Comparison between the Intraoral Radiographs and the Cone-Beam Computed Tomography (CBCT) for periodontal assessment

การเปรียบเทียบการประเมินสภาวะปริทันต์ด้วยภาพรังสีในช่องปากและภาพรังสีโคนบีมคอมพิวท์โทโมกราฟี

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ABSTRACT

Aim: To compare the periodontal assessment by the intraoral radiograph and the CBCT. Material and Methods: Fifteen subjects received clinical, intraoral radiographic and CBCT examinations. Three examiners performed the periodontal assessment including diagnosis, prognosis, infrabony defect classification and treatment decision. The periodontal assessment by the intraoral radiograph and the CBCT was compared. Results: The periodontal assessment by intraoral radiographs was likely to underestimate the disease severity and treatment. The overall concordance between the intraoral radiographs and the CBCT was high for periodontal diagnosis and prognosis, but was moderate to poor for the infrabony defect classification and treatment decision. In addition, the periodontal assessments by the CBCT provided more consistent results among examiners than those by the intraoral radiograph. Conclusion: The periodontal assessment by the intraoral radiograph and the CBCT was different. The use of CBCT may provide additional benefit over the traditional intraoral radiograph for periodontal assessment.

บทคัดย่อ

วัตถุประสงค์: เพื่อเปรียบเทียบการประเมินสภาวะปริทันต์โดยใช้ภาพรังสีในช่องปากและภาพรังสีโคนบีมคอมพิวท์โทโมกราฟี วัสดุและวิธีการ: ผู้ป่วยจำนวน 15คน ได้รับการตรวจทางคลินิก, ตรวจทางรังสีในช่องปากและทางรังสีโคนบีมคอมพิวท์โทโมกราฟี ผู้ให้การประเมิน 3คนจะให้การวินิจฉัยและการพยากรณ์สภาวะปริทันต์ จำแนกลักษณะและวางแผนการรักษาการสูญสลายของกระดูกแนวดิ่ง โดยใช้ข้อมูลจาก ภาพรังสีในช่องปากและภาพรังสีโคนบีมคอมพิวท์โทโม-กราฟี ผล: การประเมินสภาพปริทันต์โดยภาพรังสีในช่องปากมีแนวโน้มที่จะให้การวินิจฉัยและการรักษาต่ำกว่าการประเมินโดยภาพรังสีโคนบีมคอมพิวท์โทโมกราฟี ความสอดคล้องกันระหว่างภาพรังสีในช่องปากและภาพรังสีโคนบีมคอมพิวท์โทโมกราฟีมีค่าสูงในการให้วินิจฉัยและการพยากรณ์สภาวะปริทันต์ แต่มีค่าความสอดคล้องปานกลางถึงต่ำในการจำแนกลักษณะและวางแผนการรักษาการสูญสลายของกระดูกแนวดิ่ง นอกจากนี้ยังพบว่าผลการประเมินของผู้ให้การประเมินทั้ง 3 คนมีความสอดคล้องกันมากกว่าเมื่อประเมินด้วยภาพรังสีโคนบีมคอมพิวท์โทโมกราฟี สรุป: การประเมินสภาวะปริทันต์โดยใช้ภาพรังสีในช่องปากและภาพรังสีโคนบีมคอมพิวท์โทโมกราฟีมีความแตกต่างกัน การใช้ภาพรังสีโคนบีมคอมพิวท์โทโมกราฟีอาจช่วยให้สามารถประเมินสภาพปริทันต์ได้ดีกว่าการใช้ภาพรังสีในช่องปาก

Key Words: Cone-beam computed tomography, Infrabony defect, Decision making

คำสำคัญ: ภาพรังสีโคนบีมคอมพิวท์โทโมกราฟี การสูญสลายของกระดูกแนวดิ่ง การตัดสินใจ

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Introduction

Periodontal disease is the consequence of the inflammatory process that occurs in the tissues surrounding the teeth in response to bacterial plaque. The inflammatory response of the periodontal tissue leads to the progressive loss of the alveolar bone, resulting in tooth loss (Loesche and Grossman, 2001). Periodontal examination is a crucial step that provides information for periodontal diagnosis, prognosis, and treatment plan. Periodontal bone loss is the hallmark of periodontal diseases. Therefore, radiographs are considered an important source of information, which complement the data obtained from the clinical examination. At present, the periapical radiograph is considered a gold standard for evaluating the level and pattern of alveolar bone destruction because it is simple, relatively low-cost and low radiation dose (Mol, 2004). However, a major limitation of these intraoral radiographs is the two-dimensional nature of the images that often obscures and underestimates the periodontal bone loss.

