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COMPARISON BETWEEN THE INTRAORAL RADIOGRAPHS AND THE CONE BEAM COMPUTED TOMOGRAPHY (CBCT) FOR PERIODONTAL ASSESSMENT

Miss Keenna Tantikul

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Periodontics
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ที่มาและความสำคัญ ข้อมูลจากภาพรังสีมีความสำคัญต่อการวินิจฉัยและรักษาโรคปริทันต์ ภาพรังสีในช่องปากมีลักษณะเป็นภาพสองมิติ ซึ่งอาจบดบังระดับการทำลายของกระดูกเบ้าฟัน ภาพรังสีโคนบีมคอมพิวท์โทโมกราฟฟีมีลักษณะเป็นภาพสามมิติ ซึ่งแก้ไขข้อจำกัดของภาพรังสีในช่องปากได้ การวิจัยนี้มีวัตถุประสงค์เพื่อเปรียบเทียบการใช้ภาพรังสีในช่องปากและภาพรังสีโคนบีมคอมพิวท์โทโมกราฟฟีในการประเมินสภาวะปริทันต์

วัสดุและวิธีการ การวิจัยนี้มีอาสาสมัคร 25คน ที่เป็นโรคปริทันต์อักเสบระดับปานกลางถึงรุนแรงและมีการสูญสลายของกระดูกแนวดิ่งที่มีความลึกอย่างน้อย 3 มิลลิเมตร อย่างน้อย 2 ตำแหน่ง อาสาสมัครทุกคนจะได้รับการตรวจทางคลินิก การตรวจทางภาพรังสีในช่องปากและทางภาพรังสีโคนบีมคอมพิวท์โทโมกราฟฟีทั้งช่องปาก ผู้ประเมินสามคนจะให้การประเมินสภาวะปริทันต์ ซึ่งประกอบด้วย การวินิจฉัยโรค การพยากรณ์โรค การจำแนกลักษณะการสูญสลายของกระดูกแนวดิ่ง และการให้แผนการรักษาโดยใช้ข้อมูลทางคลินิกและข้อมูลทางภาพรังสี ผลการประเมินสภาวะปริทันต์จากภาพรังสีในช่องปากและภาพรังสีโคนบีมคอมพิวท์โทโมกราฟฟีจะถูกนำมาเปรียบเทียบกัน นอกจากนี้ยังทำการประเมินความสอดคล้องกันระหว่างผู้ประเมินในการประเมินสภาวะปริทันต์ด้านต่างๆ ด้วย

ผลการศึกษา ความสอดคล้องระหว่างภาพรังสีในช่องปากกับภาพรังสีโคนบีมคอมพิวท์โทโมกราฟฟีในการวินิจฉัยโรค การพยากรณ์โรค การจำแนกลักษณะการสูญสลายของกระดูกแนวดิ่งและการให้แผนการรักษาเท่ากับ 79.3%, 69.5%, 44.7% และ 64.2% ตามลำดับ การประเมินจากภาพรังสีในช่องปากมักให้การวินิจฉัยโรค การพยากรณ์โรค และการจำแนกจำนวนผนังกระดูกของการสูญสลายของกระดูกแนวดิ่งต่ำกว่าการประเมินจากภาพรังสีโคนบีมคอมพิวท์โทโมกราฟฟี ค่าความสอดคล้องกันระหว่างผู้ประเมิน (เฟลิสคัปปา) ของภาพรังสีโคนบีมคอมพิวท์โทโมกราฟฟีมีค่าสูงมาก (0.87-0.94) และสูงกว่าภาพรังสีในช่องปาก (0.59-0.88) ในการประเมินสภาวะปริทันต์ทุกประเภท ค่าเปอร์เซ็นต์ความสอดคล้องกันทั้งหมดของผู้ประเมินทั้งสามคนเท่ากับ 63.4-88.4% สำหรับภาพรังสีในช่องปาก และเท่ากับ 87.8-94.0% สำหรับภาพรังสีโคนบีมคอมพิวท์โทโมกราฟฟี ค่าความสอดคล้องกันจากการประเมินด้วยภาพรังสีโคนบีมคอมพิวท์โทโมกราฟฟีมีค่าสูงกว่าภาพรังสีในช่องปากในทุกด้านอย่างมีนัยสำคัญทางสถิติ

สรุป การประเมินสภาวะปริทันต์โดยภาพรังสีในช่องปากและภาพรังสีโคนบีมคอมพิวท์โทโมกราฟฟีมีความแตกต่างกัน การประเมินจากภาพรังสีในช่องปากมักจะให้การวินิจฉัยโรค การพยากรณ์โรค และการจำแนกจำนวนผนังกระดูกของการสูญสลายของกระดูกแนวดิ่งต่ำกว่าการประเมินจากภาพรังสีโคนบีมคอมพิวท์โทโมกราฟฟี การประเมินสภาวะปริทันต์จากภาพรังสีโคนบีมคอมพิวท์โทโมกราฟฟีให้ความสอดคล้องกันระหว่างผู้ประเมินสูงกว่าการประเมินด้วยภาพรังสีในช่องปาก

ภาควิชา ปริทันตวิทยา	ลายมือชื่อนิสิต ....
สาขาวิชา ปริทันตศาสตร์	ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก ....
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KEENNA TANTIKUL: COMPARISON BETWEEN THE INTRAORAL RADIOGRAPHS AND THE CONE BEAM COMPUTED TOMOGRAPHY (CBCT) FOR PERIODONTAL ASSESSMENT. ADVISOR: ASST. PROF. KANOKWAN NISAPAKULTORN, Ph.D., pp.

Background: The radiograph is an important source of information for periodontal diagnosis and treatment. The two-dimensional nature of the intraoral radiograph often obscures the periodontal bone loss. Cone beam computed tomography (CBCT) provides three-dimensional images that overcome the limitation of the intraoral radiograph. The aim of this study was to compare the use of intraoral radiographs and CBCT images for periodontal assessment

Methods: The study included 25 subjects who had moderate to advanced periodontitis and had at least 2 infrabony defects of ≥3 mm deep. All subjects received full mouth clinical examination, intraoral and CBCT radiographs. Three examiners performed the periodontal assessment including periodontal diagnosis, prognosis, infrabony defect classification and treatment decision, based on the clinical and radiographic data. The periodontal assessment by the intraoral radiograph and the CBCT was compared. The inter-examiner agreement on periodontal assessment was evaluated.

Results: The concordance between the intraoral radiograph and the CBCT for periodontal diagnosis, prognosis, infrabony defect classification, and infrabony defect treatment were 79.3%, 69.5%, 44.7% and 64.2%, respectively. Assessment by the intraoral radiograph was likely to underestimate periodontal diagnosis, prognosis, and the number of infrabony defect wall. The inter-examiner agreement (Fleiss'kappa) of the CBCT group was very high (0.87-0.94) and was higher than that of the intraoral radiograph (0.59-0.88) for all types of assessment. The percent complete agreement among examiners was 63.4-88.4% for the intraoral radiograph and was 87.8-94.0% for the CBCT. The agreement was significantly higher among the CBCT group than the intraoral radiograph group for all types of assessment.

