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## RESEARCH ARTICLE

## QUANTIFICATION OF INTRA OSSEOUS BONE DEFECTS BY CONVENTIONAL VERSUS 3D DIMENSIONAL IMAGING TECHNIQUES - AN IN VIVO STUDY.

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### Abstract

**Background:-** The aim of this prospective cross sectional study was to determine the accuracy of CBCT in quantifying intra-osseous periodontal bone defects.

**Methods:-** 5 patients with intra-bony defects were selected and 10 defects were assessed. A total of 60 measurements were performed. Periapical radiographs and Cone beam CT scan images were obtained. Height and depth of each defects was measured using appropriate software. Direct measurements were done during surgical interventions using a periodontal probe and were considered the standard reference. Measurements made by all three modalities were compared to each other.

**Results:-** Linear measurements for all defects revealed no statistical differences between CBCT and direct intra-surgical measurements with respect to the height as well as the depth of the defect. There was a significant difference when comparing peri-apical radiographs to the other two methods. IOPA measurements were only 74.3% accurate as compared to the standard intra-surgical whereas the CBCT measurements were 86.5%.

**Conclusion:-** All three modalities proved to be useful for identifying interproximal periodontal defect but CBCT took the lead with better accuracy in reproducing the clinical measurement of intra-bony periodontal bone defects and better visualization of the extent of the defect.

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### Introduction:-

Currently, periodontal disease is considered one of the most prevalent oral diseases affecting the adult population<sup>1</sup>. The hallmarks of periodontal disease are inflammation, attachment loss, bone resorption, and eventually tooth mobility. Estimation of bone loss is of utmost importance in diagnosing periodontal disease, selecting the

treatment modality and in determining prognosis. Current approaches to accurately diagnose periodontal disease include clinical probing of gingival tissues and an adjunctive use of radiographs to evaluate osseous structure.<sup>2</sup>

Current conventional imaging includes bitewings, peri-apical (PA) and panoramic radiographs, with the main radiographic technique used for periodontal diagnosis being the paralleling extension cone method<sup>3</sup>. These are easily acquired, cheap and provide high-resolution images; however they are not without limitations. The chief drawback is the problem of conspicuity which is largely the result of the presence of overlying anatomic structures and the representation of a 3D structure depicted by a two dimensional (2D) image.<sup>4</sup> The difficulty to reproduce angles over time leads to lack of standardisation.<sup>5</sup>

There is ample research demonstrating that funnel-shaped or lingually located defects cannot be detected<sup>6</sup> and that destruction of the buccal plate can be undiagnosed or undistinguished from lingual defects<sup>7</sup>. This makes it difficult to obtain an effective evaluation of periodontal bone loss, especially crater defects. Further studies comparing radiographs to pre-surgical measurements concluded that bone loss can be underestimated by; 1.5 mm, with large variations between examiners<sup>8</sup>. Consequently, traditional radiography remains a limited diagnostic tool<sup>9</sup>.

To address these issues, computed tomography (CT) has been explored because of its ability to produce accurate three-dimensional imaging without distortion. However, limitations such as high radiation, machine size, machine cost, complexity, and relatively low resolution have made this approach impractical<sup>10</sup>. Recently, cone beam computed tomography (CBCT) has turned this concept into potential reality because these lower-cost small machines produce high-quality data. The cone beam computed tomography has been used for imaging of the temporo-mandibular joint<sup>11</sup>, evaluating oral osseous lesions<sup>12</sup>, assessing maxillofacial deformities<sup>13</sup> and in preoperative planning of dental implants<sup>14</sup>. It may be adequate to visualize periodontal alveolar bone changes and emerge as a feasible tool in periodontal diagnosis. Yet there is little research to establish the use of this technique as a valid method for periodontal bone measurements.

Research comparing the use of CBCT to 2D radiographs in artificial bone defects has shown that CBCT has a sensitivity of 80–100% in the detection and classification of bone defects, while intraoral radiographs present a sensitivity of 63–67%.<sup>15</sup> In vitro studies involve no patient motion. Motion can, and often does, lead to CBCT image degradation.<sup>16</sup> In vivo research on this subject is also very limited to provide us with strong evidence. With these considerations in mind and with reference to current literature, the aim of this study was to verify the diagnostic accuracy of CBCT for intra-osseous periodontal bone defects, linearly, by using the peri-apical radiograph and direct intra-surgical measurement as a reference standard.