Cone-beam computed tomography (CBCT) is an advance in imaging for visualizing bony structures in the head and neck region (Miracle and Mukherji, 2009). CBCT enables cross-sectional and three-dimensional analysis with a potentially low radiation dose. At present, CBCT has been widely used in dentistry to solve complex diagnostic and treatment planning problems such as those related with dental implants, craniofacial fractures, and orthodontics. However, the applications of CBCT in the periodontal field appear to be limited.

The infrabony defect is a clinical parameter that significantly influences the periodontal prognosis and treatment decision. The infrabony defect is often related to a more advanced stage of periodontitis and the prognosis of the teeth with these defects may improve considerably when periodontal regenerative treatment is performed. Success of the periodontal regeneration depends mainly on the size, shape, and angle of the defect (Eickholz et al., 2004; Laurell et al., 1998). Therefore, it is important to correctly identify and classify the defects to choose the most appropriate treatment. The three-dimensional morphology of the infrabony defect is often obscure in the intraoral radiographs. However, CBCT scans have been shown to overcome this problem. Although, the accuracy of CBCT in the assessment of infrabony defects appears to be well established (de Faria Vasconcelos et al., 2012; Mengel et al., 2005; Misch et al., 2006; Noujeim et al., 2009; Vandenberghe et al., 2008), the evidence for the benefit of CBCT for periodontal diagnosis and treatment planning is limited. This information is important to justify the use of the CBCT in periodontal treatment. Therefore, it is the aim of this study to explore whether the CBCT would give additional benefit over the intraoral radiographs in giving periodontal diagnosis and prognosis. In addition, the value of the CBCT for classification and making treatment decision of the infrabony defects will be determined.

Objectives of the study

1. To compare the intraoral radiograph and the CBCT images in the assessment of periodontal diagnosis and prognosis.

2. To compare the intraoral radiograph and the CBCT images in the classification and treatment decision of the infrabony defects.

Methodology

Study subjects

The study group comprised of 15 consecutive patients who attended the Graduated Periodontology Clinic and met all of the following inclusion criteria: 1)

has moderate to advanced chronic or aggressive periodontitis, 2) has at least 14 remaining teeth, and 3) has at least two infrabony defect of ≥3 mm deep in the periapical radiograph. The subjects were excluded if they were pregnant at the time of the study or had medical conditions that do not allow conventional periodontal treatment. The informed consents were given. The study was approved by the Ethics Research Committee of the faculty of Dentistry, Chulalongkorn University (HREC-DCU 2013-015).

Clinical examination

All subjects received full mouth periodontal examination and the periodontal charts were recorded. The probing depth and the clinical attachment level were recorded at 6 sites/ tooth, using a UNC-15 probe (Hufriedy, Chicago, Illinois, USA). Furcation involvement was determined using a Naber's probe and recorded according the Glickman's classification (Glickman, 1958). Tooth mobility was evaluated using two blunt instruments and classified according to the Miller's index (Miller, 1938).

Intraoral radiographs and cone-beam computed tomography (CBCT) acquisition

All subjects received full mouth periapical radiographs and vertical bitewings of the posterior teeth. The radiographs were obtained using a parallel long cone technique. The radiographs were taken with an intra-oral radiographic machine (Kodak 2200 intraoral X-ray system, Eastman Kodak Co, Rochester, New York, USA) at 75 kV 15 mA using F speed, sized 2 films (Kodak Insight, Carestream Dental LLC, Atlanta, USA). Each intraoral radiograph was digitally converted on a flatbed scanner with transparency adapter (Expression 10000XL, Epson, USA) at 600 dpi and saved as a JPEG file.

CBCT were performed using the 3DX Accuitomo 170 machine (J. Morita, Kyoto, Japan). Cylindrical volumes of 100x100 mm, 85 kV, 5 mA, and voxel sizes of 0.25 mm were used.

Periodontal diagnosis and prognosis

The periodontal diagnosis of each tooth was classified based on clinical attachment loss and radiographic bone loss, as early, moderate, and advanced periodontitis. Early periodontitis had clinical attachment loss of 1-2 mm and bone loss <25%. Moderate periodontitis had clinical attachment loss of 3-4 mm and bone loss 25-50%. Advanced periodontitis had clinical attachment loss of >4 mm and bone loss >50% (Engebretson et al., 2005; Lindhe et al., 1999). Periodontal prognosis was classified as good, fair, poor, questionable, and hopeless, according to McGuire and Nunn (McGuire and Nunn, 1996). Good: Less than 25% of attachment loss, relatively easy to maintain. Fair: 25-50% 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. 2+ mobility or greater. Hopeless: Inadequate attachment to maintain the tooth. Extraction performed or suggested.

