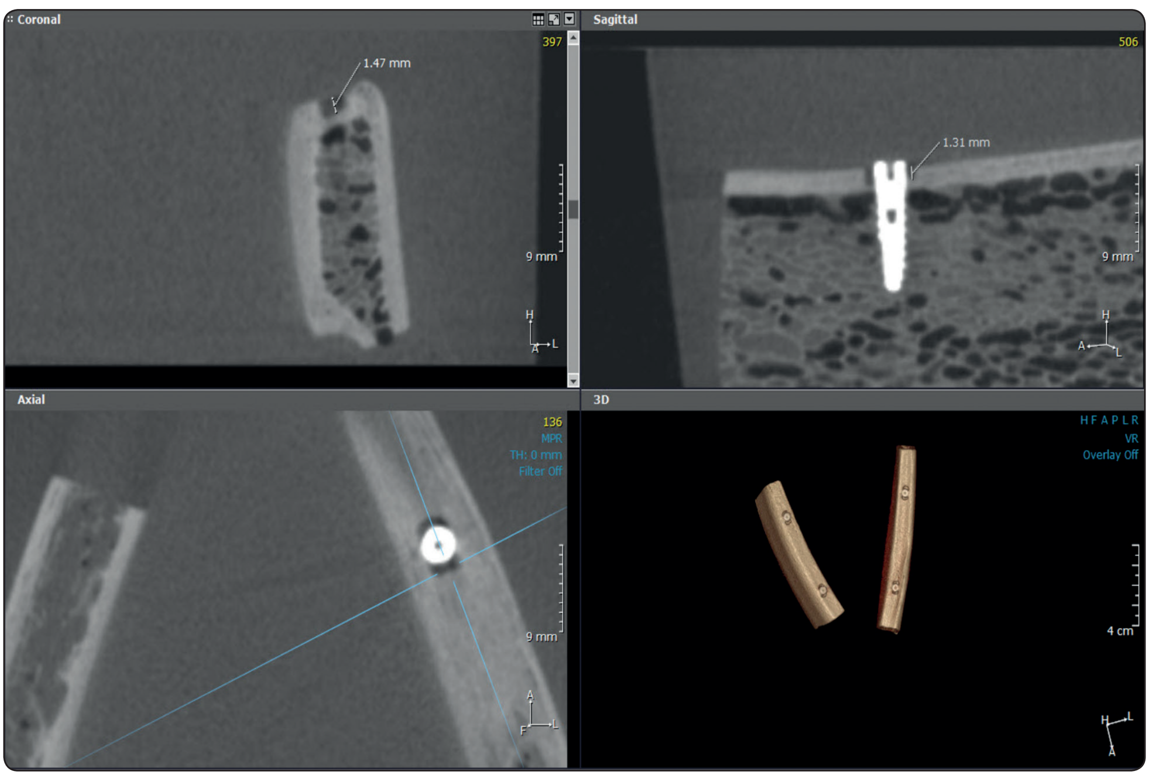

Fig. 3: Showing linear measurements of a peri-implant defect in both coronal and sagittal views