Conclusions: The assessment by the intraoral radiograph and the CBCT was significantly different. The periodontal assessment by intraoral radiographs was likely to underestimate the periodontal diagnosis, prognosis, and infrabony defect classification. The assessments by the CBCT provided more consistent results among examiners than those by the intraoral radiograph.

Department: Periodontology
Field of Study: Periodontics
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Student's Signature ....
Advisor's Signature ....

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CONTENTS

Page

THAI ABSTRACT iv

ENGLISH ABSTRACT v

ACKNOWLEDGEMENTS vi

CONTENTS vii

LIST OF TABLES ix

LIST OF FIGURES..x

CHAPTER I INTRODUCTION 1

Background and significance 1

Research questions 3

Objectives.. 3

Field of Research 3

Limitation of Research.. 3

Application and Expectation of Research 4

CHAPTER II LITERATURE REVIEW... 5

Periodontal diagnosis and prognosis 5

Infrabony defect 6

Intraoral radiograph... 8

Computed tomography.. 9

The accuracy of the CBCT 11

CHAPTER III MATERIALS AND METHODS.. 18

Study subjects.. 18

Clinical examination... 18

Intraoral radiographs and CBCT acquisition 18

Periodontal diagnosis and prognosis 19

Infrabony defect classification and treatment 19

Periodontal assessment 20

Statistical analysis.. 22

Page

CHAPTER IV RESULT 23

CHAPTER V DISCUSSION 29

REFERENCES 34

VITA 36

LIST OF TABLES

PAGE

1. Definition of prognosis category according to McGuire and Nunn's classification. 6
2. Studies of the CBCT in periodontal assessment 14
   Studies of the CBCT in periodontal assessment (Continue) 15
   Studies of the CBCT in periodontal assessment (Continue) 16
   Studies of the CBCT in periodontal assessment (Continue) 17
3. Characteristic of the study subjects 24
4. Distribution of periodontal assessment by the intraoral radiographs and the CBCT 25
5. The concordance of periodontal assessment between the intraoral radiographs and the CBCT 26
6. The Fleiss' kappa values of inter-examiner agreement on periodontal assessment by the intraoral radiographs and the CBCT 27
7. The complete agreement of periodontal assessment among three examiners by the intraoral radiographs and the CBCT 28

LIST OF FIGURES

PAGE

1. Classification of infrabony defect 8
   (A) One-wall infrabony defect 8
   (B) Two-wall infrabony defect 8
   (C) Three-wall infrabony defect 8
2. The example of conventional CT and CBCT 11
   (A) High efficiency conventional CT scanner 11
   (B) Modern CBCT scanner 11
3. The periapical and the vertical bitewing radiographs of the upper right posterior area. 21
4. A simulated panoramic image of the upper and lower teeth. 21
5. A Screen capture of the CBCT images 22
   (A) Axial view 22
   (B) Three-dimensional view 22
   (C) Sagittal view. 22
   (D) Coronal view. 22

CHAPTER I

INTRODUCTION

Background and significance

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 (Cochran 2008). In general, the bone level can be assessed by the radiograph, bone sounding under local anesthesia, or direct visualization during surgery (Åkesson, Håkansson et al. 1992). The most common method of bone level assessment is the radiograph. 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. The bitewing radiograph, either horizontal or vertical, may also be used to supplement the periapical radiograph. However, there are some limitations. The major limitation of the intraoral radiograph is the two-dimensional image of the three-dimensional structures. In many cases, it is hard to differentiate the bone level between the buccal and lingual aspect, especially in the infrabony defects. Several studies reported that the amount of bony destruction is underestimated in the intraoral radiograph (Fuhrmann, Bucker et al. 1995; Eickholz and Hausmann 2000; Vandenberghe, Jacobs et al. 2007; Mol and Balasundaram 2008; Noujeim, Prihoda et al. 2009). The limitations associated with the two-dimension nature of intraoral radiographs suggested that an imaging technique, which allows three-dimension visualization of teeth and periodontal bone defects, would be of great benefit for the accurate assessment of periodontal diseases.

Computed tomography (CT) is a radiographic technique that enables cross-sectional and three-dimensional analysis. For most dental practitioners, the use of CT scan has been limited because of the cost, availability, and radiation dose consideration. Cone-beam computed tomography (CBCT) is an advance in imaging for visualizing bony structures in the head and neck region (Miracle and Mukherji 2009). The 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.

Although the radiographic images obtained from intraoral radiograph are adequate for routine periodontal diagnosis and treatment planning, a number of clinical situations may require multiplanar images such as the infrabony defect. 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 teeth with infrabony defect 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 (Laurell, Gottlow et al. 1998; Eickholz, Horr et al. 2004). 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 radiograph. 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 (Mengel, Candir et al. 2005; Misch, Yi et al. 2006; Vandenberghe, Jacobs et al. 2007; Vandenberghe, Jacobs et al. 2008; Noujeim, Prihoda et al. 2009; de Faria Vasconcelos, Evangelista et al. 2012; Braun, Ritter et al. 2013), the evidence of the benefit of the CBCT for periodontal diagnosis and treatment planning has been limited. This information is important to justify the use of the CBCT in periodontal diagnosis and treatment. Therefore, it is the aim of this study to explore whether the CBCT would give additional benefit over traditional intraoral radiographs in giving periodontal diagnosis and prognosis. In addition, the value of the CBCT for classification and treatment decision of the infrabony defect was determined.

Research questions

1. Are there any differences between the intraoral radiograph and the CBCT for the assessment of periodontal diagnosis and prognosis?
2. Are there any differences between the intraoral radiograph and the CBCT for the assessment of infrabony defect classification and treatment?

Objectives

1. To compare the intraoral radiograph and the CBCT for the assessment of periodontal diagnosis and prognosis.
2. To compare the intraoral radiograph and the CBCT for the assessment of infrabony defect classification and treatment.

Field of Research

This is a clinical research with the cross-sectional analytical study design.

Limitation of Research

This research is cross-sectional in nature. A longitudinal study that determines the accuracy of the CBCT in term of the actual infrabony defect type and treatment at time of surgery will be of great benefit.

Application and Expectation of Research

This study was the first study that explores the value of CBCT for the assessment of periodontal diagnosis and prognosis. In addition, the value of CBCT for the assessment of infrabony defect classification and treatment was determined. The result of this study will provide useful information to justify whether the CBCT is of benefit for periodontal treatment.

