THE ROLE OF CBCT FOR PREOPERATIVE EVALUATION OF MANDIBULAR THIRD MOLAR SURGERY: THE CASE OF NERVE APPROXIMATION

NATAKORN SAE-NGOW

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE (DENTISTRY)
FACULTY OF GRADUATE STUDIES
MAHIDOL UNIVERSITY
2011

Thesis
entitled

THE ROLE OF CBCT FOR PREOPERATIVE EVALUATION OF MANDIBULAR THIRD MOLAR SURGERY: THE CASE OF NERVE APPROXIMATION

....
Mr. Natakorn Sae-Ngow,
Candidate

....
Asst. Prof. Boonjira Anukul,
B.Sc., D.D.S., M.S.,
Diplomate American Board of Oral and Maxillofacial Surgery
Major advisor

....
Asst. Prof. Suchaya Damrongsri,
D.D.S., M.S.,
Diplomate American Board of Oral and Maxillofacial Radiology
Ph.D. (Oral Biology)
Co-advisor

....
Prof. Banchong Mahaisavariya,
M.D.,
Diplomate Thai Board of Orthopedics
Dean
Faculty of Graduate Studies
Mahidol University

....
Assoc. Prof. Waranun Buajeeb
B.Sc., D.D.S., M.Sc. (Oral Medicine)
Ph.D. (Oral Biology)
Program Director
Master of Science Program in Dentistry
(International Program)
Faculty of Dentistry
Mahidol University

Thesis
entitled

THE ROLE OF CBCT FOR PREOPERATIVE EVALUATION OF MANDIBULAR THIRD MOLAR SURGERY: THE CASE OF NERVE APPROXIMATION

was submitted to the Faculty of Graduate Studies, Mahidol University
for the degree of Master of Science (Dentistry)
on
April 4, 2011

....
Mr. Natakorn Sae-Ngow,
Candidate

....
Assoc. Prof. Vacharee
Changsiriwatanathumrong,
B.Sc., D.D.S., M.S.,
Diplomate American Board of Oral and
Maxillofacial Surgery
Chair

....
Asst. Prof. Boonjira Anukul,
B.Sc., D.D.S., M.S.,
Diplomate American Board of Oral and
Maxillofacial Surgery
Member

....
Asst. Prof. Suchaya Damrongsri,
D.D.S., M.S.,
Diplomate American Board of Oral and
Maxillofacial Radiology
Ph.D. (Oral Biology)
Member

....
Prof. Banchong Mahaisavariya,
M.D.,
Diplomate Thai Board of Orthopedics
Dean
Faculty of Graduate Studies
Mahidol University

....
Assoc. Prof. Theeralaksna Suddhasthira,
D.D.S., Ph.D. (Biomedical Science),
Dean
Faculty of Dentistry
Mahidol University

ACKNOWLEDGEMENT

I am heartily thankful to those who made this thesis possible, my supervisor, Ajarn Boonjira Anukul and Ajarn Suchaya Damrongsri, whose encouragement, guidance and support from the initial to the final level enabled me to develop an understanding of the subject, also Ajarn Kumpee Songkampol who liken to another one advisor.

I am grateful to Ms. Natchalee S., the statistician for the great helpful advices and marvelous statistic analyses. Mr. Chawin A., the technician for such breathtaking all graphics and animations.

I wish to thank my family members, my mom and dad for their generous support, understanding and love.

Lastly, I offer my regards and blessings to all of those who supported me in any respect during the completion of the project.

NATAKORN SAE-NGOW

THE ROLE OF CBCT FOR PREOPERATIVE EVALUATION OF MANDIBULAR THIRD MOLAR SURGERY: THE CASE OF NERVE APPROXIMATION

NATAKORN SAE-NGOW 5236395 DTDT/M

M.Sc. (DENTISTRY)

THESIS ADVISORY COMMITTEE: BOONJIRA ANUKUL, B.Sc., D.D.S, M.S., Diplomate American Board of Oral and Maxillofacial Surgery, SUCHAYA DAMRONGSRI, D.D.S., M.S., Diplomate American Board of Oral and Maxillofacial Radiology, Ph.D.

ABSTRACT

This study aimed to compare the accuracy of CBCT and panoramic radiographs in predicting the relationship between the inferior alveolar nerve and the mandibular third molar with the clinical outcome, neurovascular bundle exposure. In the cases where exposure was detected and found to be injuried, neurosensory conditions were followed by up to 6 months healing time. Methods: This prospective clinical trial was conducted in patients registered with the department of oral and maxillofacial surgery for the surgical removal of their mandibular third molar between June 2010 to Feb 2011. The collected data included demographic data, panoramic radiographs, CBCT, intra-operative data, and post-operative neurosensory status. Statistical methods were done to detect the significant variables, and to compare the accuracy of CBCT and panoramic radiographs. Results: 84 impacted teeth from 58 patients were removed during this study. Neurovascular bundle exposure was found in 29 teeth and injury occurred in 4 teeth. A significant panoramic sign was the darkening of the root (p=0.041). Conclusion: Although the CBCT image was no more accurate than the panoramic radiograph in predicting neurovascular bundle exposure, it’s valuable for the 3D relationship that takes advantage of revealing the bucco-lingual position of the IAC relative to the mandibular third molar, so that the surgeon can be aware of possible complications.

KEY WORDS: CBCT / THIRD MOLAR SURGERY / INFERIOR ALVEOLAR NERVE INJURY / NEUROVASCULAR BUNDLE EXPOSURE

61 pages

การใช้เครื่องถ่ายภาพรังสี 3 มิติแบบโคนบีมสำหรับการประเมินตำแหน่งของฟันกรามล่างซี่ที่ 3 ในขากรรไกรล่าง: ในผู้ป่วยที่ฟันมีความสัมพันธ์ใกล้ชิดกับเส้นประสาทในขากรรไกรล่าง

THE ROLE OF CBCT FOR PREOPERATIVE EVALUATION OF MANDIBULAR THIRD MOLAR SURGERY: THE CASE OF NERVE APPROXIMATION

ณัฐกร แซ่เหง่า 5236395 DTDT/M

วท.ม. (ทันตแพทยศาสตร์)

คณะกรรมการที่ปรึกษาวิทยานิพนธ์ : บุญจิรา อนุกูล, Diplomate American Board of Oral and Maxillofacial Surgery., สุชยา ดำรงค์ศรี, Ph.D.

บทคัดย่อ

การศึกษานี้มีจุดมุ่งหมายเพื่อเปรียบเทียบความแม่นยำในการทำนายความสัมพันธ์ระหว่างเส้นประสาทอินฟีเรียอัลวิโอลาร์กับฟันกรามล่างซี่ที่สาม ในภาพรังสี 2 ชนิด คือภาพรังสีพาโนรามิคและภาพรังสีคอมพิวเตอร์แบบโคนบีม โดยเปรียบเทียบกับผลทางคลีนิคคือ การเผยผึ่งของมัดเส้นประสาทร่วมหลอดเลือด ซึ่งในกรณีที่เกิดการเผยผึ่งของมัดเส้นประสาทร่วมหลอดเลือดร่วมกับการรับความรู้สึกของผู้ป่วยบริเวณขากรรไกรล่างผิดไปผู้ป่วยจะได้รับการรักษาที่เหมาะสมและติดตามผลเป็นเวลา 6 เดือน การศึกษานี้ทำในฟันกรามล่างซี่ที่สามจำนวน 84 ซี่ จากผู้ป่วย 54 ราย ในเดือนมิถุนายน พ.ศ. 2553 ถึงเดือนกุมภาพันธ์ พ.ศ. 2554 มีการเก็บข้อมูลทางประชากรศาสตร์ ข้อมูลภาพรังสี และข้อมูลทางคลีนิค โดยพบการเผยผึ่งของมัดเส้นประสาทร่วมหลอดเลือดจำนวน 29 ซี่ ในจำนวนนี้พบปัญหาการบาดเจ็บของเส้นประสาทอินฟีเรียอัลวิโอลาร์จำนวน 4 ซี่ และ darkening of the root เป็นลักษณะทางภาพรังสีพาโนรามิคที่แสดงความสัมพันธ์อย่างมีนัยสำคัญทางสถิติกับผลทางคลีนิค(p=0.041) กล่าวโดยสรุปแม้ภาพรังสีคอมพิวเตอร์แบบโคนบีมจะไม่แม่นยำกว่าภาพรังสีพาโนรามิคในการทำนายผลทางคลีนิค คุณค่าของภาพรังสีคอมพิวเตอร์แบบโคนบีมในการแสดงความสัมพันธ์ แบบ 3 มิติที่ทำให้ทราบตำแหน่งท่อเส้นประสาทร่วมหลอดเลือดอินฟีเรียอัลวิโอลาร์ ในแนวใกล้แก้ม-ใกล้ลิ้น ก็ยังคงมีความสำคัญต่อผู้ทำการผ่าตัดในการหลีกเลี่ยงปัญหาแทรกซ้อนที่อาจเกิดขึ้น

61 หน้า

CONTENTS

		Page
ACKNOWLEDGEMENTS		iii
ABSTRACT (ENGLISH)		iv
ABSTRACT (THAI)		v
LIST OF TABLES		vii
LIST OF FIGRURES		viii
LIST OF ABBREVIATIONS		xi
CHAPTER I	INTRODUCTION	1
CHAPTER II	LITERATURE REVIEWS	8
CHAPTER III	MATERIALS AND METHODS	24
CHAPTER IV	RESULTS	41
CHAPTER V	DISCUSSION	49
CHAPTER VI	CONCLUSION	53
REFERENCES		54
BIOGRAPHY		61

LIST OF TABLES

Table	Page
2-1: List of current CBCT devices	14
3-1: Pell-Gregory classification	30
3-2: Winter's classification	31
3-3: Panoramic radiograph data collection table	33
3-4: CBCT data collection table	34
4-1: Inter-observer agreement	43
4-2: Sensitivity, specificity, PPV, NPV, accuracy and Univariate adjusted odds ratio	43
4-3: Details of predictive variables	44
4-4: CT interpretation	45
4-5: Interruption of the superior cortical line	45
4-6: Darkening of the root	46
4-7: Diversion of the canal	46
4-8: Narrowing of the canal	47
4-9: Deflected root	47
4-10: Multivariate logistic regression analysis	48

LIST OF FIGURE

Figure	Page
1-1: This panoramic radiograph shows #48 complete bony class I position C vertical angulation impacted tooth with superimposition to inferior alveolar canal in middle one-third level of tooth root.	2
1-2: These periapical films show #48 tooth with superimposition to inferior alveolar canal. The root tips are dark when inferior alveolar canal pass through.	4
1-3: This panoramic radiograph shows, this 26 years old woman has 4 impacted teeth including their relationship to adjacent structures.	4
1-4: CBCT images of #48 impacted tooth by 3D Accuitomo by J. Morita Mfg. Corp. In coronal view shows inferior alveolar canal is in the middle of #48 root, while the panoramic radiograph shows superimposition between the two structures.	5
2-1: This periapical film shows #48 tooth with superimposition to inferior alveolar canal.	9
2-2: These two periapical films show parallax technique to localize position of inferior alveolar canal to #48 root.	10
2-3: This picture represent the good quality of panoramic image include symmetry of structures in midline. The position of mandible is in focal trough so the panoramic image will be sharp.	11
2-4: This picture represent the panoramic image of the patient that is not positioned correctly and the anterior teeth are in front of focal trough. The teeth appear blurred due to out of focus and skinny. The spinal column may also be superimposed over the ramus of the mandible.	11
2-5: This picture represent the panoramic image of the patient is in slump position. The ghost images of cervical spine are overlapped to the anterior teeth.	11

LIST OF FIGURE (cont.)

Figure	Page
2-6: Stages and Steps involved in reconstruction of acquired projection data to form volumetric data.	20
3-1: Interruption of the superior cortical line.	25
3-2: Darkening of the root.	26
3-3: Diversion of the canal.	26
3-4: Narrowing of the canal.	26
3-5: Narrowing of the root.	27
3-6: Deflected root.	27
3-7: Dark and bifid root.	27
3-8: Root curvature.	32
3-9: Root extension.	32
3-10: This CBCT image shows #38 tooth impaction. In coronal view (lower left), inferior alveolar canal appearance is jammed to lingual plate by tooth root.	35
3-11: This CBCT image shows #48 tooth impaction. In coronal view (lower right), inferior alveolar canal is attached to tooth root without cortication line between these two structures.	35
3-12: This CBCT image shows #48 tooth impaction. In coronal view (lower right), inferior alveolar canal is attached to tooth root with thin cortication line between these two structures.	36
3-13: This CBCT image shows #48 tooth impaction. In coronal view (lower right), inferior alveolar canal is attached to tooth root with cortication line thickness less than 1mm.	36
3-14: This CBCT image shows #48 tooth impaction. In coronal view (lower right), inferior alveolar canal is attached to tooth root with cortication line thickness more than 1mm.	37
3-15: Data sheet form. The circle shows collected intraoperative data.	37

LIST OF FIGURE (cont.)

Figure **Page**

3-16: Grading algorithm for evaluating trigeminal nerve injury by Zuniga and Essick. 38

3-17: Data sheet form. The circle shows collected postoperative neurosensory data. 39

LIST OF ABBREVIATIONS

Fig	:	Figure
CT	:	Computed tomography
CBCT	:	Cone beam computed tomography
IAN	:	Inferior alveolar nerve
IAC	:	Inferior alveolar canal
TMJ	:	Temporomandibular joint
<	:	Less than
>	:	More than
≥	:	Equal or more than
≤	:	Equal or less than
±	:	Plus or minus
/	:	Per
%	:	Percentage

CHAPTER I
INTRODUCTION

1.1 Background and rationale

In the past, dental caries would lead to only simple restoration or extraction of that problemed tooth and left the patients with residual ridge. But at present, dental profession is advanced far from the former times. Many technologies have been utilized to manage pathological conditions, preserve the structures, and restore functions. Even though some pathologies are hopeless, the replacement technologies, in other words renewal can be made somehow in some cases so the patients can function normally. Although advanced technologies are developed to create the good quality of life through stage of the art investigation for early detection of diseases, disease prevention and less of diseases, some problems still exists; such as developmental deformities and malformation such as tooth-size dental arch discrepancies and mal-position which leads to tooth impaction.

