RESEARCH ARTICLE

Comparison of clinical values between cone beam computed tomography and conventional intraoral radiography in periodontal and infrabony defect assessment

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Objectives: The use of CBCT for periodontal diagnosis and treatment plan is limited. The aim of this study is to compare the assessment of periodontal conditions and infrabony defects between conventional intraoral radiography (IOR) and CBCT.

Methods: The study included 25 subjects who had periodontitis and at least two infrabony defects. All subjects received clinical periodontal examination, IOR and CBCT. Three periodontists assigned periodontal diagnosis and prognosis of each tooth. For teeth with infrabony defects, the number of defect walls and treatment was determined. IOR and CBCT assessment was compared.

Results: There were 666 teeth and 123 infrabony defects. The overall concordance between IOR and CBCT for periodontal diagnosis, prognosis, infrabony defect type and infrabony defect treatment were 79.3%, 69.5%, 44.7% and 64.2%, respectively. IOR underestimated diagnosis, prognosis and the number of infrabony defect walls at 16.4%, 24% and 37.4%, respectively. IOR and CBCT had poor concordance for periodontal regeneration (43.3%). Tooth extraction was more prevalent when assessed by CBCT (35.0% vs 22.7%). CBCT had excellent interexaminer agreement (Fleiss' kappa 0.87–0.94) and higher percentage of complete agreement among examiners than IOR for all assessments.

Conclusions: IOR underestimated the severity and prognosis of periodontal disease. CBCT was superior to IOR for evaluation of infrabony defect morphology and treatment. CBCT provides excellent agreement among examiners on periodontal and infrabony defect assessment. *Dentomaxillofacial Radiology* (2017) **46**, 20160461. doi: 10.1259/dmfr.20160461

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Introduction

Periodontitis is characterized by periodontal bone loss and clinical attachment loss (CAL). Clinical and radiographic examinations are essential for determining

periodontal diagnosis, prognosis and treatment plan. At present, intraoral radiography (IOR) including periapical and bitewing radiographs are widely used for evaluating the level and pattern of alveolar bone destruction. It is simple to acquire with relatively low cost and low radiation dose.¹ However, a major limitation of IOR is the two-dimensional (2D) nature of the images that often obscures and underestimates periodontal bone loss.^{1–3} Therefore, an imaging technique that

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allows three-dimensional (3D) visualization of teeth and periodontal bone defects could be of great benefit for an accurate assessment of periodontal bone loss.

CBCT is an advanced imaging technique that enables cross-sectional and 3D analysis of bony structures in the head and neck region. Unlike conventional CT scanners, which must provide sufficient contrast to visualize differences in soft tissues, CBCT is mostly used to differentiate bone from soft tissue. Therefore, much low-powered X-ray generators can be used, and the radiation dose is much lower than that of medical CT.⁴ Currently, CBCT has been widely used in dentistry for complex diagnostic evaluation and treatment planning such as those related with dental implants, craniofacial fractures and orthodontics. However, the applications of CBCT in periodontics appear to be limited. Routinely, IOR is seemingly adequate for periodontal diagnosis and treatment planning. Nevertheless, in the area with complex anatomical structures, *e.g.* multi-rooted teeth, floor or border of maxillary sinus and also infrabony defects, a radiographic interpretation by means of IOR seems to be insufficient to provide accurate information. This leads to the poor clinical decision-making in complicated cases. CBCT apparently enables to provide 3D information which may overcome the drawback of the original 2D image acquired from IOR. An infrabony defect is a clinical parameter that significantly influences periodontal prognosis and treatment decision. It is often related to the advanced stage of periodontitis, and the prognosis of teeth with infrabony defects may improve considerably when periodontal regenerative treatment is performed. Success of periodontal regeneration depends mainly on the size, shape and angle of the defect.^{5–7} Therefore, it is important to correctly identify and classify the defect to select the appropriate treatment. CBCT images provide the 3D morphology of an infrabony defect, which is often obscure on the intraoral radiograph.

Most studies on CBCT in periodontics focused on the accuracy of CBCT in measuring and identifying the bone defects.^{8–12} Studies regarding the benefit of CBCT for periodontal diagnosis and treatment planning are limited.^{13,14} The extent to which the 3D information from CBCT influences diagnosis and treatment planning of periodontal disease is unclear. Therefore, the aim of this study was to compare IOR and CBCT assessment on periodontal diagnosis, prognosis, as well as infrabony defect type and treatment. This information is important to guide and justify the use of CBCT in periodontal practice.

