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CBCT Evaluation of Periodontal Bony Defects and Graft Outcome: Protocol Standardization – A Need of the Hour.

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Abstract

Cone beam computed tomography (CBCT) has emerged in the dental and maxillofacial imaging as a 3-d alternative to medical computed tomography (ct). Its sub – millimetre isotropic voxel resolution allowing the non-orthogonal sectioning of the obtained data sets with minimum magnification and distortion elucidates its potential for periodontal assessment.

The CBCT method for evaluating and scoring bone graft outcome is based on site evaluation as cemento-enamel junction (cej) to marginal bone level of the tooth adjacent to the graft, marginal bone level to the root apices of the tooth adjacent to the graft, labiolingual alveolar bone graft thickness and increase in the density dependent on mineral apposition likely induced by the graft.

This paper deals with the use of CBCT related to the periodontal and graft outcome assessments need for protocol standardization.

Keywords: CBCT Periodontal Assessment, Mean Error Of Measurement, Specificity, Sensitivity.

Introduction

Periodontium is defined as the specialized tissues that both surround and support the teeth, maintaining them in the maxillary and mandibular bones. The word comes from the greek terms 'peri-'meaning "around" and -odont, meaning "tooth". [1] a very important part of this support system of the tooth is comprised of the alveolar bone. Alveolar bone is defined as the parts of maxilla and mandible that form and support the socket of the teeth. [2] alveolar bone loss is the hallmark of periodontal disease progression and the prevention of this bone loss is the key to maintaining periodontal health. [3] from a clinician's point of view, it is of utmost importance to make a correct assessment of the bone condition which is critical for the diagnosis, treatment planning and prognosis of the periodontal disease.

Oral radiology has always been a vital diagnostic aid in the detection of such bony defects in periodontology by demonstrating changes in the bone height and architecture. Over the years, conventional radiographs complementing periodontal diagnosis such as periapical, bitewing and panoramic have been used as the diagnostic tools. However, the use of these radiographs is limited to advanced cases, as these modalities are capable of detecting alveolar bone loss only when 30% to 50% of the bone mineral in the pathologic area is destroyed. The limitations of two-dimensional (2d) radiography such as superimposition, distortion and underestimation of periodontal bony defects contests its credibility.[4] the introduction of cone beam computed tomography (CBCT) by arai et al. And mozzo et al. Offers 3d exploration and more accurate imaging as opposed to 2d imaging. [5]

Since its introduction, CBCT has rapidly ingressed itself into the dental setting due to the multitude of advantages it possess over conventional radiographs and medical ct which due to high radiation dose, cost, availability, longer scanning time, poor resolution and difficulty in interpretation was utilized restrictively . Several studies having compared the two-dimensional and three-dimensional imaging modalities have shown superiority of CBCT in terms of sensitivity for detection of bone defects with the sensitivity being 80%-100% as opposed to 63%-67% of intra-oral radiographs. Conventional ct provide anisotrophic voxels whereas CBCT provides isotrophic voxels. The sub-millimetric resolution ranging from 0.4mm to 0.09mm, provided by CBCT is precise enough for measurements required to fulfil the exactness needed for implant size assessment. [5] moreover, the ability to view the alveolar bone in three dimensions and to make measurements at any location could significantly improve periodontal diagnosis.

CBCT is a variation of the traditional computed tomography. It has been described as the gold standard for imaging the oral and maxillofacial area. Its three dimensional (3d) imaging against sliced two dimensional (2d) images of ct, makes it eminently suitable for periodontal diseases. Ambiguity in reporting and lack of standardisation of protocol in reporting of periodontal defects with respect to measurements and not visual assessments alone should emphasize on the attention needed by the maxillofacial radiologist.

The purpose of this review is to provide insight about the efficiency of CBCT in evaluating dehiscence, fenestration, furcation involvement, periodontal bone loss, intrabony defects, crater and alveolar bone graft outcome. To date, there is a paucity of documentation regarding standardized protocols for evaluation and assessment of these alveolar defects to aid the clinicians to methodically reach to the correct diagnosis and treatment planning as well as analyse outcomes of treatments given. This review considers the various methods presented till date to measure these periodontal defects and seeks to propose appropriate protocol for such cases.

Discussion

Diversity has been seen in the patterns of alveolar bone loss and rate of bone loss in different individuals as a result of the progression of periodontal diseases which has stimulated a great deal of speculation and interest to come up with methods to measure and study these changes and ultimately treat such cases.