### **Material and methods:-**

The study was conducted in the Department of Periodontology, Manipal college of Dental Sciences, Manipal University, Mangalore, Karnataka. The study was initiated after approval from the Institutional Ethical committee. The study employed a prospective, double-blinded, comparative cross-sectional design.

Patients who were systemically healthy, vital teeth in whom interproximal intra-bony defects were present (>5mm), 2 or 3 walled defects and vertical bone defects of  $\geq 2$  mm on IOPA (intra oral peri-apical) radiograph were included in the study. Subjects who were immune-compromised, smokers, pregnant and lactating women, those taking any drugs (steroids, anticoagulants, anti-epileptics etc.) which are known to affect the healing and clotting mechanisms, causing gingival enlargement, and those with horizontal defects were excluded from the study.

The study protocol was in accordance with the ethical principles of the Declaration of Helsinki of 2008 as revised in 2013. Patients gave written informed consent to participate in the study. All the subjects signed a written informed consent form prior to being included in the study.

A total of five patients were selected. All patients who were undergoing non-surgical periodontal therapy with an additional need for surgical interventions were consequently selected from January 2014 to March 2014.

Clinical examination of all the subjects included measurement of oral hygiene status (Full mouth Plaque & Gingival index, pocket probing depth (PD) and clinical attachment loss (CAL)). A UNC-15 (GDC, PCP UNC-15) graduated periodontal probe calibrated to the nearest millimetre was used (Figure 1). The PD was recorded from the gingival margin to the base of the pocket. The CAL was determined by measuring the distance from the cement enamel

junction (CEJ) to the base of the pocket. Upon clinical examination if the patient met the inclusion criteria, they were subjected to a routine peri-apical radiograph with grid using the Long cone paralleling technique. For a more detailed view a CBCT scan for the involved tooth was also taken. So, each patient was subjected to an intra-oral peri-apical radiograph and a CBCT scan.

The IOPA radiograph was done for each selected site using a long cone paralleling technique where the film was placed parallel to the specific tooth with the central ray of the x-ray device perpendicular to the tooth of interest. The same film holder (XCP, RINN DENTSPLY) was used for all the radiographs. The F-speed film (Kodak Care stream Health Inc. New York, USA) mount with millimetre grid scale was used. All radiographs were digitalized using a digital camera (Cannon IXUS 105; 12.1 mega-pixels) and transferred to the computer in JPEG format. The IOPA radiograph of the area of interest was thoroughly examined prior to surgery. (Figure 2)

CBCT scanning was performed using the clinically available machine (ProMax3DMid ProFacePLANMECA). The images were obtained using CBCT, and measurements were performed using the appropriate software. The present investigation used reconstructed 1.0 mm slices (voxel size) because this increment closely represents the same error of measurement when using a periodontal probe and because smaller slices decreases the image resolution.<sup>17</sup> Images were analysed by axial, cross-sectional and sagittal reconstructions. The kVp, mA and scan duration was preset on the machine and inherently varied from patient to patient on the basis of built-in jaw size and field of view. (Figure 3)

All Peri-apical films were analysed using the Image J software, designed by National Institute of Health (NIH). The CBCT scanners inbuilt software had an electronic measuring tool to the nearest hundredth of a millimetre. All CBCT images were saved in DICOM format (Digital Imaging and Communications in Medicine) and were identical for each measurer as they were established by the same investigator, saved, and loaded at each session. The examiners used only one computer, and screen settings remained unchanged (1280 x 1024 resolution). The examiners had the ability to change bone density and the size of the image to aid in optimal viewing.

