CHARACTERISTICS OF MAXILLARY SINUS SEPTA USING CONE BEAM CT

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ABSTRACT

This retrospective study was based on the analysis of cone beam computed tomography (CT) images of the patients who visited the Oral and Maxillofacial Radiology Clinic, Faculty of Dentistry, Mahidol University. The sample population was 203 patients; 92 males and 111 females with a mean age of 46.6 years, ranging between 20 to 84 years. The aim of the study was to find and analyze the characteristics of maxillary sinus septa including prevalence, location, height and orientation.

The prevalence of maxillary sinus segments with septa was 32.75% (94 of 287 total sinuses) and 36.45% (74 of 203 patients). Thirty-one point three five percent (88 of 272) septa were detected in dentate/partially edentulous (PE) ridge whereas 40% (6 of 15) were found in completely edentulous (CE) ridge. There were no significant differences of the prevalence of septa between the two groups (PE & CE ridge). The anatomical location of septa demonstrated that 22% (22 septa) were located in the anterior region, 26% (26 septa) in posterior region, and a greater prevalence of 52% (52 septa) were in the middle region. Septa height measurement varied in different locations. The mean height of the septa was 5.87 ± 3.01 mm in the medial area, 5.15 ± 2.69 in the middle area, and 4.73 ± 2.51 in the lateral area respectively.

All surgical intervention in the posterior maxillary region require detailed knowledge of the patient's maxillary sinus and any anatomical variation such as the septa in order to determine the exact planning of surgery and to avoid unnecessary complications.

KEY WORDS: MAXILLARY SINUS SEPTA/ CONE BEAM CT/
DENTAL IMPLANT

41 pages

การประเมินคุณลักษณะของโพรงอากาศแม็กซิลลาโดยการใช้ภาพรังสีโคมบีมซีที
CHARACTERISTICS OF MAXILLARY SINUS USING CONE BEAM CT

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บทคัดย่อ

การศึกษาข้อมูลย้อนหลังนี้เกี่ยวกับการวิเคราะห์ภาพถ่ายรังสีโคนบีมซีทีของผู้ป่วยที่คลินิกรังสีวิทยาช่องปากและแม็กซิลโลเฟเชียล คณะทันตแพทยศาสตร์ มหาวิทยาลัยมหิดล ในช่วงมกราคม 2556 ถึง มิถุนายน 2557 โดยมีกลุ่มตัวอย่าง 203 คน (ชาย 92 คน หญิง 111 คน อายุระหว่าง 20 ถึง 84 ปี ค่าเฉลี่ย 46.6 ปี) โดยทำการวิเคราะห์คุณลักษณะของผนังกั้นโพรงอากาศแม็กซิลล่าในด้าน ความชุก ตำแหน่ง ความสูง และทิศทางการวางตัว

พบความชุกของผนังกั้นโพรงอากาศแม็กซิลลา 94 จาก 287 โพรงอากาศ (ร้อยละ 32.75) ในคนไข้ 74 คนจากกลุ่มตัวอย่างทั้งหมด (ร้อยละ 36.45) โดยพบผนังกั้นโพรงอากาศแม็กซิลลาร้อยละ 31.20 ในกลุ่มคนไข้สันเหงือกมีฟันหรือไร้ฟันบางส่วนในขณะที่พบ ร้อยละ 40 ในกลุ่มคนไข้สันเหงือกไร้ฟันสมบูรณ์ โดยพบว่าไม่มีความแตกต่างอย่างมีนัยสำคัญระหว่างกลุ่ม 2 กลุ่มผู้ป่วย ในส่วนตำแหน่งของผนังกั้นนั้น พบในบริเวณด้านหน้า ร้อยละ 22 ด้านหลัง ร้อยละ 26 และพบมากที่สุดในตำแหน่งกึ่งกลางร้อยละ 52 ความสูงของผนังกั้น แตกต่างกันไปในแต่ละตำแหน่ง โดยมีค่าเฉลี่ยที่ 5.87 ± 3.01 มม. ในตำแหน่งใกล้กลาง 5.15 ± 2.69 ในตำแหน่งกึ่งกลาง และ 4.73 ± 2.51 ในตำแหน่งไกลกลางตามลำดับ

การผ่าตัดในบริเวณส่วนหลังของขากรรไกรบนจำเป็นต้องทราบข้อมูลของผู้ป่วยและมีความรู้เกี่ยวกับโพรงอากาศแม็กซิลลารวมถึงกายวิภาคที่อาจผันแปรไปเช่นการปรากฏของผนังกั้นโพรงอากาศ เพื่อที่จะกำหนดและวางแผนการรักษาในการผ่าตัดและหลีกเลี่ยงอาการแทรกซ้อนที่อาจเกิดขึ้นได้

41 หน้า

CONTENTS

CONTENTS (cont.)

LIST OF TABLES

LIST OF FIGURE

LIST OF ABBREVIATIONS

CT	Computed Tomography
CBCT	Cone Beam Computed Tomography
3D	Three-dimensional
MPR	Multi-planar reformatted
CE	Completely edentulous
PE	Partially edentulous

CHAPTER I
INTRODUCTION

1.1 Significance of problem

Nowadays, dental implant is widely used as a treatment option for solving partial and complete edentulism. The use of osseointegrated implants is now safe, efficient, and considered as a reliable way to improve quality of life for the patients.[1, 2] The survival rate and the success rate of implant treatment depend on several factors are more than 95%.[3, 4] However, implant treatment could be complicated if alveolar bone volume is insufficient.

Implant placement in atrophic posterior maxilla is challenging, because after tooth loss, the edentulous of alveolar process still resorbs continuously and leads to deficiency of vertical bone dimension.[2, 5] The proximity of maxillary sinus to the alveolar ridges is caused by sinus pneumatization, in addition to resorption of the alveolar ridge due to tooth extraction. This phenomenon varies from one individual to another and even from side to side.[6-8] Preprosthetic surgical procedures, for example, alveolar bone grafting and sinus floor elevation is necessary for treatment of dental implants in such patients.[9] This technique increases the vertical bone support and allows anchorage for dental implants in the atrophic posterior maxillary region.

Nowadays, the maxillary sinus floor elevation has been considered a relatively safe procedure. Autogenous bone graft and many different subantral grafting materials have been used over decades. However, severe complications including perforation of the Schneider's membrane, hemosinus, oroantral fistula, and sinusitis may occur during and after the surgical procedure.[10, 11]

The perforation of the Schneider's membrane is the most frequent complication during sinus floor elevation, and in some studies, the prevalence offer complication about 30%.[9, 12] Generally this complication is associated with the presence of maxillary sinus septa that may make it difficult to prevent tearing of the Schneider's membrane. This anatomical variation was first described by Underwood

in 1910 (also call Underwood's septa). They are walls of cortical bone within maxillary sinus that divide the floor of maxillary sinus into several compartments.[13] Krennmair et al. further categorized the septa into primary and secondary septa, with the primary septa arising from the development of the maxilla, while the secondary septa were described to arise from the irregular pneumatization of the sinus floor following tooth loss. Moreover, the septa may have different heights and orientations.[7, 14]

Understanding and knowledge of the maxillary sinus anatomy and the possible anatomical variations such as its prevalence, location and morphology is necessity for the success of the sinus lift operation. Thus, an exact and definitive radiological evaluation is required.[15, 16] Previously dental panoramic radiography, computed tomography (CT) and cone beam computed tomography (CBCT) have been used to identify the maxillary sinus septa.[5-7, 14-17] Study based on panoramic imaging can only approximate the size and location of the septa because of the two-dimensional nature of radiograph.[18] Using CT imaging generate three-dimensional data; however, the resolution of CT imaging is anisotropic and the effective dose of radiation is relatively high.[19] Today, CBCT imaging is an integrated diagnostic tool to assess sinus anatomy before dental implant treatment.[9] CBCT imaging comes up with high resolution isotropic volumetric data with high geometric accuracy at a low effective radiation dose than CT.[20, 21]

The prevalence of maxillary sinus septa varies from 16 to 58% in the literature.[6, 7, 13, 15, 16] The location of septa was mostly in the posterior region of sinus distal to the third molar roots described by Underwood.[13] However, some studies presented a higher prevalence of septa in middle region, from distal area of the second premolar to the distal area of the second molar.[15, 22] Recently, literature reviews further study on the topic of septa height predominant septa in gender as well as prevalence comparison in dentate and edentulism but still controversy.[23, 24]

All the surgical intervention in the posterior maxillary region require detailed knowledge of patient's maxillary sinus anatomy and any irregularities of the maxillary sinus floor such as these septa in order to determine exact planning of surgery and help to avoid unnecessary complication. Thus, the purpose of this study is to evaluate the characteristics of maxillary sinus septa in a group of Thai population by using CBCT.

1.2 Research question:

1.2.1 What are the characteristics including prevalence, location, height, and morphology of maxillary sinus septa?

1.2.2 Are there relationship or differences between the prevalence of maxillary sinus septa and the variables of the sex, the age group, and the type of alveolar ridge (dentate/partially edentulous versus completely edentulous segment)?