CHAPTER II

LITERATURE REVIEW

Periodontal diagnosis and prognosis

The achievement of periodontal treatment depends on diagnosis and prognosis which leads to an appropriate treatment plan. Commonly, the diagnosis of periodontal disease based on the clinical condition and radiographic information. According to the American Association of Periodontology 1999, the significant features of chronic periodontitis are the amount of periodontal bone loss and attachment destruction which is consistent with the presence of local factors (Armitage 2004). The severity of chronic periodontitis is generally classified based on clinical attachment level (CAL) as the followings; early = CAL 1-2 mm; moderate = CAL 3-4 mm, and advanced = CAL >4 mm (Lindhe, Ranney et al. 1999). The amount of periodontal bone loss has also been classified as early, moderate, advanced which was <25%, 25-50%, and >50% bone loss, respectively (Engebretson, Lamster et al. 2005).

Periodontal prognosis is defined as a prediction of tooth survival. Several studies proposed different periodontal prognosis criteria (Hirschfeld and Wasserman 1978; Becker, Becker et al. 1984; Becker, Berg et al. 1984; McGuire and Nunn 1996). The assignment of prognosis is based on many factors such as the percentage of bone loss, the deepest probing depth, the pattern of bone loss, tooth mobility, and crown-to-root ratio (McGuire and Nunn 1996). According to McGuire and Nunn, the prognosis was classified as good, fair, poor, questionable and hopeless prognosis (Table 1).

Table 1 Definition of prognosis category according to McGuire and Nunn's classification.

Prognosis category	Definition
Good	(One or more of the following): Control of the etiologic factors and adequate periodontal support as measured clinically and radiographically to assure the, tooth would be relatively easy to maintain by the patient and clinician assuming proper maintenance.
Fair	(One or more of the following): Approximately 25% attachment loss as measured clinically and radiographically and/or Class I furcation involvement. The location and depth of the furcation would allow proper maintenance with good patient compliance.
Poor	(One or more of the following): 50% attachment loss with Class II furcation. The location and depth of the furcation would allow proper maintenance, but with difficulty.
Questionable	(One or more of the following): Greater than 50% attachment loss resulting in a poor crown-to-root ratio. Poor root form. Class II furcation not easily accessible to maintenance care or Class III furcation. 2+ mobility or greater. Significant root proximity
Hopeless	Inadequate attachment to maintain the tooth. Extraction performed or suggested.

Infrabony defect

The Infrabony defect is a clinical parameter that has significant influence on periodontal diagnosis, prognosis and treatment decision. The infrabony defect is defined as periodontal bone destruction, resulting in the bottom of the defect apical to the alveolar crest. The infrabony defects are classified on the remaining osseous wall as one-wall, two-wall, or three-wall infrabony defect (Goldman and Cohen 1958) (Figure 1). The presence of this defect is often related to a more advanced stage of periodontitis and a risk of disease progression, if the periodontal treatment has not been performed. Various approaches have been proposed for the treatment of the infrabony defects such as scaling and root planing with or without access flap surgery, and periodontal regeneration. Periodontal regeneration is the treatment that allows restoration of the lost periodontal bone and attachment, which can be achieved by bone grafting, guided tissue regeneration (GTR), or the combination of both bone graft and GTR. Several studies reported that the regeneration treatment in the infrabony defects provided more favorable outcome than conventional periodontal therapy (Cortellini, Pini Prato et al. 1995; Cortellini, Pini Prato et al. 1996; Eickholz, Benn et al. 1996; Tonetti, Cortellini et al. 1998; Froum, Weinberg et al. 2001; Needleman, Worthington et al. 2006). However, many factors affected the outcome of regenerative treatment of the infrabony defect. One of the most important factors was the defect morphology. Many studies reported that the result of periodontal regeneration in narrow and deep infrabony defects with depth ≥ 3 mm showed greater amount of clinical attachment gain, bone gain and reduction of probing depth than in wide and shallow defects (Laurell, Gottlow et al. 1998; Klein, Kim et al. 2001; Eickholz, Horr et al. 2004; Pagliaro, Nieri et al. 2008). The studies also demonstrated that two-wall and three-wall infrabony defects had potential for regeneration (Mellonig 1984; Renvert, Garrett et al. 1985). The wide and shallow one-wall infrabony defect gave less favorable outcome for regeneration treatment (Klein, Kim et al. 2001; Eickholz, Horr et al. 2004). The open flap debridement (OFD) is one of the recommendation treatments for the infrabony defect. Meta-analysis of treatment outcome with OFD demonstrated that the average clinical attachment gain was 1.78 mm and the defect filled with new bone could be expected approximately 1.1 mm (Lang 2000). In summary, the defect morphology seems to be a significant factor that influences the treatment outcome. Therefore, it is important to correctly identify and classify the defects to choose the most appropriate treatment.

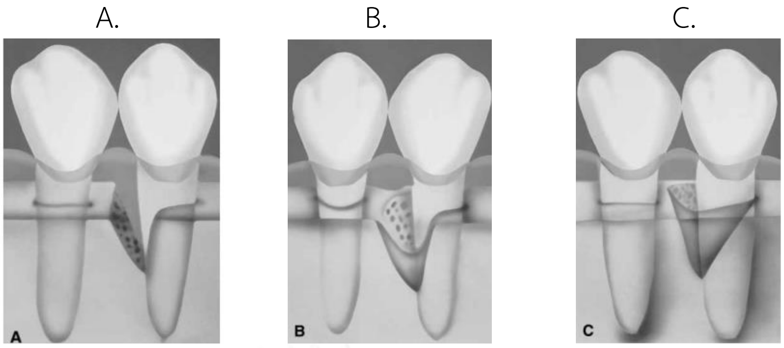

Figure 1 (A) One-wall, (B) two-wall, and (C) three-wall infrabony defects (Papapanou and Tonetti 2000)

Intraoral radiograph

Radiographs are considered as an important source of information that complements the clinical data. Radiographic examinations provide the information of the bone level and pattern of bone loss that cannot be detected in clinical examination. Conventional radiographic methods for the bone level assessment are the intraoral radiograph, which include periapical and bitewing radiograph, and panoramic radiographs. At present, the technique of choice for the bone level assessment is the intraoral radiograph because it is simple to acquire, relative low-cost and low radiation dose (Mol 2004). The intraoral radiograph should be obtained using the long cone parallel technique to represent an accurate bone level. However, the patient's anatomy, e.g., shallow palatal vault or torus palatinus, may not allow the correct film placement, leading to the distortion of the true bone level. Furthermore, a complete periodontal examination also requires the periapical radiograph of all remaining teeth as well as horizontal or vertical bitewings of the posterior teeth. For the full dentate patient, as many as 18-22 films may be needed. Therefore, some investigators suggested that the panoramic radiograph supplemented with the intraoral radiograph in selected areas might be another option, which is relatively simple without the need for many intraoral manipulations (Molander, Ahlqwist et al. 1995). However, the panoramic radiograph has limitations in term of image magnification and distortion, especially in the incisor region

(Åkesson, Håkansson et al. 1989). Moreover, due to the nature of the projection geometry used, the artifacts and superimposed images commonly occur. The major limitation of conventional radiographs is the two-dimensional images of the three-dimensional structures. Therefore, many anatomic structures such as buccal and lingual cortical plates may superimpose. In many cases, such as the infrabony defect, it is difficult to describe the defect morphology correctly. Several studies reported that the amount of bony destruction is underestimated in the conventional radiographs. The intraoral radiograph showed the underestimation of the bone level ranged from 1.03 to 3.0 mm (Åkesson, Håkansson et al. 1992; Tonetti, Pini Prato et al. 1993; Fuhrmann, Bucker et al. 1995; Eickholz and Hausmann 2000), and the panoramic radiographs showed underestimated 3.3 mm from gold standard (Åkesson, Håkansson et al. 1992). Previous studies reported the intraoral radiograph has a sensitivity of 20 – 83 % in the detection and classification of bone defects, while three-dimensional imaging technique has a sensitivity of 91 - 100% (Fuhrmann, Bucker et al. 1995; Vandenberghe, Jacobs et al. 2008; Braun, Ritter et al. 2013). Due to the limitations associated with the conventional radiographs, the computed tomography (CT) that provides three-dimensional information of bone architecture might be a useful tool for periodontal diagnosis, prognosis, and treatment planning.

