Evaluation of Accuracy of Cone Beam Computed Tomography in Assessment of Periodontal Defects

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ABSTRACT
Background: Periodontitis is a chronic inflammatory disease triggered by dysbiotic oral microbiota and an imbalanced host immune response, resulting in progressive damage to the periodontal attachment apparatus with subsequent intrabony defect production. **Aim:** To evaluate the accuracy of cone-beam computed tomography (CBCT) in periodontal defects measurement. Primary objective: 3D volumetric assessment of intrabony defects. Secondary objective: prognosis, prediction, and treatment planning. **Patients and methods:** This cross-sectional study evaluated 180 periodontal defects, excluding 60 being associated with stage I/II periodontitis or meeting exclusion criteria. The final analysis included 120 defects from 40 cases (23 males, 17 females, aged 29-58 years). Cases were selected from Al-Azhar University's outpatient clinics (Oral Medicine, Periodontology, Oral Diagnosis, and Dental Radiology, Assiut Branch). Clinical assessments were conducted at the university clinics, while imaging was performed at a private dental center. **Results:** very high degree of inter-observer agreement was obtained, Insignificant distinction has been found among CAL (mean) and CEJ-crest distance in Stage III and furcation involvement on periapical and bitewing radiographs, while a significant distinction was observed in Stage IV. For CBCT, insignificant distinction has been noted among CAL (mean) and linear measurements in Stage III and Stage IV, but a significant distinction was seen in furcation involvement. Additionally, insignificant correlation has been found among CBCT linear and volumetric measurements in Stage III, Stage IV, or furcation involvement. **Conclusion:** CBCT diagnoses advanced periodontal cases with high accuracy, providing virtual models of intrabony defects describing both linear and 3D bone loss enhancing treatment planning ultimately improving prognosis and treatment outcomes.
Key words: Cone Beam Computed Tomography: Periodontitis; Furcation.

INTRODUCTION

Periodontitis refers to a microbiome-driven chronic inflammatory disease due to reciprocally reinforced interactions among dysbiotic microbiome and the host inflammatory response, resulting in progressive destruction of the attachment apparatus with subsequent production of intabony defects. Intrabony defects are vertical defects of the alveolar bone having a special morphology in other words it may be self-contained or non-self contained[1].

Traditionally, two-dimensional radiography, including periapical, bitewing, and panoramic films, can be used in the assessment of alveolar bone status, on the other hand, the three-dimensional morphology of a periodontal defect can be difficult to be adequately determined utilizing two-dimensional digital X-rays in cases of intrabony defects and furcation involvement [2].

Cone beam computed tomography, a relatively recent imaging technique, can give an accurate 3D vision of the bony architecture. Cone beam CT generates 3D volumetric images, which provide axial, coronal, and sagittal multiplanar images, rendering images throughout the periodontal treatment phase [3].

It has been reported that cone beam CT-assisted segmentation modalities can yield sharp 3D representations of intrabody and furcation involvement defects in terms of location, extent, number of walls, and morphology of the defect. Unfortunately, the utilization of CBCT-based segmentation modalities is still limited [4].

The goal of the investigation was to evaluate the accuracy of cone-beam computed tomography in periodontal defects measurement. Primary objective: 3D volumetric assessment of intrabody defects. Secondary objective: prognosis, prediction, and treatment planning.

PATIENTS AND METHODS

This cross-sectional clinical and radiographic investigation evaluated 180 periodontal defects. Sixty defects were excluded due to association with stage I or II periodontitis or meeting exclusion criteria. The final analysis included 120 defects from 23 males and 17 females, aged 29-58 years. Cases have been selected from the outpatient clinics of the Department of Oral Medicine, Periodontology, Oral Diagnosis, and Dental Radiology at Al-Azhar University, Assiut Branch. Clinical assessments have been conducted in the clinics, and imaging was performed at a private dental center.

The study groups were categorized based on measurements performed on cases with stage III periodontitis, stage IV periodontitis, and cases involving furcation involvement.

