Original Article

Comparative Evaluation of Cone-beam Computed Tomography versus Direct Surgical Measurements in the Diagnosis of Mandibular Molar Furcation Involvement

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Abstract

Aim: Periodontists frequently experience inconvenience in accurate assessment and treatment of furcation areas affected by periodontal disease. Furcation involvement (FI) most commonly affects the mandibular molars. Diagnosis of furcation-involved teeth is mainly by the assessment of probing pocket depth, clinical attachment level, furcation entrance probing, and intraoral periapical radiographs. Three-dimensional imaging has provided advantage to the clinician in assessment of bone morphology. Thus, the present study aimed to compare the diagnostic efficacy of cone-beam computed tomography (CBCT) as against direct intrasurgical measurements of furcation defects in mandibular molars. **Subjects and Methods:** Study population included 14 patients with 25 mandibular molar furcation sites. CBCT was performed to measure height, width, and depth of furcation defects of mandibular molars with Grade II and Grade III FI. Intrasurgical measurements of the FI were assessed during periodontal flap surgery in indicated teeth which were compared with CBCT measurements. Statistical analysis was done using paired *t*-test and Bland–Altman plot. **Results:** The CBCT versus intrasurgical furcation measurements were 2.18 ± 0.86 mm and 2.30 ± 0.89 mm for furcation height, 1.87 ± 0.52 mm and 1.84 ± 0.49 mm for furcation width, and 3.81 ± 1.37 mm and 4.05 ± 1.49 mm for furcation depth, respectively. Results showed that there was no statistical significance between the measured parameters, indicating that the two methods were statistically similar. **Conclusion:** Accuracy of assessment of mandibular molar FI by CBCT was comparable to that of direct surgical measurements. These findings indicate that CBCT is an excellent adjunctive diagnostic tool in periodontal treatment planning.

Keywords: *Cone-beam computed tomography, diagnostic imaging, furcation defects, periodontitis*

Introduction

Destructive periodontal disease is an inflammatory condition primarily infectious in nature perpetuating attachment and alveolar bone loss. This destruction progresses apically exposing the furcation of multirooted teeth causing irreversible bone loss in interradicular area.[1]

Limited accessibility through furcation entrances combined with complex anatomy and morphology of molar teeth pose difficulty for effective instrumentation of furcation defects.[2] Besides, the furcation morphology facilitates bacterial plaque retention, hampers professional and personal plaque control, thus creating an environment favoring periodontal destruction. Hence, teeth with furcation involvement (FI) have a poorer prognosis than teeth without FI.[1] A thorough knowledge of furcation anatomy and precise assessment of degree of FI is important for accurate assessment of the etiological factors, diagnosis, prognosis, and treatment of involved teeth.[1]

According to proceedings of the World Workshop in Clinical Periodontics, teeth with FI are at greater risk of tooth loss than those without such involvement.[3] Diagnosis of FI is mainly by assessment of probing pocket depth (PPD), clinical attachment level (CAL), furcation entrance probing, and use of intraoral periapical and panoramic radiographs. However, in most cases, due to limited physical access to furcation depths, morphological variations coupled with measurement errors, it is difficult to accurately analyze furcations clinically.[2]

Although we routinely employ conventional two-dimensional (2D) radiographs for diagnosing bone levels in periodontal disease, the magnification and distortion

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caused because of the projection geometry of X-ray beam makes accurate diagnosis almost impossible. These 2D radiographs generate images with tooth roots superimposed on region of interest, thus obscuring bony changes such as FI, buccal, and lingual alveolar bone defects.[4]

More recently, limitations of 2D radiographs can be overcome by the use of cone-beam computed tomography (CBCT) imaging technique, which provides 3D volumetric images with multiplanar reconstruction in axial, coronal, and sagittal planes without magnification. CBCT collects high-resolution 3D data at lower cost and reduced radiation doses than conventional CT.[5] Hence, the present study was undertaken to investigate the accuracy of CBCT in assessing mandibular molar FI by comparing it to direct surgical measurements during furcation surgery.