Computed tomography

Computed tomography (CT) is a radiographic technique that enables cross-sectional and three-dimensional analysis. An application of the CT in periodontal treatment has been investigated. The study showed that the CT could detect 100% of infrabony defects (Fuhrmann, Bucker et al. 1995); also, the studies reported the deviations of bone level in the CT ranged from 0.2 to 0.41 mm compared to the surgical measurement (Fuhrmann, Bucker et al. 1995; Naito, Hosokawa et al. 1998). However, the clinical application of CT scan in dentistry has been limited because of the high equipment cost, availability, and radiation dose consideration.

Cone beam-computed tomography (CBCT) is an advance in CT imaging that has emerged as a potentially low dose cross-sectional technique for visualizing bony structures in the head and neck region (Miracle and Mukherji 2009). The first CBCT system became commercially available for the maxillofacial imaging in 1998. Contrary to the conventional CT, it consists of a conical radiographic source and a high performance digital panel detector. The x-ray source and detector rotate around a patient, which acts as a fulcrum. Most CBCT machines are similar in size to a conventional panoramic machine (Figure 2). The CBCT allows the creation of accurate images, not only in the axial planes but also two-dimensional images in the coronal, sagittal, and even oblique or curved image planes. The process referred to the multiplanar reformation (MPR). The CBCT provides clear images of high contrast structures and is well suited for evaluating bone. An effective dose in the broad range of 19-368 μSv can be expected, depending on exposure parameters and the selected field of view (FOV) size. Most CBCT scans have effective doses between 30 and 130 μSv (Pauwels, Beinsberger et al. 2012). In comparison, standard panoramic radiography delivers 24.5 μSv and conventional CT with a similar FOV delivers 474-1160 μSv (Loubele, Bogaerts et al. 2008; Ludlow and Ivanovic 2008). The National Council on Radiation Protection and Measurements in 2003 reported that the average effective dose from natural background radiation in U.S was about 3,000 μSv per year (Ludlow, Davies-Ludlow et al. 2008). Therefore, the CBCT may be associated with an effective dose equivalent to 4-15 days of background radiation, while the panoramic radiograph has effective dose approximately 3 days and the conventional CT has effective dose approximately 2-5 months of background radiation. Image quality can vary considerably with dose. Images acquired with higher radiation exposure often produce better image quality (Loubele, Jacobs et al. 2005). In addition, the CBCT image resolution can be as small as 0.08 mm, compared to 0.5-1 mm for the conventional CT (White 2008). 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.

A. B.

Figure 2 (A) High efficiency conventional CT scanner and (B) modern CBCT scanner

The accuracy of the CBCT

In vitro studies demonstrated that the accuracy of linear measurement of the periodontal defects in dry skulls or cadavers by the CBCT, as compared with gold standard (histological specimens or physical measurement), provided a significant advantage over the conventional radiographs. The CBCT could detect all defects with mean deviation of 0.13 – 1.67 mm, while the conventional radiograph could detect only the interproximal defects with mean deviation of 0.19 – 1.66 mm (Mengel, Candir et al. 2005; Misch, Yi et al. 2006; Vandenberghe, Jacobs et al. 2008; de Faria Vasconcelos, Evangelista et al. 2012; Braun, Ritter et al. 2013; Fleiner, Hannig et al. 2013). In addition, the CBCT images offer a three-dimensional interpretation of the infrabony defect morphology and permit accurate classification of the defect according to the number of surrounding bone walls into one-, two-, or three-wall defects (Vandenberghe, Jacobs et al. 2007; de Faria Vasconcelos, Evangelista et al. 2012; Braun, Ritter et al. 2013). Several in vitro studies demonstrated that the CBCT measurement was more accurate than the intraoral radiograph to detect the periodontal bony defects. The CBCT had a sensitivity of 91 – 100% in the detection and classification of the infrabony defects (Vandenberghe, Jacobs et al. 2008; Braun, Ritter et al. 2013) and had a sensitivity of 94.8 – 100% in furcation defects (Vandenberghe, Jacobs et al. 2008; Braun, Ritter et al. 2013; Fleiner, Hannig et al. 2013).

Clinical studies on the accuracy of the CBCT for periodontal bone measurements have been demonstrated. Feijo et al. (2012) measured the horizontal periodontal defects using the CBCT, compared to the measurement during the surgical intervention. They found that the CBCT measurements was comparable to the surgical measurement and overestimated the clinical measurement by 0.25 mm. Grimard et al. (2009) compared the measurements from the intraoral radiograph and the CBCT to direct surgical measurements for the evaluation of periodontal regeneration outcome. They found that CBCT correlated strongly with the surgical measurements (r=0.89-0.95), whereas the intraoral radiograph correlated less favorable (r=0.53-0.67). Assessment of the infrabony defect fill showed that the difference between the intraoral radiograph and the surgical measurements (0.8 mm) was two times larger than that of the CBCT measurements (0.4 mm).

The value of CBCT for diagnosis and treatment planning was evaluated. Walter et al. (2009) studied in twelve patients with chronic periodontitis and clinically detectable furcation involvements of maxillary molars were included. Compared to the CBCT scans, clinical furcation detection was accurate in 27%, overestimated in 29%, and underestimated in 44%. The underestimation was as high as 75% among the sites with more advanced stage of furcation involvement (degree 2 and 3). Twenty-five molars were considered for furcation surgery, which allowed the intra-surgical evaluation of the defects (Walter, Weiger et al. 2010). Overall, 84% of the CBCT data were confirmed by the intra-surgical findings, whereas 14.7% were underestimated, and only 1.3% were overestimated. The high correlation between the intra-surgical findings and the CBCT supports the value of CBCT for furcation assessment. The role of CBCT for treatment decision of molar furcations was also determined (Walter, Weiger et al. 2012). It was shown that data from the CBCT facilitated a reduction in treatment cost and time for treatment of maxillary molar furcations, amounting to 915 Swiss franc and 136 minutes, respectively. Recently, Qiao et al (2014) also demonstrated the accuracy of the CBCT in assessment of maxillary furcation defects. This study showed that 82.4% of the CBCT data were confirmed by intra-surgical finding with a Kappa value of 0.917. Therefore, the use of the CBCT as an additional diagnostic tool appeared to be justified when invasive treatments are planned. Studies of the CBCT in periodontal assessment were summarized in table 2.