Inclusion criteria: Periodontitis cases classified as stage III and stage IV, exhibiting clinical attachment loss greater than 5 mm requiring surgical intervention, as well as upper and lower molars with furcation involvement, were included in the study.

Exclusion criteria: Those with systemic diseases (e.g., uncontrolled diabetes, hypertension, hepatic or renal conditions), disorders affecting bone metabolism, heavy smokers, pregnant or lactating individuals, and cases involving maxillary and mandibular third molars.

The study groups were categorized based on measurements performed on cases with stage III periodontitis, stage IV periodontitis, and cases involving furcation involvement.

Methods

All cases received initial therapy, involving scaling and root planning with hand tools and ultrasonic devices, along with oral hygiene instructions. A thorough clinical examination followed, measuring periodontal pocket depth (PD) and clinical attachment loss (CAL) at six sites per tooth (mesio-buccal, mid-buccal, disto-buccal, mesio-lingual, mid-lingual, and disto-lingual) using a periodontal probe.

Also, cases underwent radiographic assessment using 2D conventional radiography (periapical and bitewing) and 3D cone beam CT (CBCT). For 2D radiography, periapical and bitewing films were obtained using a Belmont Phot-X IIS device (70 KV, 3 mA, 2 seconds) with Planmeca Romexis software (version 6.4), and CEJ-crest distance has been estimated and recorded on mesial and distal sites. For CBCT, images were acquired using a Planmeca Promax 3D unit (90 KV, 8 mA, 80*50 mm FOV, 0.16 mm voxel size, 12 seconds exposure time) and analyzed using Planmeca Romexis software (version 6.4) to measure CEJ-crest distance and periodontal parameters on sagittal and cross-sectional planes. 3D volumetric assessment of bony defects was performed using Invivo 6.0 software (Osteoid USA) for segmentation and STL file generation, followed by defect segmentation using Plasty Cad software (version 1.7, Diemme Italy) through the following steps[5], Landmarks and planes were determined by importing DICOM files into Invivo 6 software. The involved jaw was separated via thresholding, defining masks for teeth and alveolar bone, which were transformed into 3D objects with STL form.[6] Defects were segmented in three planes using Plasty Cad software, with contralateral bone contours as templates for buccal/palatal margins and automatic thresholding for mesial/distal and superior/inferior borders[5]. Digital subtraction generated 3D models of defects, allowing assessment of volume, surface area, and dimensions using Invivo 6 software. To verify CBCT accuracy in volumetric measurements, DICOM files were analyzed blindly by two calibrated observers, including an experienced radiologist. Measurements were repeated for inter-observer reliability, and results were statistically analyzed[7,8]. Data analysis included comparing CAL with CEJ-crest distance on 2D and 3D CBCT images, correlating CAL with volumetric measurements, correlating CBCT linear and volumetric measurements and assessing inter-observer agreement for defect volume.