Materials and methods

Study subjects

The subjects were recruited from patients who first-time visited the Graduated Periodontology Clinic, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand,

between October 2013 to January 2014. Of 104 patients, 25 patients met the inclusion criteria and agreed to participate in the study. The inclusion criteria were (1) had moderate to advanced chronic periodontitis, (2) had at least 14 remaining teeth and (3) showed at least 2 infrabony defects of ≥ 3 mm deep on a periapical radiograph. The subjects were excluded if they had medical conditions that did not allow conventional periodontal treatment. All patients were informed of the purpose of the study, and informed consents were signed. The study was approved by the Ethics Research Committee of the Faculty of Dentistry, Chulalongkorn University.

Clinical and radiographic examination

All subjects received a full-mouth periodontal examination by one operator (Ke.T), and periodontal charts were recorded. The probing depth and clinical attachment level were measured at six sites/tooth, using a UNC-15 probe (Hu-Friedy PCPUNC 15, Chicago, IL). Bleeding on probing was recorded as presence or absence at the six sites/tooth. Furcation involvement was determined using a Nabers's probe and recorded according to Glickman's classification.¹⁵ Tooth mobility was evaluated using two blunt instruments and classified according to the Miller's index.¹⁶

All subjects received IOR comprising full-mouth periapical radiographs and vertical bitewings of the posterior teeth, using the long-cone parallel technique. The radiographs were taken with an intraoral radiographic machine (KODAK 2200 Intraoral X-ray System; Carestream Dental LLC, Atlanta, GA) at 70 kV, 7 mA, exposure time 0.2–0.4 s, using F-speed and Size 2 films (KODAK INSIGHT; Carestream Dental LLC, Atlanta, GA). Each intraoral radiograph was digitally converted on a flatbed scanner with transparency adapter (EPSON Expression®10000XL; Epson, Long Beach, CA) at 600 dpi and saved as a JPEG file (Figure 1). The CBCT scans were performed using the 3D Accuitomo

Figure 1 A digitized intraoral radiograph; a periapical view using the lone-cone parallel technique.

170 machine (J Morita, Kyoto, Japan). Cylindrical volumes of 100×100 mm, 80 kV, 5 mA, exposure time of 17.5 s and a voxel size of 0.25 mm were used.

Periodontal and infrabony defect assessment

Periodontal assessment including periodontal diagnosis and prognosis was performed on all teeth by three periodontists. Periodontal diagnosis was classified as early, moderate and advanced periodontitis, based on CAL and radiographic bone loss.^{17,18} Early periodontitis corresponds to a CAL of 1–2 mm and/or a bone loss of <25%. Moderate periodontitis corresponds to a CAL of 3–4 mm and/or a bone loss of 25–50%. Advanced periodontitis corresponds to a CAL of >4 mm and/or bone loss >50%. Periodontal prognosis was classified as good, fair, poor, questionable and hopeless.¹⁹ The criteria were as follows: good—adequate periodontal support, relatively easy to maintain; fair—approximately 25% attachment loss and/or Class I furcation involvement; poor—50% attachment loss with Class II furcations; questionable—greater than 50% attachment loss, poor crown-to-root ratio, Class II or Class III furcations, second degree mobility or greater; and hopeless—inadequate attachment to maintain the tooth, extraction suggested.

Infrabony defect assessment was performed on teeth with an infrabony defect of ≥ 3 mm depth on a periapical radiograph. The assessment included infrabony defect classification and treatment. An infrabony defect was classified as a one-wall, two-wall or three-wall defect.²⁰ For a combination defect, the defect type was categorized according to the main characteristics of the defect. CBCT was used as a reference in classifying the infrabony defect morphology. The treatments of infrabony defect were classified as periodontal regeneration, open flap debridement or extraction. In general, periodontal regeneration was considered when the bony defect depth was ≥ 4 mm, had two or three walls, or the defect angle was narrow. Open flap debridement was considered when the bony defect depth was <4 mm, had one or two walls, or the defect angle was wide. Extraction was considered when there was inadequate periodontal support to maintain the tooth in health and function.^{5–7}