Subjects and Methods

Study population

Patients in age group of 20–60 years, reporting to the Department of Periodontics, Vydehi Institute of Dental Sciences and Research Centre, Bengaluru, India, were considered for the study. Patients clinically and radiographically diagnosed with moderate-to-severe chronic periodontitis with a PPD ≥6 mm in at least one mandibular molar with Grade II or Grade III FI indicated for periodontal surgery were included in the study. Mandibular third molars, pregnant or lactating women, patients with uncontrolled systemic diseases, and smokers were excluded from the study. Teeth with furcation caries, metallic crowns in CBCT irradiation area, amalgam fillings near alveolar crest, teeth indicated for extraction, and teeth with Grade I or Grade IV FI were also excluded from the study. Fourteen patients with 25 sites who complied with the above inclusion and exclusion criteria were recruited for the study. Informed consent was obtained from all participants before the study. The study period was from January 2015 to September 2016. Ethical clearance for the study was obtained from the Institutional Ethics Committee.

Study protocol

At baseline, periodontal status of the patient was assessed using the PPD and CAL measurements and clinical grading of the FI was done. Intraoral periapical radiograph (IOPA) was taken on the selected mandibular molar before surgery to determine the degree of furcation FI. This was followed by CBCT measurements performed to measure the deepest vertical and horizontal (width and depth) furcation defects at each furcation entrance for the specified tooth. On post-CBCT, all patients underwent full-mouth scaling and root planing. Direct surgical defect measurements were made in patients indicated for furcation surgery [Figure 1a-f].

Method of data collection

Clinical parameters

PPD and CAL were measured using UNC 15 (PCPUNC-15, Hu-Friedy, Chicago, IL, USA) probe at baseline. FI was measured at two sites (Buccal and Lingual) using Nabers Periodontal Probe and UNC 15. Grading of furcation was according to Glickman's classification system.[6] All the clinical parameters were assessed by a single calibrated examiner.

Radiographic parameters

Intraoral periapical radiographs

IOPAs were taken on the selected mandibular molars before surgery to determine the degree of FI. Radiographs may

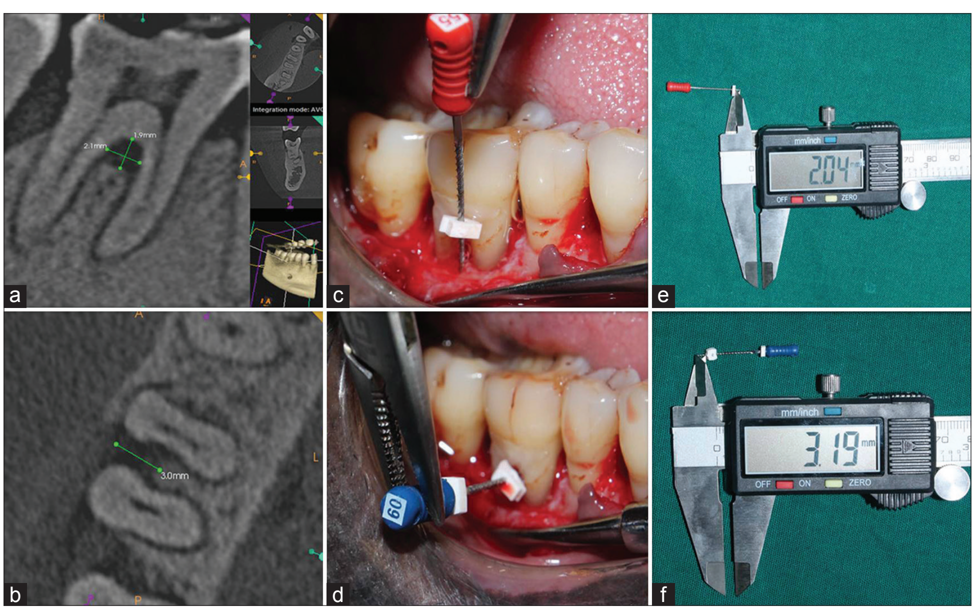

Figure 1: Measurement of furcation height, width, and depth by cone beam computed tomography (a and b) and direct surgical measurements (c and d) using digital vernier caliper (e and f)

or may not depict the FI in Grade II furcation. Grade III furcations display the defect as a radiolucent area in the crotch of the tooth.