To reach an appropriate diagnosis, it is important to accurately evaluate the bone morphology and identify the defects seen in the patient. The periodontal disease process begins with the inflammation of gingiva. Extension of this inflammation to the bone leads to the destruction of the alveolar bone and marks its transition to periodontitis. On clinical probing, in most of the studies it has been suggested that a distance of 2 mm from the cementoenamel junction (cej) to the alveolar crest reflects normal periodontium. [6-8] when this distance is more than 2 mm, it indicates the presence of periodontal bone loss.

According to goldman and cohen (1958) [9], osseous defects can be classified as:

A. Suprabony Defects

B. Infrabony Defects

a. Infrabony Defects

- One-Walled Defect
- Two-Walled Defect
- Three-Walled Defect
- Combined Defect

b. Craters

C. Inter Radicular Defects

a. Horizontal Defects(Glickman's 1958 Classification)[10]

- Grade I – Incipient Bone Loss
- Grade Ii- Partial Bone Loss (Cul-De-Sac)
- Grade Iii- Total Bone Loss –Through-And-Through
- Grade Iv- Bone Loss Similar To Grade Iii With Gingival Recession Exposing The Furcation Area

b. Vertical Defects (Tarnow And Fletcher's 1984 Classification)[11]

- Sub-Class A (0-3mm)
- Sub-Class B (4-6mm)
- Sub-Class C (>7mm)

Pritchard In 1965[12] Has Classified Those Osseous Defects Caused By Periodontal Disease As

- Interproximal Craters
- Inconsistent Margins
- Hemisepta
- Furca Invasions
- Intrabony Defects (Infrabony Defects With Three Osseous Walls),
- Combinations Of These Defects
- Anatomic Aberrations Of The Alveolar Process, I.E. Thick Marginal Ledges, Exostoses, And Tori
- Fenestrations
- Dehiscence

Fenestration and Dehiscence

Fenestration is a term derived from the latin word 'fenestra' which means 'window'. Fenestrations can be described as secluded areas of denuded root where the surface is blanketed only by the periosteum and gingiva, but marginal bone is intact. When the facial bone overlying the root is very thin, this denudation extends through the marginal bone and the defect is called a dehiscence. [13] according to davies et al.[14] , "alveolar bone defect is considered as dehiscence when there is the absence of at least 4 mm of cortical bone apical to the margin of interproximal bone while fenestration is an isolated defect leading to exposure of root surface without involving the marginal alveolar bone.

When 2d imaging is utilized, visualization of labial/buccal and lingual bone plates is not possible because of image superimposition associated with conventional radiographs, and because gingival covering interferes with clinical analysis. [15] Dehiscence too escapes diagnosis routine radiographic diagnosis because of the overlapping imaging of the surrounding bony tissues. [16]

When these defects are visualized using CBCT, its advantages over 2d imaging such as high resolution and sensitivity due to small voxel size and evaluation of anatomy without superimposition of neighbouring structures makes it the choice of diagnostic tool.

Mengel et al. Assessed height and width of dehiscence using CBCT. They concluded that the height of dehiscence could be measured with only 0.28 ± 0.20mm systemic error and the width of dehiscence 0.21 ± 0.15mm errors. Mean CBCT total measurement error was found to be 0.19 ± 0.11mm. [17] mengel et al. Conducted another study to measure dehiscence on implants and concluded the systematic difference to be 0.22mm. In both these studies the authors compared traditional ct to CBCT at 0.125mm voxel size and showed similar results. The authors concluded the image quality of CBCT to be superior to ct. [18] ising et al. In their study assessed the height of dehiscence fromCEJto its most apical part and found the CBCT mean error of measurement to be 0.4mm.[19] a study conducted by misch et al used CBCT to measure intrabony and dehiscence defects at 0.4mm voxel size and found the systematic difference in height of both defects to be 0.41mm.[20] the most affirmative study was done by leung et al. Wherein measurements for both dehiscence and fenestrations were done on CBCT with an aim to evaluate sensitivity and specificity of CBCT in diagnosis of these defects.[21]