Grid markings on the radiographs and the CBCT scanned images were used to measure the following two measurements: (Figure 2,3)

1. Height of the defect: Distance from CEJ to coronal part (C) of defect. (CEJ-C);
2. Depth of the defect: Distance from CEJ to apical part (base) (A) of defect. (CEJ-A)

Periodontal bone defects were then measured during the surgical intervention using the cement-enamel junction, crest of the defect and base of the defect as the reference points. The direct surgical measurements were made using a UNC-15 graduated periodontal probe placed in a line parallel to the long axis of the tooth. The measurements taken were same as that recorded for CBCT and IOPA. Measurements falling between two marks of the periodontal probe were rounded up to the nearest millimetre. (Figure 4)

#### **Statistical Analysis:-**

Statistical analysis was performed using statistical software (SPSS.v.20). Coefficients of variation, using Pearson's method, were calculated to determine variability within the examiners and among the techniques. Interclass correlation was done to compare the accuracy of CBCT, IOPA and intra-surgical measurements. Paired t test was used to assess if the means of each of the six groups were statistically different from each other. The six groups are listed in the table.

Finally, A sample size of 6 achieved 83% power to detect a difference of -0.6 between the null hypothesis mean of 0.0 and the alternative hypothesis mean of 0.6 with an estimated standard deviation of 0.4 and with a significant level (alpha) of 0.5000 using a two-sided one-sample t-test.

Since 6 is a very small value for statistical analysis, the study had a sample size of 10.

**Results:-**

Five patients who met the inclusion criteria were selected for the study from January to March 2014. A total of ten defects were assessed and 60 measurements were performed. For measurement and validation purposes, both single- and multi-rooted teeth were considered. In order to represent different cortical and cancellous bone structures, both maxillary and mandibular teeth were included in the study. In order to classify the presence of alveolar bone loss, a distance of 3 mm from the CEJ to the Alveolar crest was used as the parameter of normality. The intra-surgical measurements are the gold standard parameter.

All defects were angular defects and the measurements were confined only to the inter-proximal area. The CBCT allowed for visualisation of defects on the buccal and lingual aspect as well. However the buccal and lingual defect measurements were not taken into consideration as these were masked in the IOPA.

The height (CEJ-C) and depth (CEJ-A) of each interproximal defect for each method was compared against the intra-surgical measurement.

Correlations between the two examiners varied between 0.09 and 0.99

The mean heights of the defects were 6.15mm, 5.28mm and 5.3mm respectively for IOPA, CBCT and intra-surgical method. The IOPA measurements showed a statistically significant difference from the other two methods. There was no statistically significant difference with respect to CBCT versus intra-surgical measurements. (Table 1, figure 5)

With respect to the defect depth, means were 9.3mm, 8.46mm and 8.28mm respectively for IOPA, CBCT and intra-surgical method. The results were statistically significant for IOPA versus the other two methods, but were not significant for CBCT versus intra-surgical. (Table 1, figure 5)

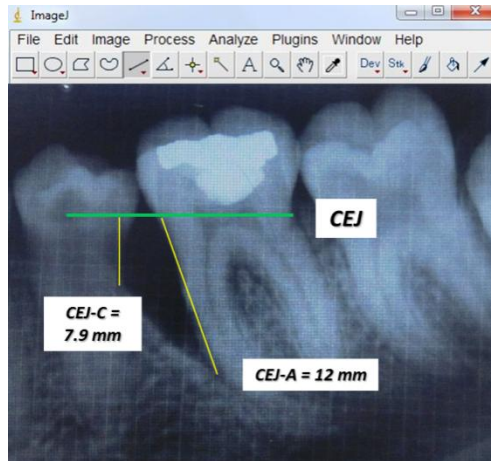
The interclass correlation depicted that the IOPA measurements were only 74.3% accurate as compared to the standard intra-surgical whereas the CBCT measurements were 86.5%. (Figure 6)