Regarding to MacGregor A.J. in 1985 (1), they found only few tooth impaction in the past, compared to now a days, particularly mandibular third molar. The most common candidate to impaction are mandibular third molar, maxillary third molar, maxillary cuspid, mandibular cuspid, mandibular bicuspid, maxillary bicuspid, and maxillary incisors, relatively. The etiology of impaction were probably thought of the diet as one of predisposing factor (1, 2, 3) and an increasing of brain size at the expense of jaw size result in there is no longer space to be the house of 32 teeth (1, 4). Many research claimed all wisdom teeth should be extracted (5, 6) because they might be causing problems so prophylactic removal should be considered. For our trend in Thailand, the case of fully bony impaction of mandibular third molar without any clinical symptoms, long term follow up guarding for any related pathology without surgical option should be considered as a primary strategy. Whereas the surgical treatment inevitably holds for partially erupted tooth in which some area of tooth intraorally exposes and risks to adverse consequences. This study only focused on preoperative imaging in risky situation of mandibular third molar surgery.

One of the most common dental surgical procedures is “mandibular third molar surgery”. It is a minor surgery that aim for one of these conditions : pericoronitis prevention or treatment, management for exclusion of unexplained pain, prevention of caries and root resorption of adjacent teeth, orthodontic considerations, teeth under dental prosthesis, crowding of mandibular incisors, prevention of jaw fracture, obstruction of orthodontic treatment, systemic health considerations, prevention of odontogenic cysts and tumors, economic considerations, periodontal disease, and preparation for orthognathic surgery (7).

In Thailand, surgical removal of mandibular third molar has been taught in the under-graduation level, so general practitioners can perform the operation on self-selected cases. Most of mandibular third molar surgeries are performed without intraoperative or postoperative difficulties. With proper planning, risks and imponderables discussion should be applied preoperatively. But sometimes even we do a common procedure, some complications cannot be avoided.

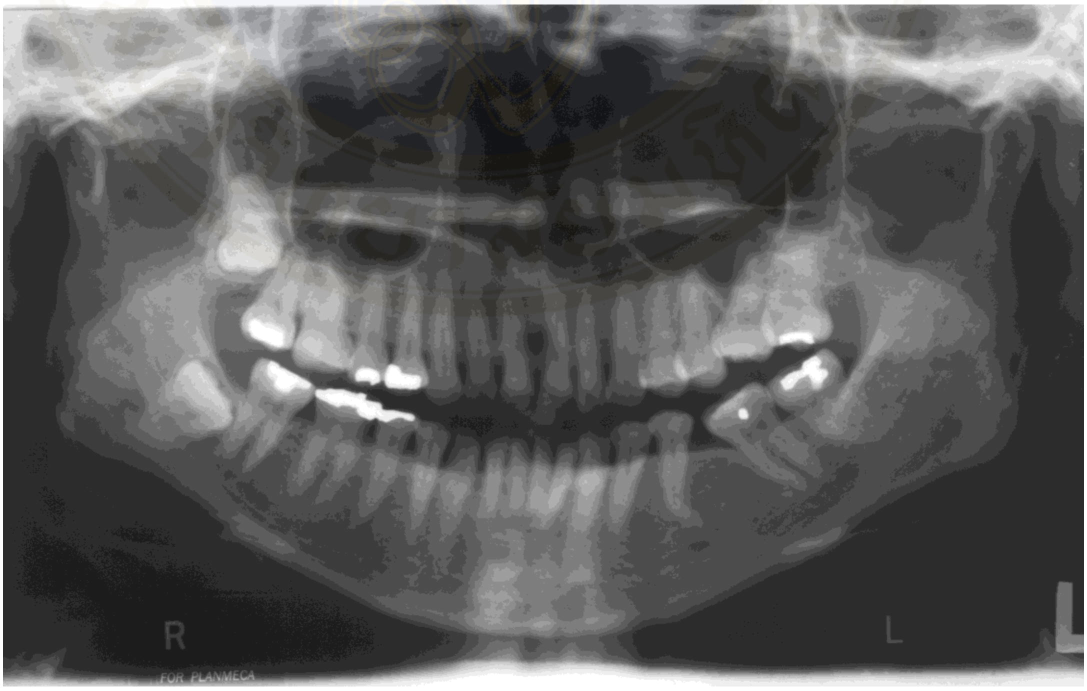


Fig. 1-1:This panoramic radiograph shows #48 complete bony class I position C vertical angulation impacted tooth with superimposition to inferior alveolar canal in middle one-third level of tooth root.

The postoperative complications of mandibular third molar surgery are localized alveolar osteitis, infection, bleeding or hemorrhage, mandibular fracture, damage to adjacent teeth, iatrogenic displacement of third molar, TMJ complications, and neurosensory disturbance (7). Neurosensory disturbance is one of the most annoying common complications, the incidence of this condition may be related to multiple factors: proximity of the tooth to the inferior alveolar canal, angulation of the impacted teeth, position of patients, anesthetic modality and most of all surgeon experiences (8).

Because it is known that direct contact between inferior alveolar nerve and the tooth root will increase the risk of nerve dysesthesia (9, 10) so preoperative radiographic examination plays an important role in preoperative assessment of the position and establishment of the relationship between the third molar and the inferior alveolar canal. Preoperative informative imaging has a great benefit in planning the manner of how the surgeon conducts the operation, predicting the postoperative occurrence of sensory impairment and emphasizing prevention. Gold standard diagnostic tool for this purpose has been the panoramic radiographs compared to routine standard periapical film. Many researchers have reported features that suggested for proximity between the two structures. Rood JP et al. (11) described a group of panoramic features that indicate close relationship. Those features are as followed; diversion of the inferior alveolar canal, darkening of the root, interruption of the white line, narrowing of the root, deflected root, narrowing of the canal, and dark and bifid root . Rood also analyzed and reported that the first three panoramic features were significantly related to inferior alveolar nerve injury following third molar extraction. Sedaghatfar et al. (12) also reported that the first four features were significantly associated with inferior alveolar nerve exposure following extraction.

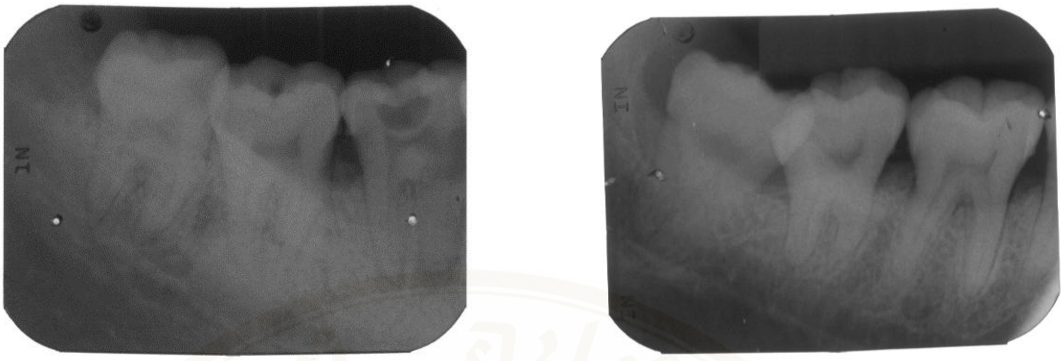


Fig. 1-2:These periapical films show #48 tooth with superimposition to inferior alveolar canal. The root tips are dark when inferior alveolar canal pass through.

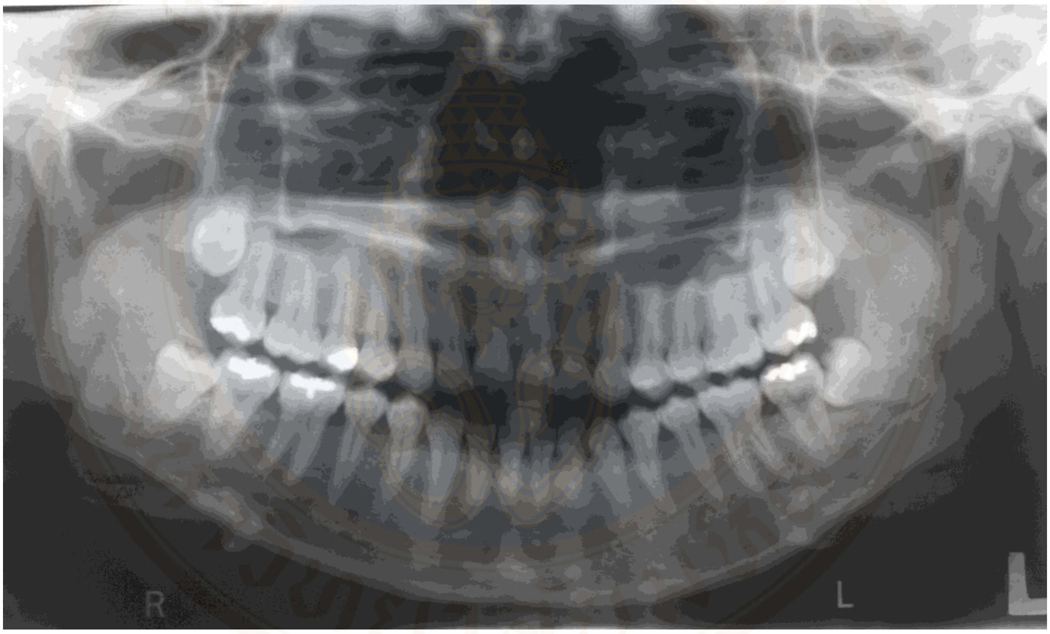


Fig. 1-3:This panoramic radiograph shows, this 26 years old woman has 4 impacted teeth including their relationship to adjacent structures.

When panoramic image suggests close relationship between inferior alveolar nerve and the tooth root, surgeon should inform patients the risk of nerve dysesthesia and request for additional investigation.

Computed tomography (CT) is the most common devices used in medical field for times, to identify the size, position and relationship of structures or suspected area in 3 dimensions. Using CT may be recommended to verify and demonstrate three-dimensional relationship between the two structures, so the surgeon can perform the surgery with minimal risks. Exposure of the inferior alveolar nerve following third molar surgery occasionally might be an evidence of possible perioperative encounter and unavoidable nerve trauma. Tay AB et al. (13) reported that the incidence of nerve injury in such cases was approximately 20%. However, obvious drawbacks of CT compared with panoramic radiograph are the higher radiation dose with additional expense.

Cone Beam Computed Tomography (CBCT) is a recent technology developed from conventional CT for many purposes mainly in dental field. CBCT, together with its advantages; reduction of the radiation dose and cheaper costs from medical CT is the suitable devices for our investigation to identify the relationship between inferior alveolar nerve and mandibular third molar.

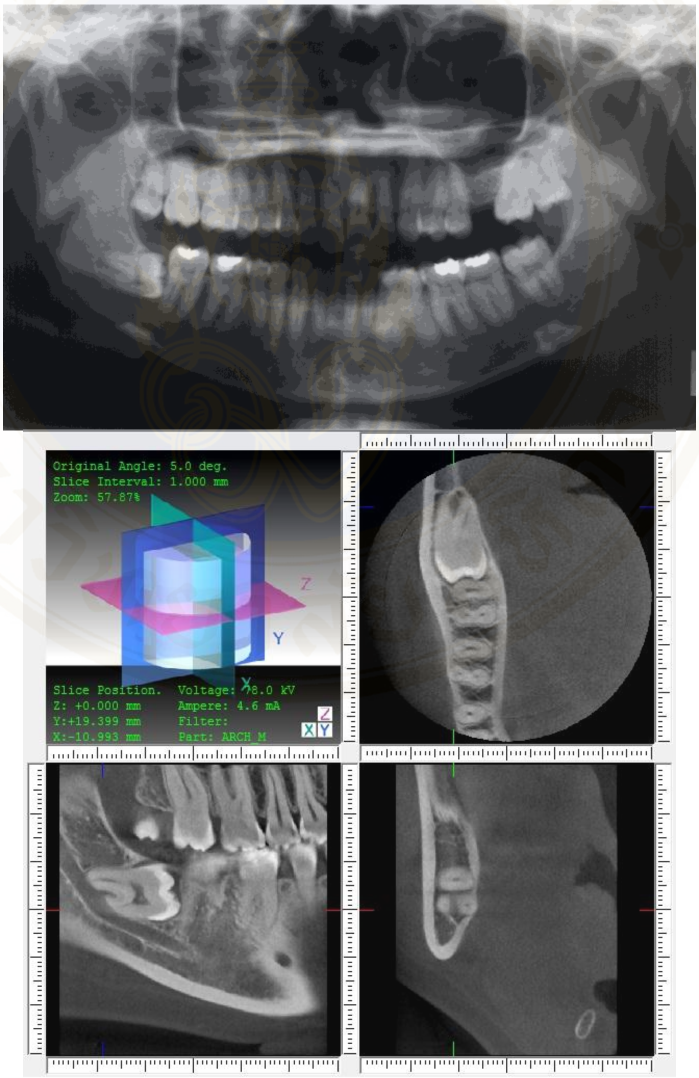


Fig. 1-4:CBCT images of #48 impacted tooth by 3D Accuitomo by J. Morita Mfg. Corp. In coronal view shows inferior alveolar canal is in the middle of #48 root, while the panoramic radiograph shows superimposition between the two structures.

Therefore, optimal preoperative imaging can help in predicting for neurosensory disturbance especially following mandibular third molar surgery. Clinicians should keep in mind about preoperative assessment and gather maximum information in order to minimized postoperative unfavorable outcome that can be avoided or eliminated.

The purpose of this study is to evaluate diagnostic accuracy of cone beam CT in predicting inferior alveolar nerve exposure following mandibular third molar surgery compared with conventional panoramic radiographs and the neurosensory conditions subsequent to surgery.

1.2 Objectives

1.2.1 To compare the accuracy of CBCT and panoramic radiographs in predicting the relationship between inferior alveolar nerve and mandibular third molar

1.2.2 To evaluate diagnostic accuracy of CBCT in predicting neurovascular bundle exposure following mandibular third molar surgery

1.2.3 To evaluate neurosensory conditions from immediate postoperative period to 6 months healing time, in neurosensory disturbance cases

1.3 Hypotheses

1.3.1 The accuracy in predicting relationship between inferior alveolar nerve and the tooth root

H_0 : x_1 no association to x_2

H_1 : x_1 association to x_2

x_1 : Prediction variable x_2 : Outcome variable

1.3.2 CBCT images have high accuracy in predicting neurovascular bundle exposure following mandibular third molar surgery

1.3.3 When neurosensory impairment occur, none of cases are permanent

1.4 Scope of this study

This study is conducted in subjects who have to remove mandibular third molar which was identified by Rood's criteria signs in panoramic radiographs that had closed-relationship between inferior alveolar canal and mandibular third molar at oral and maxillofacial surgery department, faculty of dentistry, Mahidol University.