Radiographic assessment

Three periodontists performed periodontal and infrabony defect assessment, based on clinical and radiographic data. The radiographic images were displayed on a 22-inch liquid crystal display monitor (ThinkVision™ L2250p; Lenovo, Quarry Bay, Hong Kong) at a screen resolution of 1680×1050 pixels. The digitized intraoral radiographs were put into a PowerPoint presentation (Microsoft®, Redmond, WA) to facilitate viewing. Each PowerPoint slide contained the periapical and bitewing radiographic images of one tooth sextant. The CBCT images were displayed using the One Volume Viewer software (J Morita) on two monitors. One monitor displayed a simulated panoramic image of the upper and lower teeth created by the Ray Sum method with

a slice thickness of 15 mm (Figure 2A). Another monitor displayed CBCT images in the axial, sagittal, coronal and 3D views (Figure 2B). One facilitator (Ke.T) used the software to show the CBCT image of each tooth, one plane at a time, to the examiners. The tooth was first orientated in 3D to make the intersection between the sagittal and coronal planes coincide with the long axis of the tooth. The slice scroll-bar was used to display the images of each tooth from the coronal to the apical direction, the mesial to the distal direction and the buccal to the lingual direction, respectively. The procedure could be repeated as requested. All examiners received clinical periodontal charts and viewed the radiographic images together. They were blinded to the identity of the study subjects. IOR assessment of each subject was performed at least 1 week prior to CBCT assessment. Each examiner independently noted his/her answer in a record form. An agreement of at least two out of three examiners was considered as a consensus. An agreement of three out of three examiners was considered as complete agreement. When each examiner gave a different answer, a discussion was required to get a consensus. There was no time restriction for image viewing and assessment. The average time for one subject was approximately 45 min and was 1.5 h for IOR and CBCT, respectively.

Statistical analysis

Commercially available statistical software (SPSS®, IBM Corp., New York, NY; formerly SPSS Inc., Chicago, IL) was used to analyze the data. The concordance between IOR and CBCT assessment was calculated. The interexaminer agreement for the assessment was analyzed using Fleiss' kappa.²¹ The difference in the percentage of complete agreement assessed by IOR and CBCT was analyzed using McNemar's test. Statistical differences with a *p*-value <0.05 were considered significant.

Results

The study comprised 25 subjects and 670 teeth. Four teeth, not clearly seen on intraoral radiographs, were excluded. Therefore, 666 teeth were analyzed. Of these teeth, 116 teeth (123 sites) had infrabony defects that met the inclusion criteria. The average probing depth and clinical attachment level of the infrabony defect was 8.0 ± 1.7 and 8.2 ± 2.4 mm, respectively. The characteristic of the study subjects is shown in Table 1.

The concordance between IOR and CBCT on periodontal and infrabony defect assessment is shown in Table 2. The overall concordance on periodontal diagnosis was good (79.3%). However, the agreement on the diagnosis of moderate periodontitis was moderate (61.7%), with an underestimation of 31.1% by IOR assessment. The overall concordance on periodontal prognosis was moderate (69.5%). Good and hopeless prognosis had good agreement, whereas fair, poor and

Figure 2 (A) A simulated panoramic image (B) A screen capture of the CBCT images showing the lower right canine in (a) axial, (b) 3D, (c) sagittal and (d) coronal view.

questionable prognosis had moderate agreement. IOR assessment underestimated the prognosis by 24%. The concordance on the infrabony defect classification was poor (44.7%) and was the lowest among all assessments. The number of infrabony defect wall was underestimated by 37.4% with IOR assessment. The overall concordance on infrabony defect treatment was moderate (64.2%). The agreement on extraction was excellent (96.4%), whereas the agreement on periodontal regeneration was poor (43.3%).

The decision on infrabony defect treatment assessed by IOR and CBCT is shown in Table 3. Of 60 sites planned for regeneration by IOR, 19 sites (31.7%) were planned for open flap debridement and 15 sites (25%) were planned for extraction by CBCT. Of 43 sites planned for extraction by CBCT, 27 sites (62.8%) were in agreement with IOR, whereas 15 sites (34.9%) were planned for regeneration by IOR.