**Figures:-**

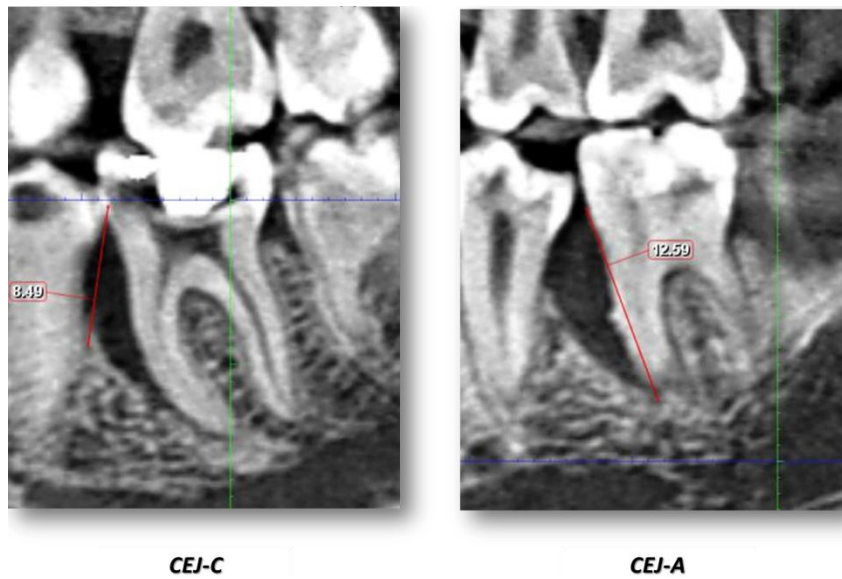
**Figure 1:** Defect measurement using UNC 15 probe.



**Figure 2:** Defect visualised on IOPA



**Figure 3:** Defect measurement on IOPA using Image J software.

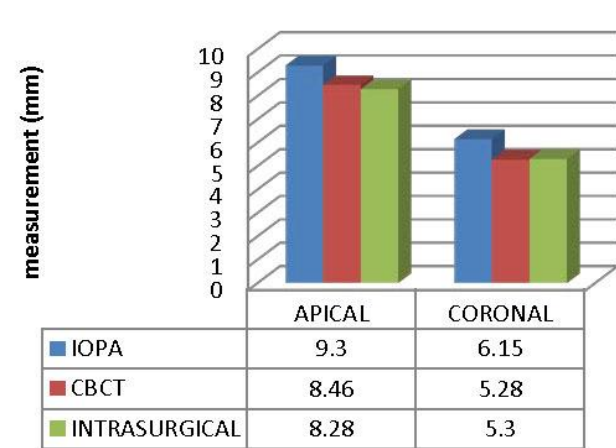


**Figure 4:** Defect measurement on the CBCT scanned image.

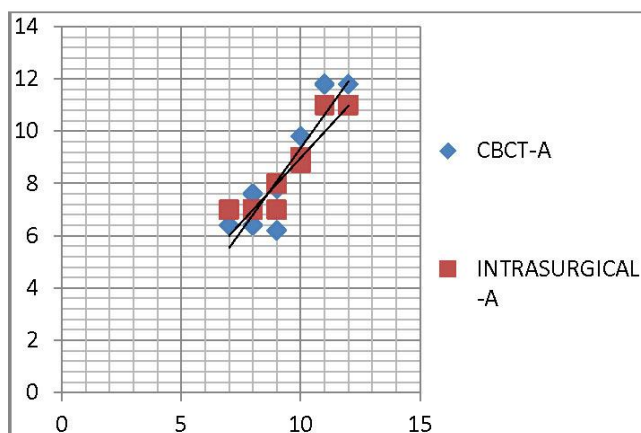


**Figure 5:** Intrasurgical defect visualization.





**Figure 6:** Graphical representation of the comparison between the accuracy of IOPA, CBCT and Intra-surgical measurements from the CEJ to the coronal and the apical extent of the defect.



**Figure 7:** Interclass correlation between the three modalities depicting that the IOPA measurements were only 74.3% accurate as compared to the standard intra-surgical whereas the CBCT measurements were 86.5% accurate.

