Evaluation of maxillary sinus on anatomical characteristics and related factors using cone beam computed tomography images

Miss Nutcha Benjaphalakron

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Oral and Maxillofacial Surgery
Department of Oral and Maxillofacial Surgery
FACULTY OF DENTISTRY
Chulalongkorn University
Academic Year 2019

การประเมินลักษณะทางกายวิภาคของโพรงอากาศข้างจมูกและปัจจัยที่เกี่ยวข้องโดยใช้ภาพรังสีโคนบีมซีที

น.ส.ณัฐชา เบญจพลากร

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาศัลยศาสตร์ช่องปากและแม็กซิลโลเฟเชียล ภาควิชาศัลยศาสตร์
คณะทันตแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2562

Thesis Title	Evaluation of maxillary sinus on anatomical characteristics and related factors using cone beam computed tomography images
By	Miss Nutcha Benjaphalakron
Field of Study	Oral and Maxillofacial Surgery
Thesis Advisor	Associate Professor Pornchai Jansisyanont, D.D.S., M.Sc., Ph.D.
Thesis Co Advisor	VANNAPORN CHUENCHOMPOONUT, D.D.S, Ph.D.

Accepted by the FACULTY OF DENTISTRY, Chulalongkorn University in Partial Fulfillment of the Requirement for the Master of Science

.... Dean of the FACULTY OF DENTISTRY

(Assistant Professor SUCHIT POOLTHONG, D.D.S., M.Sc., Ph.D.)

THESIS COMMITTEE

.... Chairman

(Associate Professor ATIPHAN PIMKHAOKHAM, D.D.S, Ph.D.)

.... Thesis Advisor

(Associate Professor Pornchai Jansisyanont, D.D.S., M.Sc., Ph.D.)

.... Thesis Co-Advisor

(VANNAPORN CHUENCHOMPOONUT, D.D.S, Ph.D.)

.... External Examiner

(Associate Professor Sirichai Kiattavorncharoen, D.D.S, M.D., Dr.med)

ณัฐชา เบญจพลากร : การประเมินลักษณะทางกายวิภาคของโพรงอากาศข้างจมูกและปัจจัยที่เกี่ยวข้องโดยใช้ภาพรังสีโคนบีมซีที. (Evaluation of maxillary sinus on anatomical characteristics and related factors using cone beam computed tomography images) อ.ที่ปรึกษาหลัก : รศ. ทพ. ดร.พรชัย จันศิษย์ยานนท์, อ.ที่ปรึกษาร่วม : อ.ทญ. ดร.วรรณาภรณ์ ชื่นชมพูนุท

วัตถุประสงค์: เพื่อศึกษาลักษณะทางกายวิภาคของโพรงอากาศข้างจมูกต่าง ๆ และหาความสัมพันธ์กับปัจจัยที่เกี่ยวข้อง ได้แก่ เพศ อายุ ตำแหน่งฟันและการสูญเสียฟัน โดยใช้ภาพรังสีโคนบีมซีที

วิธีการศึกษา: ภาพรังสีโคนบีมซีทีย้อนหลัง จำนวน 370 โพรงอากาศข้างจมูก หรือ 185 คน จากภาควิชารังสีวิทยา คณะทันตแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย โดยศึกษาลักษณะทางกายวิภาคของโพรงอากาศข้างจมูกต่าง ๆ ได้แก่ ความสูงของสันกระดูก ความหนาผนังด้านข้างของโพรงอากาศข้างจมูก ผนังกั้นโพรงอากาศข้างจมูก หลอดเลือด posterior superior alveolar ความหนาของเยื่อบุโพรงอากาศข้างจมูก และรูเปิดของโพรงอากาศข้างจมูก และหาความสัมพันธ์กับปัจจัยที่เกี่ยวข้อง ได้แก่ เพศ อายุ ตำแหน่งฟันและการสูญเสียฟัน

ผลการศึกษา: พบค่าเฉลี่ยความสูงของสันกระดูกเท่ากับ 12.13 ± 3.64 มิลลิเมตร ค่าเฉลี่ยความหนาผนังด้านข้างของโพรงอากาศข้างจมูกเท่ากับ 2.23 ± 0.95 มิลลิเมตร พบผนังกั้นโพรงอากาศข้างจมูก 22.43% ส่วนใหญ่พบแนวจากด้านแก้มสู่ด้านเพดานปาก 89.13% และพบบริเวณระหว่างฟันกรามบนซี่ที่ 1 ถึงฟันกรามบนซี่ที่ 2 66.3% พบหลอดเลือด posterior superior alveolar 32.16% ซึ่งส่วนใหญ่พบในผนังกระดูก 52.85% และมีขนาดน้อยกว่า 1 มิลลิเมตร 80.31% หลอดเลือดส่วนใหญ่อยู่สูงจากสันกระดูกมากกว่า 15 มิลลิเมตร คิดเป็น 65.28% ค่าเฉลี่ยความหนาของเยื่อบุโพรงอากาศข้างจมูกเท่ากับ 1.3 ± 2.05 มิลลิเมตร พบรูเปิดของโพรงอากาศข้างจมูกไม่อุดตัน 94.05% และส่วนใหญ่พบบริเวณระหว่างฟันกรามบนซี่ที่ 1 ถึงฟันกรามบนซี่ที่ 2 โดยค่าเฉลี่ยระยะรูเปิดของโพรงอากาศข้างจมูกจากพื้นโพรงอากาศข้างจมูกเท่ากับ 30.03 ± 5.08 มิลลิเมตร

สรุป: แม้ว่าลักษณะทางกายวิภาคของโพรงอากาศข้างจมูกมีความสัมพันธ์กับ เพศ อายุ ตำแหน่งฟันและการสูญเสียฟัน แต่ก็มีความหลากหลายแตกต่างกันไปตามแต่ละบุคคล ดังนั้นควรประเมินด้วยภาพรังสีโคนบีมซีทีก่อนการรักษา เพื่อการวางแผนการรักษาอย่างเหมาะสมและหลีกเลี่ยงการเกิดภาวะแทรกซ้อนต่าง ๆ

สาขาวิชา	ศัลยศาสตร์ช่องปากและแม็กซิลโลเฟเชียล	ลายมือชื่อนิสิต ....
ปีการศึกษา	2562	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....
		ลายมือชื่อ อ.ที่ปรึกษาร่วม ....

6175813032 : MAJOR ORAL AND MAXILLOFACIAL SURGERY

KEYWORD: Maxillary sinus, Residual ridge height, Lateral wall thickness, Sinus septa, Posterior superior alveolar artery, Sinus membrane thickness, Ostium, Cone beam computed tomography, Sinus augmentation, Sinus lift

Nutcha Benjaphalakron : Evaluation of maxillary sinus on anatomical characteristics and related factors using cone beam computed tomography images. Advisor: Assoc. Prof. Pornchai Jansisyanont, D.D.S., M.Sc., Ph.D. Co-advisor: VANNAPORN CHUENCHOMPOONUT, D.D.S, Ph.D.

Objective: The aim of this study was to evaluate prevalence of the anatomical characteristics in maxillary sinuses; and its association with sex, age, tooth area and dental status using cone beam computed tomography (CBCT).

Methods: Retrospectively reviewed CBCT images of maxillary sinuses from 370 sinuses in 185 patients at the Faculty of Dentistry, Chulalongkorn University were evaluated. Residual ridge height (RRH), lateral wall thickness (LWT), sinus septa, posterior superior alveolar artery (PSAA), membrane thickness (MT) and ostium were evaluated and compared according to sex, age, tooth area and dental status.

Results: Mean RRH was 12.13 ± 3.64 mm. Mean LWT was 2.23 ± 0.95 mm. Prevalence of septa was 22.43%. The most orientation of the septa was mediolateral (89.13%). Septa was mostly at the first molar and second molar region (66.3%). PSAA were detected in 32.16% and most (52.85%) had an intraosseous location. The diameter was mostly <1 mm (80.31%). Most PSAAs (65.28%) were >15 mm from the alveolar crest. Mean MT was 1.3 ± 2.05 mm. The ostium was mostly patency (94.05%) and located at the first molar and second molar region (95.98%). Mean distance of ostium from the sinus floor was 30.03 ± 5.08 mm.

Conclusion: Although the anatomical characteristics of maxillary sinus related to sex, age, tooth area and dental status, they also had variation. The surgeon should evaluate case by case using CBCT for planning surgery, in order to minimize the risk of complications related to sinus surgery.

Field of Study:	Oral and Maxillofacial Surgery	Student's Signature ....
Academic Year:	2019	Advisor's Signature ....
		Co-advisor's Signature ....

ACKNOWLEDGEMENTS

This research would not have been possible without the ongoing support and guidance of the following people, for which I would like to take this opportunity to thanks.

Firstly, I would like to express my sincere gratitude to my advisor, Associate Professor Pornchai Jansisyanont for the useful concept, comments, patience, motivation, and engagement through the learning process of this master thesis. His valuable advices helped me in all the time of research and writing of this thesis.

Subsequently, my completion of this project could not have been achieved without the supports of my co-advisor, Instructor Vannaporn Chuenchompoonut. Her insightful comments and thorough consultation throughout the project also supported me in developing the project.

Besides, my sincere thanks also go to Assistant Professor Dr. Soranun Chantarangsu for her kindness and advice in statistical analysis.

In addition, I would like to thank to my thesis committee, including Associate Professor Dr. Atiphan Pimkhaokham and Associate Professor Dr. Sirichai Kiattavorncharoen for the useful suggestions and kindness in being committee members.

Finally, I would like to thank all staffs of the Department of Radiology, Faculty of Dentistry, Chulalongkorn University that were kindly for support during this research.

Nutcha Benjaphalakron

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

Chapter I Introduction

1. Title

Evaluation of maxillary sinus on anatomical characteristics and related factors using cone beam computed tomography images

การประเมินลักษณะทางกายวิภาคของโพรงอากาศข้างจมูกและปัจจัยที่เกี่ยวข้องโดยใช้ภาพรังสีโคนบีมซีที

2. Background and Rationale

Maxillary sinus is the paranasal sinus that impacts the maxillofacial surgeons. The presence of the maxillary sinus above the surgical area complicate the installation of implants. As following the loss of upper posterior teeth, bone resorptions cause an expansion of the inferior aspect of the maxillary sinus. (1) That results in inadequate bone height to support dental implant. Accordingly, sinus augmentation or sinus lift is required to elevate the sinus floor for increasing the vertical height, prior to successful implants placement. (2)

The most common complication of sinus lift is perforation of the sinus membrane. The perforation rate was 19.5% (up to 58.3%) and other complications such as excessive bleeding or sinusitis also occurred. (3)

The risk of sinus membrane perforation was increased by the sinus anatomical variations. Post-operative complications such as sinusitis and loss of graft materials may be induced by the sinus membrane perforation. Moreover, Schneiderian membrane is an important structure for containing bone graft. The maxillary sinus septum is one of these variations. The technique of sinus lift may be difficult with a septum. (4, 5) In addition, lateral sinus wall thickness should be considered before sinus augmentation. It is possible to evaluate for minimizing the occurrence of a Schneiderian membrane perforation during an osteotomy. (6)

The other intra-complication is bleeding. Posterior superior alveolar artery (PSAA) must be taken into consideration owing to the potential risk of bleeding during the procedure. Surgery that involves the artery during bony window preparation can lead to bleeding. The vision of surgical field will be concealed by bleeding and the chance of maxillary sinus membrane perforation will increase. (7)

Postoperative complication of sinus augmentation is sinusitis. The reduction of the patency, or complete obstruction ostium associated with the risk of postoperative sinusitis and this can lead subsequently graft failure. (8) Besides, sinus membrane thickness might indicate a higher correlation with sinusitis and is an anatomic factor that effect sinus membrane perforation and cause implant failure. Thick Schneider's membrane more than 2 mm is less prone to perforated during surgery and therefore it reduces the incidence of complication. (9) In addition, Shanbhag et al. found that sinus membrane thickening was a reliable predictor of ostium obstruction. (10)

Although maxillary sinus can be visualized on the Water's view, panoramic radiograph, magnetic resonance imaging (MRI), computed tomography (CT) and cone-beam computed tomography (CBCT). However, CBCT is extremely useful for evaluating bone and provides clear images with highly contrasted structures. It displays maxillofacial anatomy and pathology with 3-dimensional visualization. So, it is well suited for imaging this area. Moreover, the use of CBCT provides more advantages than medical CT. This technique is advantageous on account of its cost-effectiveness, higher resolution, easier operation, lower radiation dose and shorter scan time compared to CT. Since CBCT images were commonly found anatomic variations and lesions of the maxillary sinus. Thus, CBCT is a diagnostic method that suitably assesses the risk and prognosis of treatment. (11-14)

Further to mentioned anatomical characteristics that have surgical relevance with the sinus surgery. Understanding of the anatomic is important when planning surgery. The sufficient knowledge of the maxillary sinus anatomy should be concerned in order to prevention of intra-operative and post-operative complications in sinus augmentation procedure. Previous studies reported various prevalence of anatomical characteristics. (11, 15-42) Moreover, the investigations showed disparate the relation of anatomical structures and sex, age, tooth area and dental status. (6, 11, 15-31, 33, 35-39, 41-49) For this reason, the purpose of this study is to assess prevalence of the anatomical characteristics in maxillary sinus and association with sex, age, tooth area and dental status using cone beam computed tomography (CBCT) images.