Infrabony defect classification and treatment decision of infrabony defects

Teeth with the infrabony defect of ≥3 mm deep in the periapical radiograph were selected for further assessment. The examiners were asked to classify the type of the infrabony defect and gave the treatment decision. The type of the infrabony defect was classified

as one-wall, two-wall, or three-wall defect. For combination defects, the defect type was categorized according to the main characteristics of the defect. The treatment decision was classified as periodontal regeneration, open flap debridement, or extraction.

Periodontal assessment

Periodontal assessment, including diagnosis, prognosis, infrabony defect classification, and treatment decision of infrabony defects were given by three periodontists, based on the clinical and radiographic data.

All examiners viewed the radiographic images and performed periodontal assessment together. The radiographic images were displayed on a 22-inch LCD monitor (ThinkVision L2250p, Lenovo, Quarry Ba, Hong Kong). For intraoral images, the digitized images were put in a Powerpoint file to facilitate viewing. For CBCT images, one operator (K.T.), trained by an experienced radiologist, used the One Volume Viewer software (J. Morita, Kyoto, Japan) to show the CBCT image of each tooth in the coronal, sagittal, and transversal views to the examiners. There was no time limit for image viewing and making periodontal assessment. The average time for completing assessment of a subject with intraoral and CBCT images were one hour and one and a half hour, respectively. The examiners were blinded to the identity of the study subject. The intraoral radiographic images of each subject were evaluated at least a week prior to the CBCT images.

Statistical analysis

Commercial available statistical software (SPSS, IBM Corp, New York, USA) was used to analyze the data. The radiographic modalities (intraoral radiographs and CBCT) were independent variables whereas the periodontal assessments (diagnosis, prognosis, infrabony defect classification and treatment decision of infrabony defects) were dependent variables. The concordance of periodontal assessment between the intraoral radiographs and the CBCT were calculated. The inter-examiner agreement of periodontal assessment was analyzed using Fleiss' kappa (Fleiss, 1971). The difference between the intraoral radiographs and the CBCT in term of the complete agreement of periodontal assessment was analyzed using the McNemar test. Statistical differences with a P-value < 0.05 is considered significant.

Result

Fifteen subjects (7 male and 8 female) with an average age of 49.2 years (range 36-59 years) participated in the study. A total of 378 teeth were included (102 upper anterior, 87 upper posterior, 101 lower anterior and 88 lower posterior teeth). Of these teeth, 76 teeth (80 sites) had infrabony defects that met the inclusion criteria.

The distribution of periodontal assessment by the intraoral radiograph and the CBCT was shown in Table 1. For periodontal diagnosis, the distribution was not different. For periodontal prognosis, the distribution in all categories was quite similar except for hopeless prognosis. The proportion of hopeless teeth was twice as high when assessed by the CBCT, as compared to the intraoral radiographs (9.5% versus 5.8%). The distribution of the infrabony defect classification and treatment decision, as assessed by intraoral radiographs and the CBCT was quite different. Higher proportions of 2-wall defects were observed by intraoral radiographs whereas higher proportions of 3-wall defects were observed by the CBCT. The decision for periodontal regeneration was high (53.9%) when assessed by intraoral radiographs whereas the decision for extraction was high (34.2%) when assessed by the CBCT.

Table 1 Distribution of periodontal assessment by the intraoral radiographs and the CBCT

Periodontal assessment	Intraoral radiograph		CBCT	
	N	%	N	%
Diagnosis				
Early	126	33.3	111	29.4
Moderate	86	22.8	80	21.2
Advanced	166	43.9	187	49.5
Prognosis				
Good	127	33.6	111	29.4
Fair	82	21.7	88	23.3
Poor	98	25.9	100	26.5
Questionable	49	13.0	43	11.4
Hopeless	22	5.8	36	9.5
Infrabony defect classification				
1-wall	13	16.3	9	11.3
2-wall	49	61.3	37	46.3
3-wall	18	22.5	34	42.5
Treatment decision of infrabony defect				
Open flap debridement	21	27.6	29	38.2
Regeneration	41	53.9	21	27.6
Extraction	14	18.4	26	34.2

The concordance of the periodontal assessment between the intraoral radiograph and the CBCT was presented in Table 2. High percent concordance was found for the assessment of periodontal diagnosis (81.2%). Moderated level of concordance was observed for the assessment of prognosis (72.5%) and treatment decision (64.5%). We observed very high concordance (90.9-100%) for diagnosis of teeth with advanced periodontitis, hopeless prognosis, and decision of extraction. However, the concordance was poor for the classification of infrabony defect (43.8%). Overall, we found that the assessment by the intraoral radiographs tends to be underestimated, when compared to the CBCT.