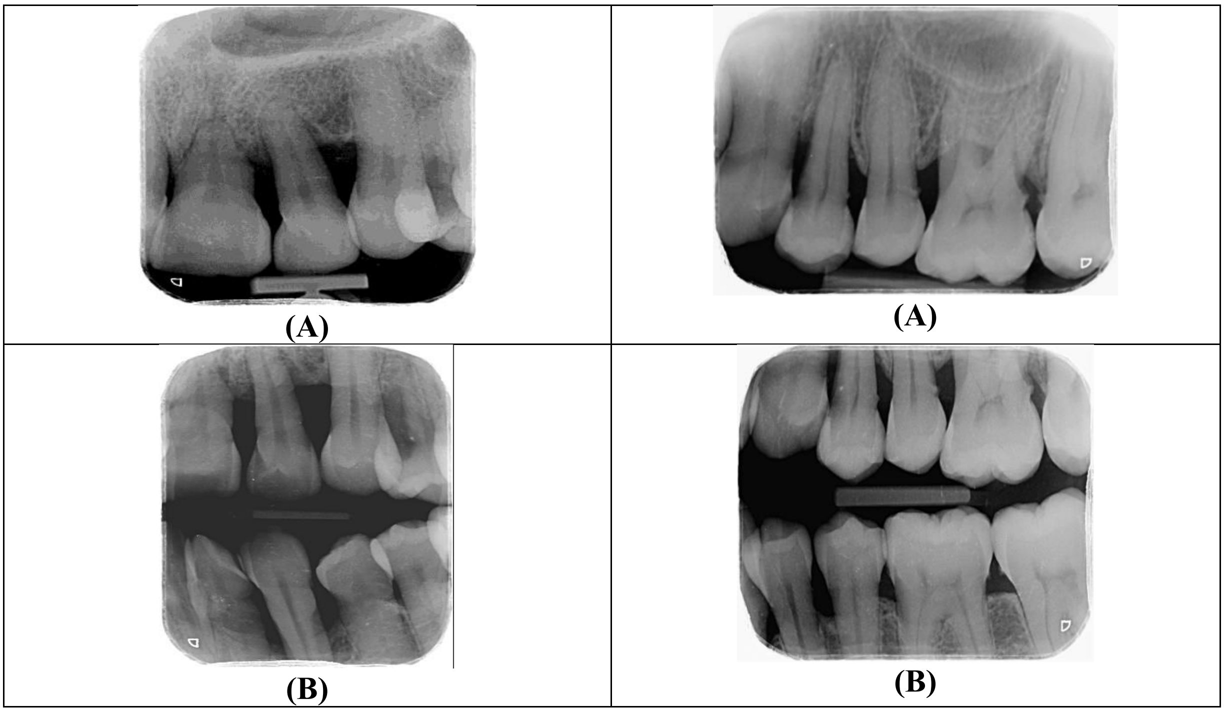
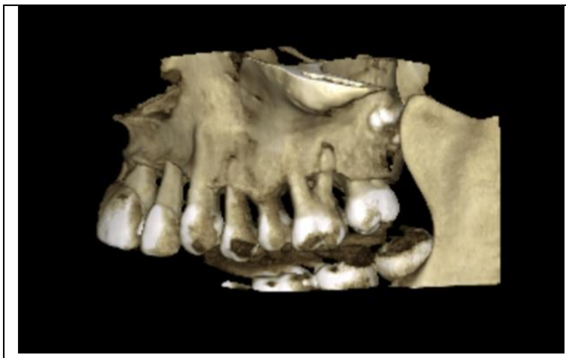


Figure (1): (A): Periapical radiography**. (B)**: Bitewing radiography



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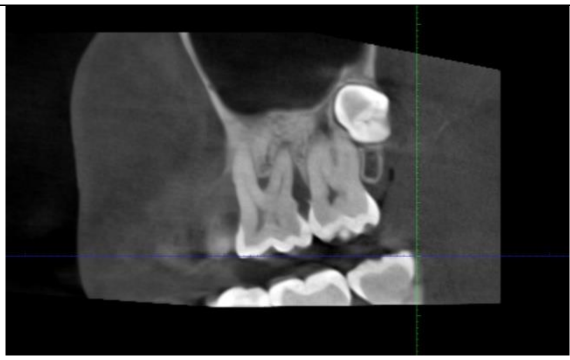

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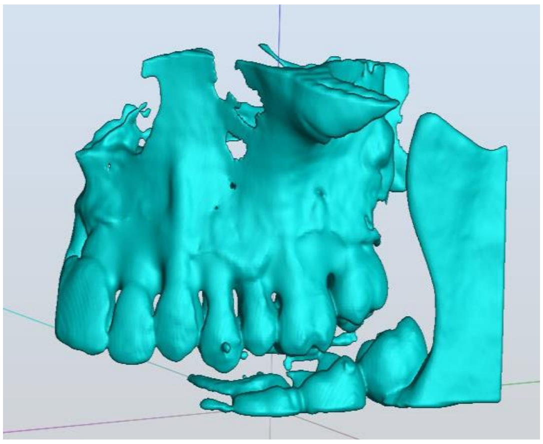
Figure (2): (A): Reconstructive view. **(B):** Sagittal view of the defects