3. Research objectives

- The purpose of the present study is to evaluate prevalence of the anatomical characteristics in maxillary sinuses using cone beam computed tomography (CBCT).
- Second purpose is to investigate association of the anatomical characteristics in maxillary sinus with sex, age, tooth area and dental status using cone beam computed tomography (CBCT).

4. Research question

- What is the prevalence of anatomical characteristics in maxillary sinus using cone beam computed tomography (CBCT)?
- Do the anatomical characteristics of maxillary sinus associate with sex, age, tooth area and dental status in cone beam computed tomography (CBCT)?

5. Hypothesis

H_0: There are no significant differences in the anatomical characteristics of maxillary sinuses on sex, age, tooth area and dental status.

H_1: There are significant differences in the anatomical characteristics of maxillary sinuses on sex, age, tooth area and dental status.

6. Conceptual Framework

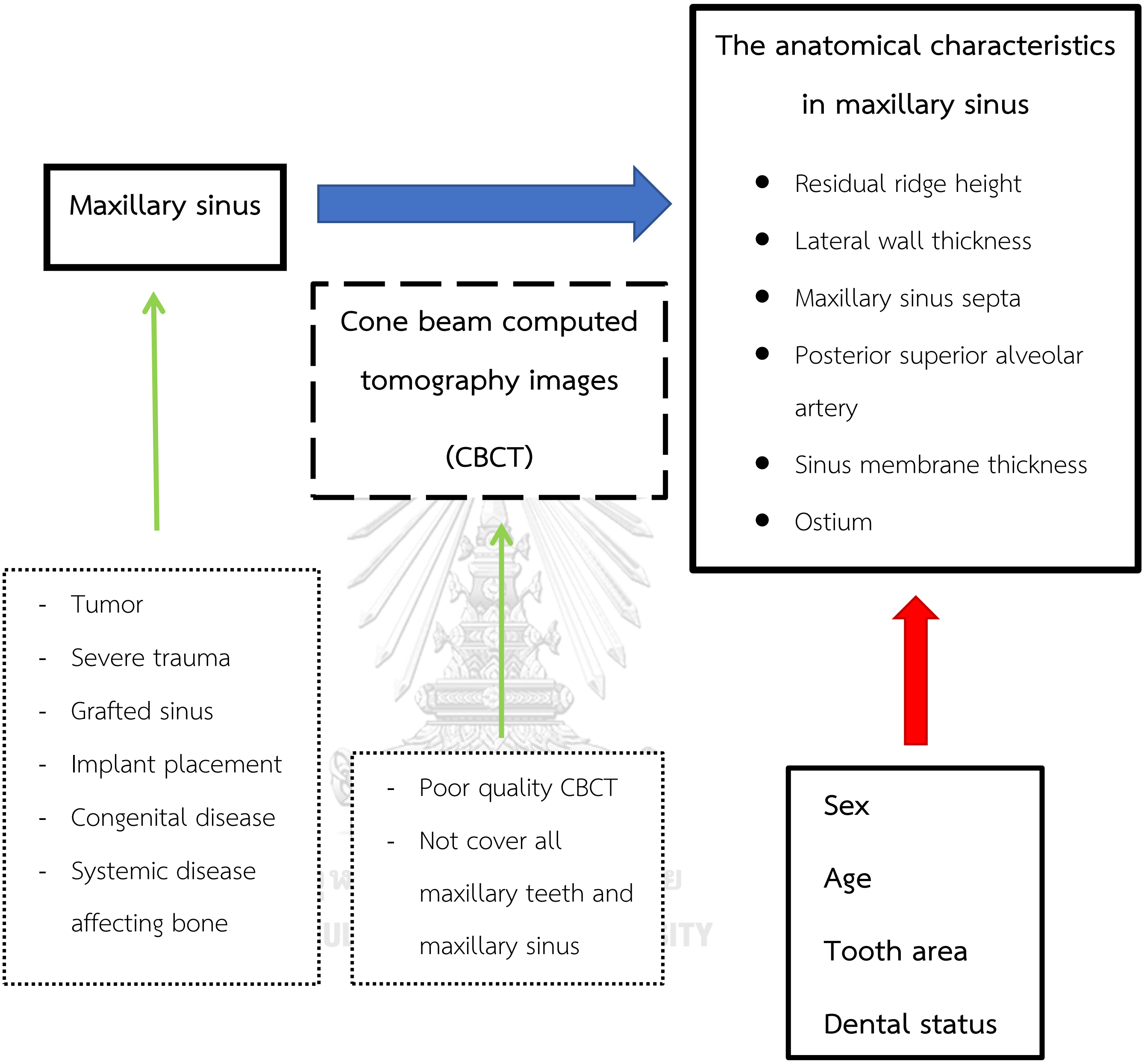

Figure 1 Conceptual framework

7. Keywords

- Residual ridge height, Lateral wall thickness, Sinus septa, Posterior superior alveolar artery, Sinus membrane thickness, Ostium, Cone beam computed tomography, Maxillary sinus, Sinus augmentation, Sinus lift

Chapter II Review of literature

1. Maxillary sinus

The maxillary sinus is a four-sided pyramid. The medial surface is formed by the lateral nasal wall. The floor of the orbit is the roof of the sinus. The posterior wall extends the length of the maxilla and steeps into the maxillary tuberosity. Anterior and lateral wall of the sinus extend to the first premolar or canine teeth. The floor of the sinus is formed by the base of the alveolar process.

The maxillary sinus is lined by respiratory epithelium, a mucus-secreting pseudostratified, ciliated, and columnar epithelium. The opening of maxillary sinus is at the end of the semi-lunar hiatus, which locate in the middle meatus between the inferior and middle nasal conchae of the nasal cavity. The cilia of lining epithelium move the mucus and any foreign material toward the ostium and drain into the nasal cavity. (1)

Blood Supply

The posterior superior alveolar artery (PSAA) and infraorbital artery, the branches of the maxillary artery, supply the lateral sinus wall, Schneiderian membrane and posterior maxillary teeth. (50, 51) The veins accompany the arteries, and drain into anterior facial vein and then to pterygoid plexus of veins. The lymphatic drainage of maxillary sinus is through the infraorbital foramen or through the ostium and then to submandibular and deep cervical lymph nodes. (7)

Nerve Supply

Superior dental nerves (anterior, middle and posterior), and infraorbital nerve supply the maxillary sinus. These are maxillary division branches of trigeminal nerve. (1)

Embryology of maxillary sinus

The maxillary sinuses are the first development of the paranasal sinuses (e.g., maxillary, frontal, ethmoid, and sphenoid). They begin in the third month of fetal development as mucosal invaginations or pouching of the ethmoid infundibula. The initial development or primary pneumatization grows as the invagination expands into the cartilaginous nasal capsule. Secondary pneumatization starts in the fifth month of fetal development.

After birth, the maxillary sinus expands or pneumatizes into the developing alveolar process. It extends from the base of the skull with anterior and inferior direction that match the growth rate of the maxilla and the development of the dentition. The sinus expanded its floor on the same horizontal level as the nasal floor about age 12 - 13 years old. (1) When the permanent teeth completely develop, the maxillary sinuses achieve their mature size about age 20 years old. (52) The sinus normally ceases the expansion after the eruption of permanent teeth, but the pneumatization of sinus will occur after the removal of posterior maxillary teeth and extends into the residual alveolar ridge. The maxillary sinus is significantly larger size in edentulous patients compared with complete dentition patients at posterior maxilla region.(1)

Besides, decreases of maxillary sinus volume or maxillary hypoplasia relate with severe congenital anomalies such as Crouzon syndrome, Apert syndrome and

Cleidocranial dysostosis. (53) In addition, H. Suzuki et al. indicated that maxillary sinusitis related with cleft lip and palate. (54)

2. Maxillary sinus augmentation

Elevation of the maxillary sinus floor was first reported by Boyne in the 1980s. (55) Maxillary sinus augmentation or sinus lift is a technique of bone reconstruction that design to increase the vertical dimension of posterior maxillary alveolar for placement of dental implants. With the evolution of predictable sinus lift methods, this technique has become one of the surgical options allowing installation of dental implants in the posterior maxilla. (2)

The most common complication of sinus lift is the Schneiderian membrane perforation. A systematic review showed the perforation rate was 19.5% (up to 58.3%) and other complications such as excessive bleeding or sinusitis also occur. (3) Although the principles of the sinus lift procedure are simple, several anatomic variations and techniques should be considered to achieve reliable outcomes. Parameters such as lateral wall thickness, presence of sinus septa, alveolar antral artery course, residual bone height, membrane thickness and ostium must be investigated and examined preliminarily.

3. Lateral wall thickness

Lateral window sinus augmentation technique has to prepare the door at this area. The Schneiderian membrane is an important structure for containing the bone graft. Consequently, the lateral sinus wall thickness must be concerned because the Schneiderian membrane can perforate during this procedure. Thick buccal bone requires more time to expose the membrane and overturning the bone window inside the sinus without perforation is challenge. (6) Besides, the thick lateral sinus wall causes difficult to free the sinus membrane because approaching membrane with a deep cleft-like cannot be reached easily by the instruments. (5) Monje et al. showed the lateral wall thickness tended to increase from the second premolar to the second molar and positively correlates with alveolar ridge heights and age. In addition, the thinner the lateral wall found with the longer the edentulous span. (46)

The schneiderian membrane should be maintained intact to contain the graft material and provide a vascular bed for it. Thereby, lateral sinus wall thickness should be considered prior sinus augmentation for minimizing the occurrence of a Schneiderian membrane perforation during osteotomy.

4. Maxillary sinus septa

Maxillary sinus septa are bony ridges in the sinus. Radiating septa vary in individual. The septa extend from the inner to the outer walls and are usually knife edged. The sinus can be divided into 2 cavities or more than 2 cavities by the septa. Opening for sinus lift with only one window may not allow adequate access for bone grafting. The sinus membrane adheres to the septa and the difficulty of membrane elevation was increased. Thereby, pre-existing septa during sinus lift with lateral window technique is affected. (4, 5) Irinakis et al. showed the incidence of membrane perforation with interfering septa was 44.7 %. (25) Low height septa with less than 2 mm do not require additional treatment. (41) The design of the lateral window was influenced by the number, location, size and orientation of the septa. As mention previously the morphology and location of the septa were necessary to concern for the best surgical approach. (4, 5)

Toraman-Alkurt M et al. demonstrated panoramic radiography images detected maxillary sinus septa with low reliability and CBCT images could provide useful information about the presence and location of the septa. (56) In agreement with systematic review study, panoramic radiographs produced 29.3 % incorrect results compared with computed tomography. In panoramic radiographs, the sagittal sinus septum may not be diagnosable and lead to the wrong assumption with narrow sinus anatomy. These may cause no bone graft of the medial aspect of the sinus cavity. (47)

The prevalence of maxillary sinus septa in CBCT images were studied by several authors. The septa's prevalence varies between 20.6 and 66.7 % based on the number of sinuses. (11, 15-21, 24-29, 41, 42) and between 27.2 and 68.4 % based on the number of patients. (15-23, 41)

Qian et al. (15) found significantly greater prevalence rate of septa in the edentulous dentition (57.4%) compared with the dentulous dentition (39.7%) similar to Pommer et al.'s result. (47)

As mention above, it demonstrated the important knowledge of sinus septa morphology in CBCT to avoid complications during surgery and to arrange an accurate treatment plan.