1.3 Research objectives:

1.3.1 To evaluate the characteristics of maxillary sinus septa

1.3.2 To evaluate the relationship or differences between the prevalence of maxillary sinus septa and the variables of the sex, the age group, and the type of alveolar ridge.

1.4 Research hypothesis:

There is no relationship or differences between the prevalence of maxillary sinus septa and the variables of the sex, the age group, and the type of alveolar ridge.

1.5 Significance of the study

This study may provide the surgeon understand the characteristics and anatomical variation of maxillary sinus. Moreover, using 3D radiographic assessment before sinus floor elevation can help to decrease complication during the procedures.

CHAPTER II
LITERATURE REVIEW

2.1 Maxillary sinus septa

Maxillary sinus septa or Underwood's septa are the projections of cortical bone which tend to partially or in some cases completely divide the floor of maxillary sinus into two or multiple chambers known as posterior recesses.[16, 25] These bony septa were presented by Underwood AS[13] in 1910, an anatomist at King's Collage London. Their shape has been described as an inverted gothic arch that originated from the inferior and rise for lateral walls of the sinus and coming to a sharp edge along its most apical border.[13, 16, 26] (Fig2.1)

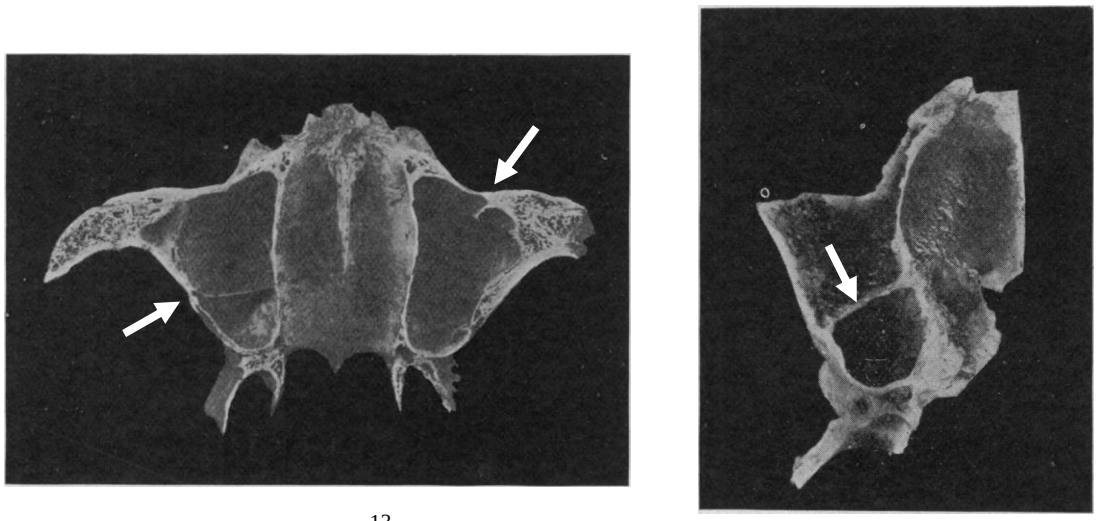

Fig. 2.1 Maxillary sinus septa[13]

The presence of maxillary sinus septa has been described in various hypotheses by several studies.[13, 14, 27, 28] Underwood reported septa arising between areas of two neighboring teeth and usually showed in three specific regions of the sinus floor, thus dividing the floor into three basins: anterior, between the second premolar and first molar roots; middle, between the first and the second molar roots; and posterior, distal to the third molar roots. Each basin follows to different periods of tooth development and eruption phases. He also found that the formation of septa may

be linked to the various phase of pneumatization.[13] Neivert proposed that the septa are derived from the fingerlike projections produced by the embryonic out-pouching of the ethmoid infundibulum, where the contiguous walls did not resorb.[27] Krennmair et al. classified the maxillary sinus septa into primary and secondary septa, for the primary septa originating from the development of maxilla, while the secondary septa were causing by the irregular pneumatization of the sinus floor after the loss of posterior teeth.[14] van der Bergh et al. proposed that septa distribute a masticatory force by carrying the struts during the dentate phase of life but that they seem to disappear slowly when teeth are lost.[29] Wen et al. further categorized into three groups based on the location, number, orientation, and size of antral septa; easy situations (class E), moderate situations (class M), and difficult situation (class D) as shown Table 2.1.[28] However, the true mechanism responsible for maxillary sinus septum development is still uncertain.

Table 2.1 Sinus septum classification[28]

Classification/ subclass	**Location**	**No. of septa**	**Orientation**	**Size (mm)**
Easy (E)				
a	Anterior to zygomatic process	1	Mediolateral	≤ 6
b	Anterior to zygomatic process	1	Mediolateral	> 6
Moderate (M)				
a	Posterior to zygomatic process	1	Mediolateral	≤ 6
b	Posterior to zygomatic process	1	Mediolateral	> 6
Difficult (D)				
a	Anterior or posterior to zygomatic process	1	Antero-posterior	≤ 6
b	Anterior or posterior to zygomatic process	1	Antero-posterior	> 6

Table 2.1 Sinus septum classification[28](cont.)

Classification/ subclass	Location	No. of septa	Orientation	Size (mm)
Difficult (D)				
c	Anterior or posterior to zygomatic process	2+	Mediolateral	

Estimate of the prevalence of maxillary sinus septa varies from 16 to 58%, most commonly taking the form of a single unilateral septum.[6, 7, 13, 15, 16] Ulm et al. stated that the prevalence of maxillary sinus septa depending on patient age and tooth loss.[30] According to the literature, the average height of septa is about 8 mm, with possible values up to 17 mm.[31] They are usually thicker at the base on the sinus floor, and then thin out in the middle. Krennmair and coworkers observe the mean height of 7.7 mm for septa identified in edentulous maxilla and 12.2 mm for the septa in dentate maxilla.[14]

The most common location of sinus septa reported by Underwood was the posterior region of sinus[13] whereas Krennmair reported the majority of septa in the anterior region of sinus both edentulous maxilla and dentate maxilla.[14] Velasquez-plata et al. found that septa can be found in all parts of the maxillary sinus, mainly medio-laterally. They are thin and are partly developed vertically. They are generally higher on the medial of the sinus and are rarely found in multiple formation.[26]

Previously, these septa were considered to be an anatomical variations without clinically-significant.[32] However, during the recent years, the “sinus lift” or “sinus elevation” surgical technique has become a new method of anchoring endosseous implants in atrophic posterior maxilla.[33] Following of creation of a window in the lateral sinus wall, elevation of a hinge door and Schneider’s membrane of the alveolar recess and subsequent placement of either autogenous bone grafts or bone substitutes lead to an augmentation of the prospective placement site.[30, 34] However, the perforation of Schneider’s membrane is the most complication during sinus floor elevation. This complication is associated with the presence of maxillary sinus septa because of the tight attachment of the membrane to the septa wall.

Moreover, when the lateral wall of sinus is opened in only one part of a sinus divided by septa, it is very difficult to insert bone graft material into the other part.[9, 12, 35] Therefore, it is essential that knowledge of sinus anatomy and any irregularities of the maxillary sinus floor such as these septa should be identified preoperatively in order to decrease the risk of sinus membrane perforation during sinus lift surgery.

2.2 Imaging for maxillary sinus septa

The available residual alveolar ridge in the maxillary molar region is limited superiorly by the floor of maxillary sinus. Assessment of the extent of this structure, including the location of septa is important in determining the bone volume available for implant placement and the possible need for bone supplementation procedure, such as sinus lift and bone augmentation.[36, 37] Thus, radiographic imaging is prerequisite to evaluate anatomical complexity in order to approach the most appropriate treatment before surgical procedure.

Intraoral radiograph: Using the parallel technique can provide information on available bone height and floor of maxillary sinus. Maxillary septa sometimes present in this image as the radiopaque lines that project a few millimeters away from the floor and the wall of the antrum. However, this technique is limited by size of images and must be concerned for image geometrical distortions if the film is not placed parallel to the long axis of the ridge and/or if the x-ray beam is not perpendicular to the film.[38, 39] Therefore, using intraoral radiograph alone cannot be suitably evaluated on maxillary sinus septa.