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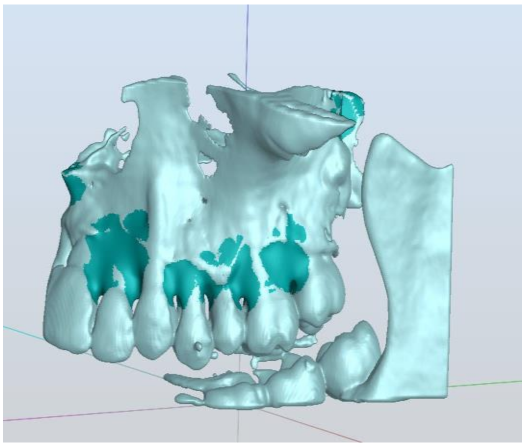

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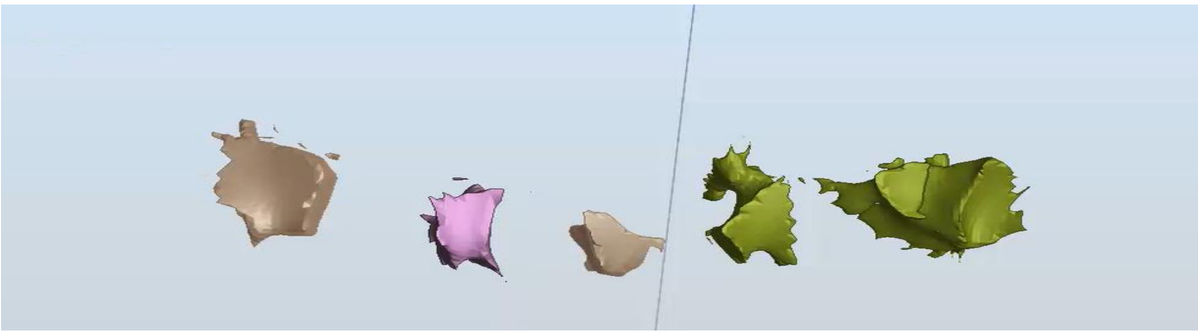

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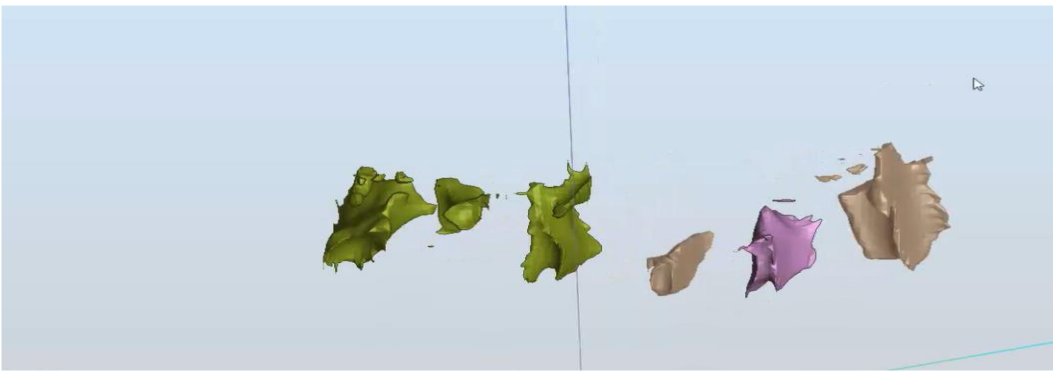

(B)

Figure (3): (A): Segmentation by filling the defects and digital subtraction with STL format to obtain 3D models**. (B):** Showing collected views of segmented 3D models

Ethical considerations

The research protocol has been permitted by the ethical committee, Faculty of Dental Medicine, Al-Azhar University, Assiut Branch.AUAREC20220009-11.

Statistical analysis

Statistical analysis has been carried out with IBM® SPSS® Statistics Version 26.0.0 for Windows. The Pearson correlation coefficient test has been applied to study the correlation among linear and volumetric data. Pearson correlation is a statistical test utilized to estimate the direction and strength of linear relationships among two variables. Standard deviation was used to compare clinical and linear radiographic results and to compare volumetric results.