5. Posterior superior alveolar artery

Posterior superior alveolar artery (PSAA) runs though the lateral wall of maxillary sinus and supplies the posterior maxillary teeth, the maxillary sinus and the Schneiderian membrane. Surgical involvement this artery during bony window preparation can lead to bleeding. The surgical field will be obscured by bleeding and the chance of sinus membrane perforation increases. (7) The risk for bleeding is higher with artery larger than 2 mm. Maridati et al. demonstrated that the damaging of PSAA less than 2 mm did not affect the performance of the surgical procedure. (57) Varying prevalence of PSAA visualization ranged from 48.6–89.3 %. (20, 26, 27, 30-40)

Velasco-torres et al. showed that the dentition status can also influence the location of the posterior superior alveolar artery. (43) Moreover, Khojastehpour et al. found the diameter of the artery increased with alveolar resorption and correlated with the number of tooth loss and age. (35)

For this reason, it is necessary to insist on the following points before operating:

- Its position (superficial, intraosseous or intrasinus) and distance from alveolar ridge

  In the intraosseous and intrasinus location, the artery can be masked by the thickness of the osseous wall. Bleeding is caused by removing the bone and unsticking the membrane.

- Its diameter

  The risk of bleeding associated with the size of PSAA. The bigger diameter's artery had greater risk of bleeding during the sinus surgery. (35)

These data may help surgeons to estimate the bleeding risk for a sinus augmentation.

6. Membrane thickness

Schneiderian membrane thickness might indicate a higher correlation with sinusitis and was an anatomical factor that effect sinus membrane perforation and cause implant failure. Previous study found mucosal thickness more than 2 mm was less prone to perforate during sinus augmentation and could tolerate compressing forces that compact the bone graft. These will be following with preferable osseointegration and more implant survival rate. (9)

The prevalence of membrane thickening ranged from 35.1 to 66% in systematic review and the cutoff point of thickening 1-3 mm was considered as normally. (58) Bayrak et al. presented that sex and age affected the membrane thickening. (59)

Carmeli et al. found the sinus floor mucosal thickening more than 5 mm had significantly greater risk for ostium obstruction. (60) Similar to Shanbhag et al. showed that thickness of up to 5 mm, 5-10 mm and more than10 mm correlated with a risk of ostium obstruction of 6.7%, 24% and 35.3%, subsequently. This study concluded that sinus membrane thickening was a reliable predictor of ostium obstruction. (10)

Thus, to reduce chance of damaging the Schneiderian membrane that covering material for vascular function, and avoid loss of bone graft into the sinus, this membrane is important structure that should be regard and evaluate carefully before the surgery.

7. Ostium

The maxillary sinus osteomeatal complex (OMC) opened at the medial sinus wall. If the ciliated epithelium of the ostium has impaired function, it could threaten the sinus physiology. (5)

The shorter of the ostium height is easier drainage of sinusal content, then it reduces the occasion of accumulated secretion. Lower ostium presented a greater correlation with normal sinusal content, while higher ostium showed presence of mucous thickening. A.B.G. de Carvalho et al. observed that male found higher ostium height. They concluded that the determining factor of presence normal sinusal content was ostium height. (61)

Moreover, Simsek Kaya et al. presented that the blockage of drainage in the maxillary sinus might be caused by the excessive bone graft below the ostium. Thereby, the surgeon should be essential particular care the patient with a low distance of the ostium from the sinus floor in sinus augmentation procedure. (20)

In sinus floor elevation, sinus drainage can be compromised by the obstruction ostium and lead to develop complications such as sinusitis and failed surgery. (8) So the patency and location of the ostium should be concerned before sinus surgery to avoid iatrogenic blockage of the ostium.

8. CBCT

CBCT are based on volumetric tomography and used a two-dimensional extended digital array providing an area detector. The x-ray source of cone-beam technique involves a single 360° scan and a reciprocating area detector move around the patient's head. CBCT can generate a three-dimensional volumetric data set and provide reconstruction images in 3 planes (axial, sagittal and coronal).

CBCT is well proper for imaging the craniofacial region because it provides clear images with highly contrasted structures and is useful for evaluating bone. The use of CBCT provides several advantages compared with medical CT:

• Limitation of X-ray beam: The collimation of the primary x-ray beam to the interested area result in reducing the size of the irradiated area and minimizing the radiation dose.

• Accurate of image: The volumetric data set comprises a 3D block of cuboid structures or voxels. Each voxel represents a specific degree of x-ray absorption. The resolution of the image is defined the size of voxels. The voxels of medical CT are rectangular cubes or anisotropic. The axial slice thickness is the longest length of the voxel. CT voxel depth is usually in 1 – 2 mm, but it can be as small as 0.625 mm. Voxel resolutions of CBCT are isotropic that equal in all 3 dimensions. This provides a submillimeter resolution range from 0.4 mm to as low as 0.08 mm (Accuitomo).

• Rapid scan time: Scan time of CBCT is rapid (5-40 seconds). The faster scanning time reduced motion artifacts from subject movement.

• Dose reduction: CBCT is significantly reduced effective dose of radiation in 98% compared with medical CT.

• Reduced image artifact: CBCT images had a low level of metal artifact, distinctly in viewing the teeth and jaws with secondary reconstructions designed. (12, 14)

The anatomical characteristics were reported to be important factors for surgical complications during sinus surgery. Therefore, three-dimensional radiographic examination using CBCT before sinus surgery could help for diagnostic evaluation and treatment planning. (11) Previous studies reported various prevalence of anatomical characteristics. (11, 15-42) Moreover, the investigations showed disparate the relation of anatomical structures and sex, age, tooth area and dental status. (6, 11, 15-31, 33, 35-39, 41-49) For this reason, the purpose of this study is to assess prevalence of the anatomical characteristics in maxillary sinus and association with sex, age, tooth area and dental status using cone beam computed tomography (CBCT) images.

Chapter III Research methodology

1. Study design

A retrospective study

2. Ethical consideration

The protocol of study was approved by the Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand. (HREC-DCU 2019-058)

3. Sample

A retrospective reviewed CBCT images from May 2017 to May 2019 of patients who presented for CBCT at Faculty of Dentistry, Chulalongkorn University. The images were acquired as part of patient care and not for research.

Sample size calculation from following formula: (62)

$$n = \frac{z^2_{1-\frac{\alpha}{2}}\, p(1-p)}{d^2}$$

Proportion (p) = 0.60

Error (d) = 0.05

Alpha (α) = 0.05

Z (0.975) = 1.959964

Sample size (n) = 369

A sample size was calculated by using data of the previous studies. (40) It was estimated that a sample size of 369 sinuses or approximately 185 subjects at the 5% significant level.

Inclusion criteria:

(1) Patients who had CBCT scan from May 2017 to May 2019.

(2) CBCT covered all maxillary arch and maxillary sinus including entire maxillary floor and the ostiomeatal complex.

(3) Age ≥ 20 years old

Exclusion criteria:

(1) CBCT had poor quality. Image is unclear or incomplete such as artifact.

(2) Patient who did not have the first premolar and the position of canine contact with second premolar due to orthodontic treatment.

(3) Patients with severe crowding at maxillary posterior teeth. Sum of displaced or overlapped teeth with more than 6 mm were severe crowding. (63)

(4) Impacted maxillary third molar superior to root of maxillary second molar.

(5) Pathology that can affect the measurement such as tumor.

(6) Patients with a known history of trauma at the maxillofacial region.

(7) Maxillary posterior teeth with periodontal disease and periapical inflammatory disease.

(8) Grafted sinus or implants placement.

(9) Patients with developmental maxillofacial anomaly e.g. cleft lip and cleft palate, cleidocranial dysostosis, Apert syndrome and Crouzon syndrome.

(10) Patients with systemic disease that affect to bone such as osteoporosis, Paget's disease, hyperparathyroidism, or maxillary osteonecrosis.

4. Variable

Independent variables:

- Sex
- Age
- Tooth area
- Dental status

Dependent variables:

- Residual ridge height (mm)
- Lateral wall thickness (mm)
- Maxillary sinus septa: Prevalence, number, type and location
- Posterior superior alveolar artery: Prevalence, location, diameter and distance from the artery to the alveolar crest (mm)
- Sinus membrane thickness (mm)
- Ostium: patency, location and distance from the ostium to the sinus floor (mm)

5. Methods

5.1 Image analysis

Using a database search, Patients who met the study's criteria seen May 2017 to May 2019 were categorized by sex, age, tooth area and dental status following:

1. Sex
    - Female
    - Male
2. Age
    - 20-29 years
    - 30-39 years
    - 40-49 years
    - 50-59 years
    - ≥60 years
3. Tooth area
    - First premolar (1PM)
    - Second premolar (2PM)
    - First molar (1M)
    - Second molar (2M)
4. Dental status
    - Edentulous area
    - Dentate area

All CBCT images were performed using 3D Accuitomo 170 (J Morita MFG. CORP., Kyoto, Japan) with 80 - 90 kVp, 5 - 10 mA and 17.5 seconds exposure time and a field of view larger or equal from 10 x 10 cm. The images were reconstructed with a voxel size of 0.25 mm. Measurements were made using the digital ruler included in the i-Dixel software (version 2.1.7.3 J morita MFG.CORP 2010, Kyoto, Japan). One examiner reviewed the CBCT scans under the close supervision of an experienced radiologist and an oral and maxillofacial surgeon.

The sinuses on both sides were assessed. The patients' demographic data were recorded according sex, age, tooth area and dental status.

The CBCT images were adjusted to make the occlusal plane parallel to the floor. The 4 reference points measured were the center of each tooth (the first premolar, second premolar, first molar, and second molar). To locate the reference points in the edentulous area, the length of this area was divided by the number of missing teeth and the center of this distance was measured.

5.2 **The anatomical characteristics of maxillary sinuses** are assessed:

(1) Residual ridge height (RRH)

(2) Lateral wall thickness (LWT)

(3) Maxillary sinus septa

(4) Posterior superior alveolar artery (PSAA)

(5) Sinus membrane thickness (MT)

(6) Ostium

5.2.1 Residual ridge height (RRH)

Measurements performed in the coronal plane. Residual ridge height (RRH) was perpendicular measured in millimeters (mm) between 2 lines, which presented the most coronal point of the alveolar crest and the lowest point of sinus floor (**Figure 2**) at 4 positions: first premolar (1PM); second premolar (2PM); first molar (1M); second molar (2M). The measurement reference points were the center of each tooth.

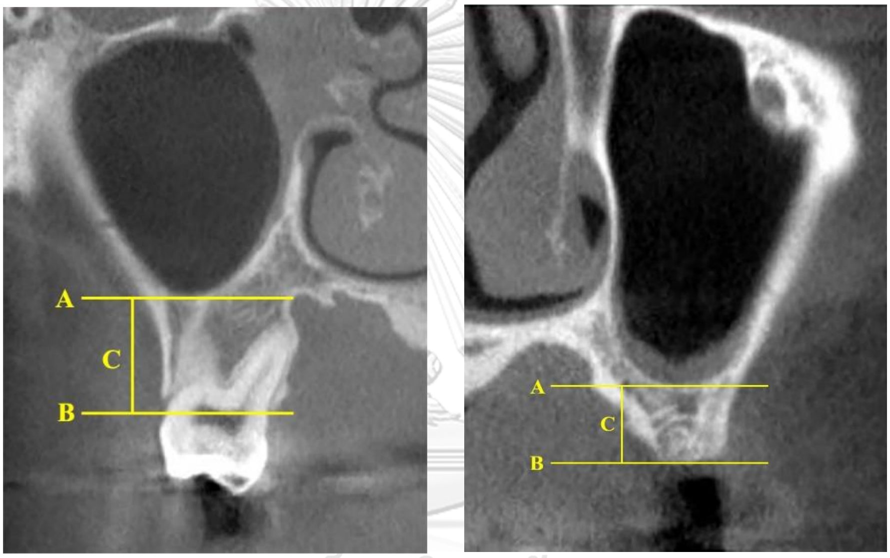

Figure 2 Measurement of residual ridge height in coronal view

A = Horizontal line at the lowest point of the sinus floor

B = Horizontal line at the most coronal point of the alveolar crest

C = The residual ridge height

5.2.2 Lateral wall thickness (LWT)

Measurements observed in the coronal plane. The thickness of the lateral wall was measured 2 millimeters from the lowest point of the sinus floor (**Figure 3**), simulating the lower osteotomy line of the lateral window access during the sinus lift procedure. (64) Measurements were performed parallel to the horizontal line and registered in millimeters at 4 positions: first premolar (1PM); second premolar (2PM); first molar (1M); second molar (2M). The measurement reference points were the center of each tooth.