Cone-beam computed tomography measurements

CBCT measurements were performed by measuring the deepest vertical and horizontal (width and depth) furcation defects at each furcation entrance. The furcation entrance served as anatomical starting point for measurements. The measuring tool provided within the Kodak software (Oblique view, Carestream 3D Imaging Software Version 3.1, C3 9300, 84 kv, 5 mA, 20 s, Voxel size of 180 μm) was used for the measurements. CBCT measurements were analyzed in axial, sagittal, and coronal sections that made the defect most visible and easily measurable. The cross sections of different planes were aligned using the furcation entrance as anatomical landmark. Back and forth scrolling in the different planes allowed to identify and measure the deepest vertical and horizontal extent of bone loss [Figure 1a and b]. These measurements were then recorded and compared to intrasurgical measurements. To obtain the accuracy of CBCT measurements, two calibrated examiners were used to calculate the measurements and mean of the measurements was taken for final analysis.

Intrasurgical measurements

Conventional flaps were reflected under local anesthesia. Debridement of periodontal osseous defects was performed at each tooth surface, and direct surgical defect measurements were made using endodontic file with stopper [Figure 1c and d]. Furcation height, width, and depth were measured by the same calibrated examiner who did the clinical measurements. To obtain maximum accuracy, a calibrated digital vernier caliper was used [Figure 1e and f]. The measurements included:

i. Height: Measured from the furcation fornix to the base of the alveolar base
ii. Width: Measured between the greatest dimensions of separation between the two roots above the crest of alveolar bone
iii. Depth: Measured from the crest of alveolar bone till the interradicular bony resistance was felt.

Statistical analysis

The sample size was calculated using power analysis before the initiation of the study. Assuming a difference of <5% between radiographic and surgical measurements, using the formula $(z\alpha)^2 \times (s)^2/(d)^2$, the total sample size needed for the study was 22. The final sample size was rounded off to 25, and hence, the study comprised 25 sites.

The study data were analyzed using MedCalc Statistical software for Windows, version 15.0, Ostend, Belgium. To check if significant variation exists between the radiographic and surgical measurements, paired *t*-test was used. Since data between the two methods did not show any significant variation, to assess the agreement level, Bland–Altman plot with 95% confidence limits was used. The mean difference between the two methods was represented by the center line and the actual mean difference represented by blue line ($P = 0.05$).

Results

Table 1 shows CBCT and intrasurgical measurements for the 25 mandibular furcation defects included in the study. The study consisted of 25 furcation sites which included 17 buccal defects and 8 lingual defects.

Table 2 shows comparison of mean and standard deviation of the furcation height, width, and depth of the furcation defects by CBCT method and intrasurgery method. The mean height of the furcation defects was 2.18 ± 0.86 mm and 2.30 ± 0.89 mm by CBCT method and intrasurgery method, respectively. Similarly, the mean width of the furcation defects was 1.87 mm and 1.84 mm while the mean depth of the furcation defects was 3.81 mm and 4.05 mm by the CBCT method and intrasurgery method, respectively. The statistical similarity between the two mean values was compared by paired *t*-test. *P* value obtained by paired *t*-test was not statistically significant. Thus, it can be interpreted that the mean values of the two methods are statistically similar. The above-mentioned findings indicate that overall both the methods are similar in measuring the furcation height, width, and depth. Hence, it can be concluded that both methods are similar in measuring the physical access of the furcation defects.