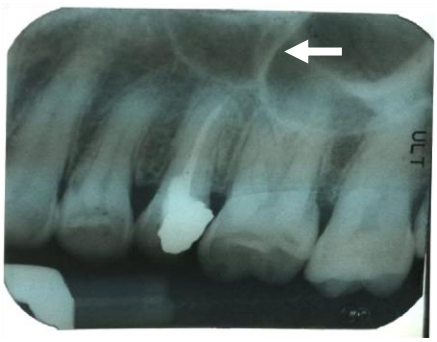

Fig 2.2 Presence of maxillary sinus septum from periapical film (arrow)

Panoramic radiograph: This image is one of the most usually utilized radiographic techniques in implant treatment. Panoramic radiograph is not only a relatively low radiation dose, it also offers important data about the form of maxillary sinus, about the form of the alveolar bone relative to the sinus floor, and about any pathological processes that may affect implant treatment.[38, 40] However, there are some disadvantages that limit the accuracy and reliability of this calculation. For example, (1) no cross-sectional images are created, and the insights gained (e.g. into the presence of septa), (2) surgeon need to watch out for artifact, distortion and blurred images.[37, 38, 40] Krennmiar et al. demonstrated the limitations of panoramic radiograph by showing and inability to correctly identify the presence or absence of maxillary sinus septa in 21.3% of the cases evaluated.[7] Kasabah et al. studied the accuracy of panoramic radiograph in the definition of maxillary sinus septa and concluded that this image can only approximate the size and location of the septa because of the two-dimensional information.[18] Some authors reported that three dimensional imaging techniques are found superior for evaluating changes in the maxillary sinus. They found that the detection of maxillary sinus septa in panoramic imaging was lower prevalence compared to three dimensional imaging.[41, 42]

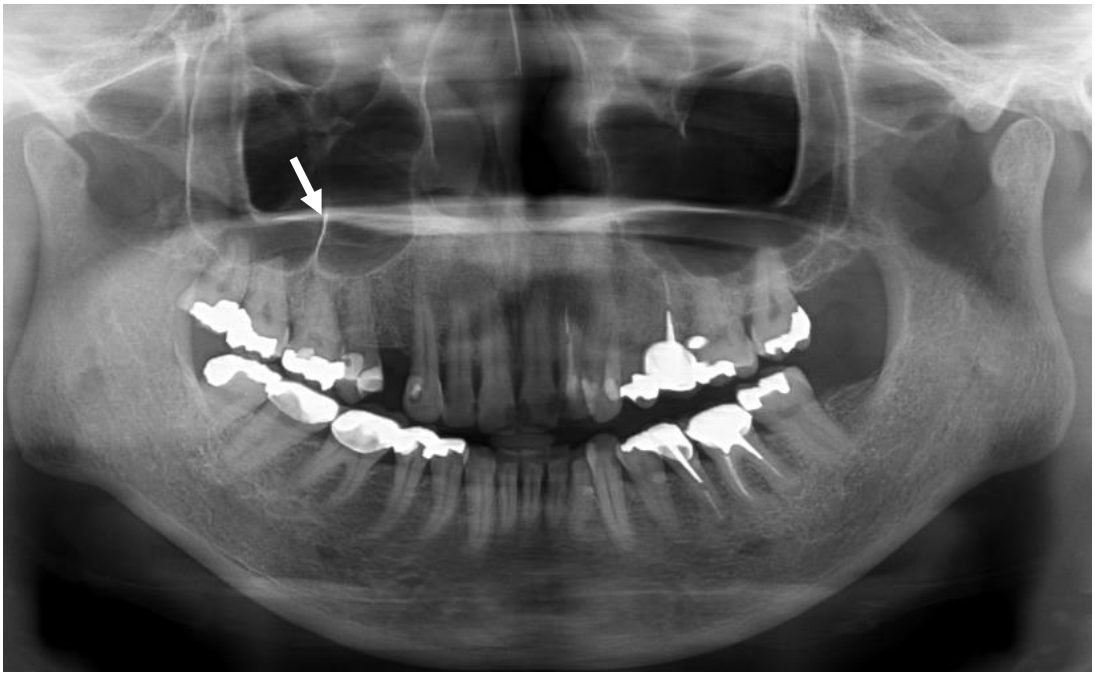

Fig. 2.3 Panoramic radiograph shows septum at right maxillary sinus (arrow).

Three-dimensional radiograph (CT and CBCT): These diagnostic assessments have a decisive value in presurgical treatment planning, particularly in situations in which the alveolar process has severe resorption, and therefore insufficient bone volume for placing dental implants such as in the atrophic posterior maxilla cases which associated with maxillary sinus structure. These situations can now be succeeded via maxillary sinus augmentation procedures.[43] In these cases, diagnostic imaging, especially using three-dimensional radiography, plays a crucial role, provides reliable and necessary information.[44]

CT consists of multiple image slices, acquired by finely collimated flat and fan beams rotating around the subject in a helical pattern whereas CBCT images are achieved by a diverging cone/pyramidal-shaped beam rotating around the subject once.[38, 45] CT information is typically obtained with the patient in a supine position, by contrast, a sitting or standing position is preferred for most CBCT scans.

2.3 CBCT for maxillary sinus septa

Both CT and CBCT techniques have been shown to have sufficient accuracy for evaluation the sinus and its structural variation in the patients with atrophic posterior maxilla who need to be treated with augmentation of maxillary sinus floor before placing implants. [38, 46] However, CBCT provides some advantages for diagnostic value compared to CT. In most cases, CBCT will offer adequate three-dimensional information on sinus anatomy to plan for sinus floor elevation procedure at a reasonably lower absorbed radiation doses and cost than CT. Standard dental protocol scans using traditional CT delivers 1.5–12.3 times greater radiation than comparable medium field of view dental CBCT scans.[21] Moreover, CBCT generates high-resolution isotropic volume data. Visualization quality of the maxillary sinus anatomy and bony structures are usually well depicted.[40, 47] While spatial resolution of CT imaging is anisotropic, that is the resolution is not equivalent for all three dimension in space. The resolution of CT per slice can be less than 1 mm whereas the spacing between slices is frequently in the range of a millimeter or more. If the spatial orientation of a structure to be imaged is known, this can be compensated by orientating the structure while it is being imaged. However, the orientation of septa is

not known in advance, therefore, compensation is not an option, and the sensitivity of CT imaging to subtle septa could be reduced.[36] Orhan et al. evaluated the maxillary sinus septa from CBCT in children and adult.[6] They concluded that CBCT was a powerful tool for generating 3-dimensional measurements of the area and also with less ionizing radiation.

In addition, some CBCT systems compete with panoramic radiography in terms of low volumetric 3D data. With carefully selected equipment, CBCT could be used instead of panoramic radiography in implant planning, as patients would only be exposed a single dose of radiation (CBCT) rather than two doses (panoramic radiography followed by CT scanning).[38]

CHAPTER III
RESEARCH METHODOLOGY

3.1 Study design

The study design was retrospective study.

3.2 Study population

This study was based on an analysis of CBCT images for posterior maxilla which were collected from the patients who visited at the Oral and Maxillofacial Radiology Clinic, Faculty of Dentistry, Mahidol University, Bangkok, Thailand during the period of January 2013 to June 2014.

3.3 Sample size calculation

The requires sample size estimation was based on the following formula

$$n = \frac{Z^2_{\alpha/2} P(1-P)}{E^2}$$

n = Required sample size

Z = Confidence level 95% (1.96)

P = Estimated prevalence (25% septa in Korea)[2]

E = Estimated margin of error (5% = 0.05)

$$n = \frac{1.96^2 \times 0.25 \times (1-0.25)}{0.05^2} = 288$$

3.4 Inclusion criteria

1. CBCT imaging of patients 20 years of age or older in the posterior maxillary area extended from the lateral wall of the nasal cavity to the posterior wall of maxillary sinus

3.5 Exclusion criteria

1. CBCT imaging with inadequate information (e.g. the field of images did not cover to maxillary alveolar bone)
2. Bone pathology presence
3. Signs of previous operation (e.g. alveolar bone augmentation)

3.6 Research instruments

1. 3D Accuitomo® 170 machine (3D Accuitomo, J Morita MFG. Corp., Kyoto, Japan) (Fig. 3.1)
2. Statistical software (SPSS version 18)

Fig. 3.1 3D Accuitomo® 170 machine (3D Accuitomo, J Morita MFG. Corp., Kyoto, Japan)

3.7 Ethic issue

This retrospective study was approved and accepted as certificate of exemption by the Institutional Review Board (IRB) and the Ethical committee on human right of Mahidol University (COE. No. MU-DT/PY-IRB 2014/025.2907) before the study had begun. The protocol was done under the guidance of Oral and Maxillofacial Radiology Department, Faculty of Dentistry, Mahidol University.

3.8 Data collection

All cases of the patient evaluation were examined and measured once by graduate student under the instruction of an experienced radiologist. 3D images in axial, sagittal, coronal and reconstructed panoramic view were used for evaluation of the presence of septa.

In this study, the direction and location of maxillary sinus septa were investigated at the floor of sinus. Each sinus cavity that presented a septum was divided into three locations (Fig. 3.2a-c): anterior (mesial to distal aspect of the second premolar), middle (from the distal aspect of the second premolar to the distal aspect of the second molar, and posterior (the distal aspect of the second molar region). To detect the course and to measure the exact height of the septa in the sinus, 2 mm thickness reconstructed panoramic images were employed. These images were derived from drawing the MPR (multi-planar reformatted) spline on the axial slice (Fig 3.3). The heights of septa were measured in three regions along the course of the septa across the sinus floor: the medial, middle, and lateral aspects. The middle aspect was measured using the middle section of the reconstructed panoramic image. For example, if the image is reconstructed in to 16 sections, the average height of 8^{th} and 9^{th} section will be inferred. If the image is reconstructed in to 15 sections, the 8^{th} section will be inferred as middle. For medial and lateral aspects, the 2^{nd} to first section and the 2^{nd} to last section will be inferred so as to reduce the error. Measurement of vertical dimension of maxillary sinus septa, a line drawn at the approximate base of the septa is established and its height is measured using a line extending from this base to the most coronal portion of the septa[26] (Fig. 3.4).