RESULTS

Linear and volumetric assessment of intrabony and furcation involvement were achieved on 2D and 3D radiographs using the following parameters.

- Volumetric assessment
  A. Comparing volumetric measurement between the two observers to attain inter-observer reliability.
  B. Correlating CBCT linear with volumetric measurement on CBCT
  C. Correlating CAL with volumetric measurement on CBCT.
- Linear measurements This were done by comparing CAL, PA/BW and CBCT linear measurements.

- 3D defect assessment

Defects were assessed by two observers blindly and separately measuring volume in mm^3, surface area in mm^2 and defect dimensions in mm as following.

Table 1: 3D assessment of multiple defects related to the previous segmented case where X defect width mesio-distally, Y defect length from CEJ-crest distance and Z defect depth Bucco-lingually.

Defect	Volume in mm^3	Surface area in mm^2	Dimensions in mm		
			X	Y	Z
Defect related to 2-3	117,84	163,79	8,49	9,63	7,12
Defect related to 3-4	60,80	103,84	6,72	7,14	4,92
Defect related to 4-5	39,87	84,38	6,38	5,71	5,05
Defect related to 5-6	101,31	161,94	8,81	7,59	7,57
Defect related to 6-7	121,15	178,32	10,69	8,48	6,16
Furcation defect related to 6	31,12	75,38	8,18	3,64	6,54

Table 2 demonstrated that a statistically insignificant distinction has been found between Observer 1 and Observer 2 in volumetric assessment of Stage III, Stage IV, and furcation involvement.

Table 2: Comparison between Observer 1 and Observer 2 in volumetric assessment of Stage III, Stage IV, and furcation involvement.

	Observer 1		Observer 2		Test value£	P-value	Sig.
	Mean ± SD	Range	Mean ± SD	Range			
Stage III	46.20 ± 21.50	13.97 – 97.02	46.11 ± 21.67	13.99 – 96.22	0.535	0.596	NS
Stage IV	103.02 ± 84.74	33.13 – 372.08	103.21 ± 84.71	33.49 – 372.27	-1.177	0.245	NS
Furcation involvement	72.80 ± 45.76	18.49 – 159.18	73.26 ± 46.11	19.33 – 159.69	-2.744	0.010	NS

P-value > 0.05: non-significant (NS); P-value < 0.05: significant (S); P-value < 0.01: highly significant (HS)
£: Paired t-test

Table 3: A statistically insignificant distinction has been found among CAL (mean) and CEJ-crest distance in periapical in Stage III and furcation involvement, while a highly statistically significant distinction has been found among CAL (mean) and CEJ-crest distance in periapical in Stage IV.

Table 3: Comparison among CAL (mean) and CEJ-crest distance in periapical in Stage III, Stage IV, and furcation involvement

	Cal (mean)		Periapical		Test value£	P-value	Sig.
	Mean ± SD	Range	Mean ± SD	Range			
Stage III	5.15 ± 0.66	3.66 – 6	5.41 ± 0.98	3.65 – 7.1	-1.502	0.141	NS
Stage IV	7.05 ± 0.84	5.66 – 8.83	7.95 ± 1.86	4.40 – 12.25	-3.666	0.001	HS
Furcation involvement	5.78 ± 1.07	3.5 – 7.83	6.23 ± 1.53	3.95 – 9.85	-1.372	0.180	NS

Table 4: A statistically insignificant distinction has been found among CAL (mean) and CEJ-crest distance in Bitewing in Stage III and furcation involvement, while a statistically significant distinction has been found among CAL (mean) and CEJ-crest distance in Bitewing in Stage IV.

Table 4: Comparison among CAL (mean) and CEJ-crest distance in Bitewing in Stage III, Stage IV and Furcation involvement

	Cal (mean)		Bitewing		Test value£	P-value	Sig.
	Mean ± SD	Range	Mean ± SD	Range			
Stage III	5.15 ± 0.66	3.66 – 6	4.92 ± 0.86	3.35 – 6.2	1.530	0.134	NS

Stage IV	7.05 ± 0.84	5.66 − 8.83	6.53 ± 1.73	4.00 − 11.70	2.244	0.029	S
Furcation involvement	5.78 ± 1.07	3.5 − 7.83	5.78 ± 1.23	3.25 − 8.4	0.027	0.979	NS

Table 5 demonstrates that a statistically insignificant distinction has been found among CAL (mean) and CBCT linear measurements in Stage III and Stage IV, but a significant distinction has been found among the two parameters in furcation involvement.