**Table1:** Comparison Of Measurements Obtained By IOPA, CBCT And Intra-Surgical.

		Mean(mm)	Std. Deviation(mm)	Mean diff(mm)	Std. Deviation diff(mm)	p Value
Pair 1	IOPA-A	9.3	1.494	0.84	0.969765	<b>0.023*</b>
	CBCT-A	8.46	2.097724			
Pair 2	CBCT-A	8.46	2.097724	0.18	0.66966	0.417
	INTRASURGICAL -A	8.28	1.628087			
Pair 3	IOPA-A	9.3	1.494	1.02	0.66966	<b>0.001*</b>
	INTRASURGICAL -A	8.28	1.628087			
Pair 4	IOPA-C	6.15	1.4539	0.87	0.579368	<b>0.001*</b>
	CBCT-C	5.28	1.451283			
Pair 5	CBCT-C	5.28	1.451283	-0.02	0.725412	0.932
	INTRASURGICAL -C	5.3	1.337			
Pair 6	IOPA-C	6.15	1.4539	0.85	1.0014	<b>0.025*</b>
	INTRASURGICAL -C	5.3	1.337			

## Discussion:-

The two-dimensional radiographic assessment and clinical examination were the only hopes for periodontal diagnosis till the advent of the three dimensional CT scan. The application of CT scan also deemed impractical due to size of the machine, radiation dose and cost. Overcoming all these limitations was the Cone Beam computed tomography, but research to substantiate its use for periodontal diagnosis has been limited. In the insight of literature, a systematic review reported that out of all the studies utilizing CBCT, only 3% were in the field of periodontology and most of them were in-vitro<sup>18</sup>.

CBCT facilitates to obtain a 360 degree image of the skull due to the generation of conic shaped beams as opposed to the fan shaped X-ray beams of the conventional CT scan machine. CBCT also results in a 15 fold reduction in the radiation absorbed by collimation of the primary X-Ray beam to a smaller area of interest<sup>19,20</sup>. There are many studies that substantiate the fact that the radiation observed via CBCT is lesser than that by the CT scan machine. Honda et al<sup>11</sup> reported a reduction from 160 to 1.19 mSv. Scaf et al reported a radiation exposure of 1.031 mSv(maxilla) & 2.426 mSv (mandible) using CT scan as opposed to 0.022 mSv in one study or to 0.15mSv for a full mouth series<sup>21</sup>. The NCRPM (National Council on Radiation Protection and Measurements) supplants the claim that the CBCT's radiation dose is within the conservative limits even at the highest CBCT exposure settings. It is likely that radiation exposure will further reduce as technology advances.<sup>22</sup>

In spite of the CBCT being recommended as a dose sparing technique, the image quality eventually depends on the actual dose applied which varies slightly among different manufacturers and patient built. In this study we used a voxel size of 1mm as this closely represents the same error of measurement when using a periodontal probe and using smaller slices tends to decrease the image resolution<sup>17</sup>. 0.4mm voxel size was used in an in vitro study by Vandenberghe et al and a 0.2mm voxel size was used in an in vivo study by Feijó et al. This change in voxel size usage is due to difference in methodology and comparisons used. In vitro studies have less radiation dose absorbed. Feijó et al in their in vivo study used a smaller voxel size because a higher dose would provide higher-resolution images in an in vivo study. They compared the CBCT measurements only to intra-surgical measurements. Since we used the 2-D radiographs and the intra-surgical measurements for reference, a voxel size of 1mm was used. However, more research, including outcome assessment of various exposure and reformatting protocols and evaluation of the diagnostic validity during clinical follow-up, is required for proper justification of various CBCT applications in dental and maxillofacial radiology.

Out of all the in-vivo investigation on this subject, 3 were case reports.<sup>23,24,25</sup> One study by K de Faria Vasconcelos et al compared the CBCT measurements to the measurements of 2-D digital images retrospectively<sup>15</sup> and another prospective study by Feijó et al prospectively compared the CBCT measurements to intra-surgical for horizontal defects.<sup>26</sup> Our study was an in vivo study and the first study as such which compared all the three modalities i.e. IOPA, CBCT and intra-surgical measurements for intra-bony angular defects. This study closely represents the day to day clinical scenario with all the relevant standardisations taken into consideration.