1.5 Benefits of study

Neurosensory disturbance is one of the most common complications that can be occurred if the surgeon is not pay attention to carry on the procedure. Sometimes it cannot be avoided in case that had an intimate relationship between inferior alveolar canal and the tooth root, preoperative assessment with proper imaging procedure is basis that is very helpful information for both surgeon and patient to decrease complications and prevent unsatisfied conditions. CBCT images have higher privilege to show exactly position of both inferior alveolar canal and mandibular third molar that we can inform patients about the risk of nerve impairment and set up the appropriate treatment planning; how we remove the tooth, how many pieces of the tooth should be splited, which way we can apply force to extract the tooth or not, and should we prepare any hemostasis material. Because even the standard protocol is usually careful procedure, but if we know what is the exactly position of these 2 structures, it will be better than.

CHAPTER II
LITERATURE REVIEWS

1. Review preoperative radiographic techniques
2. Review of cone beam computed tomography

1. Review preoperative radiographic techniques

After weeks of the discovery in 1895 by Roentgen, the x-ray for radiological examination has been used in dental radiology. It was first used for intraoral radiography, then extraoral imaging; the panoramic radiography and the cephalometric radiography were used in the 1950s to early 1960s (14).

The mandibular third molar surgery is now a common procedure in dental practice. Most of surgeries are performed with little or no risk of difficulties. However, there is some situations such as a close relationship between mandibular third molar and inferior alveolar canal or lingual plate, in which damage to adjacent structures such as inferior alveolar nerve (15, 16, 19) or lingual nerve (17, 18, 19) may occur and leave patients with suffering. Therefore, preoperative evaluation with radiography of mandibular third molar takes an essential part of preoperative examination.

In recent decades the development of CT, MRI, nuclear medicine, and ultrasonography has a major part in diagnostic procedure. CT is the technology of x-ray-based imaging that produces 3D images. The conventional CT is mainly used in medical purposes, so it may call medical CT. For three decades we are now present the newer technology developed from CT and used primarily in Oral and Maxillofacial region that is called CBCT. The application of CBCT in dentistry provides great benefits that will be well-described in the next content. This review provides an overview of preoperative radiographic imaging currently use before mandibular third molar surgeries are performed underlying each of these technologies.

Current radiographic techniques for mandibular third molar evaluation

1. Intraoral radiography

It is the most common method to evaluate any hard tissues, in this case mandibular third molars. This technique should be available to all dentists and accessible in any dental facilities. However, this technique has a few of scientific documentation on observation the periodontal status compare preoperative to postoperative examination of mandibular third molar (20, 21).

Normally intraoral radiographs are two-dimensional images of three-dimensional structures, superimposition and indistinctness of objects can occur especially when the films reveal superimposition of mandibular third molar and inferior alveolar canal.

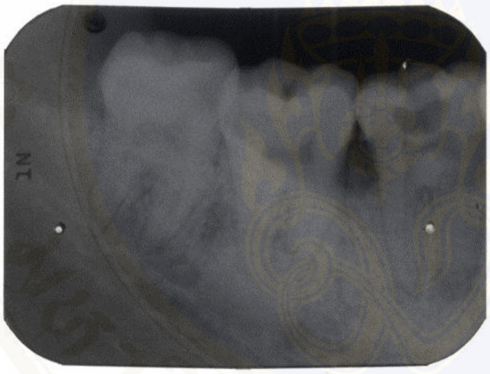


Fig. 2-1:This periapical film shows #48 tooth with superimposition to inferior alveolar canal.

Using a parallax technique (22, 23), known as the shift tube technique the anatomical relationship between different structures can be determined. But limitation of this technique still exists due to the cooperation by patient, difficulty in placing film in the mouth, direction for an appropriate x-ray beam, and the most important how to identify the exact point reference between two structures are the causes that will be an obstacle of clear diagnosis.

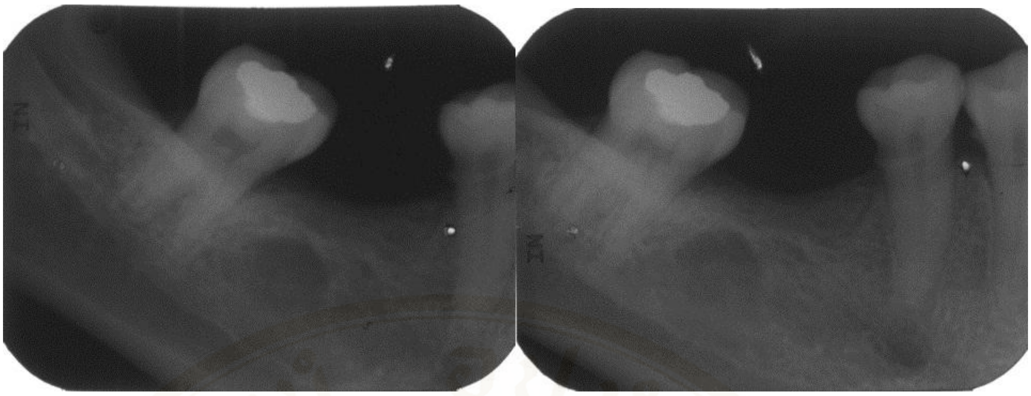


Fig. 2-2:These two periapical films show parallax technique to localize position of inferior alveolar canal to #48 root.

2. Panoramic radiography

It is a technique for producing a single image of both jaws, which provides an overview of oral hard tissue, including teeth, foreign bodies, any pathologies that make bone density change; cysts or tumors, and conditions within the jaws. This technique gives great information on the position of the inferior alveolar canal in the vertical plane but it has a limitation on giving an information of position of the canal in horizontal direction (10). Besides, even the fact that the focal trough is thick enough to see the full thickness of both maxilla and mandible (24), the presence of ghost images (Fig. 2-5), an unpredictable magnification and distortion image can be found if the position of patients is outside the focal through (25). So lingual position of patient will be projected upwards and reduced the accuracy of the assessment, in this case, the inferior alveolar canal by torus mandibularis or sialoliths (Fig. 2-4). The assessment of the canal in the vertical direction is unsteady because the technique produces a sharp image layer of limited width, small errors may prevent visualization of the inferior alveolar canal and obscure the view of fine details such as root anatomy.

Fig. 2-3:This picture represent the good quality of panoramic image include symmetry of structures in midline. The position of mandible is in focal trough so the panoramic image will be sharp.

Fig. 2-4:This picture represent the panoramic image of the patient that is not positioned correctly and the anterior teeth are in front of focal trough. The teeth appear blurred due to out of focus and skinny. The spinal column may also be superimposed over the ramus of the mandible.

Fig. 2-5:This picture represent the panoramic image of the patient is in slump position. The ghost images of cervical spine are overlapped to the anterior teeth.

3. Posteroanterior (PA) open mouth radiography (26)

This technique is usually valuable for determination of both the relationship between teeth and inferior alveolar canal as well as the inclination of the mandibular third molar in the bucco-lingual direction. In case that other conventional techniques fail to reveal the relationship between tooth root and inferior alveolar canal in the bucco-lingual position, this imaging can be applied.

In our experienced, unfortunately we have not used this technique for localization the mandibular third molar position.

4. Cone beam computed tomography (CBCT)

Detail of this technique and rational is described in next content.

Other technologies such as conventional tomography, conventional computed tomography, MRI, nuclear medicine, and ultrasonography is not currently a routine examination for the operation of mandibular third molar, so its role in preoperative imaging before surgery remains obscure.

This is a guideline from Flygare L and Ohman A in 2008 (26) with modification by our experienced for preoperative imaging of mandibular third molar surgery currently using in Thailand.

A strategy for preoperative evaluation before mandibular third molar surgery:

1. Intraoral radiographs (bisecting or parallel technique with periapical film) or panoramic radiograph is sufficient in almost cases, especially if there is no superimposition of the tooth roots and inferior alveolar canal.

2. If the relationship between mandibular third molar and inferior alveolar canal cannot be readily interpreted from the plain films alone, supplement with CBCT or low-dose CT for 3-D relationship are recommended (27).

2. Review of cone beam computed tomography

Cone Beam Computed Tomography (CBCT), also known as Cone Beam Volumetric Imaging (CBVI) or Cone Beam Volumetric Tomography (CBVT), is a recent technology that provides 3D radiographic images of structures with accuracy and submillimeter resolution (28). Those images are accomplished by using "one" rotating gantry to which an x-ray source and detector synchronously move around the patient's head, which is stabilized with a head holder. A cone-shaped x-ray beam is directly pointed through the middle of area of interest onto an area detector at the opposite side. During a complete or sometimes partial rotation, multiple sequential planar projection images of the field of view (FOV) are acquired. Because CBCT exposure incorporates the entire FOV, only one rotation is required for data image reconstruction.

History of CBCT development

In 1982, cone beam computed tomography was first developed from conventional computed tomography originally for angiographic purpose at Mayo clinic (29), based on the principle of Dynamic Spatial Reconstructor (DSR). Clinical application of this device at that time was for the examination of blood vessels in many key areas of the body, including brain, kidneys, pelvis, legs, lungs, heart, and neck.

Then in 1984, Feldkamp, Davis, and Kress (30) used filtered-back projection for three-dimensional image reconstruction from cone-beam (CB) projections.

Saint-Felix D et al. in 1994 (31), developed a CTA CBCT system based on the gantry of a conventional CT scanner which reconstructs vasculature from a set of digitally subtracted angiography (DSA) images.

Cho PS et al. in 1995 (32), used cone beam CT for radiotherapy applications.

Kawata Y et al. in 1996 (33), also developed CBCT CTA system for disease detection.

Schueler BA et al. in 1997 (34), developed CBCT CTA scanner based on a biplanar C-arm system.

Fahrig R et al. (35) developed CBCT system based on an image intensifier and C-arm for use in angiographic purpose.

Jaffray DA and Siewerdsen JH (36, 37, 38) developed CBCT system for radiotherapy guidance based on an amorphous silicon(a-Si:H) flat-panel detector.

Wincent K et al. (39) also developed a C-arm plus image intensifier system for interventional angiography.

Ning R et al. in 2000 (40), developed CBCT angiography imager based on GE 8800 CT scanner with an image intensifier - CCD chain and later with a flat-panel detector. Then in 2001 (41) they developed CBCT-based imaging systems for mammography.

Zhong J et al. (42) developed the wavelet-based denoising algorithm possesses to improve the detectability of small breast tumors by the real-time flat panel detector-based cone-beam computed tomography (CBCT).

Yu H et al. (43) developed a backprojection-filtration algorithm for nonstandard spiral cone-beam CT to create general exact images.

Kyriakou Y et al. (44) used the effect of the z-flying focal spot (zFFS) technology to generate 3-D images in 64-slice spiral cone-beam computed tomography (CT) scanner.

Schäfer D et al. (45) used the correct motion field with the motion-compensated reconstruction to generate the reconstructed images with cone beam CT.

Currently, many commercial systems are available commercially, through 2011 there are many different CBCT devices (46) as shown in table 2-1.

Table. 2-1:List of current CBCT devices

Model	Manufacturer	Max. FOV (HxW) (cm)	Min. Voxel (mm)	2D Options
Next Generation (Platinum) i-CAT	Imaging Sciences International	17x23	0.125	Pano
Classic i-CAT	Imaging Sciences International	16x22	0.2	No
NewTom 3G	ImageWorks	20x20x20	0.2	No
CB MercuRay	Hitachi Medical	20x20x20	0.2	No

Model	Manufacturer	Max. FOV (HxW) (cm)	Min. Voxel (mm)	2D Options
Quolis Alphard 3030	Asahi Roentgen (Belmont)	18x20	0.125	No
3D eXam	KaVo	17x23	0.125	No
Kodak 9500	Kodak Dental Systems	18x21	0.2	No
ProMax 3D Max	Planmeca	17x22	0.125	No
Master 3DS	VATECH	19X20	0.164	No
PaX-Zenith3D	VATECH	19x24	0.08	Pano
NewTom 9000	Aperio Services	15x15x15	0.3	No
NewTom VGi	ImageWorks	15x15	0.075	No
NewTom VGi Flex	ImageWorks	15x15	0.15	No
Galileos Compact	Sirona	12x15x15	0.3	No
Galileos Comfort	Sirona	15x15x15	0.15	No
Scanora 3D	Soredex	7.5x14.5	0.133	Pano
SkyView	MyRay	15x15x15	0.16	No
GXCB-500	Gendex	8x14	0.125	No
GXCB-500 HD	Gendex	8x14	0.125	Yes

Model	Manufacturer	Max. FOV (HxW) (cm)	Min. Voxel (mm)	2D Options
MiniCAT	Xoran Technologies	12x17	0.2	No
Picasso-Trio	VATECH	7x12	0.2	Pano/Ceph
PaX-Duo3D	VATECH	12x8.5	0.08	Pano
Iluma	IMTEC (3M)	14X21	0.09	No
xCAT ENT	Xoran Technologies	14x24	0.4	No
PaX-Reve3D	VATECH	15x15	0.08	Pano/Ceph
3D Accuitomo 170	J. Morita	12x17	0.08	No
ProMax 3D	Planmeca	8x8	0.16	Pano/Ceph
PreXion 3D	PreXion, Inc.	8x7.5	0.1	No
AUGE ZIO	Asahi Roentgen	7x8	0.125	Pano/Ceph
9000 3D	Kodak Dental Systems	4x5	0.076	Pano
9000 3DC	Kodak Dental Systems	4x5	0.076	Pano/Ceph
PaX-500ECT	VATECH	5x5	0.186	Pano/Ceph
PaX-Uni3D	VATECH	5x8	0.08	Pano/Ceph
PaX-Flex3D	VATECH	5x8	0.12	Pano/(Ceph)

Model	Manufacturer	Max. FOV (HxW) (cm)	Min. Voxel (mm)	2D Options
CB Throne	Hitachi Medical	10x10x10	0.125	No
3D Accuitomo	J. Morita	3x4	0.125	No
3D Accuitomo FPD	J. Morita	6x6	0.125	No
3D Accuitomo 80	J. Morita	8x8	0.08	NO
Veraviewepocs 3D 40	J. Morita	4x8	0.125	Pano/Ceph
Veraviewepocs 3D 80	J. Morita	8x8	0.125	Pano/Ceph
Veraviewepocs 3De	J. Morita	4x8	0.125	Pano/Ceph
Suni3D	Suni Medical Imaging	5x8	0.2	Pano/Ceph
ORION RCB-888	Ritter Imaging	8.5x8.5	0.1	No
Finecube XP62	Yoshida	7.5x8.1	0.1	No

Although CBCT has been used for medical purpose for almost three decades, its true potential has not been yet fully tapped. Only recently has it become possible to develop CBCT clinical systems that are both 3-5 times less expensive than conventional ones and the size of the machines has been upgraded to be small enough to be used in the OR, medical offices, emergency rooms, and intensive care units. Besides these, CBCT can give us more accurate images of hard tissue structures than medical CT (28) due to isotropic voxels itself while being significantly reduced dose up to 98% compared with conventional fan-beam CT systems (47, 48, 49, 50).