Table 5: Comparison among CAL (mean) and CBCT linear measurements in Stage III, Stage IV, and furcation involvement

	Cal (mean)		**CBCT linear measurements**		**Test value£**	**P-value**	**Sig.**
	Mean ± SD	**Range**	**Mean ± SD**	**Range**			
Stage III	5.15 ± 0.66	3.66 − 6	5.24 ± 0.79	3.74 − 6.53	-0.770	0.446	NS
Stage IV	7.05 ± 0.84	5.66 − 8.83	7.14 ± 1.44	4.74 − 11.01	-0.392	0.697	NS
Furcation involvement	5.78 ± 1.07	3.5 − 7.83	6.63 ± 1.21	3.55 − 8.98	-3.388	0.002	HS

Table 6 demonstrates non statistical significant correlation between CAL (mean) and CBCT Volumetric measurements in stage III, while in Stage IV there were non statistical significant correlation between CAL (mean) and CBCT Volumetric measurements, while in Furcation involvement there were non statistical significant correlation between CAL (mean) and CBCT Volumetric measurements in both observers.

CBCT Volumetric measurements	**Cal (mean)**					
	Stage III		**Stage IV**		**Furcation involvement**	
	r	**P-value**	**r**	**P-value**	**r**	**P-value**
Observer 1	-0.168	0.301	0.209	0.144	-0.111	0.560
Observer 2	-0.142	0.383	0.215	0.135	-0.111	0.560
Average	-0.130	0.423	0.211	0.142	-0.111	0.560

Table 7 In Stage III, statistically insignificant correlation has been found among CBCT linear measurements and CBCT volumetric measurements, while in Stage IV, statistically insignificant correlation has been found among CBCT linear measurements and CBCT volumetric measurements, while in furcation involvement, statistically insignificant correlation has been found among CBCT linear measurements and CBCT volumetric measurements.

Table 7: Correlation among CBCT linear measurements and CBCT volumetric measurements in Stage III, Stage IV, and furcation involvement

CBCT Volumetric measurements	CBCT linear measurements					
	Stage III		Stage IV		Furcation involvement	
	r	P-value	r	P-value	r	P-value
Observer 1	-0.009	0.957	0.067	0.643	0.045	0.812
Observer 2	0.036	0.827	0.069	0.633	0.045	0.812
Average	0.037	0.822	0.065	0.653	0.045	0.812

DISCUSSION

A complete knowledge of the three-dimensional morphology of a periodontal defect is essential in periodontal therapies, as it is closely correlated with achieving an accurate diagnosis and selecting the appropriate treatment modality for optimal long-term outcomes. However, accurately determining the three-dimensional morphology of a periodontal defect poses a challenge when relying exclusively on two-dimensional digital x-ray. Therefore, CBCT has been suggested for the diagnosis of periodontitis[9]**.**

Cone beam computed tomography has revolutionized diagnosis of periodontal defects by providing 3d virtual models of the defects leading to tailored treatment plans accurately assessing defect morphology, designing optimal flap design and selecting appropriate bone graft material type and volume[10].

Determining prognosis of a periodontal defect is challengeable however CBCT has a crucial role in predicting defect resolution by anticipating the level of defect fill and monitoring treatment response optimizing intrabony defect treatment outcomes[11].

In the present study we found a very high degree of agreement among the two observers concerning volumetric measurements, indicating very high accuracy of CBCT in volumetric measurements of intrabony defects and furcation involvements.

This is consistent with an investigation performed by **Daniel Palvokis et al,**[12] They reported insignificant distinction among the defect volume measured radiographically and intra-surgically.