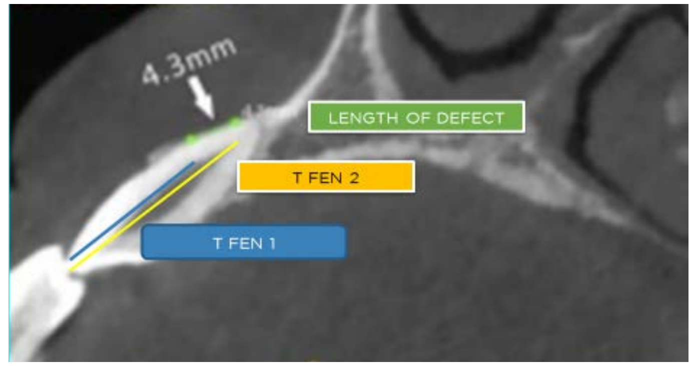


Fig. 1: fenestration height: t fen 2 – t fen 1

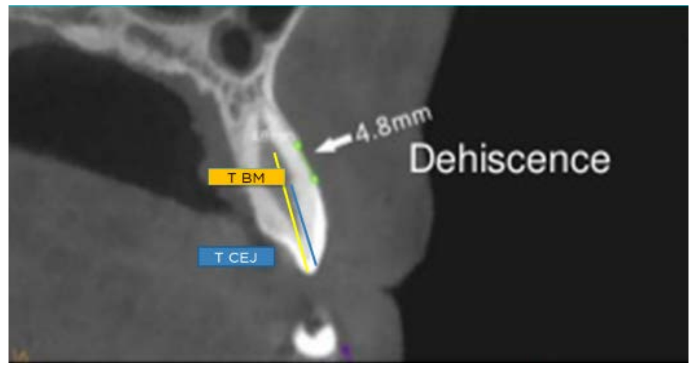


Fig.2: dehiscence height: t bm – t cej

T fen 1- the distance from the cusp tip to the most coronal border of a fenestration along a line parallel to the long axis of the tooth.

T fen 2- the distance from the cusp tip to the most apical border of a fenestration along a line parallel to the long axis of the tooth

t bm- the distance from the cusp tip to the most coronal bone margin measured along a line parallel to the long axis of the tooth

t cej- the distance from the cusp tip to theCEJparallel to the long axis of the tooth. Buccal cusps were used for posterior teeth and midincisal tips were used for anterior teeth

Therefore, by using a voxel size of 0.38mm at 2ma and a spatial resolution of 0.6mm, bone margin can be located with an accuracy of 0.6mm that is minimum thickness required for fenestration and dehiscence to be measurable. The diagnostic value of CBCT for detection of buccal defects was high for fenestrations with a sensitivity and specificity of 0.8 and for dehiscence specificity-0.95 and sensitivity- 0.4. Therefore, CBCT was more sensitive for fenestration.

Furcation involvement:

According to the glossary of terms of the american academy of periodontology, a furcation involvement exists when periodontal disease has caused resorption of bone into the bi- or trifurcation area of a multi-rooted tooth. [22]

2d radiographic diagnosis of furcation can be done using paralleling, periapical and bitewing technique. However, superimposition of palatal root or thick bone may obscure the furcation. In 1980, ross and thompson reported that radiographs were able to detect furcation invasion in 22% maxillary and 8% mandibular molars. This discrepancy was attributed to the difference in bone densities of the maxillary amd mandibular arches. [23] philstrom et al. The study indicated that modifying the furcation anatomy by osseous surgery contributes to a better therapeutic outcome. [24]

The most affirmative study was done by walter. He assessed the accuracy of CBCT in detecting furcation involvement in maxillary molars in patients with generalized advanced chronic periodontitis. He calculated furcation involvement (fi) in axial plane by measuring the distance between the outer root surface and interradicular bone to the nearest mm giving its buccopalatal depth. (fig 3)then assessment was done on sagittal and transverse sections.[25] (fig 4)the degree of fi was graded according to hamp et al.[26] CBCT and intrasurgical assessment of maxillary molar fi were found to be in substantial agreement. It was concluded that, CBCT enables an exact estimation and classification of fi. It visualises root morphologies with root proximities or root fusions, relevant for treatment decision making. Fi was classified at 3 sites: buccal, mesiopalatal and distopalatal on intrasurgical examination of the suspected maxillary molars. 84% of CBCT data were confirmed by intrasurgical findings indicating a high degree of accuracy, 14.7% were underestimated on CBCT and 1.3% overestimated on CBCT. Thus, it can be stated that CBCT proved to be superior diagnostic tool to iopa and clinical evaluation of fi, the best method being intrasurgical. CBCT facilitates a more detailed molar region.