The relevant statistical data, namely sex, age, appearance of septum or septa, number of septa, height, direction, locations of septa on each maxillary sinus floor in dentate, partially edentulous, and fully edentulous maxilla alveolar ridge were recorded.

Fig 3.2a Maxillary sinus septum at anterior location

Fig 3.2b Maxillary sinus septum at middle location

Fig 3.2c Maxillary sinus septum at posterior location

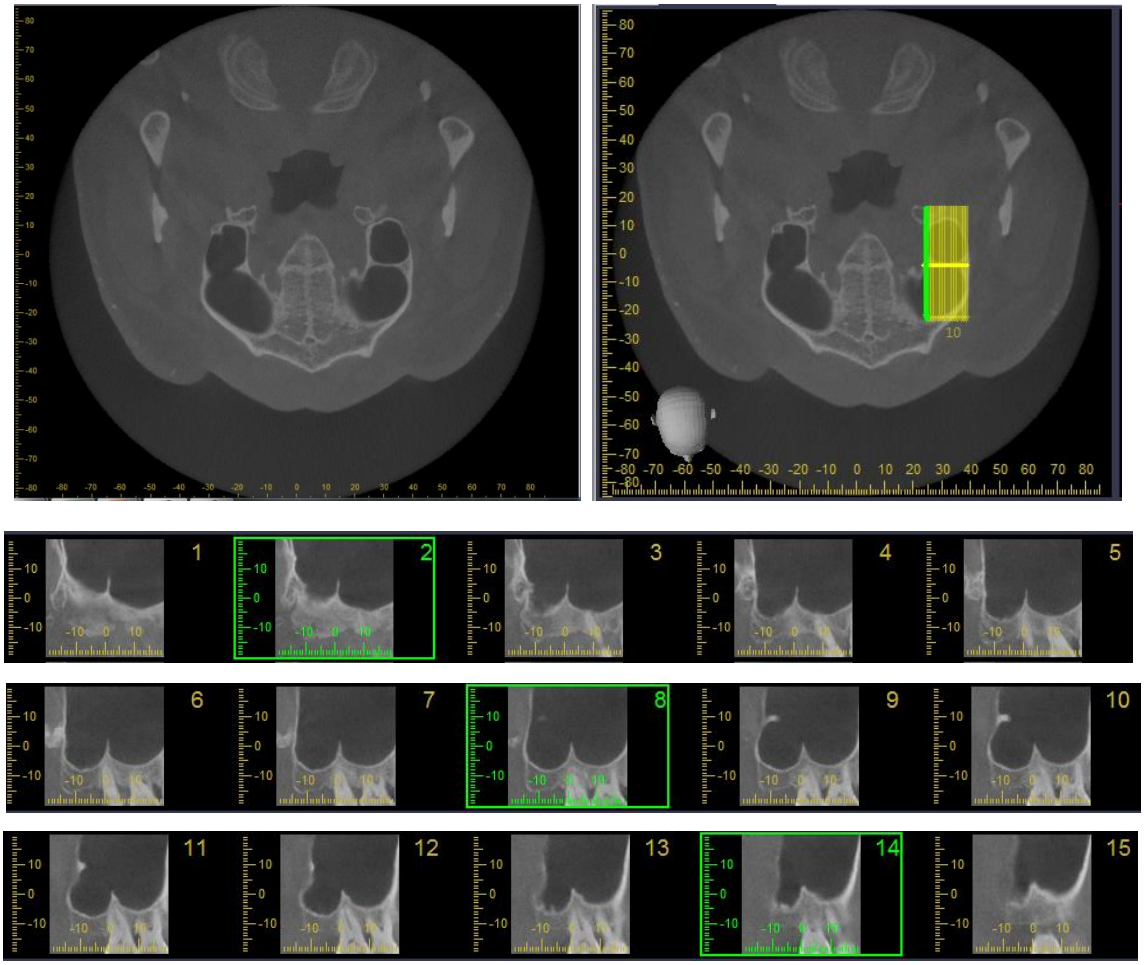

Fig 3.3 The heights of septa were measured in three regions along the course of the septa across the sinus floor: the medial, middle, and lateral aspects.

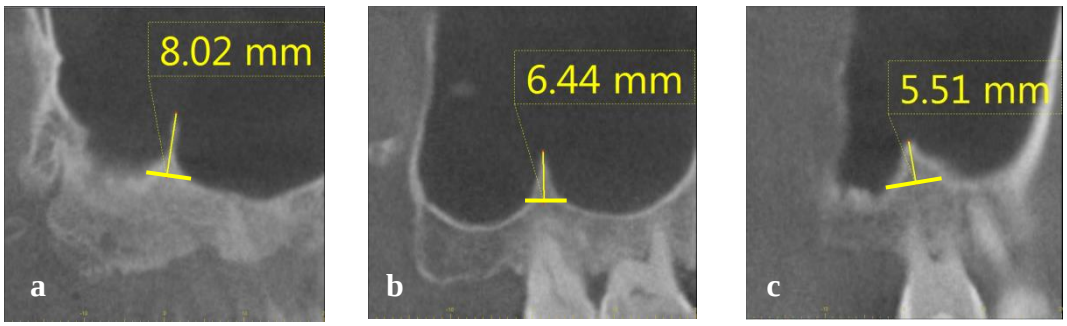

Fig 3.4 Measurement of vertical dimension of maxillary sinus septa, a line drawn at the approximate base of the septa is established and its height is measured using a line extending from this base to the most coronal portion of the septa (a. septum height at medial aspect, b septum height at middle aspect, and c septum height at lateral aspect).

3.9 Data analysis

After collecting all the information, statistical analyses were interpreted using the t-tests to examine whether there are significant differences between the prevalence of maxillary sinus septa and the variables of sex. In addition, chi-square analysis was employed to interpret the data between the prevalence of maxillary sinus septa and the variables of age groups. P-values less than 0.05 are selected as the statistical significance. Further, data of height were collected and thereafter interpreted using t-test with P-value less than 0.05 to examine whether there are significant differences among locations.

CHAPTER IV
RESULTS

This study was based on a retrospective analysis of CBCT images for posterior maxilla which were collected from the patients of the Oral and Maxillofacial Radiology Clinic, Faculty of Dentistry, Mahidol University, Bangkok, Thailand. Results were divided into following parts:

1. Patients data and the prevalence of maxillary sinus septa
2. Orientation of maxillary sinus septa
3. Morphology of maxillary sinus septa
4. Location of maxillary sinus septa
5. Height of maxillary sinus septa
6. Uncommon orientation of maxillary sinus septa

4.1 Patients data and the prevalence of maxillary sinus septa

CBCT imaging for posterior maxilla was obtained on a total of 240 patients during the period of January 2013 to June 2014. However, 37 of 240 patients were excluded (Table 4.1) because of bone pathologic appearance or signs of previous operation e.g. alveolar bone augmentation.

Table 4.1 Summary of excluded patients

	Number
Bone pathology in the maxillary sinus	9
Previous operation	4
Patient age < 20 years	24
Total	37

The data and prevalence of maxillary sinus septa were shown in table 4.2. Total number of 287 sinuses was obtained from 203 patients (92 males and 111 females). 74 patients (36.45%) present one or more sinus septa: 33 of 92 in males and 41 of 111 in females. Ages of population in this study range from 20 to 84 years (mean 46.56 ± 17.53 years) classified into 3 groups. The first group (73 of 203 patients) is the patients whose ages range from 20 to 40 years old, the second group is the patients whose ages range from 41 to 60 years old, and the last group is the patients whose ages are more than 60 years old. The prevalence of septa was found in 28 out of 73 (38.36%) patients in the first group, and the septa in the second group were demonstrated as 29 out of 87 (35.38%) patients, and finally the prevalence of septa was shown as 17 out of 43 (39.53%) patients in the last group. The different prevalence of septa between sex and ages of patient were compared. However, no significant differences (P-value > 0.05) were found between the groups.

The prevalence of sinus segments with septa was found 94 of 287 sinuses (32.75%) as shown in table 4.3. Septa were detected 88 of 272 (31.35%) in dentate/partially edentulous ridge whereas in completely edentulous ridge were found 6 of 15 (40.00%). The different prevalence of septa between dentate/partially edentulous and completely edentulous segments was compared. However, no significant differences (P-value > 0.05) were found between two groups.