Our study results showed that with respect to the depth of the defect, the IOPA showed a mean **over estimation of 1.02 mm** as compared to intra-surgical, and the CBCT showed a mean **over estimation of 0.18mm**. With respect to defect height, the IOPA showed a mean **over estimation of 0.85mm** as compared to intra-surgical, and the CBCT showed a mean **underestimation of 0.02mm**. Also the buccal and lingual extent of the defect were masked in the IOPA so the IOPA did not allow us to visualize deepest point of the defect if it lied in the vestibular areas. The CBCT images however allowed clear visualisation of the buccal and lingual extent of the defect. The exact morphology of the defect could thus be visualised. The IOPA still led to a mean over estimation of the defect measurements in the inter-proximal areas possibly because of errors in projection geometry and difference in the film placement for the different areas of the jaw. It was seen that there was more over-estimation in the anterior region, but the posterior region either over or underestimated.

Our study results were in agreement with an in vitro study by Vandenberghe et al who reported a significant difference between the 2-D radiographs and the CBCT. At 0.4mm voxel size, a mean error of 0.29 mm was detected on the 2D-CCD as compared to the CBCT, indicating that the CBCT demonstrated values closer to the gold standard<sup>27</sup>. Similarly, Misch et al showed that CBCT measurements were as accurate as direct measurements using a periodontal probe in experimentally created buccal and lingual defects.<sup>10</sup>

Feijó et al in their human study reported no statistically significant difference between clinical and CBCT measurements for horizontal bone defects in the maxillary posterior region. We are uncertain why the results of the present study differed from that of Feijo et al. It is possible that it can be due to the difference in the type of defects of both the studies. Another probable cause could be that we have taken all the areas of the jaw in to consideration whereas Feijo et al had a sample that consisted only of maxillary posterior teeth. The difference in the morphology and the result of difficult visualization during the clinical examination, mainly in the distal aspects may play a role as well.

It is worth noting that a 0.5-mm discrepancy between clinically and radio-graphically estimated bone levels is considered clinically acceptable.<sup>5</sup> The clinical measurements were obtained using probes with an accuracy of 1 mm, whereas CBCT measurements allowed an accuracy of up to three decimal places. These differences can cause some discrepancy in the comparison. So, further clinical studies are necessary to lay down certain guidelines and criteria's which will work as sure shot indications for the use of 3D imaging methods in periodontal diagnosis and treatment planning.

### **Conclusion:-**

CBCT measurements compared well to the intra-surgical measurements in the quantification of intra-osseous periodontal bony defects. Considering the several advantages, limitations and risks of both modalities, though CBCT has higher cost and effective radiation dose, it provides more accurate details than IOPA especially in determining the size of the interproximal defects and the morphology of angular defects where the apex of the defect lies in the buccal or lingual area. One may conclude that the use of CBCT should only be reserved for relatively more complex periodontal treatment planning such as prognostic planning and surgery for complex periodontal defects. It should not be used explicitly for every case, however when in doubt we must not think twice before using the CBCT images as a cue.

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### **References:-**

1. Scaf G, Morihisa O LLC. Comparison between inverted and unprocessed digitized radiographic imaging in periodontal bone loss measurements. *J Appl Oral Sci.* 2007;15:492–94.
2. Jeffcoat MK. Current concepts in periodontal disease testing. *J Am Dent Assoc.* 1994;125(8):1071–78.
3. Jeffcoat MK. Radiographic methods for the detection of progressive alveolar bone loss. *J Periodontol.* 1992;63(4 Suppl):367–72.
4. Mol A, Balasundaram A. In vitro cone beam computed tomography imaging of periodontal. *Dentomaxillofac Radiol.* 2008;37:319–324.
5. Mol A. Imaging methods in periodontology. *Periodontol.* 2004;(34):34–48.
6. Ramadan AB MD. A roentgenographic study of experimental bone destruction. *Oral Surg Oral Med Oral Path.* 1962;15:934–43.
7. Rees T, Biggs NL CC. Radiographic interpretation of periodontal osseous defects. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 1971;2:141–53.
8. Eickholz P HE. Accuracy of radiographic assessment of interproximal bone loss in intrabony defects using linear measurements. *Eur J Oral Sci.* 2000;108:70–3.
9. Hirschmann PN. Radiographic interpretation of chronic periodontitis. *Int Dent J.* 1987;37:3–9.
10. Misch K a, Yi ES, Sarment DP. Accuracy of cone beam computed tomography for periodontal defect measurements. *J Periodontol.* 2006 ;77: 1261-1266
11. Honda K, Arai Y, Kashima M et al. Evaluation of the usefulness of the limited cone-beam CT (3DX) in the assessment of the thickness of the roof of the glenoid fossa of the temporomandibular joint. *Dentomaxillofac Radiol.* 2004;33:391–5.