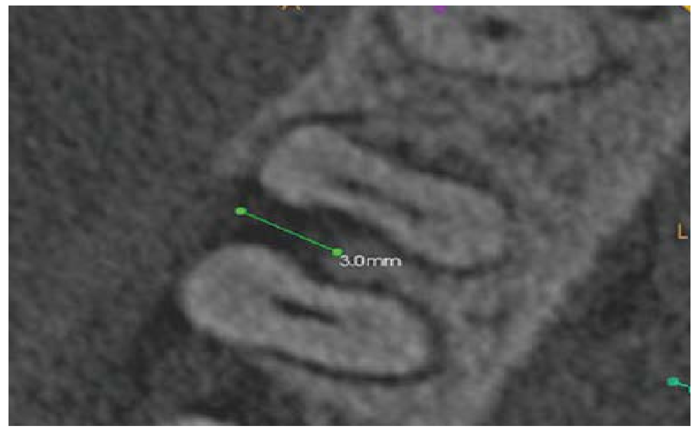


Fig 3: Fig 3-axial plane- calculation of fi by measuring the distance between the outer root surface and interradicular bone to the nearest mm giving its buccopalatal depth.

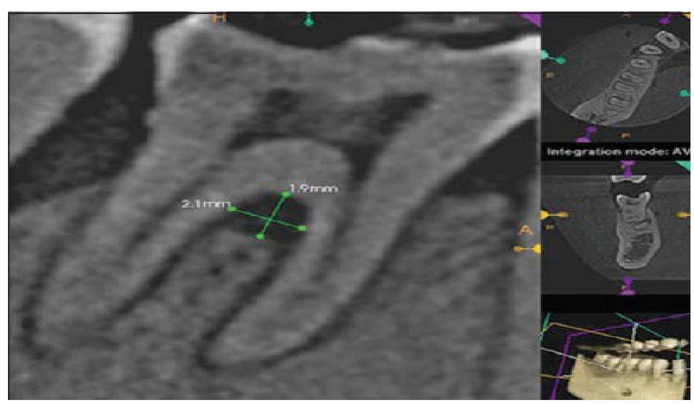


Fig. 4: Assessment on sagittal and transverse sections

Periodontal bone loss

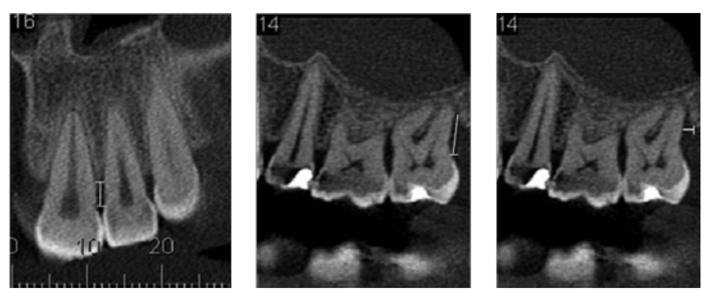
Transition from gingivitis to periodontitis is characterised by chronic inflammatory response leading to irreversible destruction of bone that supports the teeth.

The use of CBCT in diagnosis of periodontal bone loss has been done in several studies. Enas anter performed an assessment of alveolar bone loss in periodontal defect on CBCT with a minimum reported mean measurement error of 0.19± 0.11mm and a maximum reported mean measurement of 1.27± 1.43mm.[27] mohan et al concluded that merits of CBCT makes it a natural fit in periodontal imaging.[28]

Acar and kamburoglu discussed CBCT merits and limitations and its role in diagnosing periodontal conditions such as alveolar one defects and outcomes of regenerative periodontal therapy and bone graft to conclude that CBCT has obvious benefits in periodontology.[29] grimard et al. Assessed different types of periodontal defects and vertical defects on CBCT where the measurements were taken once at initial surgery and once at re-entry surgery. The type of measurement taken was fromCEJor base of restoration (if found) to the alveolar crest and to the base of defect, at the initial and re-entry surge/ries. The mean errors of CBCT measurements fromCEJto alveolar crest initially were 0.1 ± 1.2mm and at the time of re-entry were 0.01 ± 0.7mm. When measured fromCEJto base of the defect initially the mean errors were 0.9 ± 0.8mm and 0.5 ± 1.1mm at the time of re-entry.[30] misch et al.'s study showed CBCT to have sensitivity of 80-100% in the detection and classification of bone defects.[31] fuhrmann et al. Compared radiographs with CBCT and found that only 60% of infraalveolar bone defects were identified on radiographs whereas 100% could be distinguished using CBCT.[32] the most affirmative study was done by vasconcelos et al. The aim of the study was to detect and localise alveolar bone loss on CBCT by taking linear measurements of the height, depth and width of the defects and identifying combined osseous defects in tomographic images. A distance of 2-3mm from theCEJto the alveolar crest was used as a parameter of normality. For young adults the distance was 1.4mm and for those over 45 years was 3mm. The voxel size used was 0.2mm.[33]