For a more detailed comparison of the two methods in measuring the physical access of furcation defects, the frequency distribution of patients based on deviation between the CBCT method and intrasurgical method in measuring the furcation height, width, and depth is presented in Table 3. For furcation defect height, in 52% of patients, the CBCT method measured lower value than intrasurgical measurements. Irrespective of the positive and negative signs, 84% of cases had deviation between − 0.50 and 0.50. For furcation defect width, in 36% of cases, CBCT measurements are lower than intrasurgical measurements and in 96% of cases; the deviation has been between −0.50 and 0.50. For furcation defect depth, in 64% of cases, CBCT measurements are lower than intrasurgical measurements and in 60% of cases; the deviation has been between −0.50 and 0.50. This indicates that the furcation defect height, width, and depth measurements by CBCT method are comparable to intrasurgical method measurements. However, the similarity level in the present study for the furcation defect depth measurements has been lower as compared to the other two physical access measurements, i.e., height and width of furcation defects.

Figure 2a-c shows agreement level between CBCT measurements and intrasurgical measurements in measuring the furcation height, width, and depth using

Table 1: Cone-beam computed tomography versus intrasurgical measurements for 25 mandibular molar furcation sites

Serial number	Tooth number	Sites	CBCT measurements			Intrasurgical measurements		
			Height	Width	Depth	Height	Width	Depth
1	36	Lingual	3.2	1.1	3.1	3.12	1.03	3.13
2	36	Buccal	2.2	2.4	3.3	2.92	2.37	4.39
3	46	Buccal	2.9	2.7	4.1	2.93	2.31	5.03
4	47	Buccal	2.4	1.8	4.1	2.89	2.21	5.77
5	46	Buccal	4.4	2.7	5.2	4.73	2.31	6.03
6	37	Buccal	1	2	4.7	1.53	2.21	4.12
7	36	Lingual	1.6	2.4	4.5	1.59	2.01	3.43
8	47	Buccal	1	2.1	3.3	2.12	2.13	3.51
9	46	Lingual	1.7	2	3.5	2.12	2.95	3.02
10	36	Buccal	3	2.3	7.7	3.42	2.49	8.01
11	46	Buccal	4.4	2.2	7.5	4.21	2.01	8.01
12	46	Buccal	2.4	2.1	3.1	2.63	1.97	4.21
13	36	Lingual	2.5	2.3	3.6	2.73	2.21	3.24
14	47	Buccal	1.6	1.6	3.1	1.23	1.32	3.23
15	46	Buccal	1.9	2.1	3	2.04	1.93	3.19
16	47	Lingual	1.9	2.1	3.6	1.63	1.83	3.26
17	36	Lingual	2.1	2.2	3.7	1.82	1.93	3.22
18	46	Buccal	2.2	1.9	3.7	1.93	1.72	3.54
19	36	Buccal	1.7	1	3.3	1.54	1.21	3.21
20	46	Lingual	1.7	1	3	1.62	1.22	3.12
21	36	Buccal	1.5	1.8	3.2	1.76	1.44	3.64
22	46	Buccal	1.7	1.2	3.4	1.82	1.54	3.72
23	36	Buccal	2.2	1.3	4.1	2.11	1.22	4.12
24	46	Buccal	1.8	1.1	4.3	1.73	1.32	4.52
25	36	Lingual	1.6	1.5	3.2	1.71	1.32	3.22

CBCT: Cone-beam computed tomography

Table 2: Comparison between cone-beam computed tomography and direct surgical measurements with respect to furcation height, width, and depth

Variables	Method	Mean±SD	Minimum	Maximum	Paired *t*-test	df	*P*
Height	CBCT	2.18±0.86	1.00	4.40	1.66	24	0.11
	Intrasurgery	2.31±0.90	1.23	4.73			
Width	CBCT	1.88±0.52	1.00	2.70	−0.44	24	0.66
	Intrasurgery	1.85±0.49	1.03	2.95			
Depth	CBCT	3.81±1.37	1.70	7.70	1.61	24	0.12
	Intrasurgery	4.05±1.49	2.43	8.01			

CBCT: Cone-beam computed tomography; SD: Standard deviation; df: Degree of freedom