Even though the accuracy of the CBCT for the assessment of infrabony defects appears to be well established, the evidence for the benefit of the CBCT for periodontal diagnosis and treatment planning is limited. This information is important to justify the use of the CBCT in periodontal treatment. Therefore, the study to explore the value of CBCT for the assessment of periodontal diagnosis, prognosis should be performed.

Table 2 Studies of the CBCT in periodontal assessment.

Authors	Models	Study design	Results and Comments
Mengel et al (2005)	6 Pig mandibles 7 Human mandibles (artificial defects)	5 examiners measured periodontal defects in 4 modalities. 1. Periapical radiographs 2. Panoramic radiographs 3. Conventional CT 4. CBCT Reference; Histologic sections measurement by reflecting stereomicroscopy	Mean deviation from reference – Periapical radiographs= 0.33mm. – Panoramic radiographs= 1.07mm. – Conventional CT= 0.16mm. – CBCT= 0.19mm. *Periapical and panoramic radiographs could measure defects only in the mesio-distal and occluso-cervical planes, while conventional CT and CBCT could measure defects in all planes.
Misch et al (2006)	2 Human dry skulls (artificial defects)	3 examiners me5asured periodontal defect in 3 modalities. 1. Periapical radiographs 2. CBCT 3. Bone sounding Reference; Physical measurement by electronic caliber	Mean deviation from reference (all sites) – Periapical radiographs= 0.27mm. – CBCT= 0.41mm. – Bone sounding= 0.34mm. Mean deviation from reference (Proximal sites) – Periapical radiographs= 0.37mm. – CBCT= 0.36mm. – Bone sounding= 0.60mm.
Vandenberghe et al (2007)	2 Human dry skulls with soft tissue substitution (natural defects)	3 examiners measured periodontal defects in 2 modalities. 1. Periapical radiographs 2. CBCT Reference; Physical measurement by digital caliber	Mean deviation from reference – Periapical radiographs= 0.19-1.66mm. – CBCT= 0.13-1.67mm. *CBCT images provided more potential in the morphological description of the defects.

Table 2 Studies of the CBCT in periodontal assessment. (Continue)

Authors	Models	Study design	Results and Comments
Mol and Balasundaram (2008)	5 Human dry skulls (natural defects)	5 examiners measured periodontal defects and assessed the presence or absence of bone loss in 2 modalities. 1. Periapical radiographs 2. CBCT Reference; Physical measurement by digital caliber	<u>The receiver operating characteristic (ROC) curves analysis</u> CBCT had sensitivity and specificity significantly higher than periapical radiographs <u>Mean deviation from reference</u> – Periapical radiographs= 1.49mm. – CBCT= 1.27mm.
Vandenberghe et al (2008)	1 Human cadaver 1 Human dry skull (natural defects)	3 examiners measured periodontal defects and classified infrabony and furcation defects in 3 modalities. 1. Periapical radiographs 2. CBCT(Panoramic 5.2mm reconstruction view) 3. CBCT (0.4mm thick cross-sectional slices) Reference; Physical measurement by digital caliber	<u>Mean deviation from reference</u> – Periapical radiographs = 0.56mm. – CBCT (Panoramic view) = 0.47mm. – CBCT (0.4mm slices view) = 0.29mm. <u>Infrabony and furcation defects classification</u> Periapical radiographs – detected infrabony defects= 71% – detected furcation defects= 56% – correctly classified infrabony defects= 29% – correctly classified furcation defects= 20% CBCT – detected infrabony defects= 100% – detected furcation defects= 100% – correctly classified infrabony defects= 91% – correctly classified furcation defects= 100%

Table 2 Studies of the CBCT in periodontal assessment. (Continue)

Authors	Models	Study design	Results and Comments
Noujeim et al (2009)	11 Human dry hemimandibles (create defects)	10 examiners assessed the presence or absence of bone defects in 2 modalities. 1. Periapical radiographs 2. CBCT Reference; An established list of defects created by the investigator	The receiver operating characteristic (ROC) curves analysis CBCT had sensitivity and specificity significantly higher than periapical radiographs
Walter et al (2009)	12 Patients	2 examiners classified the furcation defects of maxillary molars by periapical radiographs with clinical data compared with the classification by periapical radiographs with clinical data with CBCT (reference).	Degree of furcation defects Periapical radiographs with clinical data – Confirmed 27% – Underestimated 44% – Overestimated 29%
Grimard et al (2009)	29 Patients	2 examiners measured the infrabony defect filled at 6 month after regeneration treatment in 2 modalities 1. Periapical radiographs 2. CBCT Reference; Re-entry surgery measurement	Mean deviation from reference (defect filled) – Periapical radiographs= 0.8mm. – CBCT= 0.4mm.
Walter et al (2010)	14 Patients	2 examiners classified the furcation defects of maxillary molars by CBCT compared with the classification by intra-surgical measurement (reference).	Degree of furcation defects CBCT – Confirmed 84% – Underestimated 14.7% – Overestimated 1.3%

Table 2 Studies of the CBCT in periodontal assessment. (Continue)

Authors	Models	Study design	Result
Feijo et al (2012)	6 Patients	1 examiners measured periodontal defects in CBCT compared with surgical measurement by probe (reference)	Mean deviation from reference CBCT= 0.25 mm.
de Faria Vasconcelos et al (2012)	1,485 Radiographic images	3 examiners measured the infrabony defects in 2 modalities. 1. Periapical radiographs 2. CBCT	– Height of alveolar crest: Significantly difference – Depth& Width of defects: No significantly difference
Braun et al (2013)	5 Pig mandibles (artificial defects)	15 examiners detected periodontal defects in 2 modalities. 1. Periapical radiographs 2. CBCT Reference; Photographs during defects preparation	CBCT detected periodontal defects significantly more accurate than the periapical radiographs.
Jonathan et al (2013)	1 Human dry skull (natural defects)	3 examiners measured periodontal defects in CBCT compared with physical measurement by probe (reference).	Mean deviation from reference CBCT= 0.36-0.69mm.
Qiao et al (2014)	15 Patients	2 examiners classified furcation defects of maxillary molars by pre-surgical probe compared with data of furcation defects classified by other 2 examiners in CBCT. Reference; Intra-surgical measurement by probe	Degree of furcation defects – Pre-surgical probe was agree with intra-surgical measurement 21.6% – CBCT was agree with intra-surgical measurement 82.4%

CHAPTER III

MATERIALS AND METHODS

Study subjects

The study group comprised 25 consecutive patients who attended the Graduated Periodontology Clinic and met all of the following inclusion criteria: 1) has moderate to advanced chronic periodontitis, 2) has at least 14 remaining teeth, and 3) has at least two infrabony defects 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. All patients were informed of the purpose of the study and the informed consents were signed. 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 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. For CBCT scanning, the 3D Accuitomo 170 machine (J. Morita, Kyoto, Japan) was used. The occlusal plane of the subjects was positioned parallel to the horizontal plane and the mid-sagittal plane was centered. The cylindrical volumes (field of view) of 100x100 mm, 80 kV, 5 mA, 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 (Lindhe, Ranney et al. 1999) and radiographic bone loss (Engebretson, Lamster et al. 2005) 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%.