Table 4.2 Summary of patient data and presence of septa

	Number	**No. of sinus segment with septa (%)**	**P-value**
Sex			
Male	92	33 (35.87)	0.88
Female	111	41 (36.94)	
Total	203	74 (36.45)	
Age			
20 - 40 years	73	28 (38.36)	
41-60 years	87	29 (33.33)	0.72
more than 60 years	43	17 (39.53)	
Total	203	74 (36.45)	

Table 4.3 The prevalence of sinus segments with septa

	Number of sinus segment	**No. of sinus segment with septa (%)**	**P-value**
Sinus			
Dentate/partial edentulism	272	88 (31.35)	0.52
Complete edentulism	15	6 (40.00)	
Total	287	94 (32.75)	

The number of septum or septa per maxillary sinus is shown in table 4.4. One septum (Fig 4.1) prevalence is 88.30% (83 out of 94 sinuses), and two septa (Fig 4.2) prevalence is 11.70% (11 out of 94 sinuses).

Table 4.4 Distribution of septa in maxillary sinus segment

No. of septa/sinus	No. of sinus	CE	Dentate/PE	Septa
1 septum/sinus	83(88.30%)	5	78	83
2 septa/sinus	11(11.70%)	1	10	22
Total	94(100%)	6	88	105

CE = Complete edentulism, PE = Partial edentulism

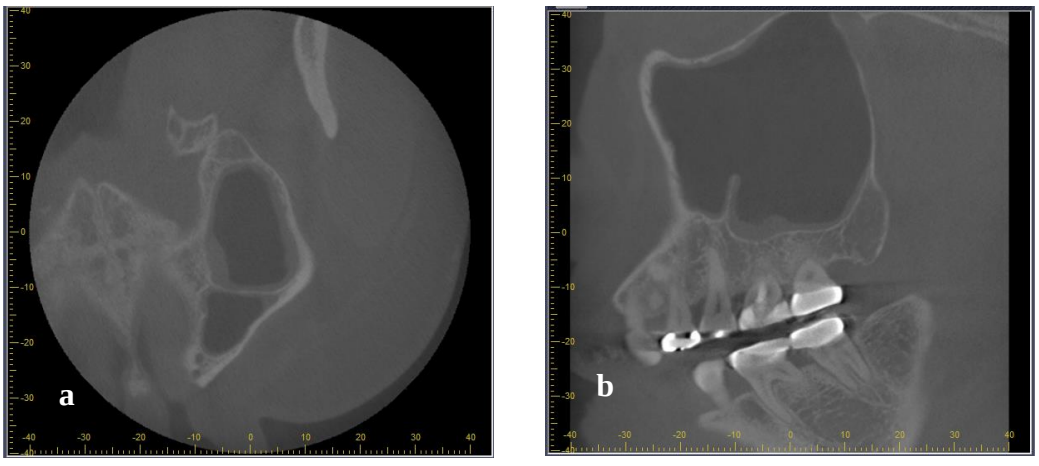

Fig 4.1 one septum per maxillary sinus

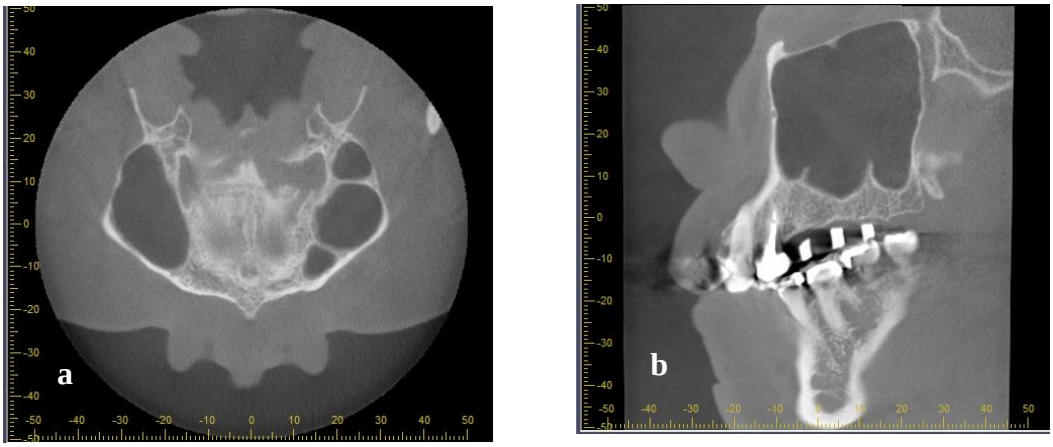

Fig 4.2 two septa per maxillary sinus

4.2 Orientations of maxillary sinus septa

The most orientation of septa was often buccolingual type, arising from the inside and extending to the outside of the sinus (Fig. 4.3). Nevertheless, 3 sinuses were found with orientation of 5 septa uncommon type. Author has put these uncommon septa aside from calculated statistical data since author cannot locate, nor measure precise values from these 5 septa, and have explained case by case in 4.6 section.

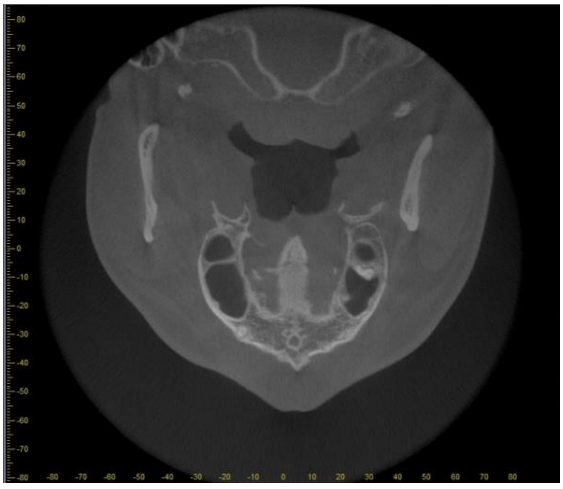

Fig. 4.3 Orientation of maxillary sinus septa; buccolingual type

4.3 Morphology of maxillary sinus septa

From 100 in our study, complete and incomplete septa are found in 93 and 7 sites respectively (Table 4.5).

Table 4.5 Morphology of maxillary sinus septa

Morphology of septum	No. of septa
Complete	93
Incomplete	7
Total	100

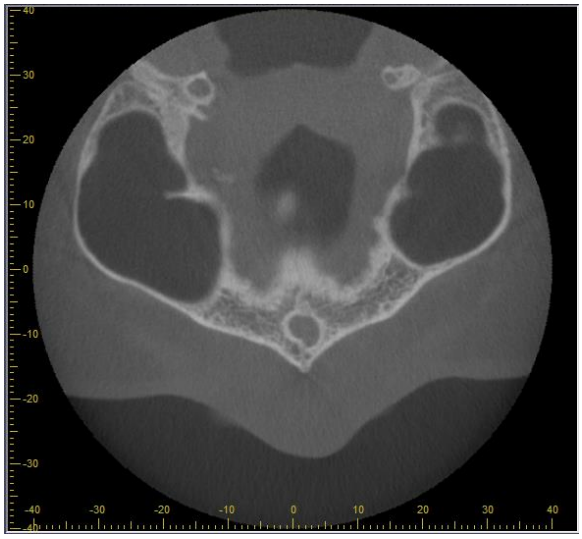

Fig 4.4 Incomplete septum

4.4 Location of maxillary sinus septa

The analysis of anatomical location of septa demonstrated that 22 septa (22.00%) were located in the anterior region, 26 septa (26.00%) in posterior regions, and greater prevalence 52 septa (52.00%) in the middle region (Table 4.6). The distributions of septa in completely and partially edentulous regions were compared. A deeper examination of dentate/partially edentulous population (Table 4.7) showed 60 of 93 septa (64.52%) prevalence of septa located apical to a maxillary tooth (primary septa), and 33 of 93 (35.48%) of septa located apical to an edentulous ridge (other septa).

Table 4.6 Summary of Septa Location Data

	Location prevalence n (%)			
	Anterior	Middle	Posterior	N septa
CE maxillary segment	2	4	1	7
Dentate/PE maxillary segment	20	48	25	93
Total	22 (22.00%)	52 (52.00%)	26 (26.00%)	100

CE = Completely edentulous, PE = Partially edentulous

Table 4.7 Summary of Septa Location Data in dentate/partially edentulous maxillary segment

	Location prevalence n (%)			
	Anterior	Middle	Posterior	N septa
Primary septa	14	31	15	60
Other septa	6	17	10	33
Total	20 (21.51%)	48 (51.61%)	25 (26.88%)	93

Primary septa = septa located apical to maxillary root; other septa = septa located apical to edentulous maxillary ridge

4.5 Height of maxillary sinus septa

Septal height measurement of each individual varied among different locations. The height ranged from 0 to 21.05 mm. The mean height of the septa was 5.87 ± 3.01 mm in the medial area, 5.15 $\pm$ 2.69 in the middle area, and 4.73 $\pm$ 2.51 in the lateral area respectively (Table 4.8). Comparing the mean values of septal height in dentate/partially edentulous with complete edentulous areas, the septal height of dentate/partially edentulous regions is statistically significant higher values at every point of measurement. When the septa demonstrated in partially edentulous regions were classified into those at the apices of the remaining teeth (primary septa) and those in the proximity of edentulous areas, the primary septa were found to be higher at all measured point (Table 4.9). However, no statistically significant differences (P-value > 0.05) were demonstrated.