To determine the agreement between examiners in giving the periodontal assessment, the Fleiss' kappa was used. The result was shown in Table 3. Overall, the strength of agreement was considered moderate to excellent (Landis and Koch, 1977). For diagnosis and prognosis, the inter-examiner agreement by the intraoral radiograph and the CBCT was comparable. However, the inter-examiner agreements assessed by the intraoral radiograph were considerably lower than the CBCT for the infrabony defect classification and treatment decision.

To determine which radiographic modalities gave a more consistent outcome of periodontal assessment among examiners, the complete agreement of periodontal assessment among three examiners was evaluated. The result was shown in Table 4. For all types of periodontal assessment, the percent complete agreement was generally higher when using the CBCT images (82.5-91.3%) than the intraoral radiographs (65.0-87.8%). The difference was statistically significant for the assessment of periodontal prognosis and infrabony defect classification. For the assessment of periodontal prognosis, the complete agreement was high in the good and hopeless category while it was relatively low in the questionable category. The percent complete agreement for the questionable prognosis was only 57.1% and 60.5% as assessed by the intraoral radiographs and the CBCT, respectively. For the classification of infrabony defects, the classification of 1- and 2-wall defects improved markedly when assessed by the CBCT.

Discussion and conclusions

The present study showed that the periodontal assessment by the intraoral radiographs and the CBCT was different. The intraoral radiograph has long been a

Table 2 The concordance of periodontal assessment between the intraoral radiographs and the CBCT

	Concordance* (%)	Underestimate† (%)	Overestimate‡ (%)
Diagnosis			
Early	83.3	16.7	-
Moderate	55.8	37.2	7.0
Advanced	92.8	-	7.2
Overall	81.2	14.0	4.8
Prognosis			
Good	82.7	17.3	-
Fair	62.2	30.5	7.3
Poor	71.4	13.2	15.3
Questionable	57.1	30.6	12.2
Hopeless	90.9	-	9.1
Overall	72.5	19.8	7.7
Infrabony defect classification			
1-wall	30.8	69.2	-
2-wall	44.9	44.9	10.2
3-wall	50.0	-	50.0
Overall	43.8	38.7	17.5
Treatment decision of Infrabony defect			
Open flap debridement	81.0	-	-
Regeneration	43.9	-	-
Extraction	100.0	-	-
Overall	64.5	-	-

*The assessment by intraoral radiographs agrees with the CBCT.

†The assessment by intraoral radiographs was underestimated compared to the CBCT.

‡The assessment by intraoral radiographs was overestimated compared to the CBCT.

gold standard for evaluating the periodontal bone support (Mol, 2004). It was used together with the clinical data to provide periodontal diagnosis, prognosis, and treatment planning of periodontal disease. However, a recent advance in cone-beam computed tomography demonstrated that the 3D images offers a more accurate and comprehensive information regarding the bony structures in the head and neck region (Miracle and Mukherji, 2009) We performed periodontal assessment on several aspects including periodontal diagnosis, prognosis, infrabony defect classification, and treatment decision of the infrabony defects. In term of periodontal diagnosis, we found that the distribution of early, moderate, and advanced periodontitis assessed by either the intraoral radiograph or the CBCT was quite similar. However, when the diagnosis of each tooth was matched and paired, it was shown that the intraoral radiograph was likely to underestimate the severity of disease. The overall concordance between the intraoral radiograph and the CBCT was high (81.2%). The concordance was highest for the advanced group (92.8%) and lowest for the moderate group (55.8%). It is important to note that more than one-third of teeth (37.2%) diagnosed as moderate from the intraoral radiograph were diagnosed as advanced from the CBCT. This finding is of clinical significant since under-diagnosis may also lead to under-treatment.

Our results showed that inter-examiner agreement on diagnosis was very high for both radiographic modalities and the percent complete agreement was significantly different. When periodontal prognosis was evaluated, the distribution of prognosis between both radiographic modalities was quite similar in all categories, except for the hopeless prognosis. The teeth with hopeless prognosis were two times higher in the CBCT group. The percent concordance was high for the good and hopeless prognosis, was moderate for the poor prognosis, and low for the fair and questionable prognosis. Similar to the periodontal diagnosis, the periodontal prognosis assessed by the intraoral radiograph was also likely to be

underestimated. The inter-examiner agreement on periodontal prognosis between both radiographic modalities was similar. However, the percent complete agreement was significantly higher for the CBCT. Using the CBCT, the percent complete agreement for the good and hopeless prognosis was very high (98.2% and 94.4%, respectively). It is possible that both categories are at the end of the spectrum, therefore, they are easier to be classified than other categories in between. The questionable prognosis had the poorest percent complete agreement. The agreement was only 57.1% and 60.5% for the intraoral radiograph and the CBCT, respectively.