Four important technological factors that converged CBCT to be more effective and capable for many clinical investigation in variety of disease situations are

1. Compact and high-quality flat-panel detector arrays
2. X-ray tubes necessary for cone-beam scanning
3. Focusing on head and neck scanning only
4. The computer power necessary for cone-beam image reconstruction

The detector arrays must be able to detect photons and send the signal to the computer, then be ready for the next cycle many of times within “one” single rotation synchronously move of an x-ray source and detector. The scan time is usually equivalent to or less than, the panoramic radiography (10 to 30 seconds) due to one rotation of gantry. Detectors were initially developed by using scintillation screens, image intensifiers (II), and charge-coupled device (CCD). Some limitations and disadvantages related to the image intensifier systems may create geometric distortions that must be addressed in the data processing software. Recently, high-resolution, flat-panel detectors are available which are composed of a screen of scintillator crystals grown onto a matrix of photodiodes embedded in a solid-state amorphous silicon (aSi:H) or selenium layer. They detect photons indirectly by means of a scintillator. The detectors will convert photons into visible light that is subsequently registered into the photo diode array where the signal-intensity charge is stored. The advantage of flat-panel detectors are less complicated, greater dynamic range and reduced peripheral distortion compare with the initial devices, however the new devices require a slightly greater radiation exposure. The other limitations of flat-panel detectors are related to linearity of response to the radiation spectrum, uniformity of response throughout the detector and bad pixels (51, 52).

The source of radiation comes from cone beam shaped, currently using a continuous x-ray beam of radiation during the rotation and allow the detector to gather the attenuated beam. Accuitomo, CB MercuRay, Iluma Ultra Cone, and PreXion 3D provide this method. However, CBCT images are not generated from all continuous beams, so the patient receives unnecessary greater exposure. The next generation of radiation source is “pulsed x-ray beam” such as; NewTom, that can be coincided while the detector gathering photon. The aim of this technology is to reduce patient radiation dose considerably and make all radiation beam to be reasonable to what patients should get (53).

Posture of patient, at present CBCT devices can scan patients in three possible positions:

1. Sitting
2. Standing
3. Supine

Seated units seem to be the most comfortable; however, they may not allow scanning of disabled or wheelchair-bounded patients. While standed units may not be able to be adjusted the height to fit wheelchair-bounded patients, and machines that require the patients to lie supine position usually take a large area may not be able for disabled patients.

More important of any patients’ position is the way to fix the patients’ head while the machines are scanning. Because of any displacement can cause distortion.

During the scan rotation, certain degree intervals of radiation to area of interest provide 2D projection images, which are called “basis” or “raw” images. The complete series of images is referred to the “projection data”. More projection data provide greater spatial and contrast resolution due to the more information. However the number of basis images should be considered under the "ALARA" (as low as reasonably achievable) principle only to produce CBCT image as sufficient for diagnostic purpose. As more projection data cause longer scan time, higher radiation dose and longer primary reconstruction time.

Cone-beam images are reconstructed by gathering datas from several hundred dimensionally accurate isotropic voxels (53, 28, 54) of the patient from different positions around a scan rotation. Then datas are immediately transferred to the computer and reconstructed the volumetric data set. The amount of individual projection frames may be from 100 to more than 600. So the reconstruction is computationally complex. In contrast with conventional CT, cone beam CT systems are performed by simple personal computer rather than workstations. Image reconstruction consists of 2 processes: acquisition process and reconstruction process, each process composed of many steps (Fig. 2-6). Once reconstruction is done, multiplanar viewing of the anatomical volume is accomplished with imaging software and presented to the clinician on screen as secondary reconstructed images in 3 orthogonal planes (axial, sagittal and coronal). Volume datas can save in a "DICOM" (Digital Imaging and Communication in Medicine) file format to facilitate sharing data between any other imaging related services.

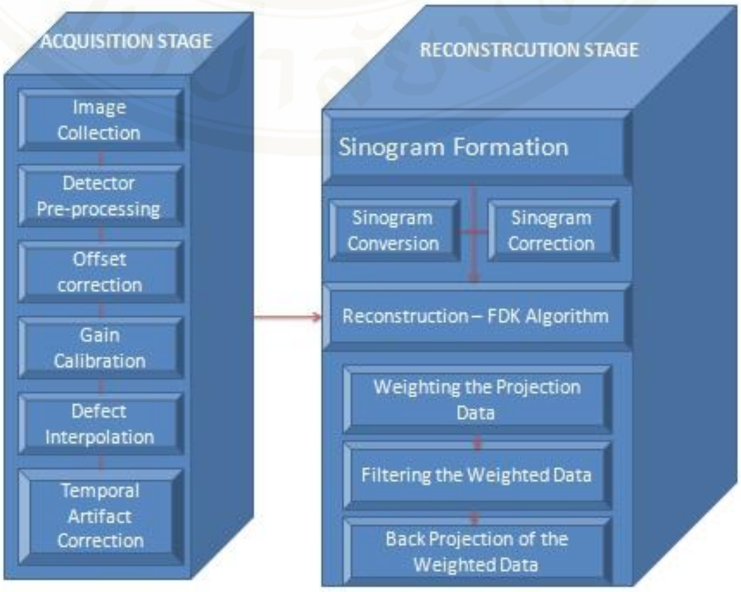


Fig. 2-6:Stages and Steps involved in reconstruction of acquired projection data to form volumetric data.

Advantages of CBCT in dentistry

1. Rapid scan time

A single rotation of gantry similar to panoramic radiography is one of the major advantages. Because artifact from movement is reduced. It takes approximately 10-20 seconds.

2. Beam limitation

An optimal area can be selected for each patient based on suspected field of view (FOV) by collimation of the primary x-ray beam.

3. Image accuracy

Sub millimeter isotropic voxels resolution between 0.076 mm to 0.4 mm results in great resolution of secondary images (axial, sagittal, and coronal) and other reconstructions. Its precision of 1:1 ratio with accurate dimensional measurements (55) is enough for any clinical measurement in oral and maxillofacial applications, such as orthodontic analysis or implant site measurement.

4. Reduced patient radiation dose

Effective dose are varies, depending on FOV selected and typed of CBCT device. Comparing with multiples of a single panoramic dose, CBCT provides radiation dose of 4-15 times that of a panoramic radiograph (47, 48, 56, 57). Comparison with maxillofacial imaging by conventional CT, CBCT provides dose reduction up to 98% (28).

5. Images demonstrating features

Because images are performed by isotropic volumetric data sets with a personal computer, then we can get varies interrelational images; secondary reconstructions (three orthogonal planes), magnification images with software measurement algorithms, multiplanar reformation or ray sum with distortion-free images, and 3D volume rendering.

Limitations of CBCT

1. Artifacts

Reconstruction of CBCT images or volumetric data set are performed by gathering photons and convert them within area detector that consists of million detector units. Ideally every units receive the photons and convert them constantly.

But in reality, many obstacles such as coefficient of regression by object and airborne are the causes that make defect.

1.1 X-ray beam artifacts;

Beam hardening

1.1.1 Cupping artifact;

Distortion of metallic structures

1.1.2 Streaks and dark bands;

They can appear between 2 dense objects

1.2 Patient-related;

Patient motions

1.3 Scanner-related;

Problems in gathering photons of detector or poor calibration

1.4 Cone-beam-related

1.4.1 Partial volume averaging

1.4.2 Under sampling

1.4.3 Cone-beam effect

2. Image noise

Using an area detector contributes to image degradation or noise from nonlinear attenuation scattered radiation.

3. Poor soft tissue contrast

Reduction of radiation dose up to 98% to medical CT are the mainly cause of less contrast CBCT images. It decreases ability of CBCT to visualize the soft tissue structure.

Current dental application of CBCT

1. Impactions
2. Inferior alveolar nerve location; pre-implant assessment
3. Airway studies for sleep apnea
4. Endodontic evaluation
5. Cephalometric and space analysis
6. Paranasal sinus evaluation
7. Jawbones lesion visualization

8. TMJ visualization
9. Trauma evaluation
10. Temporary anchorage devices evaluation
11. 3D virtual models
12. Other CAD/CAM devices
13. Periodontium evaluation

CHAPTER III
MATERIALS AND METHODS

3.1 Study design

This study was a prospective clinical trial, which mainly compared the accuracy of CBCT to panoramic radiographs in the ability for prediction of the exact relationship between inferior alveolar nerve and mandibular third molar that would intra-operatively be verified following surgical removal of those teeth.

3.2 Study population

The study population was composed of consecutive out patients of oral and maxillofacial surgery clinic, faculty of dentistry, Mahidol University, who were referred for surgical removal of impacted teeth with preoperative panoramic radiographs previously taken by oral and maxillofacial radiology clinic between June 2010 and February 2011. The patients whose panoramic radiographs showed mandibular third molar root superimposed with the inferior alveolar canal, and did not match with any exclusive criteria, were informed about this study in details. The patients who were interested and met the criterion of the study were recruited and required to sign the consent forms ethically approved by Institution Review Boards (IRB) of Mahidol University.

3.3 Study site

This study was done at the Faculty of Dentistry, Mahidol University, Bangkok, Thailand. All inclusive patients were sent to be evaluated both panoramic and CBCT radiographs at the oral and maxillofacial radiology clinic, then returned to oral and maxillofacial surgery clinic for removal of mandibular third molar.

3.4 Sample size

The sample was calculated by using the following formula for a single population.

$n_0 = (Z_\alpha)^2PQ / (d)^2$

Where:

P = associated probability value (0.32); From: The Prognostic value of panoramic radiography of inferior alveolar nerve damage after mandibular third molar removal: Retrospective study of 400 cases, Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009.

Q = $1- P_0$ (0.68)

d = 10%

α = 0.05/2

Therefore:

$n_0 = (1.96)^2(0.32)(0.68) / (0.1)^2$

= 84

3.5 Inclusion criteria

All the patients that came to oral and maxillofacial surgery clinic for surgical removal of mandibular third molar and had one or more of the following of panoramic features suggested a close relationship of the mandibular third molar root to the inferior alveolar canal.

1. Interruption of the superior cortical line;

Immediately disappeared by the tooth structure. Cortical lines are the two radio-opaque lines that constitute the “roof” and “floor” of inferior alveolar canal.

Fig. 3-1:Interruption of the superior cortical line.

2. Darkening of the root;

Loss of density of the root; the root appears darker.

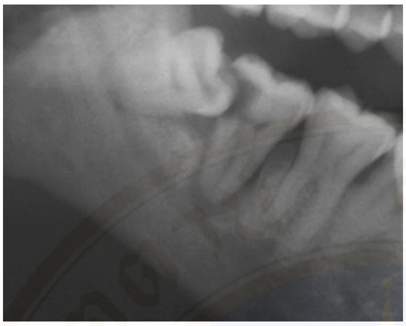


Fig. 3-2:Darkening of the root.

3. Diversion of the canal;

Inferior alveolar canal changes its direction, when it crosses the mandibular third molar.

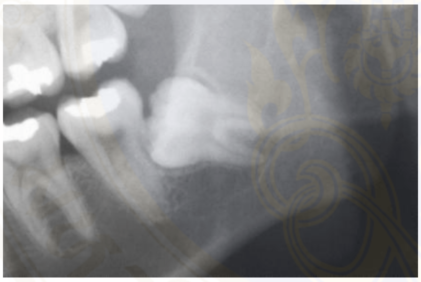


Fig. 3-3:Diversion of the canal.

4. Narrowing of the canal;

Inferior alveolar canal reduces its diameter, when it crosses the mandibular third molar.

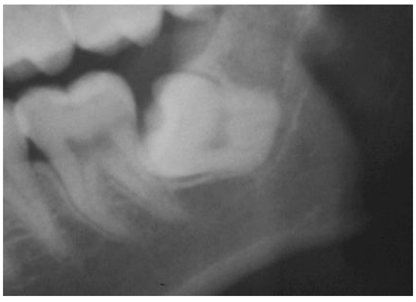


Fig. 3-4:Narrowing of the canal.

5. Narrowing of the root;

Perforation of the root by the inferior alveolar canal.

Fig. 3-5:Narrowing of the root.

6. Deflected root (Root hooked around the inferior alveolar canal);

Abrupt deviation of the root, when it reaches the inferior alveolar canal.

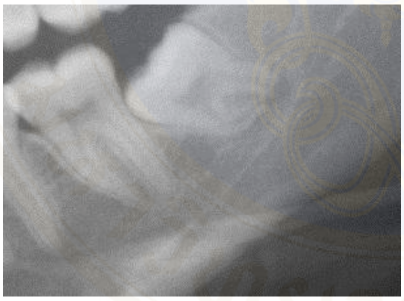


Fig. 3-6:Deflected root.

7. Dark and bifid root;

Double periodontal membrane shadow of bifid apex, when the inferior alveolar canal crosses.

Fig. 3-7:Dark and bifid root.

8. Other signs that panoramic radiograph shows mandibular third molar root superimposed with the inferior alveolar canal.

3.6 Exclusion criteria

Patients who reached one or more of exclusion criteria were excluded out of this study.

1. Patients who do not have additional CBCT
2. Patients who have neurological deficit prior to treatment
3. Patients whose neurovascular bundle cannot be identified after the surgery
4. Patients who cannot be follow up
5. Patients who is in pregnancy period

3.7 Research process

First, oral surgeon (N.S. and B.A.) selected cases that could be recruited by screening all panoramic radiographs then forwarded the films of patients who participated to the study to the radiologists (K.S. and S.D.).

The patients whose panoramic radiographs showed the selected features and did not match with any exclusive criteria will be assigned to review patient information sheet of the project. If patient decided to have additional investigation; CBCT, the consent forms needed to be signed. After the radiologists finished CBCT and sent the data to oral surgeon, the standard procedure to remove mandibular third molar was proceeded. Neurovascular bundle exposure was identified immediately after the surgery finished by N.S. or B.A. On the day of 1st follow up, neurosensory test was done. In the case of nerve impairment, treatment protocol for nerve injury was applied. Neurosensory function of healing IAN would be periodically evaluated to 6 months healing time. Both panoramic radiographs and CBCT were done, examined, and analyzed by two oral radiologists independently.