Periodontal prognosis was classified based on individual tooth conditions as good, fair, poor, questionable, and hopeless (McGuire and Nunn 1996). 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, 2 degree mobility or greater. Hopeless: Inadequate attachment to maintain the tooth, extraction performed or suggested.

Infrabony defect classification and treatment

All teeth with 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 based on the clinical and radiographic data. The type of the infrabony defect was classified as one-wall defect, two-wall defect, or three-wall defect. For combination defects, the defect type was categorized according to the main characteristics of the defect.

The treatment of infrabony defect was classified as periodontal regeneration, open flap debridement, or extraction based on clinical and radiographic information. In general, periodontal regeneration was considered when the bony defect depth was ≥4 mm, had two- or three-wall, or the defect angle was narrow. Open flap debridement was considered when the bony defect depth was <4mm, had one- or two-wall, or the defect angle was wide. Extraction was considered when there was inadequate support to maintain the tooth in health and function (Laurell, Gottlow et al. 1998; Eickholz, Horr et al. 2004).

Periodontal assessment

Periodontal assessment, including diagnosis and prognosis of all teeth, classification and treatment decision of infrabony defects were given by three periodontists, based on the clinical and radiographic data. The radiographic images were displayed on a 22-inch LCD monitor (ThinkVision L2250p, Lenovo, Quarry Ba, Hong Kong) at a screen resolution of 1680 x1050 pixels. For intraoral radiographs, the digitized images were put into a PowerPoint file to facilitate viewing (Figure 3). For CBCT radiographs, the images were reconstructed using the One Volume Viewer software (J. Morita, Kyoto, Japan) and displayed on two monitors. One monitor displayed a simulated panoramic image of the upper and lower teeth, created by the Ray Sum method with the slice thickness of 15 mm (Figure 4). Another monitor displayed the CBCT images in the axial, sagittal, coronal, and 3D views. A screen capture of the CBCT images was shown in Figure 5. One operator (KT), trained by an experienced radiologist, used the One Volume Viewer software to show the images of each tooth in different planes to the examiner. All examiners analyzed the clinical periodontal charts and viewed the radiographic images together. Each examiner gave his/her own periodontal assessment. The agreement of at least 2 out 3 examiners was considered the consensus. The agreement of 3 out 3 examiners was considered the complete agreement. When each examiner gave different answer, a discussion was required to reach the consensus. There was no time restriction for image viewing and making periodontal assessment. The average time for completing assessment of a subject was 45minutes for intraoral images and one and a half hour for CBCT images. 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.

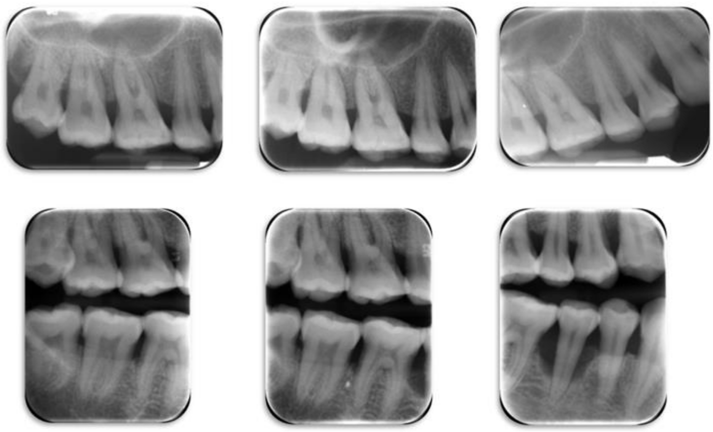

Figure 3 The periapical and the vertical bitewing radiographs of the upper right posterior area.

Figure 4 A simulated panoramic image of the upper and lower teeth.

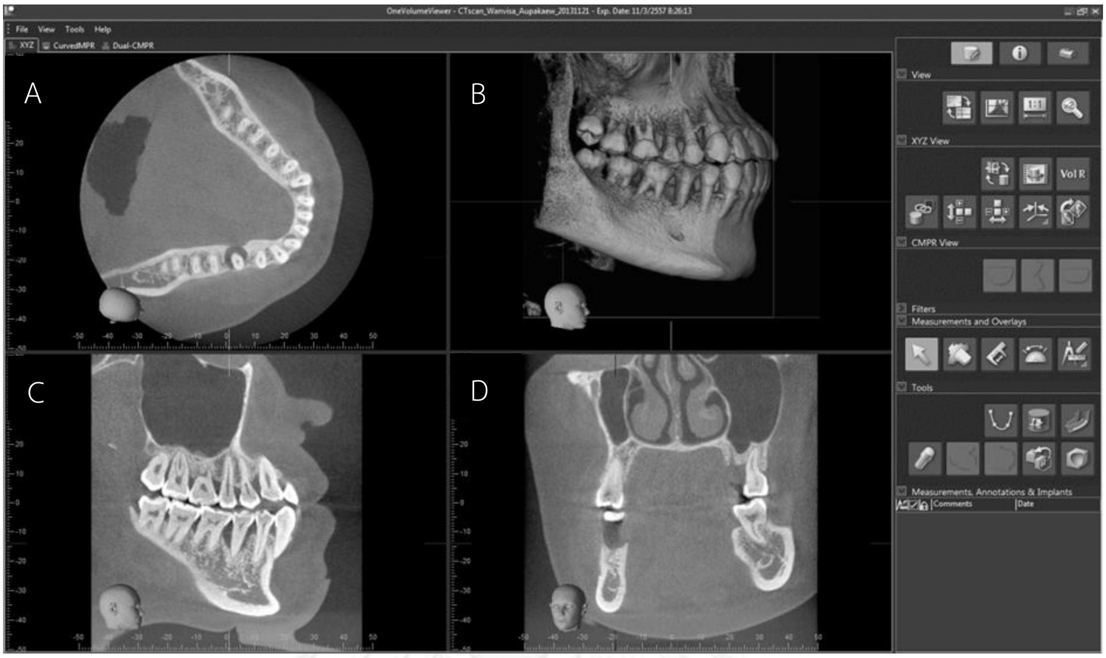

Figure 5 A Screen capture of the CBCT images (A) axial (B) 3D (C) sagittal and (D) coronal view.

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 infrabony defect treatment) were dependent variables. The concordance of periodontal assessment between the intraoral radiograph and the CBCT were calculated and analyzed. The inter-examiner agreement of periodontal assessment was analyzed using Fleiss' kappa (Fleiss 1971). The difference between the intraoral radiograph 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.