For the classification of infrabony defect, we showed that the distribution of defect types between radiographic modalities was different. Interestingly, the infrabony defect classification had the lowest concordance among different periodontal assessments examined. The concordance was only 50% for the 3-wall defect and as low as 30.8% for the 1-wall defect. The infrabony defect classification by the intraoral radiograph was likely to underestimate the number of defect wall. In addition, the inter-examiner agreement (Fleiss' kappa = 0.599) and the percent complete agreement (65%) assessed by the intraoral radiographs was also poor. These findings confirmed that the intraoral radiograph is not an effective tool to evaluate the infrabony defect morphology. However, the defect classification and the agreement between examiners were improved markedly when the CBCT was used. This was in agreement with several studies that showed the accuracy of CBCT in measuring and classifying the infrabony defects (de Faria Vasconcelos et al., 2012; Misch et al., 2006; Noujeim et al., 2009; Vandenberghe et al., 2008).

Table 3 The Fleiss' kappa values of inter-examiner agreement on periodontal assessment by the intraoral radiographs and the CBCT

	Intraoral radiograph	CBCT
Diagnosis	0.874	0.907
Prognosis	0.792	0.792
Infrabony defect classification	0.599	0.801
Treatment decision of infrabony defect	0.685	0.833

The treatment decision of the infrabony defects depends largely on the accurate classification of the defect morphology (Eickholz et al., 2004; Laurell et al., 1998). In turn, appropriate treatment decision is crucial since each treatment involves different amount of treatment time and cost. Series of studies by Walter and colleagues showed that the use of CBCT provided detailed information of furcation involvement and a reliable basis for treatment decision (Walter et al., 2009; Walter et al., 2010). Cost analysis showed that the data from CBCT facilitated a reduction in treatment costs and time for periodontally involved maxillary molars (Walter et al., 2012).

To our knowledge, this is the first study that compared the periodontal assessment between the intraoral radiograph and the CBCT in terms of periodontal diagnosis, prognosis, infrabony defect classification, and treatment decision of the infrabony defect. We showed that the assessment by the CBCT resulted in two times less number of teeth that required periodontal regeneration (41 versus 21) and a two times more number of teeth that required extraction (26 versus 14). The concordance of the assessment between the intraoral radiograph and the CBCT was low for

Table 4 The complete agreement of periodontal assessment among three examiners by the intraoral radiographs and the CBCT

	Intraoral radiograph (%)	CBCT (%)	P-value[a]
Diagnosis			
Early	90.5	97.3	-
Moderate	77.9	82.5	-
Advanced	91.0	91.4	-
Overall	87.8	91.3	0.112
Prognosis			
Good	90.0	98.2	-
Fair	73.2	78.4	-
Poor	70.4	86.0	-
Questionable	57.1	60.5	-
Hopeless	81.8	94.4	-
Overall	76.5	85.7	0.001
Infrabony defect classification			
1-wall	53.9	77.8	-
2-wall	61.2	83.8	-
3-wall	83.3	84.9	-
Overall	65.0	82.5	0.014
Treatment decision of infrabony defect			
Open flap debridement	57.1	89.7	-
Regeneration	82.9	76.2	-
Extraction	64.3	84.6	-
Overall	72.4	84.2	0.078

[a]McNemar test

regeneration (44%), but reach 100% for the extraction. This means that all teeth deemed extraction from the intraoral radiographs were also planned for extraction from the CBCT. Interestingly, eleven teeth planned for regeneration and one teeth planned for the open flap debridement from the intraoral radiograph was considered extraction when assessed by the CBCT. Clinically, decision for extraction in periodontally compromised teeth is often difficult to judge. It appeared that the data form CBCT significantly assist the judgment of extraction with a high agreement among examiners (Fleiss' kappa = 0.83).

In conclusion, we showed that the periodontal assessment as determined by the intraoral radiograph and the CBCT was different. The periodontal assessment by intraoral radiographs was likely to underestimate the disease severity and treatment. The overall concordance between the intraoral radiographs and the CBCT was high for periodontal diagnosis and prognosis, but was moderate to poor for the infrabony defect classification and treatment decision. In addition, the periodontal assessments by the CBCT provided more consistent results among examiners than those by the intraoral radiograph. Therefore, the use of CBCT may provide additional benefit over the traditional intraoral radiographs in periodontal assessment, especially those involved infrabony defect classification and treatment decision.

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