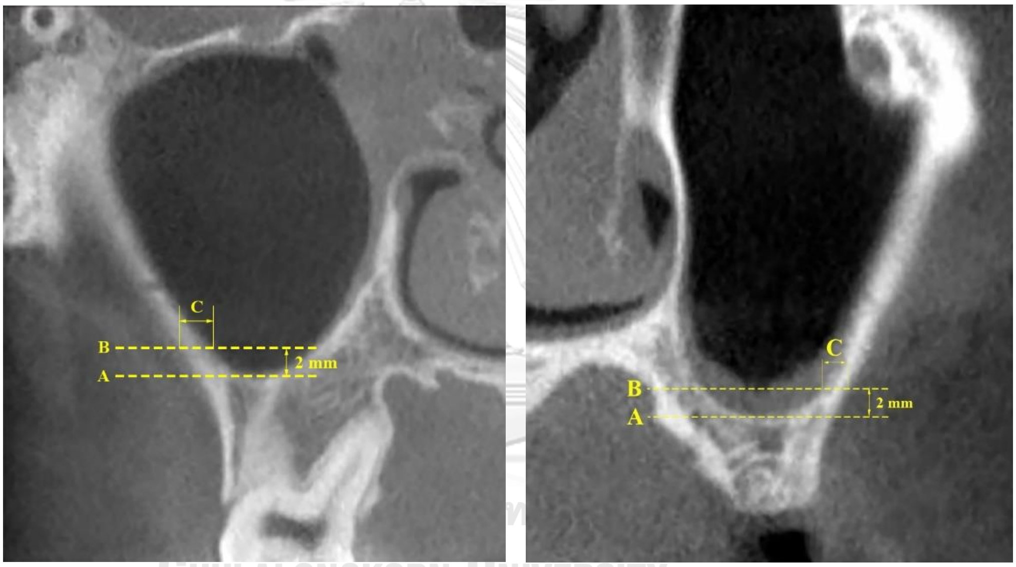

Figure 3 Measurement of lateral wall thickness in coronal view

A = Horizontal line at the lowest point of the sinus floor

B = Horizontal line of 2 mm from the lowest point of the sinus floor

C = The lateral wall thickness

5.2.3 Maxillary sinus septa: Prevalence, number, type, orientation and location

Multiplanar reconstruction images (axial, coronal and sagittal) were assessed for detection of maxillary sinus septa. If the height of the septa was more than 2 mm, the septa included in this study.

Numbers of septa was recorded.

The type of septa was divided into 2 types: (20)

1. Complete septa: divided the sinus into separate anatomic cavities (**Figure 4A**)
2. Incomplete septa (**Figure 4B**)

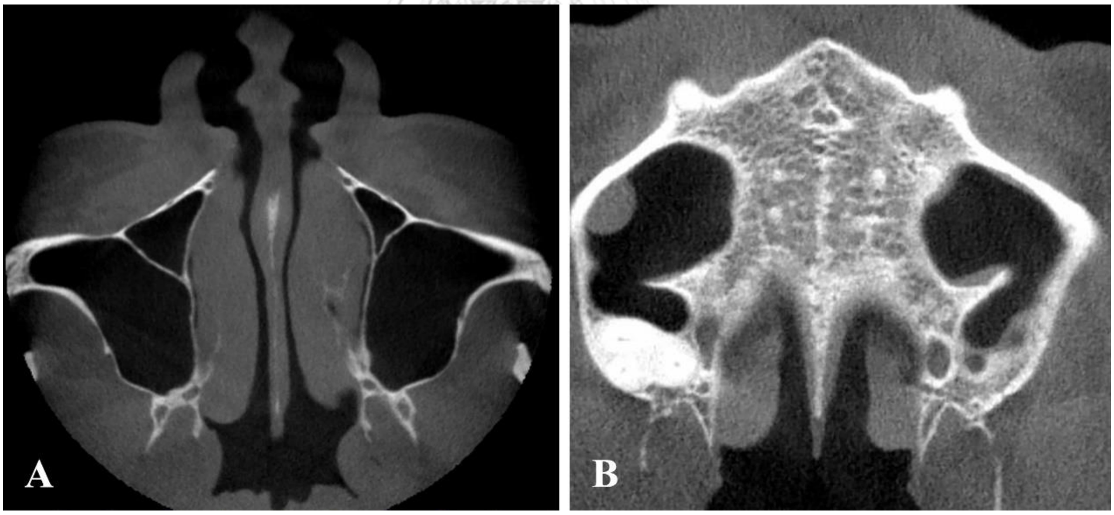

Figure 4 Axial view of maxillary sinuses illustrated a complete septum (A) and an incomplete septum (B)

The orientation of septa was divided into 3 classes: (47) (**Figure 5**)

1. Mediolateral: displayed in the bucco-palatal direction in the arch connects the buccal and palatal floors.
2. Sagittal: displayed parallel to the orientation sagittal plane.
3. Transverse: displayed parallel to the sinus floor

Figure 5 The orientation of septa
(Arrows indicate the septa)

(A) Mediolateral septum showed in a sagittal cut of the maxillary sinus
(B) Sagittal septum showed in a coronal cut of the maxillary sinus
(C) Transverse septa showed in a coronal cut of the maxillary sinus

The location of the maxillary sinus septa was classified into 3 classes: (18) (**Figure 6**)

1. Anterior: the area between the anterior wall of the sinus and the distal of the second premolar
2. Middle: the area between the distal of the second premolar and the distal of the second molar.
3. Posterior: the area between the distal of the second molar and the posterior wall of the sinus.

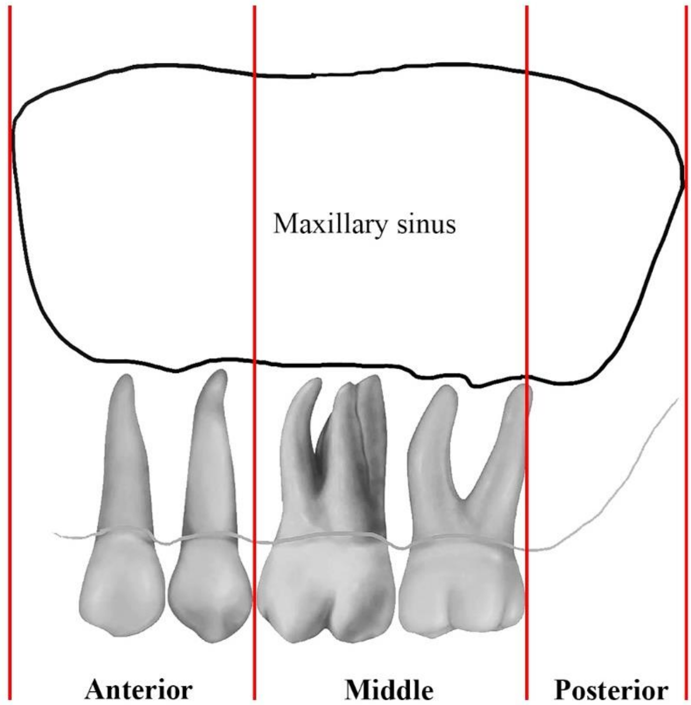

Figure 6 The classified location of maxillary sinus

5.2.4 **Posterior superior alveolar artery (PSAA)**: Prevalence, location, diameter and distance from the artery to the alveolar crest (mm)

The prevalence of the PSAA was examined in the coronal sections and multiplanar reconstruction was used to confirm that the regions contained an artery.

The location of the PSAA was divided into 3 types: (31)

1. Intra-sinus or below the sinus membrane (**Figure 7A**)
2. Intraosseous (**Figure 7B**)
3. Superficial or at the outer cortex of the lateral sinus wall (**Figure 7C**)

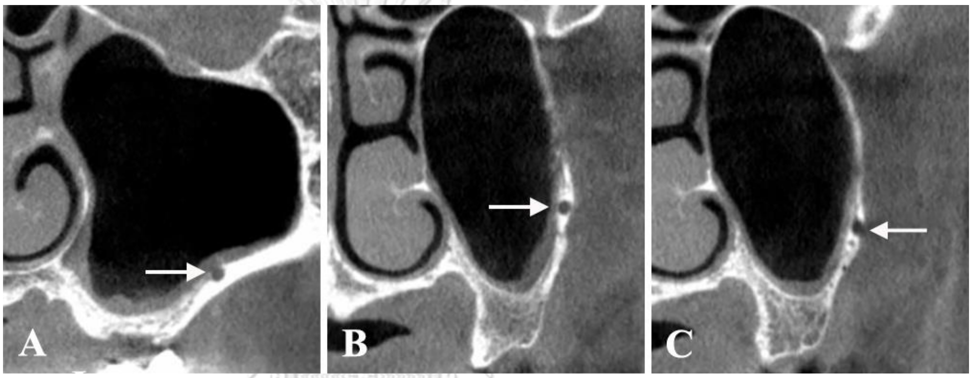

Figure 7 The location of the posterior superior alveolar artery in coronal view of maxillary sinuses

A: Intra-sinus B: Intraosseous C: Superficial (Arrows indicate the artery location)

The diameter of the artery was measured in millimeters (mm) and divided into 3 categories: (30)

1. Less than 1 mm
2. 1-2 mm
3. More than 2 mm

The distance between the lower borders of the PSAA and the most coronal point of the alveolar crest was measured in millimeters (mm) **(Figure 8)** at 4 positions: first premolar (1PM); second premolar (2PM); first molar (1M); second molar (2M). The measurement reference points were the center of the first premolar, second premolar, first molar and second molar.

The distance was divided into 2 groups. (20)

1. Less than or equal to 15 mm
2. More than 15 mm

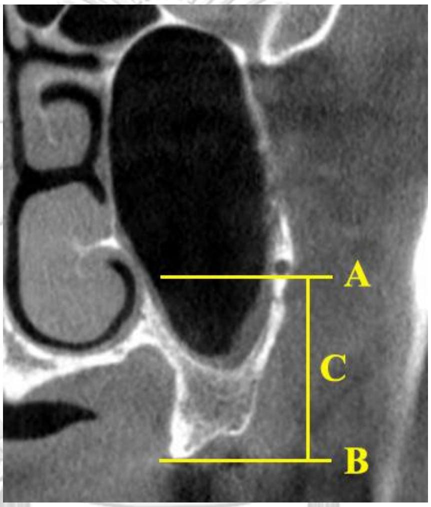

Figure 8 Measurement between the posterior superior alveolar artery and the alveolar crest in coronal view of maxillary sinus

A = Horizontal line is the lower border of the artery

B = Horizontal line is the most coronal point of the alveolar crest

C = The distance of the artery from the alveolar crest

5.2.5 Sinus membrane thickness (MT)

The thickness of the sinus membrane was measured perpendicular to underlying bone at the base of the sinus (**Figure 9**) in 4 positions: first premolar (1PM); second premolar (2PM); first molar (1M); second molar (2M). The measurement reference points were the center of each tooth. The thickness of the sinus mucosa was measured in millimeters (mm).

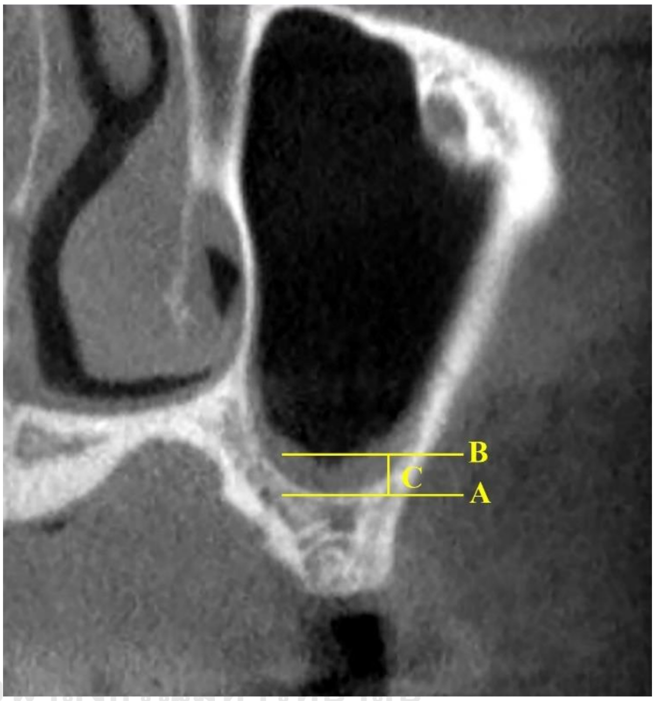

Figure 9 Measurement of the sinus membrane thickness in coronal view of maxillary sinus

A = Horizontal line at the lowest point of the sinus floor

B = Horizontal line at the highest border of the sinus membrane

C = The sinus membrane thickness

5.2.6 Ostium: Patency, location and distance from inferior border of the ostium and the lowest point of the maxillary sinus floor (mm)

Ostium patency was evaluated in the coronal view of each sinus and categorized as "patent" or "obstructed". If it is filled with mucosa or had anatomic blockage, it will be classified to obstructed. (**Figure 10**) (11) Obstructed ostium could not accurately identify, therefore we did not measure the location and distance of theirs.