Bland–Altman plot. Bland–Altman plot is a statistical procedure to measure the agreement level on two measurements. If the two methods are similar, then mean difference between the two methods should be 0 which is represented by the center line and the actual mean difference has been represented by blue line. In addition, 95% confidence limits are also represented in the plot. The mean value for furcation defect height obtained was −0.12 as shown in Figure 2a. The upper and lower limit values obtained were 0.61 and −0.85, respectively. *P* value obtained by comparing the mean value, i.e., −0.12 with 0 using one sample *t*-test, was not statistically significant; hence, we can deduce that the mean difference is similar to 0. Further, out of the 25 observations, 24 observations lie between the upper and lower limits and there is no specific pattern of distribution observed, i.e., the observations are randomly distributed. The above-mentioned findings clearly indicate that there is good agreement between CBCT method measurements and intrasurgical measurements in measuring furcation height. The mean value for furcation defect width obtained was 0.03 as shown in Figure 2b. The upper and lower limit values obtained were 0.64 and −0.59, respectively. *P* value obtained by comparing the mean value, i.e., 0.03 with 0, was not statistically significant, implicating that the mean difference is similar

Table 3: Distribution of the patients based on deviations between cone beam computed tomography method and intrasurgical method in measuring the furcation height, width, and depth

Height		Width		Depth	
Deviation level	**Frequency (%)**	**Deviation level**	**Frequency (%)**	**Deviation level**	**Frequency (%)**
<−1.00	1 (4.0)	<−1.00		<−1.00	4 (16.0)
−1.00-−0.51	3 (12.0)	−1.00-−0.51	1 (4.0)	−1.00-−0.51	4 (16.0)
−0.50-−0.11	8 (32.0)	−0.50-−0.11	7 (28.0)	−0.50-−0.11	6 (24.0)
−0.10-−0.01	1 (4.0)	−0.10-−0.01	1 (4.0)	−0.10-−0.01	3 (12.0)
0	0	0	0	0	0
0.01-0.10	5 (20.0)	0.01-0.10	4 (16.0)	0.01-0.10	3 (12.0)
0.11-0.50	7 (28.0)	0.11-0.50	12 (48.0)	0.11-0.50	3 (12.0)
0.51-1.00	0	0.51-1.00		0.51-1.00	1 (4.0)
>1.00	0	>1.00		>1.00	1 (4.0)