In the cases of infrabony defects, measurements of the buccal and palatal/lingual surfaces in cross sectional tomographs were done. Evaluation for vertical or angular defects is done on axial sections with sections assessed apically first and then in cervical direction. The number of walls in apical portion of the defect is often greater than its occlusal portion in which case it is termed as combined osseous defect. Axial slices are made parallel to the occlusal plane for better visualisation of the morphology of periodontal bone defects. (fig 5 and fig 6)

Thus, it can be stated that a statistical difference of $p<0.05$ was seen between measurements of the distance from theCEJto the alveolar crest when compared with intraoral periapical radiographs. CBCT measurements of the periodontal bone loss were found to be more accurate than iopa and surgical measurements. CBCT offers significant advantages when detecting and locating vertical bone defects and is justified for periodontal surgical planning of patients with severe periodontal disease especially for regenerative or mucogingival surgical planning. It also allows for identification of combined angular osseous defects through a 3d evaluation of the alveolar crest.



a **b** **c**

Fig 5: Fig 5 (a) measurement taken fromCEJto alveolar crest in the mesial surface of the tooth (height of the defect); 5(b) measurement fromCEJto the bottom of the defect (apex); 5(c) the width of the defect on the mesial surface of the tooth (fromCEJto extreme distance of the other edge of the alveolar crest).

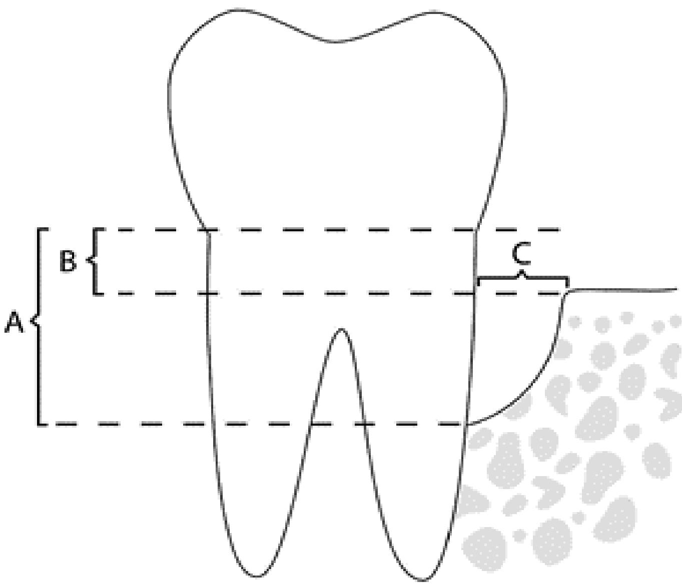


Fig 6- a- height from CEJto apex of defect, b- height of defect, c- width of defect (diagrammatic representation of fig. 5)

Fig 7: axial section-wall defects

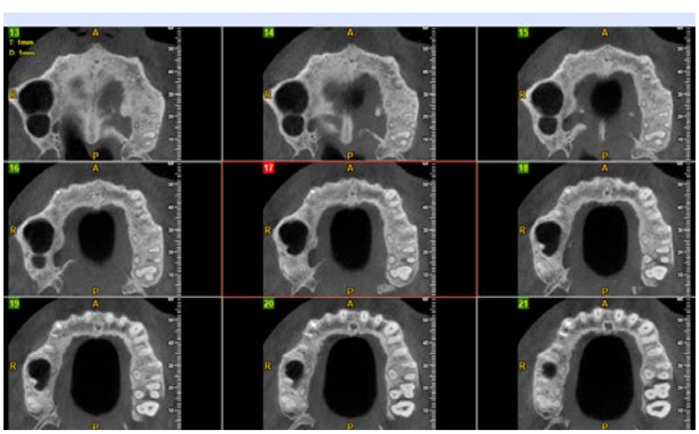


Fig 8: axial section- combined defect

The most affirmative study was done by vandenberghe et al. Who assessed topography of the craters. (fig 9) the type of measurements taken was the CEJto alveolar crest and bone crater depth. (fig 10). It was concluded that, the average CBCT measurement error of the crater for panoramic reconstructed view was 0.47mm and cross sectional images was 0.29mm. [34]