Interexaminer agreements of CBCT were higher than those of IOR for all assessments (Table 4). The Fleiss' kappa of CBCT assessment was excellent.²² The Fleiss' kappa of IOR assessment was excellent for diagnosis and prognosis, substantial for infrabony defect treatment and

moderate for infrabony defect classification. CBCT had a significantly higher percentage of complete agreement than IOR for all assessments.

Table 1 Characteristics of the study subjects

Variables	Values
Age (years)	
Mean $\pm$ SD (range)	48.8 $\pm$ 9.3 (30–59)
Gender (male/female)	11/14
Number of teeth	
Incisors and canines	293
Premolars	185
Molars	188
Total	666
Number of infrabony defects (site/tooth)	
Incisors and canines	27/26
Premolars	35/33
Molars	61/57
Total	123/116
Infrabony defect PD (mm)	
Mean $\pm$ SD (range)	8.0 $\pm$ 1.7 (5–13)
Infrabony defect CAL (mm)	
Mean $\pm$ SD (range)	8.2 $\pm$ 2.4 (3–16)

CAL, clinical attachment loss; PD, probing depth; SD, standard deviation.

Table 2 Concordance between intraoral radiography (IOR) and CBCT on periodontal and infrabony defect assessment

	Prevalence				Concordance ^a (%)	Underestimation ^b (%)	Overestimation ^c (%)
	IOR		CBCT				
Assessment	n	%	n	%			
Periodontal diagnosis							
Early	236	35.4	191	28.7	75.8	24.2	–
Moderate	167	25.1	175	26.3	61.7	31.1	7.2
Advanced	263	39.5	300	45.0	93.5	–	6.5
Overall					79.3	16.4	4.3
Periodontal prognosis							
Good	237	35.6	191	28.7	75.5	24.5	–
Fair	168	25.2	189	28.4	66.1	26.8	7.1
Poor	148	22.2	149	22.4	65.5	21.0	13.5
Questionable	88	13.2	88	13.2	61.4	29.5	9.1
Hopeless	25	3.8	49	7.3	88.0	–	12.0
Overall					69.5	24.0	6.5
Infrabony defect classification							
1 wall	21	17.1	15	12.2	38.1	61.9	–
2 wall	72	58.5	56	45.5	44.5	45.8	9.7
3 wall	30	24.4	52	42.3	50.0	–	50.0
Overall					44.7	37.4	17.9
Infrabony defect treatment							
Open flap debridement	35	28.5	46	37.4	74.3	–	–
Regeneration	60	48.8	34	27.6	43.3	–	–
Extraction	28	22.7	43	35.0	96.4	–	–
Overall					64.2	–	–

^aAssessment by IOR agreed with CBCT.

^bAssessment by IOR was underestimated compared with CBCT.

^cAssessment by IOR was overestimated compared with CBCT.

Discussion

IOR has been widely used for evaluating periodontal bone support. Together with clinical data, it provides periodontal diagnosis, prognosis and treatment planning of periodontal disease. However, since the technology of CBCT has been introduced to provide 3D images, CBCT appears to enable more accurate and comprehensive information of periodontal bone defects.²³ To explore the value of CBCT in periodontal diagnosis and treatment planning, we compared the assessment of periodontal and infrabony defect by IOR and CBCT. In this study, CBCT assessment was used as a standard to which IOR assessment was compared. This was supported by several studies showing that CBCT provided accurate assessments of periodontal bone loss when compared with direct measurements from cadaver specimens, histological specimens and surgical interventions of the patients.^{3,9,24,25}

This present study showed that IOR assessment tends to underestimate the severity of periodontal disease. Approximately one-third of teeth diagnosed as moderate periodontitis by IOR were diagnosed as advanced

periodontitis by CBCT. Several studies also showed that IOR underestimates the amount of periodontal bone loss and obscures the presence of periodontal bone defects.^{3,9,12,13} This finding is of clinical importance because underdiagnosis may lead to inappropriate prognosis and treatment.