3.8 Data collection and research instruments

This study inspected 5 main areas:

1. Demographic data
2. Panoramic radiograph
3. CBCT
4. Intraoperative data
5. Postoperative neurosensory status

1. Demographic data

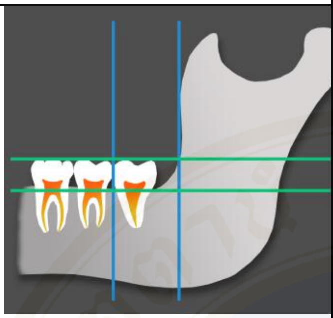
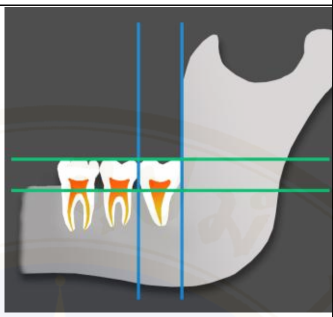
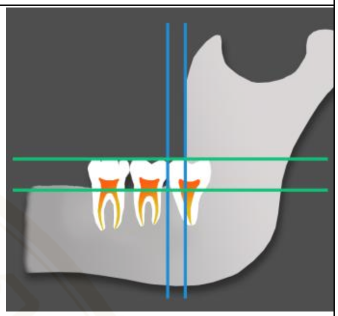
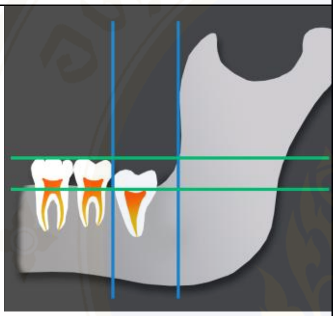
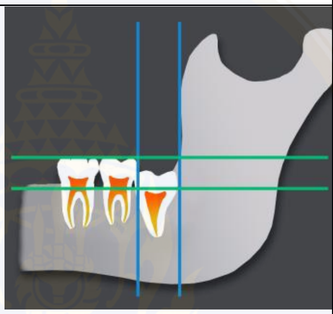
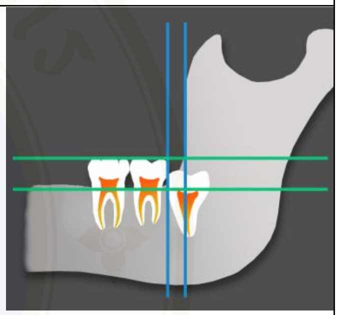
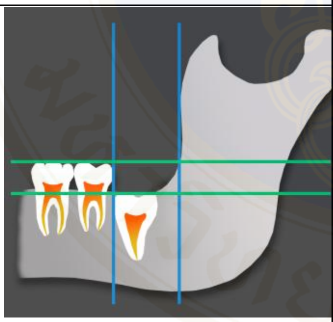
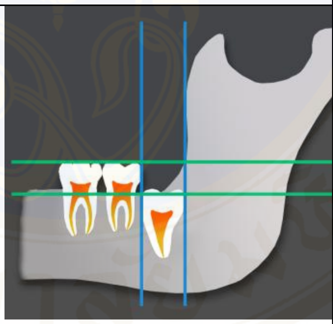
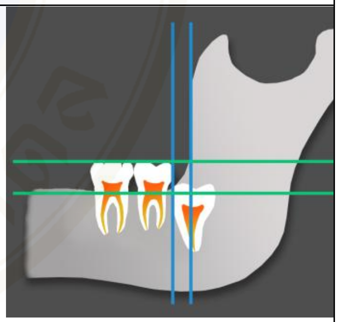
All age and gender of the patients in this study were recorded.

2. Panoramic radiographs

Conventional panoramic radiographs, Planmeca Proline XC were used in this study. All panoramic radiographs were analyzed by the two radiologists and collected of these following datas.

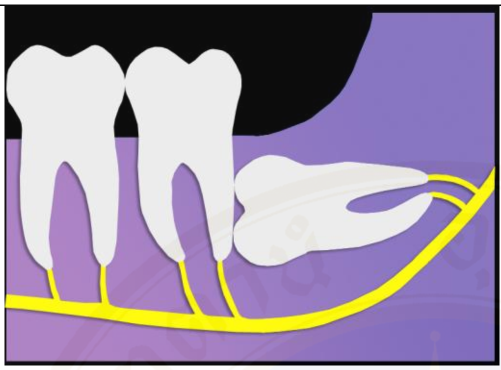
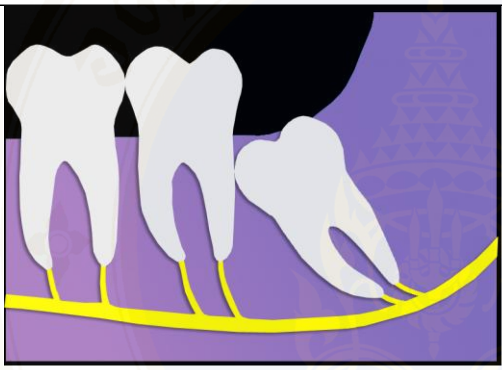
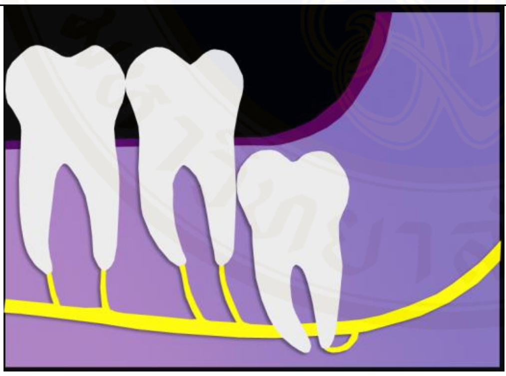
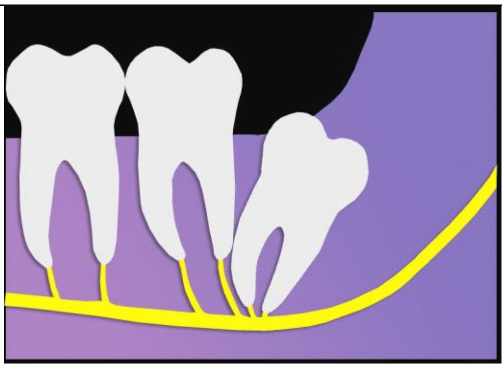
2.1 Pell-Gregory classification (58)

Table. 3-1:Pell-Gregory classification

	I	II	III
A			
B			
C			

2.2 Winter's classification

Table. 3-2:Winter's classification

	Horizontal angulation
	Mesio-angulation
	Vertical angulation
	Disto-angulation

2.3 Root curvatures (59)

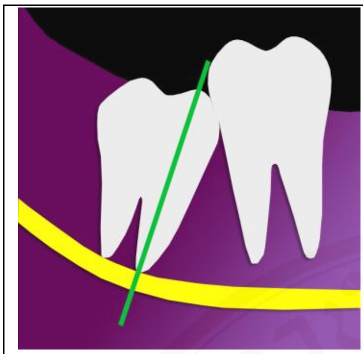
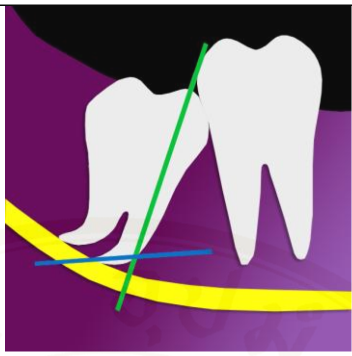
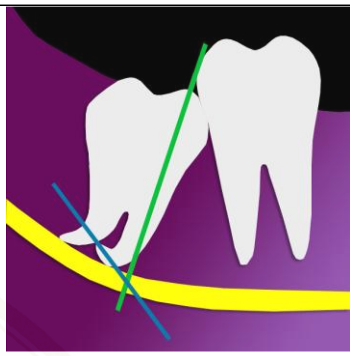
		
Root Curvature 0-45 degree	Root curvature 45-90 degree	Root curvature 90++ degree

Fig. 3-8:Root curvature.

2.4 Extent of root tip - inferior alveolar canal overlaps (60)

Three groups were established based on the distance of the tooth to the IAC;

1. One or more of root apices locate inferiorly to inferior cortical line of IAC level
2. One or more of root apices superimpose with IAC more than half of the diameter or locate at inferior cortical line of IAC
3. One or more of root apices superimpose with IAC less than half of the diameter of IAC

		
1	2	3

Fig. 3-9:Root extension.

2.5 The signs indicating close spatial relationship

The panoramic features that indicate close relationship has been well-described in many studies (11, 12). In this study, all panoramic features conform to the above inclusion criteria were collected. All 7 signs were evaluated in every panoramic radiograph and graded into 5 scale point as shown in table 3-3.

Table. 3-3:Panoramic radiograph data collection table

PANORAMIC	**Rating Scale**				
	Definitely present 5	Probably present 4	Uncertain 3	Probably absent 2	Definitely absent 1
Interruption of white line					
Darkening of root					
Diversion of canal					
Narrowing of root					
Narrowing of canal					
Deflection of root					
Dark and bifid apex					

Only 4 or 5 point were counted as a positive value to that feature and used for statistical analysis.

3. CBCT

3D Accuitomo (J. Morita Mfg. Corp.) was used for all patients in this study. Position of inferior alveolar canal compared to the root of mandibular third molar and the presence or absence of direct contact between the tooth root and the canal contents were three dimensionally evaluated and recorded as shown in table 3-4.

Table. 3-4:CBCT data collection table

Position of IAC compared to the root (coronal section)	Buccally	Inferiorly	Inter-radicularly	Lingually	Others

Minimum distance of IAC to the root	5	4	3	2	1

Position of inferior alveolar canal compared to the root of mandibular third molar was selected to be observed on coronal section of CBCT. Then distance between inferior alveolar canal and the root was three dimensionally evaluated for the minimum distance.

Only 4 or 5 point were counted as a direct contact which means positive value to that feature and used for statistical analysis.

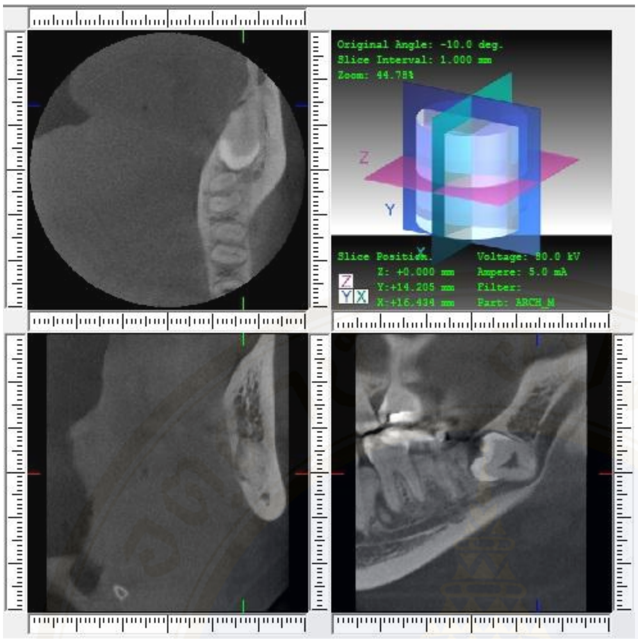


Fig. 3-10:This CBCT image shows #38 tooth impaction. In coronal view(lower left), inferior alveolar canal appearance is jammed to lingual plate by tooth root.

5 = inter-radicular or contact break with canal appearance changed

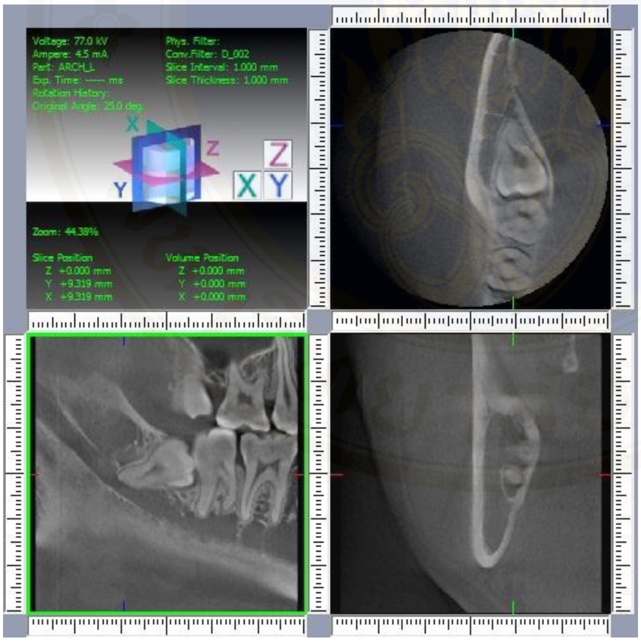


Fig. 3-11:This CBCT image shows #48 tooth impaction. In coronal view(lower right), inferior alveolar canal is attached to tooth root without cortication line between these two structures.

4 = contact break without canal appearance changed

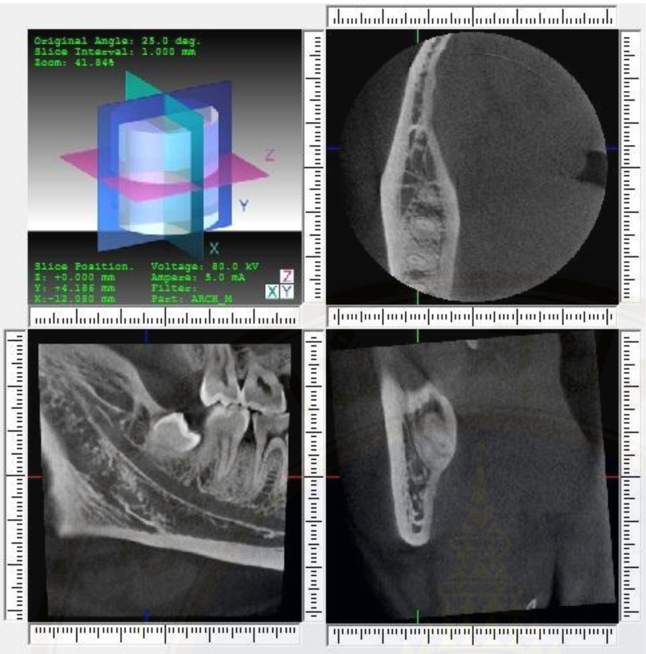


Fig. 3-12:This CBCT image shows #48 tooth impaction. In coronal view(lower right), inferior alveolar canal is attached to tooth root with thin cortication line between these two structures.