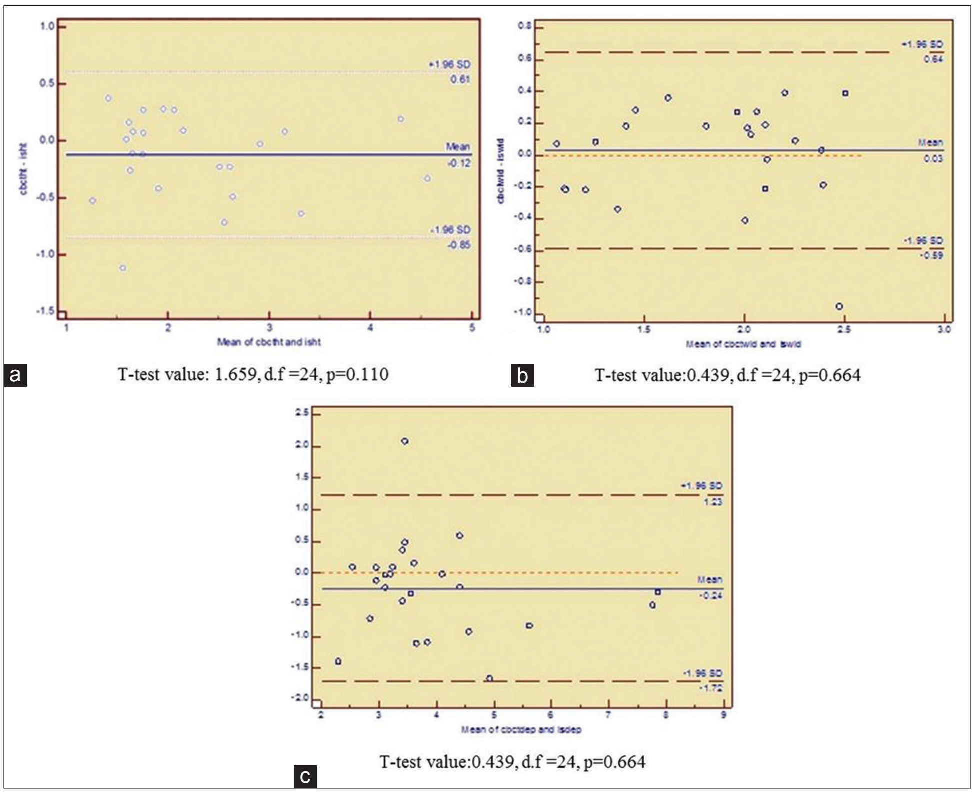

Figure 2: Agreement level between cone beam computed tomography measurements and intrasurgical measurements using Bland–Altman plot for furcation height (a), furcation width (b), and furcation depth (c)

to 0. Again, 24 out of the 25 observations lie between the upper and lower limits with no specific pattern of distribution observed, indicating that good agreement exists between CBCT and intrasurgical measurements for furcation width. The mean value for furcation defect width obtained was −0.24 as shown in Figure 2c. The upper and lower limit values obtained were 1.23 and −1.72, respectively. *P* value obtained by comparing the mean value, i.e., −0.24 with 0, was not statistically significant and 24 observations of the 25 were within the upper and lower limits with no specific pattern of distribution clearly indicating an agreement between CBCT and intrasurgical measurements for furcation depth.

Discussion

The anatomical limitations associated with maxillary and mandibular molars make diagnosis of furcation invasions difficult. However, clinical diagnosis of FI is helpful for periodontal treatment planning. Periodontal therapy most often is selected based on the clinical assessment of the severity of these furcation invasions. A study used the Glickman system to classify FIs in maxillary molars and compared measurements taken during initial patient examination with those made after surgical debridement. The study showed that only 62% of furcations were diagnosed correctly before surgery, with 28% initially underestimated and 10% overestimated.[7]

Ever since X-rays were discovered, the primary mode for capturing, displaying, and storing radiographic images has been the X-ray film. The X-ray films are the most commonly used radiographic aids for diagnosis as most dentists are well acquainted with its technique and interpretation. However, though radiographs are useful diagnostic aids, they are not very accurate for several reasons. The result of a study showed that FI in maxillary molars are more frequently detected by radiographic examination rather than clinical examination, while mandibular molars' FIs were more often detected by clinical examination rather than radiographic examination.[8] Differences in alveolar bone density which covers the maxillary and mandibular molar furcations may be important cause for this disparity. Therefore, use of both methods of evaluation, i.e., clinical and radiographic, is required to detect FI.

Another study highlighted the inadequacy of 2D measurement techniques and said that these techniques lack sensitivity to measure 1 mm of bone loss and that radiographic changes are not appreciated on these films until at least 1.9 mm of bone resorption has occurred.[9] Similarly, another study showed that there was about 1.41–2.58 mm underestimation of amount of bone loss with the use of periapical radiographs for radiographic assessment.[10] Owing to these drawbacks, CBCT has revolutionized dental imaging from 2D to 3D images and expanded its role of from being a mere diagnostic tool to providing image guidance for operative and surgical procedures.

A study compared assessment of periodontal bone architecture using 2D intraoral digital images obtained using a charged couple device and 3D full-volume CBCT-based imaging modalities. They concluded that CBCT images demonstrated more potential than intraoral digital images for describing periodontal bone defect morphologies.[11] Similar results were described in another study which used a dry skull with artificial defects and full-volume CBCT and demonstrated the accuracy of CBCT by comparing it with direct measurement of interproximal areas with a periodontal probe.[12]

In the present study, mandibular molars with FI were included. To obtain more accurate measurements, CBCT was taken before intrasurgical assessment. The purpose of this study was to investigate the accuracy of dental CBCT in assessing FI in mandibular molars by comparing it with direct measurements during furcation surgery.