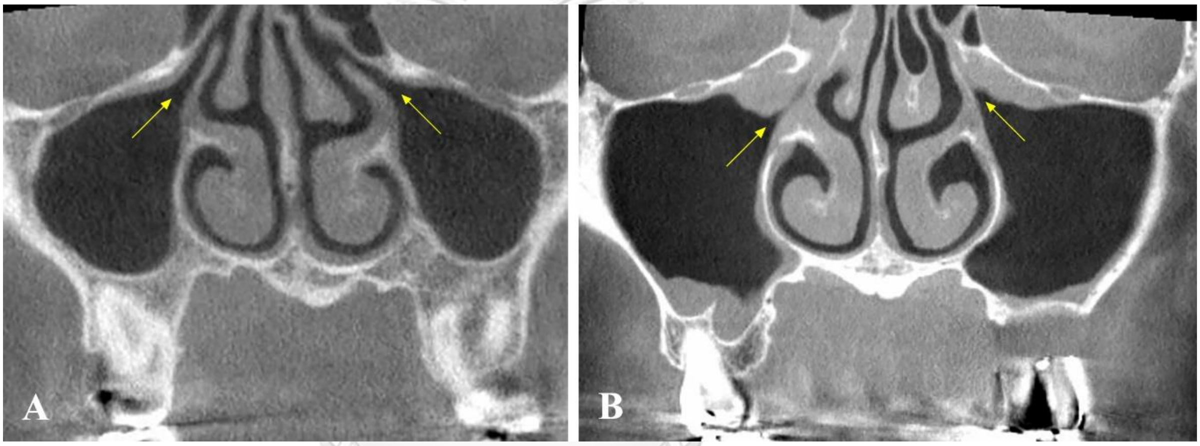

Figure 10 Coronal view of maxillary sinuses illustrated patent ostium (A) and obstructed ostium (B). Arrows indicate the ostium.

The location of the maxillary sinus ostium was classified into 3 classes (**Figure 6**) : (20)

1. Anterior: the area between the anterior wall of the sinus and the distal of the second premolar
2. Middle: the area between the distal of the second premolar and the distal of the second molar.
3. Posterior: the area between the distal of the second molar and the posterior wall of the sinus.

The distance: A measurement was drawn a vertical line from the inferior border of the ostium and the lowest point of the maxillary sinus floor, perpendicular to the occlusal plane and calculate in millimeters (mm). (**Figure 11**)

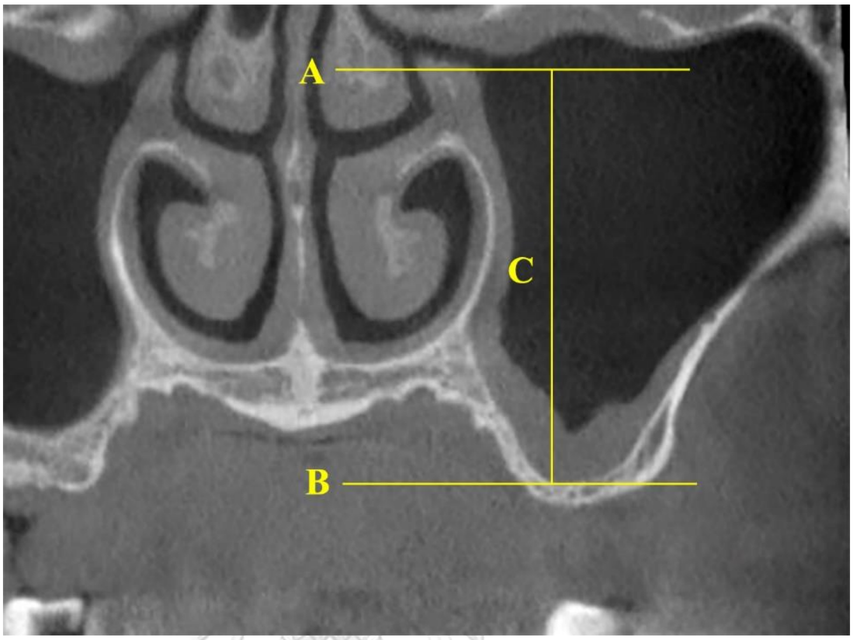

Figure 11 Measurement distance of the maxillary sinus ostium in coronal view

A = Horizontal line is the inferior border of the ostium.

B = Horizontal line is the lowest point of the maxillary sinus floor.

C = The distance of the maxillary sinus ostium.

6. Statistical analysis

Data were recorded as the frequency (%) and the mean ± standard deviation (SD). The data were analyzed by using statistical software (SPSS version 22.0, IBM, NY, USA).

All quantitative data parameters were evaluated with the Kolmogorov-Smirnov test for normal distribution test. For normal distribution data, independent t-test was applied for two groups comparison and ANOVA was used for comparison of more than two samples. For non-parametric data, Mann Whitney U test was applied for two sample comparison and Kruskal Wallis H test was used for comparison of two or more samples.

Qualitative data were evaluated with Chi-square test. Spearman's rank correlation test was used for calculation of correlation. A p-value of less than 0.05 was considered statistically significant.

The examiner repeated evaluation 40 sinuses with a minimum time gap of 2 weeks to test intra-observer reliability. Kappa coefficient was used for nominal data. Intraclass correlation coefficient (ICC) was evaluated ordinal and quantitative data.

7. Collected data table

ID	Side	Gender	Date of birth	Date of CBCT	Age	Age	1PM	2PM	1M	2M	Dental status	Residual ridge height				Lateral wall thickness			
	0= Left 1= Right	0 = Male 1 = Female				0= 20-29 1= 30-39 2= 40-49 3= 50-59 4= ≥60	0= Edentulous space 1=Dentate space				0= Edentulous 1= Partially edentulous 2= Fully dentate	1PM	2PM	1M	2M	1PM	2PM	1M	2M
1																			
2																			
3																			
4																			
5																			

ID	Side	Sinus septa					Posterior superior alveolar artery																	Membrane thickness (mm)				Ostium		
	0= Left 1= Right	Detect 0= Not detect 1= Detect	Number	Type 0= Incomplete 1= Complete	Orientation 0= Mediolateral 1= Sagittal 2=Transverse	Location 0= Anterior 1= Middle 2= Posterior	Detect 0= Not detect 1= Detect				Location 0= Intrasinus 1=Intraosseous 2= Superficial	Diameter (mm)				Diameter 0 = < 1mm 1 = 1-2 mm 2 = > 2 mm				Distance (mm)								Patency 0= Patent 1= Obstruct	Location 0= Anterior 1= Middle 2= Posterior	Distance (mm)
							1PM	2PM	1M	2M		1PM	2PM	1M	2M	1PM	2PM	1M	2M	1PM	2PM	1M	2M	1PM	2PM	1M	2M			
1																														
2																														
3																														
4																														
5																														

8. Expected benefit

Understand of the anatomic characteristics that are important for planning surgery in order to facilitate prevention of intra and post-operative complications

9. Budget

1. Documents	3,000 Bath
2. Publication fee	2,000 Bath
Total	5,000 Bath

Chapter IV Results

CBCT images from 185 patients or 370 sinuses were included in this study. The intra-observer reliability coefficients were range 0.865-1. There were no significant differences between left and right sides in all variable, thus the data from both sides were combined. The patients comprised 23.24% males and 76.76% females. The mean age was 48.66 ± 16.6 and the range was 20-87 years. Most of the patients were fully dentate (61.62%) and ≥ 60 years old comprised the largest percentage (31.89%) (**Table 1** & **2**). 149 sinuses (40.27%) CBCT images presented the variation of maxillary sinus that did not extend anteriorly to the first premolar area.

Table 1 Frequency of samples according to age group and dental status

Sex	N	%	Age group (years)	N	%	Dental status	N	%
Male	43	23.24	20-29	39	21.08	Edentulous	15	4.06
Female	142	76.76	30-39	18	9.73	Partially edentulous	127	34.32
			40-49	28	15.14	Fully dentate	228	61.62
			50-59	41	22.16			
			≥60	59	31.89			
Total	185	100	Total	185	100	Total	370	100

Table 2 The distribution of dental status in each tooth area

Area	Dental status			
	Edentulous area (N)	%	Dentate area (N)	%
First premolar	53	14.32	317	85.68
Second premolar	57	15.41	313	84.59
First molar	83	22.43	287	77.57
Second molar	67	18.11	303	81.89

1. **Residual ridge height (RRH)**

Mean residual ridge height was 12.13 ± 3.64 mm and mean of each tooth position was shown in **Table 3**. The first premolar had the highest RRH and the first molar had the lowest RRH.

Table 3 Mean residual ridge height in each tooth area

Area	N	Residual ridge height (mm)		
		Mean ± SD	Min	Max
First premolar	221	18.46 ± 7.16	4.78	36.29
Second premolar	370	14 ± 5.77	2.72	32.97
First molar	370	8.76 ± 3.69	1.25	22.26
Second molar	370	9.61 ± 3.03	1.56	21.74
Overall mean residual ridge height	370	12.13 ± 3.64	4.27	24.55

Male had statistically significant different with female except the first premolar area. (**Table 4**) Female tended to have a greater residual ridge height than male.

Table 4 Residual ridge height divided by sex in each tooth area

Area	Sex	N	%	Residual ridge height (mm) (Mean ± SD)	p-value [a]
First premolar	Male	51	13.78	17.51 ± 7.31	0.249
	Female	170	45.95	18.74 ± 7.10	
Second premolar	Male	86	23.24	12.35 ± 4.91	0.002*
	Female	284	76.76	14.50 ± 5.92	
First molar	Male	86	23.24	7.63 ± 2.84	0.001*
	Female	284	76.76	9.10 ± 3.85	
Second molar	Male	86	23.24	8.93 ± 2.89	0.021*
	Female	284	76.76	9.81 ± 3.05	
Overall mean residual ridge height	Male	86	23.24	10.95 ± 3.66	0.000*
	Female	284	76.76	12.48± 3.73	

[a] Mann Whitney U test

* Significant difference $p < 0.05$

For dental status, Edentulous area had significant different with dentate area at second premolar, first molar and second molar. (**Table 5**) Dentate area had a tendency of residual ridge height more than edentulous area.

Table 5 Residual ridge height divided by dental status in each tooth area

Area	Dental status	N	%	Residual ridge height (mm) (Mean ± SD)	p-value [a]
First premolar	Edentulous area	34	9.19	17.28 ± 7.49	0.368
	Dentate area	187	50.54	18.67 ± 7.09	
Second premolar	Edentulous area	57	15.41	12.52 ± 6.09	0.02*
	Dentate area	313	84.59	14.27 ± 5.68	
First molar	Edentulous area	83	22.43	7.88 ± 4.26	0.007*
	Dentate area	287	77.57	9.01 ± 3.48	
Second molar	Edentulous area	67	18.11	8.53 ± 3.46	0.003*
	Dentate area	303	81.89	9.84 ± 2.88	
Overall mean residual ridge height	Edentulous	15	4.05	11.17 ± 3.31	0.111
	Partially edentulous	127	34.32	11.70 ± 3.74	
	Fully dentate	228	61.62	12.43 ± 3.58	

[a] Mann Whitney U test

* Significant different $p < 0.05$

Relationship between RRH and age was tested by Spearman's rank correlation. The second molar area had significantly low residual ridge height in elderly. (**Table 6**)

Table 6 Correlation between residual ridge height and age in each tooth area

Correlation between residual ridge height and age		
Area	p-value [a]	r
First premolar	0.491	-
Second premolar	0.057	-
First molar	0.552	-
Second molar	0.007*	- 0.141
Overall mean residual ridge height	0.976	-

[a] Spearman's rank correlation

* Significant different $p < 0.05$

2. **Lateral wall thickness (LWT)**

Mean lateral wall thickness was 2.23 ± 0.95 mm and mean of each area demonstrated in **Table 7.** LWT tended to increase form the first premolar to the first molar and decrease in the second molar.