Table 4.8 Summary of septal height measurement

	Height (mm) (mean ± SD)			
	Medial	Midpoint	Lateral	N septa
CE maxillary segment	4.57 ± 1.54	4.11 ± 1.29	3.09 ± 1.33	7
Dentate/PE maxillary segment	6.12 ± 3.13*	5.31 ± 2.75*	4.94 ± 2.88*	93
Total	5.87 ± 3.01	5.15 ± 2.69	4.73 ± 2.51	100

CE = Completely edentulous, PE = Partially edentulous

* The differences were statistically significant ($P < 0.05$)

Table 4.9 Summary of septal height measurement in dentate/partially edentulous maxilla

	Height (mm) (mean ± SD)			
	Medial	Midpoint	Lateral	N septa
Primary septa	5.98 ± 2.72	5.57 ± 2.68	4.88±2.93	60
Other septa	5.92 ± 2.75	4.70 ± 2.65	4.70±3.19	33
Total	6.12 ± 3.13	5.31 ± 2.75	4.94 ± 2.88	93

Primary septa = septa located apical to maxillary root; other septa = septa located apical to edentulous maxillary ridge

4.6 Uncommon orientation of maxillary sinus septa

Case 1 Oblique septum

From the panoramic image (Fig. 4.5) of female partial edentulous patient at the age of 60 years old, septum originated from the floor of left sinus in the middle region (first molar area) was found in the vertical direction with 13.07 mm of height. However, after investigating CBCT image (Fig 4.6), the septum is found in the oblique direction from anterolateral aspect to posteromedial aspect. The height of this septum gradually decreases from 10.92 mm to 6.85 mm.

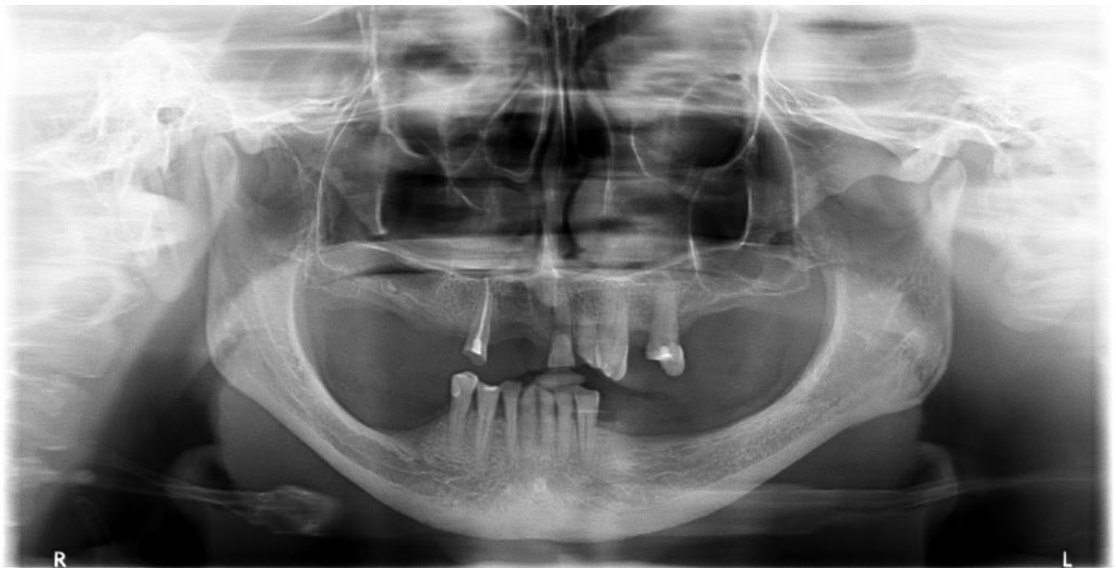

Fig. 4.5 Septum at right maxillary sinus from panoramic image (case 1)

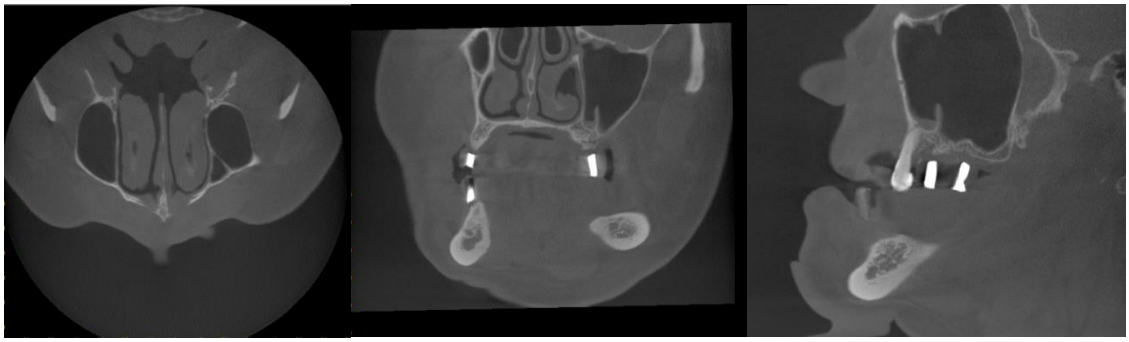

Fig. 4.6 Right oblique septum from CBCT image (case 1)

Case 2 Sagittal septum

From the panoramic image (Fig 4.7), complete septum was found on each side of maxillary sinus in male dentate patient at the age of 21 years old. They are both originated from the root of second premolar to the roof of sinuses. When coronal views of CBCT images were investigated, both septa also showed complete vertical orientation from anterior to posterior wall of sinuses. After axial view was examined, the length of right septum orientating from the anterior to the posterior wall of sinus was 20 mm (Fig. 4.8). On the other hand, the orientation of left septum was approximately one-fourth (9.44 mm) of the distance between anterior wall and posterior wall of sinus (Fig 4.9).

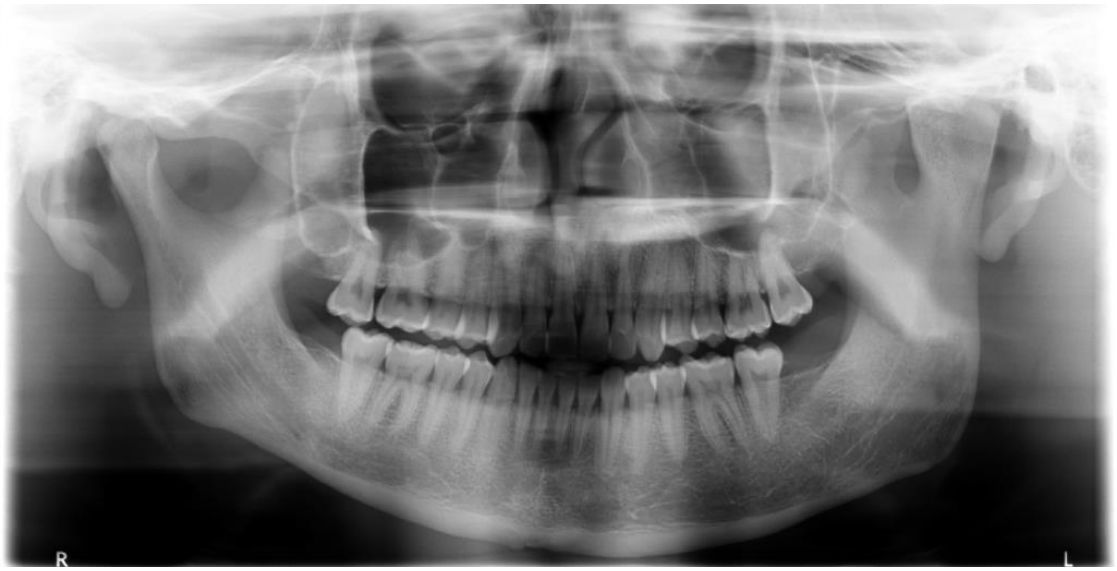

Fig. 4.7 Septum at right maxillary sinus from panoramic image (case 2)

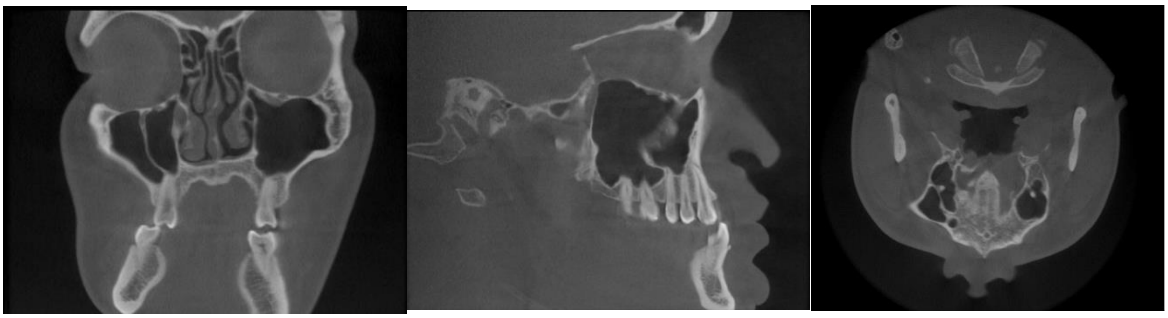

Fig. 4.8 Right sagittal septum from CBCT image (case 2)