Consistent with periodontal diagnosis, IOR appeared to underestimate periodontal prognosis. Compared with CBCT, IOR underestimated prognosis in 24% of teeth and overestimated prognosis in 6.5% of teeth. The concordance of the fair/poor/questionable group was lower than the good/hopeless group. This means that IOR was less accurate for assessing the prognosis in the intermediate categories. Interestingly, the proportion of teeth with hopeless prognosis was twice as high when assessed by CBCT (7.3% vs 3.8%). As making the decision on whether to save or extract teeth with advanced periodontal condition is always a dilemma to clinicians, such additional information obtained from CBCT images may assist in making a more aggressive prognosis and selecting an appropriate treatment for a patient. When the percentage of complete agreement was assessed, both IOR and CBCT groups showed the

Table 3 Treatment of infrabony defects (site) assessed by intraoral radiography (IOR) and CBCT

Treatment		CBCT			
		Open flap debridement	Regeneration	Extraction	Total
IOR	Open flap debridement	26	8	1	35
	Regeneration	19	26	15	60
	Extraction	1	0	27	28
	Total	46	34	43	123

Table 4 Interexaminer agreement and complete agreement for periodontal and infrabony defect assessment by intraoral radiography (IOR) and CBCT

Assessment	Interexaminer agreement (Fleiss' kappa)		Complete agreement (%)		p-value
	IOR	CBCT	IOR	CBCT	
Diagnosis					
Early			92.4	98.0	
Moderate			76.6	90.0	
Advanced			92.0	94.0	
Overall	0.88	0.94	88.4	94.0	<0.001
Prognosis					
Good			90.0	98.4	
Fair			75.0	87.8	
Poor			75.0	89.9	
Questionable			68.1	78.4	
Hopeless			80.0	87.7	
Overall	0.82	0.91	80.3	90.1	<0.001
Infrabony defect classification					
1-wall			57.2	86.7	
2-wall			62.5	89.3	
3-wall			70.0	88.5	
Overall	0.59	0.87	63.4	88.7	<0.001
Infrabony defect treatment					
Open flap debridement			65.7	89.1	
Regeneration			83.3	82.4	
Extraction			67.9	90.7	
Overall	0.73	0.87	74.8	87.8	0.010

highest agreement for good prognosis and the lowest agreement for questionable prognosis. This finding suggests that examiners were more likely to agree upon good prognosis, whereas it was less likely to obtain consensus among examiners for questionable prognosis.

We found that infrabony defect classification had the lowest concordance among all assessments. The overall concordance was only 44.7% and ranged from 38.1% to 50%. The assessment by IOR was likely to underestimate the number of defect walls. In addition, the examiner's agreement for IOR assessment of infrabony defect classification was low. These findings suggested that IOR was not an effective tool to evaluate the infrabony defect morphology. By contrast, the examiner's agreement improved markedly when CBCT was used. The result was in correspondence with several studies regarding the accuracy of CBCT in measuring and classifying the infrabony defects.^{3,9,11,12}

The treatment decision of infrabony defects depends largely on the accurate assessment of defect morphology.^{5,6} Appropriate treatment decision is crucial because each treatment involves a different amount of treatment time and cost. Previous studies showed that the use of CBCT provided detailed information of furcation involvement and a reliable basis for treatment decision.^{13,26,27} Cost analysis indicated that CBCT facilitated a reduction in treatment cost and time for maxillary molars.¹⁴ In this study, we found that CBCT assessment resulted in a lower number of teeth that required periodontal regeneration and a higher number of teeth that required extraction. The concordance of the assessment between IOR and CBCT was low for periodontal regeneration (43.3%) but very high (96.4%) for extraction. This means that almost all teeth planned for

extraction by IOR were also planned for extraction by CBCT. By contrast, less than half of the sites planned for regeneration by IOR were confirmed by CBCT assessment. Detailed analysis showed that one-fourth of the sites planned for regeneration by IOR were considered to be extracted by CBCT. This raises concern on the accuracy of IOR for periodontal regeneration planning. Regarding the decision on tooth extraction, the use of CBCT significantly improved the examiner's agreement. Our data suggested that CBCT is valuable for decision making that involves periodontal regeneration and tooth extraction.

This study showed that CBCT was beneficial for assigning periodontal diagnosis and prognosis. It should be noted that periodontal diagnosis and prognosis were given on an individual tooth basis and infrabony defect treatment was given on a site basis. In this study, 7 out of 116 teeth had two infrabony defects. The assessment was based on clinical data (probing depths, clinical attachment levels, tooth mobility, furcation involvement) and radiographic data (IOR and CBCT). Many factors are known to influence the prognosis and treatment plan such as age, cigarette smoking, patient's systemic condition, patient's compliance, strategic importance of the tooth and prosthetic plan. In order to reduce the number of factors that influence the examiner's decision and to focus on the effect of radiographic modalities on the assessment, those factors mentioned above were not taken into account for analysis.