3 = contact with cortication

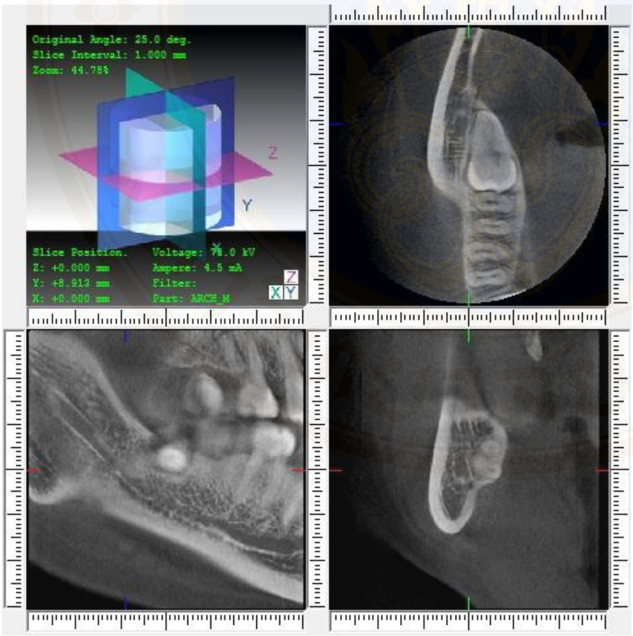


Fig. 3-13:This CBCT image shows #48 tooth impaction. In coronal view(lower right), inferior alveolar canal is attached to tooth root with cortication line thickness less than 1mm.

2 = cortication 0-1 mm

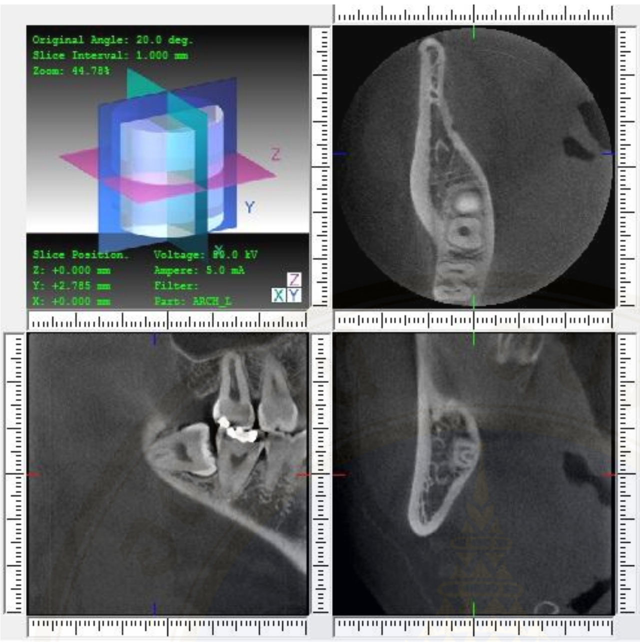
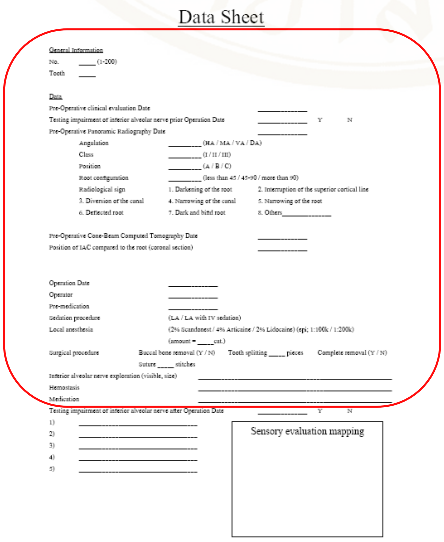


Fig. 3-14:This CBCT image shows #48 tooth impaction. In coronal view(lower right), inferior alveolar canal is attached to tooth root with cortication line thickness more than 1mm.

1 = cortication more than 1 mm

4. Intraoperative data

All patients in this study underwent surgical removal of those analyzed teeth. The clinical data were used to confirm the result of radiographic images. Datas were collected as showed.



Data Sheet

General Information
No. _____ (1-200)
Tooth _____

Data
Pre-Operative clinical evaluation Date _____________
Testing impairment of inferior alveolar nerve prior Operation Date _____________ Y N
Pre-Operative Panoramic Radiography Date _____________
Angulation _________ (HA / MA / VA / DA)
Class _________ (I / II / III)
Position _________ (A / B / C)
Root configuration _________ (less than 45 / 45-90 / more than 90)
Radiological sign 1. Darkening of the root 2. Interruption of the superior cortical line
3. Diversion of the canal 4. Narrowing of the canal 5. Narrowing of the root
6. Deflected root 7. Dark and bifid root 8. Others_____________

Pre-Operative Cone-Beam Computed Tomography Date _____________
Position of IAC compared to the root (coronal section) _____________

Operation Date _____________
Operator _____________
Pre-medication _____________
Sedation procedure (LA / LA with IV sedation)
Local anesthesia (2% Scandonest / 4% Articaine / 2% Lidocaine) (epi; 1:100k / 1:200k)
(amount = _____cat.)
Surgical procedure Buccal bone removal (Y / N) Tooth splitting _____ pieces Complete removal (Y / N)
Suture _____ stitches
Inferior alveolar nerve exploration (visible, size) _____________
Hemostasis _____________
Medication _____________
Testing impairment of inferior alveolar nerve after Operation Date _____________ Y N
1) _____________
2) _____________
3) _____________
4) _____________
5) _____________

Sensory evaluation mapping

Fig. 3-15:Data sheet form. The circle shows collected intraoperative data.

5. Post-operative neurosensory status

All patients were asked about neurosensory status in the first follow up appointment or 7-10 post-operative days and data were recorded. In case of neurosensory deficit, further investigations were done as in Fig. 3-16 and recorded, then treated and followed up for 6 months period.

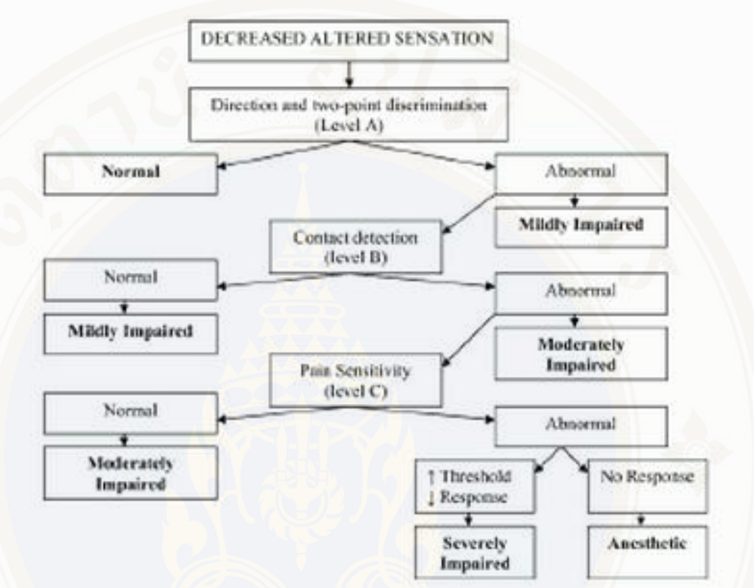
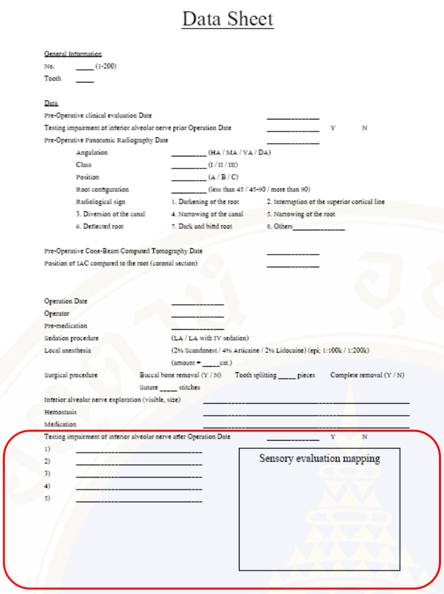


Fig. 3-16:Grading algorithm for evaluating trigeminal nerve injury by Zuniga and Essick.

Neurosensory examination by subjective evaluation were done in all cases, in cases of dysesthesia, mapping were also done before objective evaluation proceeded.

The mechanoceptive testings, light touch and two-point discrimination were done and recorded. Then the nociceptive testings, pain and thermal, were followed and recorded.



Data Sheet

General Information

No. _____ (1-200)

Tooth _____

Data

Pre-Operative clinical evaluation Date _____________

Testing impairment of inferior alveolar nerve prior Operation Date _____________ Y N

Pre-Operative Panoramic Radiography Date _____________

Angulation _________ (HA / MA / VA / DA)

Class _________ (I / II / III)

Position _________ (A / B / C)

Root configuration _________ (less than 45 / 45-90 / more than 90)

Radiological sign 1. Darkening of the root 2. Interruption of the superior cortical line

3. Diversion of the canal 4. Narrowing of the canal 5. Narrowing of the root

6. Deflected root 7. Dark and bifid root 8. Others_____________

Pre-Operative Cone-Beam Computed Tomography Date _____________

Position of IAC compared to the root (coronal section) _____________

Operation Date _____________

Operator _____________

Pre-medication _____________

Sedation procedure (LA / LA with IV sedation)

Local anesthesia (2% Scandonest / 4% Articaine / 2% Lidocaine) (epi; 1:100k / 1:200k)

(amount = _____cat.)

Surgical procedure Buccal bone removal (Y / N) Tooth splitting _____ pieces Complete removal (Y / N)

Suture _____ stitches

Inferior alveolar nerve exploration (visible, size) _____________

Hemostasis _____________

Medication _____________

Testing impairment of inferior alveolar nerve after Operation Date _____________ Y N

1) _____________

2) _____________

3) _____________

4) _____________

5) _____________

Sensory evaluation mapping

Fig. 3-17:Data sheet form. The circle shows collected postoperative neurosensory data.

3.9 Data analysis

The statistical analyses of all data were carried out with SPSS for windows version 16. The association of each variable with the neurovascular bundle exposure was tested by either Pearson Chi-Square test or Fisher's Exact test, except age was tested by Mann-Whitney U test due to nonparametric variable. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for each radiographic feature indicating a close relationship of the mandibular third molar root to the inferior alveolar canal. Univariate odds ratio of variables associated with neurovascular bundle exposure were also calculated.

All variables were introduced into multivariate logistic regression analysis, forward stepwise method to calculate for the significant signs. Statistical significance was accepted for p-value of <0.05 and 95% confidence intervals (CIs).

Inter-observer agreement was judged by Cohen Kappa statistic. A kappa value of <0.40 was considered poor, 0.40-0.59 was fair, 0.60-0.74 was good, and 0.75-1.00 was excellent agreement.

3.10 Limitation of study

Our study had some limitations. First, screening panoramic radiographs to select cases that could be recruited by the oral surgeons before sending to the oral radiologists might have resulted in the selection bias. Another was the clinical findings of neurovascular bundle following the surgery that might be missed, even all surgical sites were carefully examined. Besides, the surgeons' experience were also might cause vary clinical outcome, even though the operations were performed by trained and experienced surgeons.

Some panoramic features (narrowing of root and dark/bifid apex) were not found in this study. Those variables might associate with outcome variable that need continuous study in the future to confirm this result.

3.11 Ethical consideration

The study was done under the permission to conduct by Institutional Review Board, Mahidol University. The patients had right to withdraw at any time of the research for any reason and standard protocols were strictly done in every steps.

Only the patients, who were interested to join this study and signed the consent voluntarily, were recruited. All the information was given in native language.

CHAPTER IV
RESULTS

The study sample consisted of 84 impacted teeth from 58 patients (24 men and 34 women) with an average age of 27.64 years (from 17 to 59 years). Following of the mandibular third molar surgery, there were 29 impacted teeth (34.52%) of which the neurovascular bundle were exposed. In the first follow up appointment, 4 teeth (4 patients; 2 men 2 women) were found dysesthesia by both subjective and objective evaluation according to Zuniga and Essick algorithm. One patient has minimal improvement of paresthesia status at right side of lower lip and chin after 6 months post surgery, but the symptom is acceptable. Two patients recovered from the symptom within 3 months while the remaining one patient is improving satisfactorily.

The inter-observer agreement of panoramic radiographs assessment by the two oral radiologists was excellent, as the κ-value ranged from 0.863 (interruption of the superior cortical line) to 0.96 (darkening of the root). As the CBCT in assessment of contact relationship between the mandibular third molar root and the inferior alveolar canal on CBCT images was also excellent, as the κ-value of 0.76 (Table. 4-1). Because of these excellent agreements, the results were randomly achieved by the software to one, and introduced to statistical analysis.

The characteristics and incidence rates of variables compared to clinical outcome were shown in Table. 4-3.

The variable, gender, in this study was not calculated. While age, was not significantly associated to the neurovascular bundle exposure by Mann-Whitney U test.

The mandibular third molars that were mostly found in this study had Pell-Gregory classification in class I (73.81%) with position A (52.38%), Winter's classification in mesioangular (45.24%), root curvature less than 45 degrees (84.52%), and one or more of root apices superimpose with inferior alveolar canal more than half of the diameter or locate at inferior cortical line of inferior alveolar canal

(41.67%). The position category of Pell-Gregory classification was the only one variable showed significantly associated to neurovascular bundle exposure (p=0.049).

As the determination of panoramic radiographic signs in 7 categories as shown in Table. 4-3, interruption of the superior cortical line was found mostly (65.48%), while narrowing of the root and dark/bifid root were not found.

Two signs from panoramic features have been found significant and associated by Pearson Chi-Square test to neurovascular bundle exposure, darkening of the root (p=0.009) and narrowing of the canal (p=0.035).

Five signs from panoramic features and CBCT interpretation of direct contact between tooth root and inferior alveolar canal were calculated for sensitivity, specificity, PPV, NPV, accuracy, and Odds Ratio. The sensitivities ranged from 17.24% to 100%, the specificities ranged from 38.18% to 92.73%. The PPVs groups were between 21.74% and 62.50%, the NPVs groups were between 60.66% to 100% (Table. 4-2).

As the CBCT, direct contact by no cortication between tooth root and inferior alveolar canal were significantly associated to neurovascular bundle exposure (p<0.001). Three-forth of patients found dysesthesia had inter-radicular relationship of inferior alveolar canal to the tooth root, and the last was lingual position in coronal view. All 4 cases were defined as paresthesia with “contact break with canal appearance changed”.

Multivariate logistic regression analysis was done by introducing all variables to the algorithm. The variables were rejected by statistic method and presented only darkening of the root and direct contact of tooth root to inferior alveolar canal in CBCT image to the model, only panoramic radiographic feature, darkening of the root showed a significant association with the clinical outcome, neurovascular bundle exposure after the mandibular third molar surgery (p=0.041) with odds ratio of 0.181 (95% CI 0.035-0.933).