Table 7 Mean lateral wall thickness in each tooth area

Area	N	Lateral wall thickness (mm)		
		Mean ± SD	Min	Max
First premolar	221	1.75 ± 0.67	0.72	5.20
Second premolar	370	2.09 ± 0.95	0.58	6.24
First molar	370	2.67 ± 1.79	0.42	18.31
Second molar	370	2.16 ± 1.34	0.52	9.10
Overall mean lateral wall thickness	370	2.23 ± 0.95	0.81	9.40

When comparing the thickness of lateral wall between sex, male tended to have a significant thicker lateral wall than female except in the second molar. (**Table 8)**

Table 8 Lateral wall thickness divided by sex in each tooth area

Area	Sex	N	%	Lateral wall thickness (mm) (Mean ± SD)	p-value [a]
First premolar	Male	51	13.78	2.26 ± 0.83	0.000*
	Female	170	45.95	1.61 ± 0.53	
Second premolar	Male	86	23.24	2.67 ± 1.07	0.000*
	Female	284	76.76	1.92 ± 0.84	
First molar	Male	86	23.24	2.93 ± 1.41	0.009*
	Female	284	76.76	2.59 ± 1.89	
Second molar	Male	86	23.24	2.57 ± 1.74	0.051
	Female	284	76.76	2.03 ± 1.16	
Overall mean lateral wall thickness	Male	86	23.24	2.64 ± 0.87	0.000*
	Female	284	76.76	2.11 ± 0.94	

[a] Mann Whitney U test

* Significant different $p < 0.05$

Lateral wall thickness had statistically significant difference in dental status except in second molar area. (**Table 9**) Dentate area had a greater lateral wall thickness than edentulous area. In fully dentate had the most thickness following by partially edentulous and edentulous.

Table 9 Lateral wall thickness divided by dental status in each tooth area

Area	Dental status	N	%	Lateral wall thickness (mm) (Mean ± SD)	p-value
First premolar	Edentulous area	34	9.19	1.56 ± 0.59	$0.033^{a,*}$
	Dentate area	187	50.54	1.79 ± 0.68	
Second premolar	Edentulous area	57	15.41	1.74 ± 0.73	$0.001^{a,*}$
	Dentate area	313	84.59	2.16 ± 0.98	
First molar	Edentulous area	83	22.43	1.96 ± 1.17	$0.000^{a,*}$
	Dentate area	287	77.57	2.88 ± 1.88	
Second molar	Edentulous area	67	18.11	2.01 ± 1.26	0.146^{a}
	Dentate area	303	81.89	2.19 ± 1.35	
Overall mean lateral wall thickness	Edentulous	15	4.05	1.68 ± 0.66	$0.000^{b,*}$
	Partially edentulous	127	34.32	2.05 ± 0.74	
	Fully dentate	228	61.62	2.37 ± 1.04	

[a] Mann Whitney U test

[b] Kruskal Wallis H test

* Significant different $p < 0.05$

Lateral wall thickness had significant association with age in the second premolar, the first molar and the overall mean lateral wall thickness. (**Table 10**) Older tended to have a thinner lateral wall.

Table 10 Correlation between lateral wall thickness and age in each tooth area

Correlation between lateral wall thickness and age		
Area	**p-value [a]**	**r**
First premolar	0.895	-
Second premolar	0.00*	-0.229
First molar	0.00*	-0.225
Second molar	0.173	-
Overall mean lateral wall thickness	0.00*	-0.214

[a] Spearman's rank correlation

* Significant different $p < 0.05$

3. Septa

The prevalence of septa within maxillary sinuses was 83 (22.43%) in this study (**Table 11**). The unilateral septa were present mostly in 48 patients (73.85%) and bilateral septa were 26.15%. 74 sinuses (89.16%) demonstrated one septum and 9 sinuses (10.84%) had 2 septa. (**Table 12**) Type of septa was mostly an incomplete septum (94.57%). The most common orientation of the septa was mediolateral (89.13%) while 9.78% showed sagittal and 1.09% showed transverse orientation. Location of septa was most common seen at the middle region (66.3%), followed by the posterior (22.83%) and the anterior (10.87%) region. (**Table 13**)

Table 11 Prevalence of septa in sinus

Septa	N (sinus)	%
No detection	287	77.57
Detection	83	22.43
Total	370	100

Table 12 Distribution of septa in patient and number of septa in sinus

Septa in patient	N (patient)	%	Number of septa in sinus	N (sinus)	%
Unilateral septa	48	73.85	1 septum	74	89.16
Bilateral septa	17	26.15	2 septa	9	10.84
Total	65	100	Total	83	100

Table 13 Distribution of type, orientation and location of septa

Type of septa	N (septa)	%	Orientation of septa	N (septa)	%	Location of septa	N (septa)	%
Incomplete septa	87	94.57	Mediolateral	82	89.13	Anterior	10	10.87
Complete septa	5	5.43	Sagittal	9	9.78	Middle	61	66.3
			Transverse	1	1.09	Posterior	21	22.83
Total	92	100	Total	92	100	Total	92	100

Detection septum in female (68.67%) was statistically significant more than male (31.33%) by using Chi-square test (p = 0.048). No relationship statistically significant of septa between age and dental status. The distribution of septa according to sex, age and dental status were shown in **Table 14 - 17**.

Table 14 Detection and number of septa in sinus according to sex, dental status and age

Septa		Detect (sinus)	%	Number of septa in a sinus			
				1 septum (sinus)	%	2 septa (sinus)	%
Sex	Male	26	31.33	21	25.30	5	6.02
	Female	57	68.67	53	63.86	4	4.82
Dental status	Edentulous	1	1.20	1	1.20	0	0.00
	Partially edentulous	29	34.94	24	28.92	5	6.02
	Fully dentate	53	63.86	49	59.04	4	4.82
Age (years)	20-29	17	20.48	16	19.28	1	1.20
	30-39	10	12.05	9	10.84	1	1.20
	40-49	13	15.66	111	133.73	2	2.41
	50-59	28	33.73	26	31.33	2	2.41
	≥60	15	18.07	12	14.46	3	3.61
Total		83	100.00	74	89.16	9	10.84

Table 15 Type of septa in sinus according to sex, dental status and age

Septa		Type of septa			
		Incomplete septa (septa)	%	Complete septa (septa)	%
Sex	Male	31	33.70	0	0.00
	Female	56	60.87	5	5.43
Dental status	Edentulous	1	1.09	0	0.00
	Partially edentulous	31	33.70	3	3.26
	Fully dentate	55	59.78	2	2.17
Age (years)	20-29	17	18.48	1	1.09
	30-39	9	9.78	2	2.17
	40-49	14	15.22	1	1.09
	50-59	29	31.52	1	1.09
	≥60	18	19.57	0	0.00
Total		87	94.57	5	5.43

Table 16 The orientation of septa in sinus according to sex, dental status and age

Septa		Orientation of septa					
		Mediolateral (septa)	%	Sagittal (septa)	%	Transverse (septa)	%
Sex	Male	27	29.35	3	3.26	0	0.00
	Female	54	58.70	6	6.52	1	1.09
Dental status	Edentulous	1	1.09	0	0.00	0	0.00
	Partially edentulous	28	30.43	5	5.43	1	1.09
	Fully dentate	53	57.61	4	4.35	0	0.00
Age (years)	20-29	16	17.39	2	2.17	0	0.00
	30-39	9	9.78	2	2.17	0	0.00
	40-49	13	14.13	1	1.09	1	1.09
	50-59	27	29.35	3	3.26	0	0.00
	≥60	17	18.48	1	1.09	0	0.00
Total		82	89.13	9	9.78	1	1.09

Table 17 The location of septa in sinus according to sex, dental status and age

Septa		Location of septa					
		Anterior	%	Middle	%	Posterior	%
Sex	Male	3	3.26	23	25.00	5	5.43
	Female	7	7.61	38	41.30	16	17.39
Dental status	Edentulous	1	1.09	0	0.00	0	0.00
	Partially edentulous	5	5.43	19	20.65	10	10.87
	Fully dentate	4	4.35	42	45.65	11	11.96
Age (years)	20-29	1	1.09	13	14.13	4	4.35
	30-39	0	0.00	7	7.61	4	4.35
	40-49	3	3.26	7	7.61	5	5.43
	50-59	3	3.26	20	21.74	7	7.61
	≥60	3	3.26	14	15.22	1	1.09
Total		10	10.87	61	66.30	21	22.83

4. Posterior superior alveolar artery (PSAA)

Posterior superior alveolar arteries were detected in 119 sinuses (32.16%). The distribution of PSAA at different tooth areas were summarized in **Table 18**. The prevalence rate in female had greater than male, especially in the first molar area had significant differences (P=0.025) **(Table 19)**. The PSAA prevalence in the first premolar area was found only 4 arteries in male. PSAA could be detected in the dentate area more than the edentulous area, especially the first molar area showed significant differences (P=0.015) **(Table 20)**. There was no significant relationship of prevalence with age.

Table 18 The prevalence of posterior superior alveolar artery in each tooth area

Area	N	Posterior superior alveolar artery	
		Detection	%
First premolar	221	4	1.81
Second premolar	370	33	8.92
First molar	370	54	14.59
Second molar	370	102	27.57

Table 19 The prevalence of posterior superior alveolar artery divided by sex in each tooth area

Area	Sex	Posterior superior alveolar artery				p-value [a]
		Detection	%	No detection	%	
First premolar	Male	4	1.81	47	21.27	0.003*
	Female	0	0.00	170	76.92	
	Total	4	1.81	217	98.19	
Second premolar	Male	12	3.24	74	20.00	0.062
	Female	21	5.68	263	71.08	
	Total	33	8.92	337	91.08	
First molar	Male	19	5.14	67	18.11	0.025*
	Female	35	9.46	249	67.30	
	Total	54	14.59	316	85.41	
Second molar	Male	28	7.57	58	15.68	0.237
	Female	74	20.00	210	56.76	
	Total	102	27.57	268	72.43	
Full mouth	Male	34	9.19	52	14.05	0.095
	Female	85	22.97	199	53.78	
	Total	119	32.16	251	67.84	

[a] Chi-square tests

* Significant different $p < 0.05$

Table 20 The prevalence of posterior superior alveolar artery divided by dental status in each tooth area

Area	Dental status	Posterior superior alveolar artery				p-value [a]
		Detection	%	No detection	%	
First premolar	Edentulous area	2	0.54	32	8.65	0.113
	Dentate area	2	0.54	185	50.00	
Second premolar	Edentulous area	7	1.89	50	13.51	0.333
	Dentate area	26	7.03	287	77.57	
First molar	Edentulous area	19	5.14	64	17.30	0.015*
	Dentate area	35	9.46	252	68.11	
Second molar	Edentulous area	22	5.95	45	12.16	0.286
	Dentate area	80	21.62	223	60.27	
Full mouth	Edentulous	6	1.62	9	2.43	0.160
	Partially edentulous	48	12.97	79	21.35	
	Fully dentate	65	17.57	163	44.05	

[a] Chi-square tests

* Significant different $p < 0.05$

The location of PSAA in different areas were shown in **Table 21**. The most frequent location was intraosseous (52.85%), followed by intra-sinus (46.11%) and superficial (1.04%). Comparison of the location with sex, age and dental status were not statistically significant.

Table 21 The location of posterior superior alveolar artery in each tooth area

Area	Location of posterior superior alveolar artery					
	Intrasinus		Intraosseous		Superficial	
	N	%	N	%	N	%
First premolar	0	0	4	100	0	0
Second premolar	7	21.21	25	75.76	1	3.03
First molar	33	61.11	21	38.89	0	0
Second molar	49	48.04	52	50.98	1	0.98
Total	89	46.11	102	52.85	2	1.04

The mean diameter of PSAA was 0.84 ± 0.2 mm (range 0.38-1.82 mm). The diameter of PSAA at different areas were presented in **Table 22**. The diameter of PSAA was less than 1 mm in most patients (80.31%) and diameter between 1 and 2 mm was 19.69%. Comparison of the diameter with age and dental status were not statistically significant in difference. The diameter was significantly different between sex except in the first premolar and the first molar area. Male had significantly a greater mean diameter of PSAA than female that demonstrated in **Table 23**.