This is also consistent with a study by **Qiao J et al,**[13] evaluating furcation defects by utilization of cone-beam computed tomography in molar teeth comparing actual defects to surgical findings as a gold standard, an agreement of eighty percent has been found among the two results. Another study conducted by **Darby et al,**[14] comparing cone-beam computed tomography values with clinical records to determine the degree of furcation involvement, indicates that twenty-two percent of clinical findings were consistent with cone-beam computed tomography, fifty-eight of furcation recordings have been highly classified, and twenty percent were deficient based on cone-beam computed tomography.

In our investigation, statistically insignificant distinctions have been found among CAL and PA/BW in stage III and among CBCT linear measurements and PA/BW. While statistically insignificant distinction has been found among CBCT and CAL, indicating high accuracy of CBCT in linear measurements of intrabony defects and reliability of two-dimensional radiography in stage III assessment. Statistically insignificant distinction has been found among CAL and CBCT linear measurements in stage IV, whereas statistically significant distinction has been found among CAL and PA/BW. This may be due to the fact that two-dimensional radiography tends to overestimate periodontal destruction in advanced periodontitis [15]

The present study results in stage III were consistent with **Wenjan Zhang et al.**[16] and **MS Nabeel Althaff et al,.**[17]who reported high correlation among CAL, CBCT, PA, and BW in intra bony defect assessment and furcation defects. Another two studies by **Faria Vasconcelos et al,.**[18] **and Misch et al,.**[19] reported equal accuracy among CBCT and periapical radiography in diagnosing bone loss.

The present study results in stage IV were consistent with two studies by **Grimard et al,.**[20] and **Li et al,**[21]**;** they reported significant distinction among surgical, CBCT, and periapical radiography. Interestingly, they reported that CBCT tends to underestimate bone loss.

In the present study, in furcation defects, a statistically insignificant distinction has been found among CAL and PA/BW, whereas a significant distinction has been found among CAL and CBCT linear measurements. This is may be due to the fact that clinicians tend to overestimate CAL measurements in furcation involvement defects [22].

Cone-beam computed tomography is likely more precise than PA/BW for periodontal evaluation, as it doesn't include the magnification and distortion frequently associated with intraoral radiography. Furthermore, cone-beam computed tomography, similar to CAL, assesses both the buccal and palatal/lingual sides of the interproximal contact regions of teeth, in contrast to PA/BW, which permits only a single measurement without distinctions among the buccal and palatal/lingual sides [23].

There is no consensus as regards the deviation of cone-beam computed tomography relative to intraoral or clinical examination due to various factors, such as CBCT unit and scanning protocol, tooth surface and location, two-dimensional radiography-related factors, probing-related factors, and clinician-related factors [24].

In the present study we found a weak relation among CAL and CBCT volumetric measurement; also, the relation was weak among CBCT linear and CBCT volumetric measurement in stages III, IV, and furcation defects in both observers. Only one study has performed that correlation and reported results in contrast to our present study [25].

Current limited evidence suggests that cone-beam computed tomography is the most precise technique for assessing the morphology of intrabony defects and furcation involvement, thereby facilitating more accurate diagnosis, treatment planning, and prognosis prediction in demanding cases. Moreover, cone-beam computed tomography might act as a realistic alternative to reentry surgery and periapical radiographs for evaluating the results of periodontal therapy. Conversely, additional research is required to assess the benefits of utilizing this method for the diagnosis and treatment of intrabony defects by taking into consideration the higher irradiation doses and cost-benefit ratio.

CONCLUSION

CBCT is primarily used for diagnosing advanced periodontal cases, balancing diagnostic benefits against higher radiation exposure. It provides precise virtual models of intrabony and furcation defects, accurately describing both linear and 3D bone loss, and is effective for treatment planning and prognosis in complex cases. Consistent with ALARA principles, 2D radiography is suitable for diagnosing stage III periodontitis with high accuracy but is inadequate for stage IV periodontitis.

RECOMMENDATION

Large sample size is needed. Further in vivo studies with 3D printable bone substitutes are needed for validation of accuracy of CBCT in regenerative periodontal procedures.

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