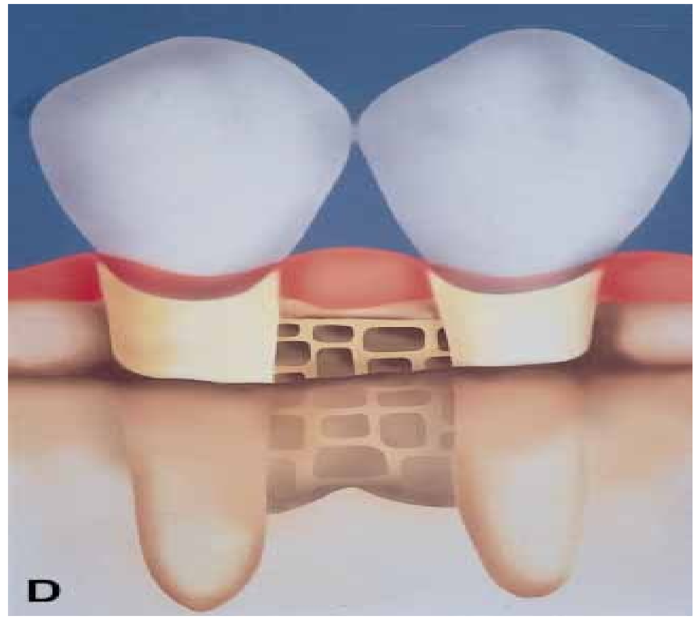


Fig 9- diagrammatic representation of osseous crater

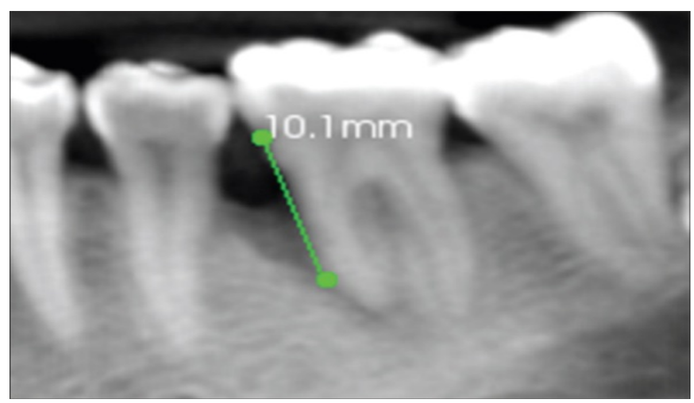


Fig 10: crater depth measurement

Alveolar bone graft outcome assessment:

Bone grafts are artificial, natural or synthetic substitutes which are used as fillers, scaffolds and mineral reservoir to induce new bone formation in areas of osseous defects in a surgical procedure in the treatment of such defects. The goals of this osseous replacement being maintenance of contour, elimination of dead space, and reduce postoperative infection; and thus enhance bony and soft tissue healing.[35]

Use of CBCT in assessing the outcome of such grafting procedures is of great importance. Thin hypo density around the area of alveolar bone graft, adjacent to the surrounding bone is an indicator for evaluating the graft integration which can be easily differentiated if evaluated on CBCT within a month of post-surgery. However, at six months follow up the bone graft should show good maturation with evidence of normal bone architecture.