Table 22 The mean diameter of posterior superior alveolar artery in each tooth area

Area	Diameter of posterior superior alveolar artery (mm)								
	Mean ± SD	Min	Max	<1 mm		1-2 mm		>2mm	
				N	%	N	%	N	%
First premolar	1.06 ± 0.51	0.74	1.83	3	75	1	25	0	0
Second premolar	0.86 ± 0.26	0.52	1.74	28	84.85	5	15.15	0	0
First molar	0.9 ± 0.2	0.52	1.74	41	75.93	13	24.07	0	0
Second molar	0.84 ± 0.23	0.38	1.96	83	81.37	19	18.63	0	0
Overall mean diameter	0.84 ± 0.2	0.38	1.82	155	80.31	38	19.69	0	0

Table 23 The mean diameter of posterior superior alveolar artery divided by sex in each tooth area

Area	Sex	Diameter (mm) (Mean ± SD)	p-value [a]
First premolar	Male	1.06 ± 0.51	-
	Female	-	
Second premolar	Male	1.01 ± 0.35	0.041*
	Female	0.78 ± 0.14	
First molar	Male	0.94 ± 0.23	0.820
	Female	0.88 ± 0.18	
Second molar	Male	0.94 ± 0.29	0.017*
	Female	0.8 ± 0.2	
Overall mean diameter	Male	0.93 ± 0.24	0.013*
	Female	0.81 ± 0.17	

[a] Mann Whitney U test

- cannot calculate due to low sample number at this area

* Significant different $p < 0.05$

Mean distance of the PSAA was 16.75 ± 3.7 mm. The mean distance in 4 positions were presented in **Table 24**. In **Figure 12** displayed the course of the PSAA, which the highest distance from alveolar crest at the first premolar and decrease to the most inferior site in the first molar area. The comparison of distance with sex and age found not statistically significant differences using independent t-test and Spearman's rank correlation. Dentate area had higher distance than edentulous area, especially the first molar area showed significant differences (P=0.000) (**Table 25**). The distance of PSAA less than 15 mm demonstrated in **Table 26 - 28**. The most arteries in this study had distance to the alveolar crest more than 15 mm (65.28%) (**Figure 13**) and had the most diameter less than 1 mm (51.81%) (**Table 29 - 31**).

Table 24 The mean distance of posterior superior alveolar artery in each tooth area

Area	Distance of posterior superior alveolar artery (mm)		
	Mean ± SD	Min	Max
First premolar	20.22 ± 7.77	12.79	27.53
Second premolar	18.77 ± 4.06	9.78	25.38
First molar	15.63 ± 3.69	6.03	23.30
Second molar	16.43 ± 3.98	6.14	28.40
Overall mean distance	16.75 ± 3.7	6.14	28.40

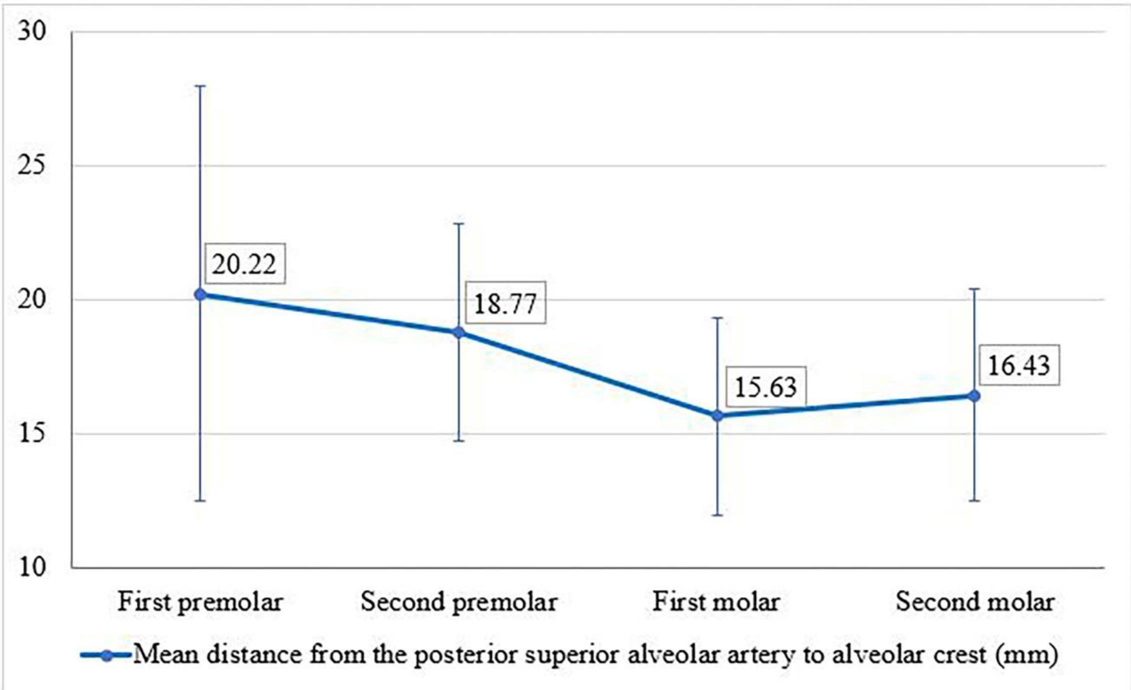

Figure 12 The distribution of the mean distance (mm) from the posterior superior alveolar artery to the alveolar crest in each tooth area

Table 25 The mean distance of posterior superior alveolar artery divided by dental status in each tooth area

Area	Dental status	Distance (mm) (Mean ± SD)	p-value [a]
First premolar	Edentulous area	13.52 ± 1.03	-
	Dentate area	26.92 ± 0.87	
Second premolar	Edentulous area	16.64 ± 4.83	0.120
	Dentate area	19.34 ± 3.73	
First molar	Edentulous area	13.29 ± 3.88	0.000*
	Dentate area	16.89 ± 2.92	
Second molar	Edentulous area	16.39 ± 5.13	0.959
	Dentate area	16.44 ± 3.64	
Overall mean distance	Edentulous	16.34 ± 1.89	0.503
	Partially edentulous	16.26 ± 4.50	
	Fully dentate	17.15 ± 3.13	

[a] Independent t-test

- cannot calculate due to low sample number at this area

* Significant different $p < 0.05$

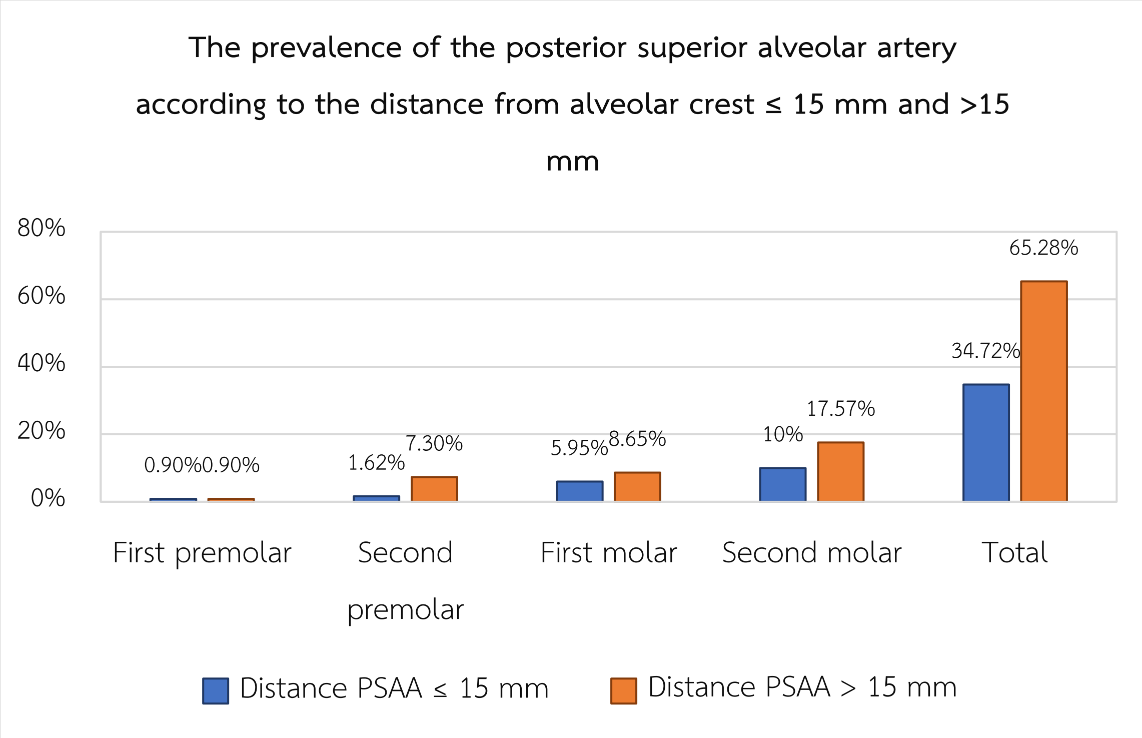

Figure 13 The distribution on the prevalence of the posterior superior alveolar artery according to the distance from alveolar crest ≤ 15 mm and >15 mm

Table 26 The location of the posterior superior alveolar artery according to the distance from alveolar crest ≤ 15 mm

Distance ≤ 15 mm	N	%	Location of the posterior superior alveolar artery					
Area			Intrasinus	%	Intraosseous	%	superficial	%
First premolar	2	0.90	0	0.00	2	0.90	0	0.00
Second premolar	6	1.62	1	0.27	5	1.35	0	0.00
First molar	22	5.95	13	3.51	9	2.43	0	0.00
Second molar	37	10.00	21	5.68	16	4.32	0	0.00
Total	67	34.72	35	18.13	32	16.58	0	0.00

Table 27 The mean diameter and diameter group of the posterior superior alveolar artery according to the distance from alveolar crest ≤ 15 mm

Distance ≤ 15 mm	Diameter (mm)			Diameter Group			
Area	Mean ± SD	Min	Max	<1 mm	%	1-2mm	%
First premolar	0.84 ± 0.00	0.84	0.84	2	0.90	0	0.00
Second premolar	0.91 ± 0.26	0.61	1.36	4	1.08	2	0.54
First molar	0.95 ± 0.21	0.66	1.74	18	4.86	4	1.08
Second molar	0.79 ± 0.21	0.38	1.33	31	8.38	6	1.62
Overall mean	0.81 ± 0.19	0.38	1.18				
Total				55	28.50	12	6.22

Table 28 The mean distances of the posterior superior alveolar artery according to the distance from alveolar crest ≤ 15 mm

Distance ≤ 15 mm	Distance (mm)		
Area	Mean ± SD	Min	Max
First premolar	13.52 ± 1.03	12.79	14.25
Second premolar	12.38 ± 1.70	9.78	14.77
First molar	12.03 ± 2.41	6.03	14.87
Second molar	12.50 ± 2.18	6.14	14.88
Overall mean	12.34 ± 2.18	6.14	14.88

Table 29 The location of the posterior superior alveolar artery according to the distance from alveolar crest > 15 mm

Distance > 15 mm	N	%	Location of the posterior superior alveolar artery					
Area			Intrasinus	%	Intraosseous	%	superficial	%
First premolar	2	0.90	0	0.00	2	0.90	0	0.00
Second premolar	27	7.30	6	1.62	20	5.41	1	0.27
First molar	32	8.65	20	5.41	12	3.24	0	0.00
Second molar	65	17.57	28	7.57	36	9.73	1	0.27
Total	126	65.28	54	27.98	70	36.27	2	1.04

Table 30 The mean diameter and diameter group of the posterior superior alveolar artery according to the distance from alveolar crest > 15 mm

Distance > 15 mm	Diameter (mm)			Diameter Group			
Area	Mean ± SD	Min	Max	<1 mm	%	1-2mm	%
First premolar	1.29 ± 0.77	0.74	1.83	1	0.45	1	0.45
Second premolar	0.85 ± 0.26	0.52	1.74	24	6.49	3	0.81
First molar	0.87 ± 0.18	0.52	1.25	23	6.22	9	2.43
Second molar	0.86 ± 0.25	0.41	1.96	52	14.05	13	3.51
Overall mean	0.85 ± 0.21	0.41	1.82				
Total				100	51.81	26	13.47

Table 31 The mean distances of the posterior superior alveolar artery according to the distance from alveolar crest > 15 mm

Distance > 15 mm	Distance (mm)		
Area	Mean ± SD	Min	Max
First premolar	26.92 ± 0.87	26.3	27.53
Second premolar	20.19 ± 2.87	15.74	25.38
First molar	18.10 ± 1.96	15.29	23.30
Second molar	18.66 ± 2.89	15.17	28.40
Overall mean	18.51 ± 2.53	15.08	28.40

5. **Membrane thickness (MT)**

Mean sinus membrane thickness was 1.3 ± 2.05 mm. Mean membrane thickness in each tooth area was shown in **Table 32**.