CHAPTER IV

RESULT

Twenty-five subjects participated in the study. There were 670 teeth. Four teeth, which were not clearly seen in the intraoral radiograph, were excluded. Therefore, a total of 666 teeth were analyzed. Of these teeth, 116 teeth (123 sites) had infrabony defects that met the inclusion criteria. The average probing depth and the clinical attachment level of the infrabony defect was 8.0 ± 1.7 mm and 8.2 ± 2.4 mm, respectively (Table 3). The distribution of periodontal assessment by the intraoral radiograph and the CBCT was shown in Table 4. We showed that the periodontal assessment by the intraoral radiograph and the CBCT was different. Compared to the CBCT, the intraoral radiograph group had higher percentage of teeth with early periodontitis and lower percentage of teeth with advanced periodontitis. Likewise, higher percentage of teeth with good prognosis and lower percentage of teeth with hopeless prognosis was observed in the intraoral radiograph group. The proportion of hopeless teeth was twice as high when assessed by the CBCT, as compared to the intraoral radiograph (7.3% versus 3.8%). The percentage of sites with 3-wall infrabony defect was also high when assessed by the CBCT. Periodontal regeneration was the treatment of choice when assessed by the intraoral radiograph. However, it is the least selected treatment when assessed by the CBCT.

Table 3 Characteristic of the study subjects

Variables	
Age	
Average (year)	48.8
Range (year)	36 - 59
Gender	
Male (n)	11
Female (n)	14
Number of teeth	
Incisors and canines (n)	293
Premolars (n)	185
Molars (n)	188
Total (n)	666
Number of infrabony defects	
Incisors and canines (site/tooth)	27 / 26
Premolars (site/tooth)	35 / 33
Molars (site/tooth)	61 / 57
Total (site/tooth)	123 / 116
Infrabony defects	
probing depth	
Range (mm)	5 - 13
Average (mm)	8.0 ± 1.7
Clinical attachment level	
Range (mm)	3 - 16
Average (mm)	8.2 ± 2.4

Table 4 Distribution of periodontal assessment by the intraoral radiographs and the CBCT

Image modality	Intraoral radiograph		CBCT	
	N	%	N	%
Diagnosis				
Early	236	35.4	191	28.7
Moderate	167	25.1	175	26.3
Advanced	263	39.5	300	45.0
Prognosis				
Good	237	35.6	191	28.7
Fair	168	25.2	189	28.4
Poor	148	22.2	149	22.4
Questionable	88	13.2	88	13.2
Hopeless	25	3.8	49	7.3
Infrabony defect classification				
1-wall	21	17.1	15	12.1
2-wall	72	58.5	56	45.5
3-wall	30	24.4	52	42.3
Infrabony defect treatment				
Open flap debridement	35	28.5	46	37.4
Regeneration	60	48.8	34	27.6
Extraction	28	22.7	43	35.0

The concordance of the periodontal assessment between the intraoral radiograph and the CBCT was presented in Table 5. Percent concordance was high for the assessment of periodontal diagnosis (79.3%). Moderated level of concordance was observed for the assessment of prognosis (69.5%) and infrabony defect treatment (64.2%). The concordance was poor for the infrabony defect classification (44.7%). The concordance between the intraoral radiograph and the CBCT was very high for giving a diagnosis of advanced periodontitis, hopeless prognosis, and decision on tooth extraction. In general, the use of the intraoral radiograph was likely to underestimate the periodontal diagnosis and prognosis, as well as the number of infrabony defect wall.

Table 5 The concordance of periodontal assessment between the intraoral radiographs and the CBCT

	Concordance (%)*	Underestimate (%)†	Overestimate (%)‡
Diagnosis			
Early	75.8	24.1	-
Moderate	61.7	31.1	7.2
Advanced	93.5	-	6.5
Overall	79.3	16.4	4.3
Prognosis			
Good	75.5	24.5	-
Fair	66.1	26.8	7.1
Poor	65.5	21.0	13.5
Questionable	61.4	29.5	9.1
Hopeless	88.0	-	12.0
Overall	69.5	24.0	6.4
Infrabony defect classification			
1-wall	38.1	61.9	-
2-wall	44.4	45.8	9.7
3-wall	50.0	-	50.0
Overall	44.7	37.4	17.9
Infrabony defect treatment			
Open flap debridement	73.4	-	-
Regeneration	43.3	-	-
Extraction	96.4	-	-
Overall	64.2	-	-

*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.

To determine the agreement between examiners in giving the periodontal assessment, the Fleiss' kappa was used. The result was shown in Table 6. 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.

Table 6 The Fleiss' kappa values of inter-examiner agreement on periodontal assessment by the intraoral radiographs and the CBCT

	Intraoral radiograph	CBCT
Diagnosis	0.88	0.94
Prognosis	0.82	0.91
Infrabony defect classification	0.59	0.87
Infrabony defect treatment	0.73	0.87

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 7. For all types of periodontal assessment, the overall percent complete agreement was significantly higher when using the CBCT images than the intraoral radiograph. For periodontal diagnosis, the percent complete agreement of moderate periodontitis improved markedly when assessed by the CBCT (76.6% vs. 90.0%). Similarly, the percent complete agreement of fair, poor, and questionable prognosis by the intraoral radiograph was improved when assessed by the CBCT. Infrabony defect classification assessed by intraoral radiographs had poor complete agreement. However, the percent complete agreement increased significantly for all types of infrabony defect when assessed by the CBCT. In term of infrabony defect treatment, the percent complete agreement between the intraoral radiograph and the CBCT was comparable for periodontal regeneration. Nonetheless, the percent complete agreement for the open flap debridement and extraction increased markedly when assessed by the CBCT.

Table 7 The complete agreement of periodontal assessment among three examiners by the intraoral radiographs and the CBCT

	Intraoral radiograph (%)	CBCT (%)	P-value*
Diagnosis			
Early	92.4	98.0	
Moderate	76.6	90.0	
Advanced	92.0	94.0	
Overall	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	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	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	74.8	87.8	<0.05

*McNemar test

CHAPTER V

DISCUSSION

The intraoral radiograph has long been a 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 three-dimensional images offers a more accurate and comprehensive information regarding the bony structures in the head and neck region (Miracle and Mukherji 2009). To explore the value of the CBCT in periodontal diagnosis and treatment planning, we compared the periodontal assessment by the intraoral radiograph and the CBCT. In this study, the assessment by the CBCT was used as a standard to which the assessment by the intraoral radiograph was compared. This was support by several studies showing that the CBCT images provided accurate measurements of periodontal bone defects when compared to the direct measurement from cadaver specimens, histologic specimens, as well as surgical measurement of the patients (Fuhrmann, Bucker et al. 1995; Mengel, Candir et al. 2005; Misch, Yi et al. 2006; Feijo, Lucena et al. 2012).