Table. 4-1: Inter-observer agreement

	κ-value
Interruption of the superior cortical line	0.863
Darkening of the root	0.960
Diversion of the canal	0.941
Narrowing of the canal	0.891
Deflected root	0.938
CT interpretation	0.760

Table. 4-2: Sensitivity, specificity, PPV, NPV, accuracy and Univariate adjusted odds ratio.

	Sensitivity	Specificity	PPV	NPV	Accuracy (%)	Odds Ratio	95% CI
Interruption of the superior cortical line	72.41%	38.18%	38.18%	72.41%	50.00%	1.621	0.609-4.317
Darkening of the root	34.48%	89.09%	62.50%	72.06%	70.24%	4.298	1.371-13.471
Diversion of the canal	20.69%	92.73%	60.00%	68.92%	67.86%	3.326	0.856-12.927
Narrowing of the canal	48.28%	74.55%	50.00%	73.21%	65.48%	2.733	1.059-7.053
Deflected root	17.24%	67.27%	21.74%	60.66%	50.00%	0.428	0.140-1.307
CT interpretation	100.00%	58.18%	55.77%	100.00%	72.62%	-	-
PPV = positive predictive value							
NPV = negative predictive value							
CI = confidence interval							

Table. 4-3:Details of predictive variables

Variable		Neurovascular bundle exposure		No exposure		P value	Statistic Method
		%		%			
Age, years							
	Range		17-59		19-55		
	Mean, SD	27.88	10.44	27.47	8.543	0.667	MW**
Gender							
	Male	37.50	9	44.12	15		
	Female	62.50	15	55.88	19		
Pell-Gregory classification							
	I	65.52	19	78.18	43		
	II	34.48	10	21.82	12		
	III	0.00	0	0.00	0	0.209	C
	A	37.93	11	60.00	33		
	B	37.93	11	32.73	18		
	C	24.14	7	7.27	4	0.049*	C
Winter's classification							
	Horizontal	51.72	15	34.55	19		
	Mesioangular	44.83	13	45.45	25		
	Vertical	3.45	1	16.36	9		
	Distoangular	0.00	0	3.64	2	0.145	F
Root curvatures							
	less than 45	86.21	25	83.64	46		
	45-90	10.34	3	9.09	5		
	more than 90	3.45	1	7.27	4	0.899	F
Root - IAC superimposition							
	1	17.24	5	20.00	11		
	2	51.72	15	36.36	20		
	3	31.03	9	43.64	24	0.383	C
Panoramic radiographic sign							
	Interruption of the superior cortical line	72.41	21	61.82	34	0.331	C
	Darkening of the root	34.48	10	10.91	6	0.009*	C
	Diversion of the canal	20.69	6	7.27	4	0.087	F
	Narrowing of the canal	48.28	14	25.45	14	0.035*	C
	Narrowing of the root	0.00	0	0.00	0	N/A	
	Deflected root	17.24	5	32.73	18	0.130	C
	Dark and bifid root	0.00	0	0.00	0	N/A	
	Others	0.00	0	0.00	0	N/A	
Position of IAC compared to the root in CBCT							
	Buccally	6.90	2	45.45	25		
	Inferiorly	100.00	29	100.00	55		
	Lingually	65.52	19	16.36	9		
	Inter-radicularly	31.03	9	0.00	0		
	Others	0.00	0	0.00	0		
Minimum distance of IAC to the root in CBCT							
	1	0.00	0	1.82	1		
	2	0.00	0	16.36	9		
	3	0.00	0	40.00	22		
	4	27.59	8	25.45	14		
	5	72.41	21	16.36	9	<.001*	C
Neurovascular bundle exposure		34.52	29	65.48	55		
Neurosensory deficit		4.76	4	0.00	0		
MW is Mann-Whitney test	** due to Kolmogorov-Smirnov Z test rejected null hypothesis						
C is Pearson Chi-Square test							
F is Fisher's Exact test							
* is significant at the 0.05 level							

Table. 4-4:CT interpretation

Crosstabulation

Count

		Neurovascular exposure		
		0	1	Total
CT	0	32	0	32
	1	23	29	52
Total		55	29	84

Sensitivity = 29/29
Specificity = 32/55
+ Prediction Value = 29/52
- Prediction Value = 32/32

Table. 4-5: Interruption of the superior cortical line

Crosstabulation

Count

		Neurovascular exposure		
		0	1	Total
Sign (1)	0	21	8	29
	1	34	21	55
Total		55	29	84

Sensitivity = 21/29
Specificity = 21/55
+ Prediction Value = 21/ 55
- Prediction Value = 21/29

Table. 4-6: Darkening of the root

Crosstabulation

Count

		Neurovascular exposure		
		0	1	Total
Sign (2)	0	49	19	68
	1	6	10	16
Total		55	29	84

Sensitivity = 10/29
Specificity = 49/55
+ Prediction Value =10/ 16
- Prediction Value = 49/68

Table. 4-7: Diversion of the canal

Crosstabulation

Count

		Neurovascular exposure		
		0	1	Total
Sign (3)	0	51	23	74
	1	4	6	10
Total		55	29	84

Sensitivity = 6/29
Specificity = 51/55
+ Prediction Value = 6/ 10
- Prediction Value = 51/74

Table. 4-8: Narrowing of the canal

Crosstabulation

Count

		Neurovascular exposure		Total
		0	1	
Sign (5)	0	41	15	56
	1	14	14	28
Total		55	29	84

Sensitivity = 14/29
Specificity = 41/55
+ Prediction Value = 14/28
- Prediction Value = 41/56

Table. 4-9: Deflected root

Crosstabulation

Count

		Neurovascular exposure		Total
		0	1	
Sign (6)	0	37	24	61
	1	18	5	23
Total		55	29	84

Sensitivity = 5/29
Specificity = 37/55
+ Prediction Value = 5/23
- Prediction Value = 37/61

Table. 4-10: Multivariate logistic regression analysis.

Classification Table[a]

Observed			Predicted N. expose 0	Predicted N. expose 1	Predicted Percentage Correct
Step 1	N. expose	0	32	23	58.2
		1	0	29	100.0
	Overall Percentage				72.6
Step 2	N. expose	0	53	2	96.4
		1	19	10	34.5
	Overall Percentage				75.0

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B) Lower	95.0% C.I.for EXP(B) Upper
Step 1[a]	rootconfig.s(1)	-21.435	7.105E3	.000	1	.998	.000	.000	.
	Constant	.232	.279	.689	1	.406	1.261		
Step 2[b]	c2s(1)	-1.710	.837	4.173	1	.041	.181	.035	.933
	rootconfig.s(1)	-21.496	6.912E3	.000	1	.998	.000	.000	.
	Constant	1.609	.775	4.317	1	.038	5.000		

a. Variable(s) entered on step 1: rootconfig.s.

b. Variable(s) entered on step 2: c2s.

CHAPTER V
DISCUSSION

In Thailand, cone beam computed tomography (CBCT) or dental CT is still a new modalities and not accessible for all facilities, in addition, the cost has to be considered for the expense of patients. The case selection for this kind of investigation has to be worthy and gives the useful information to decrease risks of postoperative mandibular third molar surgery complications. Even CT and CBCT in many studies (28, 60, 61, 62, 63, 64, 65, 66) showed many advantages, some cases may not require CBCT investigation. A routine examination such as intraoral radiography or panoramic radiography, can give preoperative information in almost of the cases, especially if there is no superimposition of the tooth roots and inferior alveolar canal (26).

Panoramic radiograph is now a standard diagnostic tool for all patients who come to assess any pathologies in addition the clinical examination require more detail involving hard tissue such as impacted teeth, tumors, cysts, etc. Therefore, panoramic radiograph is the most suitable for preoperative assessment of mandibular third molars in detail for size and shape of that teeth as well as the angulation according to Winter's classification, the class and position according to Pell-Gregory classification in sagittal plane,. The number and shape of the roots as well as their stage of development are also of interest, including the most important feature is their relationship with the mandibular canal.

Although panoramic radiograph can be used as a screening image for predicting the risk of nerve injury, indicate the high risk of IAN injury. In these cases it cannot provide the accurate position of two structures; the mandibular third molar and the inferior alveolar canal, what the relationship of these are. The IAC may be on buccally, lingually, or interradicularly to the tooth root and showed up in panoramic radiograph with superimposition of mandibular third molar and inferior alveolar canal. The patient may risk neurovascular bundle exposure/injury. The limitations of plain film imaging are well discussed (26, 27, 59).

In this study, data in 5 categories were collected: demographic data (gender, age), panoramic radiograph data, CBCT data, intraoperative data, and postoperative neurosensory status data. 58.62% of patients were women. 44.12% of those found neurovascular bundle exposed and 13.33% of that exposed faced to neurosensory deficit, implied to injury. However, gender variable was not calculated and should be evaluated in another context considered in gender by controlling others variables.

Many studies have found age has direct variation to inferior alveolar nerve injury (13, 69, 70), while some others did not detect the relationship (9). This study shows age and neurovascular bundle exposure were not significantly associated.

The signs of panoramic radiograph that indicated a high risk of neurovascular bundle exposure or inferior alveolar nerve injury following mandibular third molar removal have been shown in many clinical studies (11, 12, 59, 62, 64, 67, 68). Our study also shows some panoramic signs have significantly associated to neurovascular bundle exposure, darkening of the root and narrowing of the canal. In most cases, the panoramic radiograph signs are detected more than a single. It is possible that those signs may correlate with each others. Multivariate logistic regression was performed to gain the radiographic sign(s) that significantly associate with outcome. The result shows darkening of the root was the only one. Similar with other studies, the darkening of the root is the strongest sign in predicting outcome whatever neurovascular bundle exposure (64) or inferior alveolar nerve injury (15, 71). As many studies also detected darkening of the root was one of the significantly associated signs in their reports (9, 11, 12, 67). Kipp DP et al. reported a significant relationship between darkening of the root and inferior alveolar nerve injury, also with Rood JP et al. showed interruption of the superior cortical line, darkening of the root, and diversion of the canal are the signs related to nerve injury according to both retrospective and prospective surveys, same as Blaeser BF et al. found in their retrospective case-control study. Sedaghatfar M et al. found the same result with Rood JP plus narrowing of the root.

Consideration of the panoramic signs as independent variables, darkening of the root and narrowing of the canal significantly associate with neurovascular bundle exposure. This result were confirmed by Univariate odds ratios found these variables does not contain value “1.00” in 95% CI which means they associated to outcome and the prediction power are 4.298 and 2.733 times to normal probability finding neurovascular bundle exposure, respectively when these signs are present.

Another categories of panoramic radiographs: Pell-Gregory classification, Winter’s classification, root curvature, and the level of tooth root superimposition, the position showed significantly associate to neurovascular bundle exposure. The correlation seems to be presumably. The deeper position usually need more bone reduction with more manipulations near the nerve position that may produce large window for direct vision using headlight to detect clinical outcome.

To compare the accuracy of panoramic radiograph and CBCT, CBCT has minimal superior accuracy (72.62%) to panoramic prediction ranged from 50.00% to 70.24%. It failed to measure significant difference, due to the high sensitivity of CBCT interpretation but low specification (58.18%). The interesting of CBCT is that the clinical outcome was 100% prediction as negative when the CBCT showed cortication between the tooth root and inferior alveolar canal, which means the presentation of cortication between the two structures implies there is no or minimal chance for neurovascular bundle exposure as well as nerve injury. Whereas the absence of cortication in CBCT images even with other predictor variables are not a reliable of possible outcome (12, 62, 69).

The predictive values are another one important indicators. They represent positive result indicates outcome or negative result that does not reach outcome, neurovascular bundle exposure or nerve injury. PPV in this study is the probability that neurovascular bundle exposure will occur when a marked sign is present, and NPV is the probability that clinical outcome will not occur when a marked sign is absent. Darkening of the root, the only significant sign in our study showed PPV of 62.50% and NPV of 72.06% with sensitivity of 34.48% and specificity of 89.09%. It has possibility that if our case members are higher, diversion of the canal that showed PPV of 60.00% and NPV of 68.92% with sensitivity of 20.69% and specificity of 92.73% may be significant.

Patients with paresthesia were found 4 cases in this study. Three-forth of patients found dysesthesia had interradicular relationship of inferior alveolar canal to the tooth root, and the last was lingual position in coronal view. All 4 cases was confirmed as neurovascular bundle exposure those exposed area were similar to contact break area found in CBCT images.

The inter-observer agreement showed excellent agreement, because of well-calibrated agreement of judge prior evaluation of images.

CHAPTER VI
CONCLUSION

Widely used standard diagnostic image for preoperative evaluation of third molar surgery has always be panoramic radiograph an important procedure to assess the position, and establish the relationship between the third molar and the vital surrounding structures, inferior alveolar nerve. The importance of the latter issue is for prevention of surgical complication such as neurosensory disturbance. The incidence of this condition may be related to unavoidable condition for instances, proximity of the tooth to the inferior alveolar canal, angulation of the impacted teeth, and root configuration. In our study CBCT was selected as for comparable preoperative image when indicated Rood's signs of nerve approximation detected on panoramic radiograph.

Two signs from panoramic features have been found significant and associated to neurovascular bundle exposure, darkening of the root and narrowing of the canal whereas for CBCT, direct contact by no cortication between tooth root and inferior alveolar canal were significantly associated to neurovascular bundle exposure ($p<0.001$). Multivariate logistic regression analysis presented only darkening of the root and direct contact of tooth root to inferior alveolar canal in CBCT image with significant association with the clinical outcome, neurovascular bundle exposure. Although CBCT showed high sensitivity of interpretation but low specification, CBCT has some superior accuracy to panoramic radiograph and the clinical outcome was 100% prediction as negative when the CBCT showed cortication between the tooth root and inferior alveolar canal. Although the CBCT image was not more accurate than panoramic radiograph in predicting neurovascular bundle exposure, its valuable for 3D relationship take an advantage of revealing a bucco-lingual position of IAC to mandibular third molar, that surgeon can appreciate for detailed planning of how to conduct the operation and the possible complications can be aware and conscious by both patient and surgeon.