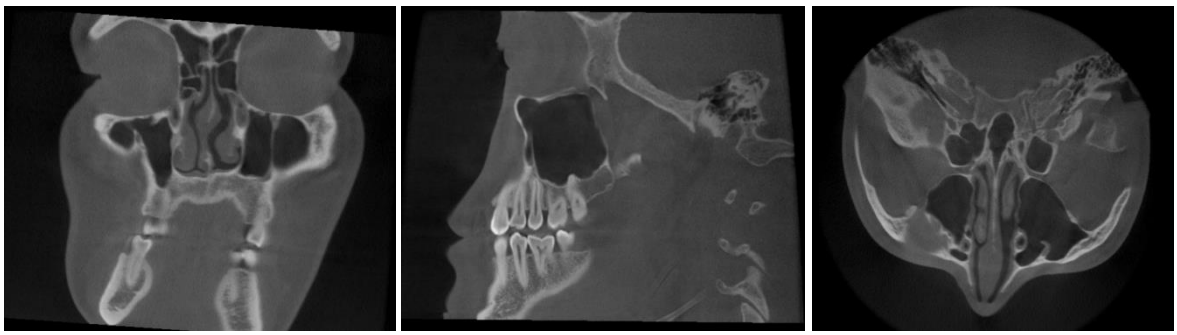

Fig. 4.9 Left sagittal septum from CBCT image (case 2)

Case 3 Complex septa

The septa in left maxillary sinus were found in 2 directions (Fig 4.10) in this 41 years old female patient. From the CBCT image, the first septum is in buccolingual direction arising from the floor of sinus at the mesiobuccal root of the first molar. The height of the septum gradually increases from 2.23 mm in lateral region to 4.47 mm in medial region.

Another septum is in the anteroposterior direction intersecting with the first septum at the middle of the first septum, and is extended to the position of palatal root of second molar. It is originated from the middle of sinus floor (see coronal view), and then gradually bends towards medial part. The average height of this septum is 6.74 mm.

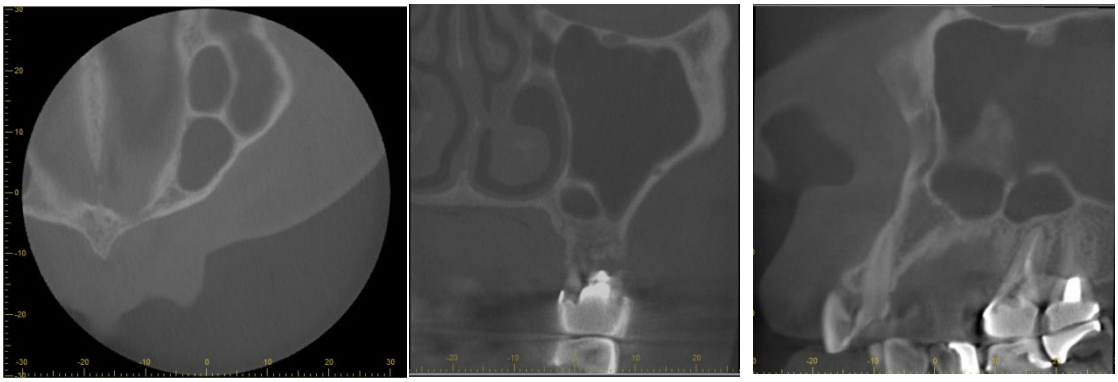

Fig. 4.10 Left complex septa from CBCT image (case 3)

CHAPTER V
DISCUSSION

The prevalence of septa in the maxillary sinus observed in this study (32.40%) is in agreement with other studies which vary from 16 to 58% calculated by the total of sinuses which have septa or on the total of patients who have septa.[5, 6] In this study, the prevalence of one or more of maxillary sinus septa was found to be 94/287 (32.75%) in the total study population: 6/15 in the completely edentulous population, and 88/272 in the dentate/partially edentulous population. In the partially edentulous population, the septa located apical to a maxillary tooth were classified as primary septa and those located apical to edentulous ridge were classified as other septa. The prevalence of septa between dentate/partially edentulous and completely edentulous segments shows no significant difference. This result is in contrast to the previous study by Kim et al.[15], which reported a significantly higher prevalence in edentulous segments than in dentate maxillary segments. One factor that affects in this study is limited sample size of complete edentulous patients.

The location of septa found in our study shows the majority in the middle region (52.00%), followed by posterior region (26.00%), and anterior region (22.00%). This outcome agrees with the result of previous study.[5, 26] Chanavaz et al.,[10] hypothesizing that because maxillary molars are often lost easier than premolars, the different phases of maxillary sinus pneumatization result in formation of antral septa. On the contrary, the study by Krennmair et al.[14] showed a higher septa prevalence in the anterior region (70-75%). Differences between the results obtained from different studies may reflect variability between methods of measurement, data gathering tool, and variation among populations studied. Nevertheless, Stover[48] criticized these conclusions that a greater prevalence of septa in the posterior segments resulting from remnant interradicular bone between adjacent maxillary molar, i.e., secondary septa, would be more likely. According to Underwood's hypothesis, there is the possibility that septa formation may be associated with time of tooth eruption, and therefore most

of the septa were in posterior segment because posterior septa are the last to develop, and they would remain for a longer period of time because of their decreased exposure time to resorptive mechanism.

Morphologically, the septa presented mostly buccolingual orientation. Their anatomic shape can be compared to an inverted gothic arch. The average height of the septa in the medial area was higher than that of lateral area. In this study, the primary septa in partially edentulous region tend to be higher than the other septa and the completely edentulous region which corresponds to the recent study by Kim et al.[15] They reported the septa in the non-atrophic/dentate maxillary segment were significantly higher than the septa in the atrophic/edentulous maxillary segment as a result of their growth and because they were not affected by the resorption of maxillary alveolar process.

The relation between the presence of septa and sex, there are difference results between authors. Neugebauer et al.[36] found that no correlation between sex and the incidence of maxillary sinus septa whereas Shen et al.[5] and Lee et al.[2] reported that the prevalence of septa was higher in men significantly. Van der Bergh et al.[29] proposed that septa distribute a masticatory force to the skull, which might offer a reason for higher septa prevalence in males. In terms of age, the prevalence of septa has no relation with the age.

The association between the presence of septa and type of edentulism; some studies reported a higher prevalence of septa in totally edentulous/atrophic areas than in partially edentulous/non-atrophic ones, with statistically significant differences.[14, 26] Kim et al.[15] stated that this is because edentulous/atrophic maxillary segments generally contain secondary septa.

Radiographic examination is crucial for evaluation of available bone and anatomical structure in posterior maxillary region.[38] Patients who have inadequate bone height for implant placement need to increase bone supplementation procedure such as sinus lift and bone augmentation. Assessment of maxillary sinus complexity including septum/septa should be precisely investigated by proper imaging.[35, 49] Panoramic imaging can only approximate the presence of septa because of the limitation of its two-dimensional radiographs and overprojected and distorted defect.[36] Three-dimensional imaging modalities are found superior to panoramic one for

evaluating changes in the maxillary sinus. Therefore, lower detection of the septa incidence were found through panoramic imaging comparing to three-dimensional imaging.[41, 42]

Several authors have studied the prevalence of maxillary sinus septa varies from 16 to 58% based on either the number of sinuses or the number of patients.[5, 6] This difference could be attributed to the difference between the radiographic examinations.[6] Compared with three-dimensional imaging (CT and CBCT), assessments of sinus septa using two-dimensional panoramic radiographs demonstrate incorrect results in 29% of cases. There is possibility that sinus septa orientation may not be detectable from panoramic radiograph, and may thus lead to invalid assumption of the actual septa presence. For example, in this study, 3 cases of uncommon septa orientation were detected in the CBCT images, but not in panoramic images.

The clinical significance of primary or secondary septa depends on their location, morphology, height, and type of surgery performed.[14] During sinus augmentation surgery, the sinus membrane is elevated and the floor is augmented with either autologous or xenogenic bone grafts.[30, 34] If septa are exist on the sinus floor Boyne and James[50] recommend cutting them with a narrow chisel and removing them with a hemostat so that the bone graft can be placed over the whole floor without interruption. Tidwell et al.[51] subdivided the facial bony wall into an anterior and a posterior part and inverted both trap doors. Septa left in situ can be removed after preparation. Actually, their removal is preferable, because a septum left in situ might tear the maxillary sinus membrane during elevation. One of the possible complications associated with perforations of the sinus membrane is the development of maxillary sinusitis.[52, 53] Therefore, a modification of the conventional surgical procedure is required when septa are presented in order to decrease unexpected complication during the operation.[54]

Nonetheless, for the cases of uncommon septa orientation, 3 cases in this study, sinus augmentation surgery for implant placement comes with significant risk of underlying complications. In certain condition, the sinus augmentation may not be a possible solution. Further study for management of uncommon septa orientation should be conducted.