12. Fuhrmann RA, Bucker A DP. Assessment of alveolar bone loss with high resolution computed tomography. *J Periodontal Res.* 1995;30:258–63.
13. Hamada Y, Kondoh T, Noguchi K et al. Application of limited cone beam computed tomography to clinical assessment of alveolar bone grafting: A preliminary report. *Cleft Palate Craniofac J.* 2005;(42):128–37.
14. Casap N, Tarazi E, Wexler A, Sonnenfeld U L, J. Intraoperative computerized navigation for flapless implant surgery and immediate loading in the edentulous mandible. *Int J Oral Maxillofac Implant.* 2005;20:92–8.
15. De Faria Vasconcelos K, Evangelista KM, Rodrigues CD, Estrela C, de Sousa TO, Silva M a G. Detection of periodontal bone loss using cone beam CT and intraoral radiography. *Dentomaxillofac Radiol.* 2012; 41, 64–69
16. Tyndall D a, Rathore S. Cone-beam CT diagnostic applications: caries, periodontal bone assessment, and endodontic applications. *Dent Clin North Am.* 2008 ;52(4):825–41
17. Mealey BL. Comparison of Clinical , Periapical Radiograph , and Cone-Beam, Volume Tomography Measurement Techniques for Assessing Bone Level Changes Following Regenerative Periodontal Therapy. *J Periodontol.* 2009;80(1):48–55.
18. Vos W De, Casselman J, Cone-beam GRJS. Cone-beam computerized tomography ( CBCT ) imaging of the oral and maxillofacial region : A systematic review of the literature. *J Oral Maxillofac Surg.* 2009;38:609–625.
19. Practice D, Scarfe WC, Farman AG. Clinical Applications of Cone-Beam Computed Tomography in Dental Practice. *J Can Dent Assoc.* 2006;72(1):75–80.
20. Estrela C, Bueno MR. Accuracy of Cone Beam Computed Tomography and Panoramic and Periapical Radiography for Detection of Apical Periodontitis. *J Endod.* 2008;34(3):273–9.
21. Scaf G, Lurie AG, Mosier KM, Kantor ML RG, ML. F. Dosimetry and cost of imaging osseointegrated implants with film-based and computed tomography. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 1997;(83):41–8.
22. Palomo JM, Rao PS HM. Influence of CBCT exposure conditions on radiation dose. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2008;105:773–82.
23. Songa VM, Jampani ND, Babu V, Buggapati L, Mittapally S. Accuracy of cone beam computed tomography in diagnosis and treatment planning of periodontal bone defects: a case report. *J Clin Diagn Res;*8(12):ZD23–ZD25
24. Sugai K, Sato S, Suzuki K IK. Intentional Severe, reimplantation of a tooth with Enamel, periodontal involvement using With, matrix derivative in combination Bone, guided tissue regeneration and Report., grafting: A case. *Int J Periodontics Restor Dent.* 2008;28:89–94.
25. Nakajima K, Yamaguchi T MK. Surgical orthodontic treatment for a patient with advanced periodontal disease: Evaluation with electromyography and 3-dimensional cone-beam computed tomography. *Am J Orthod Dentofac Orthop.* 2009;136:450–9.
26. Feijó CV, Joyce DDS, Feitosa G. Evaluation of Cone Beam Computed Tomography in the Detection of Horizontal Periodontal Bone Defects : An In Vivo Study. *Int J Periodontics Restor Dent.* 2012;32(5):162–169.
27. Vandenberghe B, Jacobs R, Yang J. Detection of periodontal bone loss using digital intraoral and cone beam computed tomography images: an in vitro assessment of bony and/or infrabony defects. *Dentomaxillofac Radiol;*37(5):252–60.