RERFERENCES

1. MacGregor A.J., 1985. The Impacted Lower Wisdom Tooth, Oxford University Press, New York, p. 3.
2. Macho G.A. and Moggi-Cecchi J., 1992. Reduction of maxillary molars in Homo sapiens sapiens; a different perspective. American Journal of Physical Anthropology, 87(2):151–159.
3. Corruccini R., 1991. Anthropological aspects of orofacial and occlusal variations and anomalies. In: Advances in Dental Anthropology, Chapter 17. Kelley, M.A. and Larson, C.S. (eds), Wiley-Liss, New York, p. 308.
4. Ebbert S. and Sangiorgio M., 1991. Facing the dreaded third molar. Prevention, 43(7):108–110.
5. Leff M., 1993. Hold on to your wisdom teeth. Consumer Reports on Health, 5(8):4–85.
6. Singh H., Lee K. and Ayoub A.F., 1996. Management of asymptomatic impacted wisdom teeth: a multicentre comparison. British Journal of Oral and Maxillofacial Surgery, 34:389–393.
7. Marciani RD. Third molar removal: an overview of indications, imaging, evaluation, and assessment of risk. Oral Maxillofac Surg Clin North Am. 2007 Feb;19(1):1-13.
8. Ziccardi VB, Zuniga JR. Nerve injuries after third molar removal. Oral Maxillofac Surg Clin North Am. 2007 Feb;19(1):105-15.
9. Kipp DP, Goldstein BH, Weiss WW Jr. Dysesthesia after mandibular third molar surgery: a retrospective study and analysis of 1,377 surgical procedures. J Am Dent Assoc. 1980 Feb;100(2):185-92.
10. Monaco G, Montevecchi M, Bonetti GA, Gatto MR, Checchi L. Reliability of panoramic radiography in evaluating the topographic relationship between the mandibular canal and impacted third molars. J Am Dent Assoc. 2004 Mar;135(3):312-8.

11. Rood JP, Shehab BA. The radiological prediction of inferior alveolar nerve injury during third molar surgery. Br J Oral Maxillofac Surg. 1990 Feb;28(1):20-5.

12. Sedaghatfar M, August MA, Dodson TB. Panoramic radiographic findings as predictors of inferior alveolar nerve exposure following third molar extraction. J Oral Maxillofac Surg. 2005 Jan;63(1):3-7.

13. Tay AB, Go WS. Effect of exposed inferior alveolar neurovascular bundle during surgical removal of impacted lower third molars. J Oral Maxillofac Surg. 2004 May;62(5):592-600.

14. History of panoramic radiography. Acta Radiol. 1996 May;37(3 Pt 2):441-5.

15. Howe GL, Poyton HG. Prevention of damage to the inferior dental nerve during the extraction of mandibular third molars. Br Dent J. 1960;199:355–363.

16. Jerjes W, El-Maaytah M, Swinson B, Upile T, Thompson G, Gittelmon S, Baldwin D, Hadi H, Vourvachis M, Abizadeh N, Al Khawalde M, Hopper C. Inferior alveolar nerve injury and surgical difficulty prediction in third molar surgery: the role of dental panoramic tomography. J Clin Dent. 2006;17(5):122–130.

17. Blackburn CW, Bramley PA. Lingual nerve damage associated with the removal of lower third molars. Br Dent J. 1989 Aug;167(3):103–107.

18. Renton T, McGurk M. Evaluation of factors predictive of lingual nerve injury in third molar surgery. Br J Oral Maxillofac Surg. 2001 Dec;39(6):423–428.

19. Carmichael FA, McGowan DA. Incidence of nerve damage following third molar removal: a West of Scotland Oral Surgery Research Group study. Br J Oral Maxillofac Surg. 1992 Apr;30(2):78–82 Review.

20. Kugelberg CF. Impacted lower third molars and periodontal health. An epidemiological, methodological, retrospective and prospective clinical, study. Swed Dent J Suppl. 1990;68:1-52.

21. Kugelberg CF, Ahlström U, Ericson S, Hugoson A. Periodontal healing after impacted lower third molar surgery. Precision and accuracy of radiographic assessment of intrabony defects. Int J Oral Maxillofac Surg. 1986 Dec;15(6):675-86.

22. Clark CA. A method of ascertaining the relative position of unerupted teeth by means of film radiographs. Odont Sec Roy Soc Med Proc. 1909-1910;3:87–90.

23. Richards AG. Roentgenographic localization of the mandibular canal. J Oral Surg. 1952 Oct;10:325–329.

24. Liang H, Frederiksen NL. Focal trough and patient positioning. Dentomaxillofac Radiol. 2004 Mar;33(2):128-9.

25. Yeo DK, Freer TJ, Brockhurst PJ. Distortions in panoramic radiographs. Aust Orthod J. 2002 Nov;18(2):92-8.

26. Flygare L, Ohman A. Preoperative imaging procedures for lower wisdom teeth removal. Clin Oral Investig. 2008 Dec;12(4):291-302.

27. Ohman A, Kivijärvi K, Blombäck U, Flygare L. Preoperative radiographic evaluation of lower third molars with computed tomography. Dentomaxillofac Radiol. 2006 Jan;35(1):30–35.

28. Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. J Can Dent Assoc. 2006 Feb;72(1):75-80.

29. Robb RA. The Dynamic Spatial Reconstructor: An X-Ray Video-Fluoroscopic CT Scanner for Dynamic Volume Imaging of Moving Organs. IEEE Trans Med Imaging. 1982;1(1):22-33.

30. Feldkamp LA, Davis LC, Kress JW. Practical cone-beam algorithm. J Opt Soc Am A. 1984 Jun;1(6):612–619.

31. Saint-Félix D, Trousset Y, Picard C, Ponchut C, Roméas R, Rougée A. In vivo evaluation of a new system for 3D computerized angiography. Phys Med Biol. 1994 Mar;39(3):583-95.

32. Cho PS, Johnson RH, Griffin TW. Cone-beam CT for radiotherapy applications. Phys Med Biol. 1995 Nov;40(11):1863-83.

33. Kawata Y, Niki N, Kumazaki T. Measurement of blood vessel characteristics for disease detection based on cone-beam CT images. IEEE Trans Nuc Sci. 1996 Dec;43(6):3348-54.

34. Schueler BA, Sen A, Hsiung HH, Latchaw RE, Hu X. Three-dimensional vascular reconstruction with a clinical x-ray angiography system. Acad Radiol. 1997 Oct;4(10):693-9.

35. Fahrig R, Fox AJ, Lownie S, Holdsworth DW. Use of a C-arm system to generate true three-dimensional computed rotational angiograms: preliminary in vitro and in vivo results. AJNR Am J Neuroradiol. 1997 Sep;18(8):1507-14.

36. Siewerdsen JH, Jaffray DA. Cone-beam computed tomography with a flat-panel imager: effects of image lag. Med Phys. 1999 Dec;26(12):2635-47.

37. Jaffray DA, Siewerdsen JH. Cone-beam computed tomography with a flat-panel imager: initial performance characterization. Med Phys. 2000 Jun;27(6):1311-23.

38. Siewerdsen JH, Jaffray DA. Cone-beam computed tomography with a flat-panel imager: magnitude and effects of x-ray scatter. Med Phys. 2001 Feb;28(2):220-31.

39. Wiesent K, Barth K, Navab N, Durlak P, Brunner T, Schuetz O, Seissler W. Enhanced 3-D-reconstruction algorithm for C-arm systems suitable for interventional procedures. IEEE Trans Med Imaging. 2000 May;19(5):391-403.

40. Ning R, Chen B, Yu R, Conover D, Tang X, Ning Y. Flat panel detector-based cone-beam volume CT angiography imaging: system evaluation. IEEE Trans Med Imaging. 2000 Sep;19(9):949-63.

41. Ning R, Chen B, Conover D, McHugh L, Cullinan J, Yu R. Flat-panel detector-based cone-beam volume CT breast imaging: preliminary phantom study. in Presented at Proceedings of SPIE - The International Society for Optical Engineering. 2001 Jun.

42. Zhong J, Ning R, Conover D. Image denoising based on multiscale singularity detection for cone beam CT breast imaging. IEEE Trans Med Imaging. 2004 Jun;23(6):696-703.

43. Yu H, Ye Y, Zhao S, Wang G. A backprojection-filtration algorithm for nonstandard spiral cone-beam CT with an n-PI-window. Phys Med Biol. 2005 May 7;50(9):2099-111.

44. Kyriakou Y, Kachelriess M, Knaup M, Krause JU, Kalender WA. Impact of the z-flying focal spot on resolution and artifact behavior for a 64-slice spiral CT scanner. Eur Radiol. 2006 Jun;16(6):1206-15.

45. Schäfer D, Borgert J, Rasche V, Grass M. Motion-compensated and gated cone beam filtered back-projection for 3-D rotational X-ray angiography. IEEE Trans Med Imaging. 2006 Jul;25(7):898-906.

46. http://3dorthodontist.com/CBCT_Machines.html

47. Ngan DC, Kharbanda OP, Geenty JP, Darendeliler MA. Comparison of radiation levels from computed tomography and conventional dental radiographs. Aust Orthod J. 2003 Nov;19(2):67-75.

48. Ludlow JB, Davies-Ludlow LE, Brooks SL. Dosimetry of two extraoral direct digital imaging devices: NewTom cone beam CT and Orthophos Plus DS panoramic unit. Dentomaxillofac Radiol. 2003 Jul;32(4):229-34.

49. Ludlow JB, Davies-Ludlow LE, Brooks SL, Howerton WB. Dosimetry of 3 CBCT devices for oral and maxillofacial radiology: CB Mercuray, NewTom 3G and i-CAT. Dentomaxillofac Radiol. 2006 Jul;35(4):219-26. Erratum in: Dentomaxillofac Radiol. 2006 Sep;35(5):392.

50. Lofthag-Hansen S, Thilander-Klang A, Ekestubbe A, Helmrot E, Gröndahl K. Calculating effective dose on a cone beam computed tomography device: 3D Accuitomo and 3D Accuitomo FPD. Dentomaxillofac Radiol. 2008 Feb;37(2):72-9.

51. Baba R, Konno Y, Ueda K, Ikeda S. Comparison of flat-panel detector and image-intensifier detector for cone-beam CT. Comput Med Imaging Graph. 2002;26(3):153–8.

52. Baba R, Ueda K, Okabe M. Using a flat-panel detector in high resolution cone beam CT for dental imaging. Dentomaxillofac Radiol. 2004;33(5):285–90.

53. Scarfe WC, Farman AG. What is cone-beam CT and how does it work? Dent Clin North Am. 2008 Oct;52(4):707-30.

54. Miles DA, Danforth RA. A Clinician's Guide to Understanding Cone Beam Volumetric Imaging (CBVI). http://www.ineedce.com/

55. Danforth RA, Miles D. Cone Beam Volume Imaging (CBVI): 3D Applications for Dentistry. http://www.learndigital.net/

56. Danforth RA, Clark DE. Effective dose from radiation absorbed during a panoramic examination with a new generation machine. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2000 Feb;89(2):236-43.

57. Gibbs SJ. Effective dose equivalent and effective dose: comparison for common projections in oral and maxillofacial radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2000 Oct;90(4):538-45.

58. Pell GJ, Gregory GT. Report on a ten year study of a tooth division technique for the removal of impacted teeth. Am J Orthod. 1942 Nov;28(11):660-666

59. Bell GW, et al. The accuracy of dental panoramic tomographs in determining the root morphology of mandibular third molar teeth before surgery. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2003 Jan;95(1):119-25.

60. Nakamori K, et al. Clinical Assessment of the Relationship Between the Third Molar and the Inferior Alveolar Canal Using Panoramic Images and Computed Tomography. J Oral Maxillofac Surg. 2008 Nov;66(11):2308-13.

61. Nakayama K, Nonoyama M, Takaki Y, Kagawa T, Yuasa K, Izumi K, Ozeki S, Ikebe T. Assessment of the relationship between impacted mandibular third molars and inferior alveolar nerve with dental 3-dimensional computed tomography. J Oral Maxillofac Surg. 2009 Dec;67(12):2587-91.

62. Tantanapornkul W, Okouchi K, Fujiwara Y, Yamashiro M, Maruoka Y, Ohbayashi N, Kurabayashi T. A comparative study of cone-beam computed tomography and conventional panoramic radiography in assessing the topographic relationship between the mandibular canal and impacted third molars. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007 Feb;103(2):253-9.

63. Suomalainen A, Ventä I, Mattila M, Turtola L, Vehmas T, Peltola JS. Reliability of CBCT and other radiographic methods in preoperative evaluation of lower third molars. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2010 Feb;109(2):276-84.

64. Ghaeminia H, Meijer GJ, Soehardi A, Borstlap WA, Mulder J, Bergé SJ. Position of the impacted third molar in relation to the mandibular canal. Diagnostic accuracy of cone beam computed tomography compared with panoramic radiography Int J Oral Maxillofac Surg. 2009 Sep;38(9):964-71.

65. Neugebauer J, Shirani R, Mischkowski RA, Ritter L, Scheer M, Keeve E, Zöller JE. Comparison of cone-beam volumetric imaging and combined plain radiographs for localization of the mandibular canal before removal of impacted lower third molars. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008May;105(5):633-42.

66. Sakabe J, Kuroki Y, Fujimaki S, Nakajima I, Honda K. Reproducibility and accuracy of measuring unerupted teeth using limited cone beam X-ray CT. Dentomaxillofac Radiol. 2007 Jan;36(1):2-6.

67. Blaeser BF, August MA, Donoff RB, Kaban LB, Dodson TB. Panoramic radiographic risk factors for inferior alveolar nerve injury after third molar extraction. J Oral Maxillofac Surg. 2003 Apr;61(4):417-21.

68. Bell GW. Use of dental panoramic tomographs to predict the relation between mandibular third molar teeth and the inferior alveolar nerve. Radiological and surgical findings, and clinical outcome. Br J Oral Maxillofac Surg. 2004 Feb;42(1):21-7.

69. Valmaseda-Castellón E, Berini-Aytés L, Gay-Escoda C. Inferior alveolar nerve damage after lower third molar surgical extraction: a prospective study of 1117 surgical extractions. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2001 Oct;92(4):377-83.

70. Chuang SK, Perrott DH, Susarla SM, Dodson TB. Age as a risk factor for third molar surgery complications. J Oral Maxillofac Surg. 2007 Sep;65(9):1685-92.

71. Szalma J, Lempel E, Jeges S, Szabó G, Olasz L. The prognostic value of panoramic radiography of inferior alveolar nerve damage after mandibular third molar removal: retrospective study of 400 cases. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2010 Feb;109(2):294-302.

BIOGRAPHY

NAME	Mr. Natakorn Sae-Ngow	
DATE OF BIRTH	8 August 1983	
PLACE OF BIRTH	Bangkok, Thailand	
INSTITUTIONS ATTENDED	2008	Doctor of Dental Surgery (DDS) Mahidol University, Thailand
	2009-2011	M.Sc. (Dentistry), Major OMS Mahidol University, Thailand
HOME ADDRESS	27, Soi Maha Wong Thai, Din Deang Road, Din Deang District, Bangkok 10400, Thailand	
CONTACT E-MAIL	klvzth@hotmail.com	
JOB EXPERIENCE	2008-present	General practitioner, Major OMS private hospital