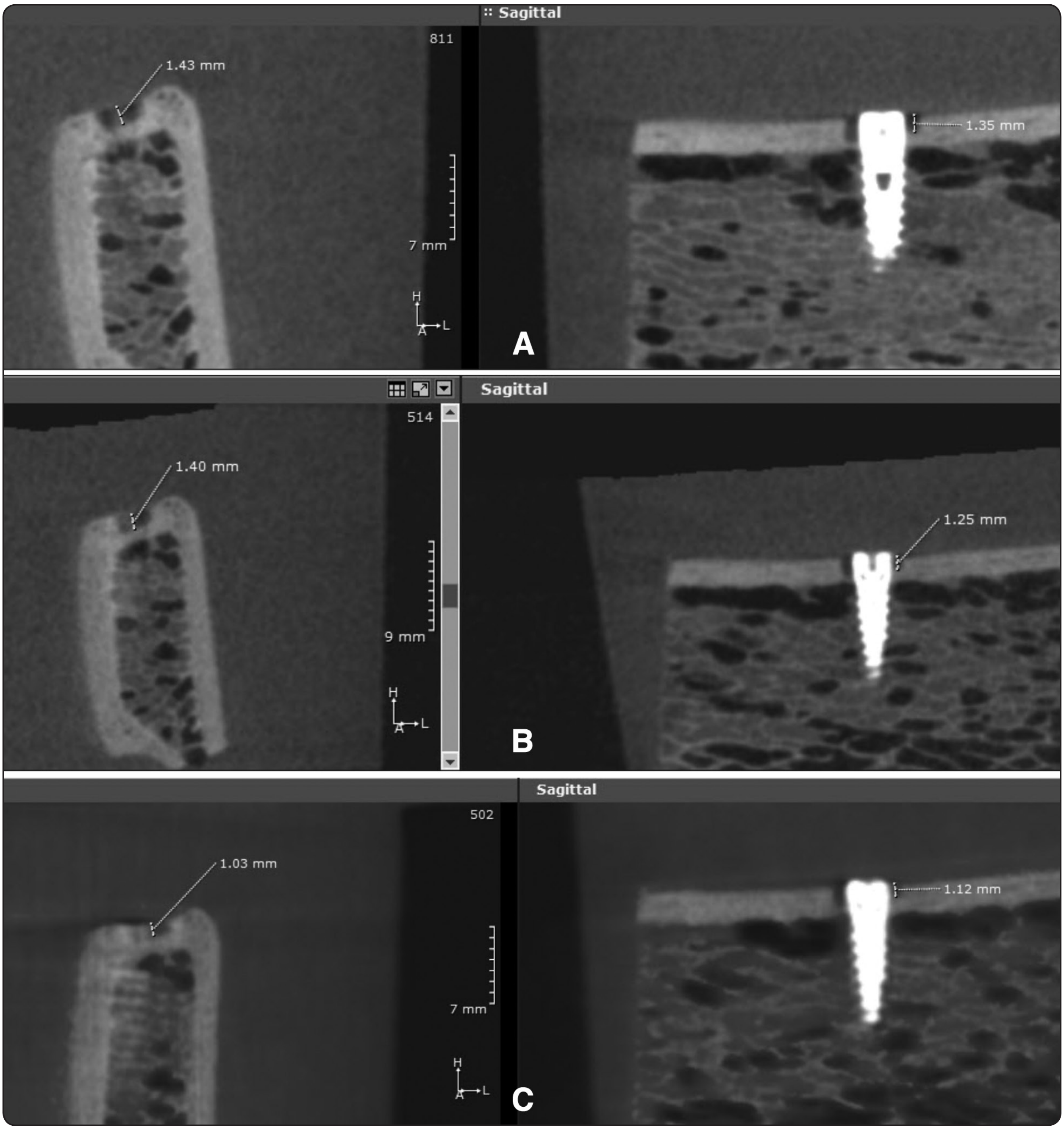

Fig. (4) Showing CBCT linear measurements in various resolutions (A) 0.25mm voxel HD Scan (B) 0.25mm voxel Quick Scan (C) 0.3mm voxel Quick Scan Plus

Data analysis:

Intra-observer and inter-observer accuracy was recorded. Then after that all the recorded data was compared with the originally created data measured by digital caliper to determine the truth and the accuracy of each imaging modality.

Statistical analysis:

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. Qualitative data were described using number and percent. Quantitative data were described using mean and standard deviation. Significance of the obtained results was judged at the 5% level &high significance <0.01 considered high statistically significant.

The used tests were

1- Kappa agreement

For reliability testing intra and inter-observer agreement for categorical variables

2 - Student t-test

For normally quantitative variables, to compare between two groups

RESULTS

Each observer interpreted the radiographs for presence or absence of crestal bone defects, and measured the defect linearly for 3 times with the same viewing condition and screen resolution. The mean was calculated for the 3 measurements. Kappa agreement (Table 1) was calculated for intra-observer reliability for each observer independently. It showed high level of agreement ranges from very good to excellent (0.86 – 1). Inter-observer reliability (Table 1) was also done between the readings for the 3 observers; it ranged from good to excellent agreement.

All CBCT readings in different voxel sizes showed high incidence level in detecting crestal bone loss around dental implant with no statistical significance between all CBCT imaging protocols. While the linear measurement accuracy for Quick Scan Plus protocol showed statistical significance (less accurate) among other imaging protocols Table (2).

TABLE (1) Shows kappa values for intra-observer and inter-observer agreements:

		1st observer	2nd observer	3rd observer
HD Scan 0.25mm voxel	1st observer	0.97		
	2nd observer	0.98	1	
	3rd observer	0.87	0.95	0.89
Quick Scan 0.25mm voxel	1st observer	0.86		
	2nd observer	0.88	1	
	3rd observer	0.93	0.74	0.98
Quick Scan Plus 0.3mm voxel	1st observer	1		
	2nd observer	0.75	0.92	
	3rd observer	0.82	0.79	1

Excellent agreement (0.9-1), Very good (0.8-0.9), Good (0.7-0.8), Fair (0.6-0.7), poor (< 0.6)

Table (2) comparing linear measurements between different CBCT imaging protocols:

	Peri-implant defect n=20 Mean ± SD	test of significance
HD Scan 0.25mm voxel	1.49±0.11	t=0.03 p=0.98
Quick Scan 0.25mm voxel	1.43±0.14	t=0.48 p=0.64
Quick Scan Plus 0.3mm voxel	1.17±0.12	t=1.89 p=0.04*

t: Student t test **** P value significant <0.05***

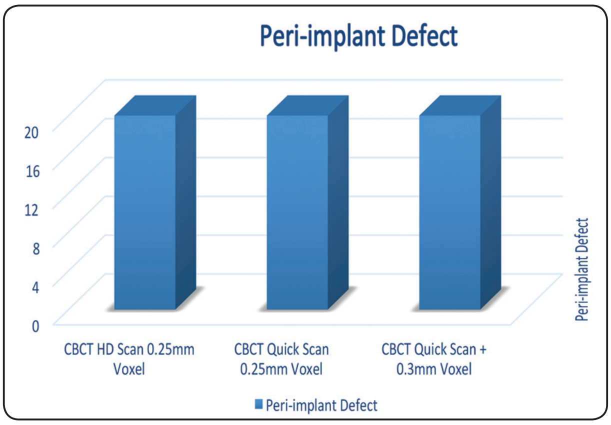

Fig. (5) Showing the incidence of crestal bone defect appearance in comparison of different CBCT imaging resolutions with small peri-implant defects.

DISCUSSION:

Postoperative imaging of dental implant is considered a mandatory in terms of assessment of implant location, stability and long run success. Periodic radiographic review is essential for monitoring the bone-implant interface, marginal peri-implant bone height and diagnosis of peri-implant bone defects. Therefore, the choice of an accurate and reliable imaging modality will help in early detection of such defects, accurate determination of defect size and selection of appropriate regenerative strategies.

So, multiple studies have been done to examine peri-implant bone defects using different radiographic techniques taking into consideration the advantages and disadvantages of each technique. Several studies [3, 16, 20-26] suggested using of CBCT images regarding many variables such as: field of view, number of frames, scan modes and even different CBCT systems [15].

According to the recommendations of the American academy of oral and maxillofacial radiology (AAOMR), intraoral periapical radiography provides adequate imaging for the postoperative implant assessment if there are no clinical signs and symptoms. Panoramic imaging may be used in cases with more extensive implant therapy. As for CBCT imaging, it's not indicated for periodic follow up of clinically asymptomatic patients [27].

The new iCAT FLX machine series provide low dose imaging protocols QuickScan and QuickScan +. Both Scanning protocols showed high accuracy in detection of shallow peri-implant bone defects with no statistical significance with the HD scans of the same voxel size. But in assessing the accuracy of linear measurements of bone defects around dental implants, QuickScan Protocol and HD Scan protocol was more superior than QuickScan + one.

These results may be attributed to the low exposure parameters of the QuickScan + protocol as it uses 90 KVP, 3 mA, and just 2 seconds exposure time. The result was high noise in the image and increase in metal artifact of the dental implant which interferes with accurate measurements of the peri-implant bone defect and accurate visualization of bone margins.

A study by **Kamburoglu K. et al.** [3] investigated the accuracy of CBCT radiography in evaluation of buccal marginal peri-implant bone defects using different fields of view. Similar to the present study, mechanical cavities were prepared using dental burs, the defects were classified into small, medium and large with different depths and widths ranging from 1 to 5mm. The authors reported that all CBCT images were of similar performance in assessment of simulated defects.

Regarding different voxel sizes and scan modes a study by **De-Azevedo-Vaz, S.L. et al.** [24] tested CBCT accuracy in evaluation of peri-implant fenestration and dehiscence using two scan modes (180°, 360°) and (0.12mm,0.2mm) voxel sizes. The authors concluded that different voxel sizes had no effect on fenestration and dehiscence detection.

Pinheiro LR. et al. [28] evaluated the effect of number of frames and FOV size of CBCT in the diagnosis of peri-implant crestal defects. It has been found that the higher detection of both small and large defects obtained by using the highest number of acquisition frames (1009 frames), smallest FOV (4x4 cm) and smallest voxel size (0.08mm), however all protocols are still adequate to evaluate crestal bone loss but special considerations should be taken for higher radiation dose in smallest voxel size.

CONCLUSION

In case of periodic postoperative follow up for asymptomatic dental implants we can use QuickScan + imaging protocol for assessment of bone around dental implants with no fear of additional radiation dose. But if we need accurate depth measurement of the bone defect or if we have symptomatic case, we recommend using QuickScan imaging protocol to use the minimal radiation dose available.

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