We found that the periodontal assessment by the intraoral radiograph and the CBCT was significantly different. The periodontal assessment included periodontal diagnosis, prognosis, infrabony defect classification, and infrabony defect treatment. For periodontal diagnosis, we showed that the assessment by the intraoral radiograph was likely to underestimate the disease severity. Approximately one-third of teeth (31.1%) diagnosed as moderate from the intraoral radiograph were diagnosed as advanced from the CBCT. Several studies also showed that the intraoral radiograph tended to underestimate the amount of periodontal bone loss and obscured the presence of periodontal bone defects (Åkesson, Håkansson et al. 1992; Tonetti, Pini Prato et al. 1993; Fuhrmann, Bucker et al. 1995; Eickholz and Hausmann 2000). The finding is of clinical importance since under-diagnosis may also to inaccurate prognosis and treatment. The concordance between the intraoral radiograph and the CBCT was also lowest for the moderate periodontitis group (61.7%), but highest for the advanced periodontitis group (93.5%). When complete agreement among examiners was examined, the assessment of moderate periodontitis by the intraoral radiograph also had lowest percent complete agreement. It appears that the intraoral radiograph was less accurate in the diagnosis of moderate periodontitis.

Similar to the periodontal diagnosis, the periodontal prognosis assessed by the intraoral radiograph was likely to be underestimated. When the prognosis from the intraoral radiograph and the CBCT was matched and paired, we found the overall concordance of 69.5%. The percent concordance was high for the good and hopeless group, but moderate for the fair, poor, and questionable group. Therefore, the intraoral radiograph may be less accurate when giving prognosis in the middle categories. Interestingly, we found a significant higher proportion of teeth with hopeless prognosis in the CBCT group. More information from the CBCT image may assist in making a more aggressive prognosis. When percent complete agreement was assessed, we observed highest agreement for the good prognosis, and lowest agreement for the questionable prognosis, for both the intraoral radiograph and the CBCT group. The finding suggested that it was easier to get a consistent result when assigning good prognosis whereas it was more difficult to get a consistent result when assigning questionable prognosis.

The three-dimensional morphology of the infrabony and furcation defect is often obscure in the intraoral radiograph. The morphology of periodontal bone loss depends on many factors such as the level of plaque front, the thickness of alveolar bone, the tooth position. Therefore, an infrabony defect usually a combination of one-wall, two-wall, or three-wall defects. In this study, the defect type was classified based on the number of the bony wall that comprised the majority of the defect. We showed that the distribution of defect types between radiographic modalities was different. The proportion of three-wall defect assessed by the CBCT was much higher than that of the intraoral radiographs (24.4% vs. 42.3%). Interestingly, the infrabony defect classification had the lowest concordance among different periodontal assessments examined (44.7%). The concordance was only 50% for the three-wall defect and as low as 38.1% for the one-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 = 0.59) and the percent complete agreement (63.4%) assessed by the intraoral radiograph 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 (Misch, Yi et al. 2006; Vandenberghe, Jacobs et al. 2008; Noujeim, Prihoda et al. 2009; de Faria Vasconcelos, Evangelista et al. 2012).

The treatment decision of the infrabony defects depends largely on the accurate classification of the defect morphology (Laurell, Gottlow et al. 1998; Klein, Kim et al. 2001; Eickholz, Horr et al. 2004; Pagliaro, Nieri et al. 2008). In turn, appropriate treatment decision is crucial since each treatment involves 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 (Walter, Kaner et al. 2009; Walter, Weiger et al. 2010; Qiao, Wang et al. 2014). Cost analysis showed that the data from CBCT facilitated a reduction in treatment costs and time for periodontally involved maxillary molars (Walter, Weiger 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 less number of teeth that required periodontal regeneration (48.8% vs. 27.6%) and more number of teeth that required extraction (22.7% vs. 35.0%). The concordance of the assessment between the intraoral radiograph and the CBCT was low for regeneration (43.3%), but very high (96.4%) for the extraction. This means that almost all of teeth deemed extraction from the intraoral radiograph were also planned for extraction from the CBCT. In contrast, teeth suggested for extraction from the CBCT were planned from the intraoral radiograph as extraction, open flap debridement, and regeneration at 63.0%, 34.9%, and 2.3%, respectively (data not shown). In addition, we showed that the inter-examiner agreement and percent complete agreement of treatment decision were significantly improved when the CBCT was used. Clinically, decision for extraction in periodontally compromised teeth is often difficult to judge. We showed that the data form CBCT significantly assist the judgment of extraction with high agreement among examiners.

We showed that the CBCT was very helpful for periodontal diagnosis and prognosis. However, it should be aware that the periodontal prognosis in this study was made on the individual tooth basis. In general, periodontal prognosis may be divided into overall prognosis and individual tooth prognosis. For overall prognosis, several factors including age, cigarette smoking, diabetes mellitus, and the patient's compliance have been shown to influence the prognosis. For individual tooth prognosis, the amount of periodontal bone support plays an important role in determining the prognosis. However, other factors such as the strategic importance of the tooth, the prosthetic plan, were also crucial for the prognosis and treatment plan (Newman, Takei et al. 2011). In this study, we intended to compare the difference when the diagnosis and prognosis were given based on the clinical data and the amount of periodontal bone support from the intraoral radiographs and the CBCT. Therefore, we did not include factors such as the age, systemic conditions, and prosthetic plan, when assigning the diagnosis and prognosis.

Although the CBCT is useful for evaluation of periodontal bone loss, there were several limitations. Evaluation by CBCT was more time consuming than that by the intraoral radiograph. In this study, the average time used for each subject was approximately 45 minutes for the intraoral radiograph, as compared to 1.5 hours for the CBCT. Evaluation by the CBCT requires skill to use the software and to interpret the data. The metal artifact, which encounters when the teeth have metal restorations, may interfere with the viewing of the bone level, especially in the three-dimensional volume rendering mode. The adjustment to reduce the artifact usually removes parts of the bone surface and may result in overestimation of periodontal bone loss. The increased radiation dose from CBCT is also another concern. Through advanced engineering, a more recent CBCT scanners offer highly detailed images with reduced dosage. The CBCT unit used for this study was the 3D Accuitomo 170 with FOV 100x100mm (J. Morita, Kyoto, Japan). This FOV size was selected to include both upper and lower teeth. Pauwels et al (2012) reported that the radiation effective dose of the 3D Accuitomo 170 with FOV 100x50 mm was 54 μSv, which was slightly higher than the effective dose of a full mouth intraoral radiographs with 4 bitewing (39.9 μSv) (Ludlow, Davies-Ludlow et al. 2008). However, this radiation dose was much lower when compared to those of convention CT systems (1320-3324 μSv)(Scarfe, Farman et al. 2006).

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 radiograph and the CBCT was high for periodontal diagnosis, moderate for the prognosis and the infrabony defect treatment, and poor for the infrabony defect classification. 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 offer additional benefits over the traditional intraoral radiographs in periodontal assessment; especially those involve the infrabony defect classification and treatment.

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