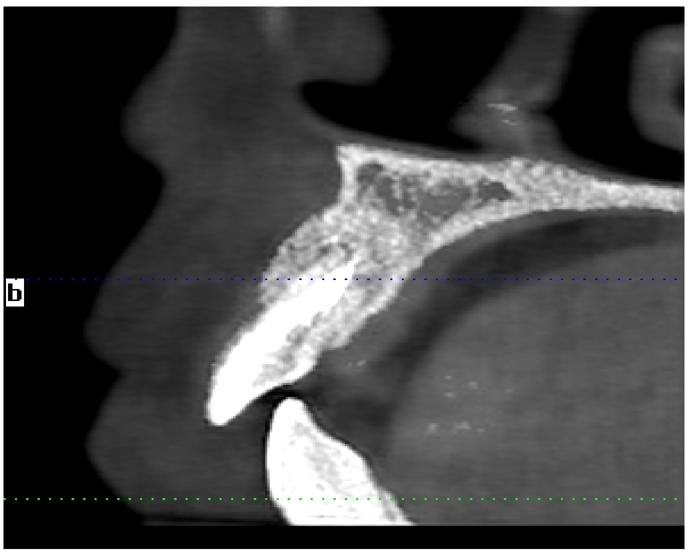


Fig 11: Thin hypodensity around the bone graft adjacent to the surrounding bone

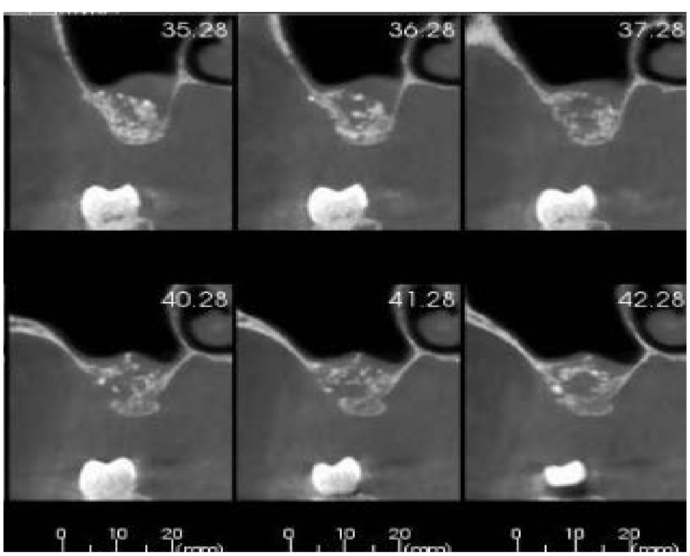


Fig. 12: Normal bone architecture

A study that quantified alveolar bone graft outcome assessment on CBCT was done by wangsrimongkol et al. [34] the study was done to develop and test assessor agreement using new CBCT examination method for evaluating and measuring the alveolar bone graft outcome. CBCT with technical parameters for image acquisition were 105kv, 9ma, fov 60mmx60mm (half arch) and voxel size of 0.2mm3 was used. The CBCT data was evaluated by 4 assessors.

The scores of alveolar bone graft outcome are as follows

A. Cej to marginal bone level of the tooth adjacent to the graft. Scoring the alveolar bone graft-

1. Cej to marginal bone ≥ 75% root length
2. Cej to marginal bone 50-74% root length
3. Cej to marginal bone 25-49% root length
4. Cej to marginal bone < 25% root length

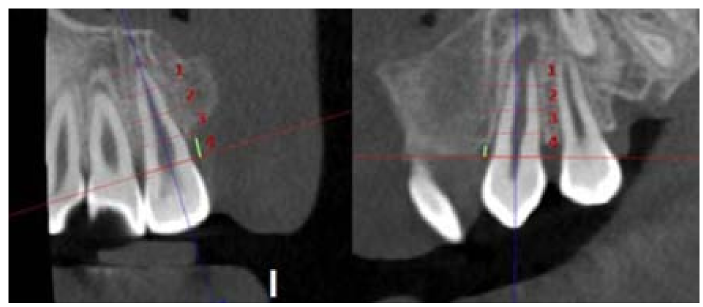


Fig. 13: Scoring the alveolar bone graft outcomes. A) CEJto marginal bone was less than 25% of root length. Score of distal marginal bone of mesial tooth adjacent to the cleft was 4.

B) The mesial marginal bone of distal tooth adjacent to the cleft was scored.

B. Marginal bone level to the root apices of the teeth adjacent to the graft. Scoring the alveolar bone graft

1. Marginal bone level to the root apex of the tooth ≤ 25% of root length
2. Marginal bone level to the root apex of the tooth 26-50% of root length

3. Marginal bone level to the root apex of the tooth 51-75% of root length
4. Marginal bone level to the root apex of the tooth > 75% of root length

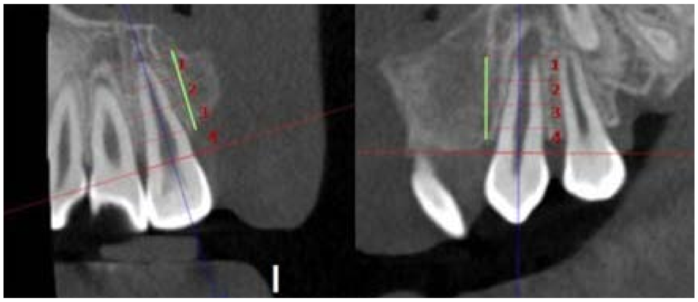


Fig 14: scoring the alveolar bone graft outcomes. A) \ marginal bone to the root apex of the mesial tooth adjacent to the cleft was more than 75% of root length. Score of distal marginal bone of mesial tooth adjacent to the cleft was 4.

B) The mesial marginal bone to the root apex of distal tooth adjacent to the cleft was scored 4

C. Labiolingual alveolar bone graft thickness. This was measured on axial sections parallel toCEJof the mesial tooth adjacent to the graft passing at cej, 3mm apical to the cej, 3mm coronally to the apex of the root and the root apex. A grid was created between the teeth adjacent to the graft in each level. Scoring the alveolar bone graft –

1. Labiolingual alveolar bone graft thickness ≤ 25% of bone graft site
2. Labiolingual alveolar bone graft thickness 26-50% of bone graft site
3. Labiolingual alveolar bone graft thickness 51-75% of bone graft site
4. Labiolingual alveolar bone graft thickness >75% of bone graft site