We found that CBCT assessment consistently showed excellent agreement among examiners. The percentage of complete agreement among examiners for CBCT ranged from 82.4% to 98% compared with 57.2% to 92.4% for IOR. Variability on diagnosis and treatment

planning among clinicians is quite common. A possible cause is inadequate information for proper judgment. The amount of periodontal bone support is an important factor that determines periodontal diagnosis, prognosis and treatment. It is clear that 3D information from CBCT gave a more thorough picture of periodontal bone morphology, which is critical for appropriate judgment of periodontal diagnosis and treatment. The percentage of complete agreement among examiners of CBCT was significantly greater than that of IOR for all assessments. The difference was substantial for infrabony defect classification and treatment. Therefore, CBCT appears to be a valuable tool for decision making related to infrabony defects.

Although CBCT is useful for the evaluation of periodontal bone loss, there are some limitations of this modality. CBCT evaluation requires an additional skill to use the software and interpret the data. In addition, CBCT assessment is more time consuming. The assessment of one subject took approximately 45 min for IOR, as compared with 1.5 h for CBCT. Unlike intraoral radiographic images that are static, CBCT images are series of images that require scrolling through different planes. In this study, rather than allowing each examiner to use software and evaluate CBCT images on his/ her own, we chose to use a facilitator to show CBCT images to examiners in a systematic way. Using a facilitator ensured that all examiners used that same amount of time for evaluation and saw the same images throughout the evaluation process. Metal artefacts are another concern in CBCT interpretation. The presence of metallic objects such as crowns, amalgam fillings or dental implants causes artefacts that may interfere with the viewing of the bone level. With the CBCT machine and the setting used in this study, we found minimal problems with metal artefacts when we assessed the bone level using 2D slices. The problem of metal artefacts was more noticeable in the volume-rendering mode (3D view). The adjustment of the threshold to reduce the artefact usually removes parts of the bone surface and may result in overestimation of periodontal bone loss, especially the thin facial bone. However, we mainly determined the bone level and morphology from the 2D slices. The 3D view was occasionally used as a supplement. We also generated and displayed a simulated panoramic image from the CBCT data on a separate monitor. This is a familiar view for clinicians and helps provide an overall picture of the case.

The increased radiation dose is a major concern for the use of CBCT. Evaluation of risks and benefits for

patients is critical. This study used the 3D Accuitomo 170 machine with a field of view (FOV) of 100 × 100 mm, 80 kV and 87.5 mA. This FOV size was selected to include all upper and lower teeth. Using this setting, the effective radiation dose was estimated to be 205 μ Sv.^{28,29} With a FOV of 100 × 50 mm, 90 kV, 87.5 mA, the effective radiation dose was reported as 54 μ Sv.³⁰ Therefore, it should be aware that the effective radiation dose increases significantly as the size of the FOV, particularly its height, increases. The effective dose of a full-mouth periapical radiograph with bitewings was reported as approximately 40 μ Sv.³¹ Thus, the CBCT dose in our study was about five times higher than that of IOR. On the other hand, this radiation dose is much lower than those of conventional CT systems (1031–3324 μ Sv).³² Although cancer risks associated with these dose levels are relatively small, it is crucial to justify the use of advanced imaging modalities because their routine use would lead to a marked increase of the dose to the population. It is essential to optimize exposures on an individual level by reducing FOVs to the region of interest and by selecting appropriate exposure parameters, based on patient size and required image quality. Although our study supports the value of CBCT in periodontal evaluation, we suggest that CBCT should be used with the FOV limited to the area of interest and for specific indications.

Conclusions

CBCT offers additional benefits over the traditional IOR on periodontal and infrabony defect assessment. Compared to CBCT, IOR assessment tended to underestimate the periodontal disease severity and prognosis. CBCT was superior to IOR for evaluation of infrabony defect morphology and was beneficial for treatment decision that involved periodontal regeneration and tooth extraction.

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