Carestream 3D Kodak software CBCT 9300 system was used in our study. Smaller the slice thickness, higher will be the spatial resolution. Therefore, to obtain accurate FI measurements, we used slice thickness of 180 μm. Whereas, previous studies used 3D Accuitomo and New Tom 3G systems, with slice thickness of 0.5 mm and 0.3 mm.[2,13-15]

In the present study, we evaluated the height, width, and depth of FI in mandibular molars using CBCT and compared it with intrasurgical measurements. The mean of the furcation height measured from the furcation fornix to base of the defect was 2.18 ± 0.86 mm by CBCT method and 2.30 ± 0.89 mm by intrasurgical method. Difference between the two methods was 0.12 mm which was not statistically significant. The result of the present study is in accordance with the findings of another study in maxillary molar FIs where they observed a difference of 0.27–0.36 mm.[2] Similarly, another study observed an error which varied from 0.16 to 0.41 mm between CBCT and actual measurements, which was consistent with findings of the present study.[16]

In the present study, CBCT and intrasurgical measurements of furcation width was 1.87 and 1.84 mm, respectively, which was in accordance with another study which measured a mean furcation width of 1.39 and 1.41 by the same methods.[2] We observed no significant differences between the CBCT and intrasurgical measurements in terms of furcation defect depth. On the contrary, the above-mentioned study observed significant differences between the methods, which could be attributed to the difference in the selection criteria of the furcation involved teeth compared to our study.[2]

Previous studies[2,13,14] used the Hamp furcation classification system[17] which uses a 3 mm increment to differentiate the degree of FI. The present study used the Glickman classification system for FI as this system uses both clinical and radiographic assessments for diagnosis and hence provides more details than the Hamp classification system which separates furcation severity by arbitrary millimeter increments. This was done to avoid a measurement error.

One of the highlights of the present study was that the actual intrasurgical measurements were done using an endodontic file and assessed with a digital vernier caliper. The digital vernier caliper has an accuracy of up to 0.2 mm and hence is more accurate. However, other studies[2,13,18,19] used Nabers probe and UNC 15 probe to carry out the intrasurgical measurements.

To obtain the accuracy of CBCT measurements, two calibrated examiners were used to calculate the measurements and mean of the measurements was taken for final analysis which is similar to another study.[2] The results of our study showed that CBCT accurately reproduced the clinical measurements of FI (height, width, and depth) which was similar to another study comparing intrasurgical and CBCT measurements.[20]

We could not access any published dental literature till date that evaluated the accuracy of CBCT versus direct surgical measurements in diagnosis of mandibular molar FIs as most studies assessed maxillary molar FIs. Due to lack of available published studies on the comparison of CBCT and intrasurgical measurements on mandibular FI, we were unable to compare and analyze our study with other studies.

The present study verified the accuracy of 3D measurements of furcation bone level by CBCT and compared it to direct surgical measurements *in vivo* which is the gold standard and found both to be comparable. Thus, CBCT-derived data provide a better morphologic assessment of the extent and severity of the bony defects of the furcation lesions, thus positively affecting periodontal diagnosis and treatment planning. However, use of CBCT as adjunctive diagnostic tool is justified, only during planning of more invasive therapies. Furthermore, more research in larger population is needed to assess the extent to which CBCT use improves patient outcomes.

Conclusion

The present study showed that CBCT and intrasurgical assessment of mandibular molar FI were found to be in good agreement, thus implying that the accuracy of assessment of mandibular molar FI by CBCT was comparable to that of direct surgical measurements. A comparable result between the groups signifies that CBCT is an excellent adjunctive diagnostic tool in periodontal treatment planning.

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Conflicts of interest

There are no conflicts of interest.

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