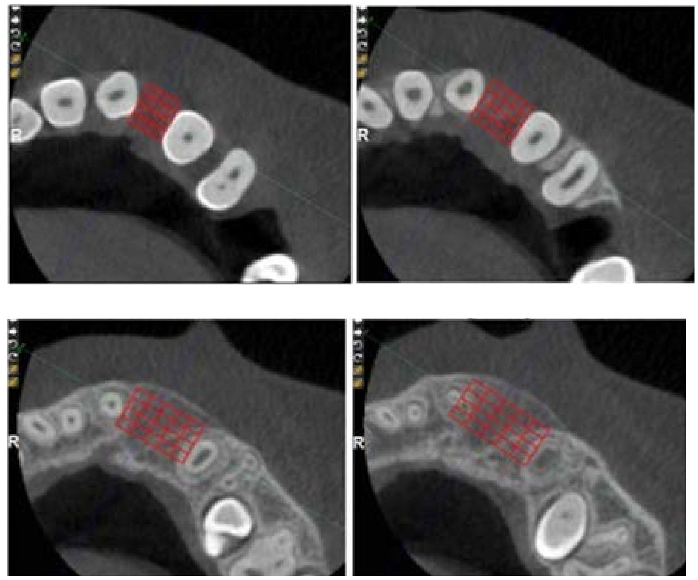


Fig. 15: These are the CBCT images 3 months after alveolar bone graft of one patient. The score of labiolingual alveolar bone grafted thickness atCEJlevel = 1, 3 mm apically to theCEJ= 1, 3 mm coronally to the apex of root = 4 and the root apex = 4.

These 3 sets of assessment criteria were incorporated into a scoring chart for the assessors.the results were that the kappa values of intra assessor were agreement in combining criteria 1, 2 & 3 were 0.82, 0.91 & 1 respectively. Thus, the study indicated that this CBCT scoring method for assessing alveolar bone graft outcome indicated very good intra and inter-observer agreement. Additionally, CBCT provides good accuracy for quantitative analysis of buccal and lingual alveolar bone thickness at different vertical levels.

Conclusion

Since the advent of CBCT several studies as stated above have been conducted which has clearly substantiated its disadvantages being outweighed by its advantages. However, the judicious use of this technology in routine dental practice has been a topic of debate. A position paper by the indian academy of oral medicine and radiology in 2019 has come up with some draft guidelines on the use of CBCT in the dental practice. Based on a moderate level of evidence, it is concluded that CBCT could be useful for fi periodontal cases but it should only be used in cases where clinical evaluation and conventional radiographic imaging do not provide the information necessary for an adequate diagnosis and proper periodontal treatment planning. CBCT measurements of the periodontal bone loss were found to be more accurate than intraoral radiographs and also surgical measurements.

The consensus being that, CBCT is not indicated as routine method of imaging periodontal bone support. Limited volume, high resolution CBCT may be indicated in selected cases of infra-bony defects and furcation lesions, where clinical and conventional radiographic examinations do not provide the information needed for management. Large volume scans are contraindicated to assess bone levels.

Thus, CBCT provides accurate measurement of intrabony defects and allows clinicians to assess dehiscence, fenestration defects, and periodontal cysts. However, bone plates thinner than the imaging spatial resolution might not be revealed by CBCT, thereby reaching a false-positive diagnosis of bone dehiscence or achieving quantitative assessments that underestimate the level of bone crest. Images with reduced voxel size are more accurate in terms of thickness and height of buccal/ lingual bone plates.

For standardized documentation and assessment of such defects, this paper proposes a simplified tabular format which the clinicians can utilize in their routine practice. It segregates the data regarding the periodontal defects/ graft outcomes into the site it is found at and its measurements which can be standardized using numerical formulas with a separate column for any additional features the clinician feels the need to make a note of. (table 1) with this protocol, we aspire to aid clinicians in easily communicating, interpretating, documenting the data obtained and ultimately reach the appropriate diagnosis and for the successful treatment of the patient.

Table1: Proposed Standardised Protocol for CBCT evaluation of Periodontal Defects & Graft Outcome.

	Site	Measurements	Additional Features
Dehiscence		Dehiscence Height – TBM- TCEJ	
Fenestration		Fenestration Height – TFEN2- TFEN1	
Periodontal Bone Loss/ Infra bony Defects	Sites with horizontal bone loss Sites with vertical bone loss	Picture for horizontal bone loss measurement Angular /Combined osseous defects	
Alveolar Bone Graft Outcome Assessment		Scores of alveolar bone graft	Hypo density around the area of Alveolar bone graft

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