CHAPTER IV
CONCLUSION

The characteristics of maxillary sinus septa are varied anatomically in each patient in the prevalence, morphology, location, and orientation. Therefore, dentist must have detailed knowledge of patient's maxillary sinus anatomy and any its irregularities. The limitation of two dimensional radiograph may lead to inaccuracy information for studying anatomy of maxillary sinus and its variation. Using appropriate radiograph like three-dimensional imaging can reduce a misdiagnosis and provide better information to avoid the complications during sinus floor elevation. In this study, only the result of maxillary sinus septa from the CBCT imaging was interpreted and actual clinical supporting evidence is deficient. Therefore, further clinical studies of characteristics of maxillary sinus and its anatomical variation is required.

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APPENDICES

APPENDIX A

สำนักงานคณะกรรมการจริยธรรมการวิจัยในคน
ประจำคณะทันตแพทยศาสตร์และคณะเภสัชศาสตร์
มหาวิทยาลัยมหิดล โทร ๐๒-๒๐๐-๗๖๒๒

ที่ ศธ ๐๕๑๗.๐๓๑๙/จธ. ๓๖๖
วันที่ ๑ สิงหาคม ๒๕๕๗
เรื่อง แจ้งผลการพิจารณาโครงการวิจัย
เรียน ทพ.ระพีพันธุ์ วิญญูปกรณ์
สำเนาเรียน ๑) อ.ดร.นพ.ทพ.บวร คลองน้อย
๒) บัณฑิตวิทยาลัย

ตามที่ ท่านได้ส่งโครงการวิจัยเรื่อง "การประเมินคุณลักษณะของผนังกั้นโพรงอากาศแม็กซิลล่าโดยการใช้ภาพรังสีโคนบีมซีที (Characteristics of Maxillary Sinus Using Cone Beam CT)" รหัสโครงการ MU-DT/PY-IRB 2014/DT049 มาเพื่อขอรับการพิจารณารับรองจากคณะกรรมการจริยธรรมการวิจัยในคนฯ นั้น

คณะกรรมการจริยธรรมฯ ได้พิจารณาโครงการวิจัยนี้มีความเห็นว่า โครงการวิจัยนี้เป็นการศึกษาคุณลักษณะและความชุกของผนังกั้นโพรงอากาศแม็กซิลล่า รวมทั้งประเมินความสัมพันธ์ระหว่างความชุกของผนังกั้นโพรงอากาศแม็กซิลล่ากับตำแหน่ง เพศ กลุ่มอายุ สันเหงือกมีฟัน และสันเหงือกไร้ฟัน โดยใช้ภาพรังสีโคนบีมซีทีจากคลินิกรังสีวิทยาช่องปากและใบหน้าขากรรไกร คณะทันตแพทยศาสตร์ มหาวิทยาลัยมหิดลของผู้ป่วยที่มีอายุตั้งแต่ ๒๐ ปีขึ้นไป ในช่วงเดือนมกราคม ๒๕๕๕ ถึง มิถุนายน ๒๕๕๗ โดยเจ้าหน้าที่ภาควิชารังสีวิทยาช่องปากและแม็กซิลโลเฟเชียลเป็นผู้สืบค้นข้อมูลและทำการปิดชื่อ นามสกุล และเลขทะเบียนของผู้ป่วยแล้วจึงนำมาให้ผู้วิจัยศึกษา จึงไม่สามารถเชื่อมโยงไปถึงเจ้าของภาพรังสีได้ ดังนั้นโครงการวิจัยนี้จึงจัดอยู่ในประเภทโครงการวิจัยที่ไม่ต้องผ่านการพิจารณาจากคณะกรรมการจริยธรรมการวิจัยในคนฯ ตามแนวทางสำหรับคณะกรรมการจริยธรรมการวิจัยในคนฯ (MU-DT/PY-IRB) Version 2 : 12/03/2014 หมวดที่ ๒ ข้อ ๓) โครงการวิจัยโดยใช้ข้อมูลที่เก็บอยู่แล้วในคลังไม่ใช่การเก็บข้อมูลใหม่ และได้ทำการลบข้อมูลส่วนบุคคลออกแล้ว (anonymized data) โดยได้ออกเอกสารยืนยันการยกเว้นการรับรอง (Certificate of Exemption) มาพร้อมนี้ และขอให้ท่านเริ่มดำเนินการวิจัยนี้ได้

จึงเรียนมาเพื่อโปรดทราบ

(รศ.ดร.ชลธชา ห้านิรัติศัย)
ประธานคณะกรรมการจริยธรรมการวิจัยในคน
ประจำคณะทันตแพทยศาสตร์และคณะเภสัชศาสตร์ มหาวิทยาลัยมหิดล

APPENDIX B

Certificate of Exemption

COE. No. MU-DT/PY-IRB 2014/025.2907

Documentary Proof of Faculty of Dentistry/Faculty of Pharmacy, Mahidol University, Institutional Review Board

Title of Project: Characteristics of Maxillary Sinus Using Cone Beam CT.
Project Number: MU-DT/PY-IRB 2014/DT049
Principle Investigator: Dr. Rapeepun Winyupakorn
Name of Institution: Faculty of Dentistry
Date of Recommendation: July 29, 2014

Faculty of Dentistry/Faculty of Pharmacy, Mahidol University, Institutional Review Board is in full compliance with International Guidelines for Human Research Protection such as Declaration of Helsinki, the Belmont Report, CIOMS Guidelines and the International Conference on Harmonization in Good Clinical Practice (ICH-GCP)

Signature of Chair:

(Associate Professor Dr.Choltacha Harnirattisai)
Chair

Office of Faculty of Dentistry/Faculty of Pharmacy, Mahidol University, Institutional Review, Board
The 50th Anniversary of HRH Princess Mahachakri Sirindhorn Building, 11st Floor, Faculty of Dentistry,
Mahidol University, 6 Yothi Street, Rajthevi, Bangkok 10400, THAILAND Tel: (662)-200-7622

APPENDIX C

สำนักงานคณะกรรมการจริยธรรมการวิจัยในคน
ประจำคณะทันตแพทยศาสตร์และคณะเภสัชศาสตร์
มหาวิทยาลัยมหิดล โทร ๐๒-๒๐๐-๗๖๒๒

ที่ ศธ ๐๕๑๗.๐๓๑๙/จธ.๒๖๕
วันที่ ๑๑ มิถุนายน ๒๕๕๘
เรื่อง แจ้งผลการพิจารณาการขอปรับเปลี่ยนรายละเอียดโครงการวิจัย
เรียน ทพ.ระพีพันธุ์ วิญญูปกรณ์
สำเนาเรียน อ.ดร.นพ.ทพ. บวร คลองน้อย

ตามที่ ท่านขอปรับเปลี่ยนโครงการวิจัยเรื่อง "การประเมินคุณลักษณะของผนังกั้นโพรงอากาศแม็กซิลล่าโดยการใช้ภาพรังสีโคนบีมซีที (Characteristics of Maxillary Sinus Septa Using Cone Beam CT)" รหัสโครงการ MU-DT/PY-IRB 2014/DT049 นั้น

คณะกรรมการจริยธรรมฯ ได้พิจารณารายละเอียดการปรับเปลี่ยนโครงการวิจัย และรับทราบการปรับเปลี่ยนรายละเอียดโครงการวิจัยเรื่องดังกล่าวแล้ว ตามเอกสารที่แนบมาพร้อมนี้

จึงเรียนมาเพื่อโปรดทราบ

(รศ. ดร.ชลธชา ห้านิรัติศัย)
ประธานคณะกรรมการจริยธรรมการวิจัยในคน
ประจำคณะทันตแพทยศาสตร์และคณะเภสัชศาสตร์ มหาวิทยาลัยมหิดล

APPENDIX D

Documentary Proof of Faculty of Dentistry/Faculty of Pharmacy, Mahidol University, Institutional Review Board

Title of Project: Characteristics of Maxillary Sinus Septa Using Cone Beam CT.
Project Number: MU-DT/PY-IRB 2014/DT049
Type of approval / acceptance: Project Amendment
1. MU-DT/PY-IRB Submission form version 2, June 5, 2015
Principle Investigator: Dr. Rapeepun Winyupakorn
Date of Approval: June 8, 2015

Faculty of Dentistry/Faculty of Pharmacy, Mahidol University, Institutional Review Board is in full compliance with International Guidelines for Human Research Protection such as Declaration of Helsinki, the Belmont Report, CIOMS Guidelines and the International Conference on Harmonization in Good Clinical Practice (ICH-GCP)

Signature of Chair:

(Associate Professor Dr.Choltacha Harnirattisai)
Chair

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PUBLICATION / PRESENTATION	Poster presentation title: Characteristics of Maxillary Sinus Septa Using Cone Beam CT. R. Winyupakorn, B. Klongnoi, R. Arayasantiparb. JADR 2014 The 62nd Annual Meeting of Japanese Association for Dental Research Dec 4th -5th, Osaka, Japan