Table 32 Mean sinus membrane thickness in each tooth area

Area	Membrane thickness (mm)		
	Mean ± SD	Min	Max
First premolar	0.64 ± 2.08	0.00	17.14
Second premolar	1.22 ± 2.46	0.00	14.56
First molar	1.69 ± 2.68	0.00	17.16
Second molar	1.24 ± 2.21	0.00	16.54
Overall mean thickness	1.30 ± 2.05	0.00	13.68

Male had statistically significant thicker sinus membrane than female in all areas. (**Table 33**)

Table 33 Sinus membrane thickness divided by sex in each tooth area

Area	Sex	N	%	Membrane thickness (mm) (Mean ± SD)	p-value [a]
First premolar	Male	51	13.78	1.54 ± 3.70	0.035*
	Female	170	45.95	0.38 ± 1.13	
Second premolar	Male	86	23.24	2.41 ± 3.38	0.000*
	Female	264	71.35	0.86 ± 1.97	
First molar	Male	86	23.24	3.00 ± 3.44	0.000*
	Female	264	71.35	1.30 ± 2.27	
Second molar	Male	86	23.24	2.03 ± 2.73	0.000*
	Female	284	76.76	1.00 ± 1.97	
Overall mean membrane thickness	Male	86	23.24	2.34 ± 2.75	0.000*
	Female	284	76.76	0.98 ± 1.67	

[a] Mann Whitney U test

* Significant different $p < 0.05$

Edentulous area had a greater membrane thickness than dentate area in the first premolar, the second premolar and the first molar area, especially the first molar had statistically significant differences. Whereas dentate area had thicker membrane than edentulous area in the second molar area. In edentulous had the most membrane thickness following by partially edentulous and fully dentate. (**Table 34**)

Table 34 Sinus membrane thickness divided by dental status in each tooth area

Area	Dental status	N	%	Membrane thickness (mm) (Mean ± SD)	p-value
First premolar	Edentulous area	34	9.19	1.02 ± 3.12	0.642 [a]
	Dentate area	187	50.54	0.58 ± 1.83	
Second premolar	Edentulous area	57	15.41	1.23 ± 2.72	0.640 [a]
	Dentate area	313	84.59	1.22 ± 2.41	
First molar	Edentulous area	83	22.43	2.14 ± 2.69	0.014 [a, *]
	Dentate area	287	77.57	1.56 ± 2.67	
Second molar	Edentulous area	67	18.11	1.19 ± 1.62	0.270 [a]
	Dentate area	303	81.89	1.25 ± 2.32	
Overall mean membrane thickness	Edentulous	15	4.05	1.92 ± 2.70	0.074 [b]
	Partially edentulous	127	34.32	1.37 ± 2.00	
	Fully dentate	228	61.62	1.21 ± 2.03	

[a] Mann Whitney U test

[b] Kruskal Wallis H test

* Significant different $p < 0.05$

Relationship between membrane thickness and age was tested by Spearman's rank correlation. Sinus membrane thickness had statistically significant association with age except in the second premolar area. (**Table 35**) Older tended to have a greater membrane thickness.

Table 35 Correlation between sinus membrane thickness and age in each tooth area

Correlation between sinus membrane thickness and age		
Area	p-value [a]	r
First premolar	0.002*	0.212
Second premolar	0.127	-
First molar	0.035*	0.11
Second molar	0.000*	0.184
Mean	0.004*	0.149

[a] Spearman's rank correlation

* Significant different $p < 0.05$

6. Ostium

94.05% of sinuses showed patency of ostium while 5.95% showed ostium obstruction. The most location of ostium was middle (95.98%) following with anterior (3.73%) and posterior (0.29%). (**Table 36**) Mean distance of ostium from the sinus floor was 30.03 ± 5.08 mm and ranged in 11.96 – 47.69 mm.

Table 36 The distribution of patency and location of ostium

Ostium	N	%	Location of ostium	N	%
Patent	348	94.05	**Anterior**	13	3.73
Obstruct	22	5.95	**Middle**	334	95.98
			Posterior	1	0.29
Total	370	100	**Total**	348	100

Male had significantly greater ostium distance than female (p=0.000). Fully dentate tended to had longer ostium distance than partially edentulous and edentulous area. Elderly had significantly shorter ostium distance (p= 0.004, r= -0.154). (**Table 37**)

Table 37 The distance of ostium divided by sex, dental status and age

Distance of ostium		Distance (mm) (Mean ± SD)	p-value
Sex	Male	33.25 ± 4.91	0.000 [a,*]
	Female	29.07 ± 4.73	
Dental status	Edentulous	28.38 ± 5.00	0.006 [b,*]
	Partially edentulous	29.01 ± 4.57	
	Fully dentate	30.70 ± 5.25	
Age (years)	20-29	31.14 ± 5.49	0.004 [c,*]
	30-39	31.48 ± 4.91	
	40-49	28.75 ± 5.73	
	50-59	30.71 ± 4.75	
	≥60	28.97 ± 4.39	

[a] Independent t-test

[b] One-way ANOVA

[c] Spearman's rank correlation

* Significant different $p < 0.05$

7. Correlation between residual ridge height and lateral wall thickness

The results showed a statistically significant greater residual ridge height with thicker lateral wall thickness in the first molar, second molar and overall mean of 4 areas. But it was controversy in the second premolar that showed a significant greater residual ridge height with thinner lateral wall thickness. (**Table 38**)

Table 38 Correlation between residual ridge height and lateral wall thickness

Correlation between residual ridge height and lateral wall thickness		
Area	**p-value [a]**	**r**
First premolar	0.106	-
Second premolar	0.029*	-0.114
First molar	0.000*	0.198
Second molar	0.002*	0.164
Overall mean	0.030*	0.113

[a] Spearman's rank correlation

* Significant different $p < 0.05$

8. Correlation between residual ridge height and membrane thickness

The results displayed a statistically significant greater residual ridge height with thinner membrane only in the first premolar. (**Table 39**)

Table 39 Correlation between residual ridge height and membrane thickness

Correlation between residual ridge height and membrane thickness		
Area	**p-value [a]**	**r**
First premolar	0.043*	-0.136
Second premolar	0.102	-
First molar	0.250	-
Second molar	0.833	-
Overall mean	0.098	-

[a] Spearman's rank correlation

* Significant different $p < 0.05$

9. Correlation between lateral wall thickness and diameter of posterior superior alveolar artery

Our results exhibited the relationship that thicker lateral wall tended to have larger diameter of PSAA. There were statistically significant differences at the first molar and overall mean of 4 areas. (**Table 40**)

Table 40 Correlation between lateral wall thickness and diameter of posterior superior alveolar artery

Correlation between lateral wall thickness and diameter of posterior superior alveolar artery		
Area	**p-value [a]**	**r**
First premolar	0.051	-
Second premolar	0.454	-
First molar	0.010*	0.349
Second molar	0.078	-
Overall mean	0.006*	0.250

[a] Spearman's rank correlation

* Significant different $p < 0.05$

10. Correlation between membrane thickness and patency of ostium

In obstruct ostium, membrane thickness showed significant thicker than patent ostium in all areas (p= 0.000). **(Table 41)**

Table 41 Correlation between membrane thickness and patency of ostium

Area	Patency	N	%	Membrane thickness (mm) (Mean ± SD)	p-value [a]
First premolar	Patent	208	94.12	0.44 ± 1.58	0.000*
	Obstruct	13	5.88	3.91 ± 4.91	
Second premolar	Patent	348	94.05	0.99 ± 2.16	0.000*
	Obstruct	22	5.95	4.82 ± 3.80	
First molar	Patent	348	94.05	1.48 ± 2.50	0.000*
	Obstruct	22	5.95	4.97 ± 3.27	
Second molar	Patent	348	94.05	1.06 ± 1.95	0.000*
	Obstruct	22	5.95	4.19 ± 3.70	
Overall mean membrane thickness	Patent	348	94.05	1.09 ± 1.81	0.000*
	Obstruct	22	5.95	4.49 ± 2.93	

[a] Mann Whitney U test

* Significant different $p < 0.05$

Chapter V Discussion

The current study evaluated the anatomical characteristics of maxillary sinus on sex, age, and dental status. The results indicated that there were some significant differences in these parameters between groups. Based on these results, the null hypothesis was rejected.

In present study, 59.72 % of CBCT images presented the maxillary sinus variation that extend anteriorly to the first premolar area. Whereas, Lim et al. studied in Asian population that showed the presence of maxillary sinus wall in this area with 80.7 % and 39.4 % in canine area. (6)

Lozano- Carrascal et al. displayed mean RRH at second premolar was 8.66 ± 3.95 mm, 4.90 ± 2.28 mm at first molar, and 5.26 ± 2.13 mm at second molar. (36) Our results showed higher mean RRH (12.13 ± 3.64 mm) than other studies. Owing to most of samples in our population were fully dentate (61.62 %) and samples of previous studies with ≥ 1 missing tooth caused a higher mean RRH. (10, 36, 65)

Our results exhibited that female had a significant greater RRH than male. Older had significantly low RRH. Dentate area had a significant tendency of RRH more than edentulous area that concurred with Farina et al. (66) RRH correlated with edentulous span. (46) As expected, the reduction in ridge height at edentulous area resulted from the apical displacement of the alveolar crest and the expansion of the sinus cavity in a cranial–caudal direction. (66) After extraction of maxillary posterior teeth, it caused the sinus pneumatization. (67, 68)

Previous study found that 91% of the sinus membrane perforation occurred with RRH < 3.5 mm, and 9% with RRH >3.5 mm. (65) In addition, Ardekian et al. found that perforation of the sinus membrane occurred in 85% of cases in RRH 3 mm, while perforation was observed in 25% in RRH 6 mm. They demonstrated low RRH as a significant risk factor for sinus membrane perforation. (69) As our results of higher mean RRH were 11.17 ± 3.31 mm in fully edentulous and 11.70 ± 3.74

partially edentulous, thereby our population had low risk of sinus membrane perforation.

Neiva et al. analyzed in European skulls and found mean of the sinus wall thickness was 0.91±0.43 mm (range 5.0 - 2.0 mm). (70) Study in korean cadavers reported LWT ranges from 1.23 to 1.86 mm. (44) In CBCT study found mean LWT in 2.1 ± 0.88 mm nearly with our study (2.23 ± 0.95). (20) This disparity might cause of differences in methods, measuring reference and race of the patients.

The results showed LWT increase from the first premolar to the first molar after which decrease in the second molar. These were similar to other studies. (6) In contrast with Kang et al. 's result, anterior region had thicker LWT than the posterior. (23) Accordingly, the access for sinus augmentation requires the application of less pressure in the premolar area. While in the first molar area might drill deeper as the LWT increases in thickness in this area. (6) The first molar area had maximum LWT 18.31 mm because one sample was sinus hypoplasia that caused thicker bone. (**Figure A** in Appendix)

We observed that male tended to have a significant thicker LWT than female in agreement with other studies. (6, 37, 44, 45) However, previous study found no correlation between sex and LWT. (46) Older tended to have a thinner LWT in our samples. In contrast with Monje et al.'s results, LWT is positively correlated with age. (46) In addition, some studies found no correlation between age and LWT. (6, 37, 45) Current study showed that dentate area had a greater LWT than edentulous area. In fully dentate had the most thickness following by partially edentulous and edentulous. These concordance with Monje et al. They found that the edentulous span with adjacent teeth influenced to mean LWT. Longer edentulous span had thinner LWT. (46) These could suggest that the result caused by sinus expansion when tooth lost.

Moreover, our results showed a significant greater RRH with thicker LWT in the first molar, second molar and overall mean of 4 areas. In the same with previous study, LWT was positively correlated with RRH or these could imply that the less RRH had the thinner the lateral sinus wall. (46)

In review literature, CBCT studies showed the septa's prevalence between 20.6 and 66.7 %. (11, 15-21, 24-29, 41, 42) The prevalence of septa in this study was 22.43%. This difference might be as a result of systematic review study that found significantly lower prevalence of the septa in Asian population. (47) Number of septa had mostly one septum in the same as other studies. (16, 19, 20, 47) The most common orientation of the septa was mediolateral (89.13%) that concurred with previous studies. (15, 16, 18-20, 22, 25, 36, 47) Location of septa was mostly at the middle region (66.3%) that like other studies. (19, 21, 22, 47-49) The presence of septa in the first molar to second molar area might be problematic since it is generally chosen for window opening. Therefore, surgeons should be aware of planning in sinus surgical procedures.

The present study showed a prevalence of septum in female (68.67%) was more than male (31.33%) and found no relationship of septa between age and dental status. Some studies reported prevalence in male more than female. (18, 49) A higher prevalence was found in younger patient. (24, 42) Besides, Hungerbuhler et al. (19) demonstrated that edentulous presented more septa compared with fully and partially dentition and this was similar to other studies. (15, 47)

In previous studies the PSAA prevalence ranged from 48.6–89.3 %, whereas, this study found a lower prevalence (32.16%). (20, 26, 27, 30-40) The different results may be due to differences in the racial variations and sample sizes between studies. In addition, the lower radiographic detection of the PSAA might be related to small diameter of artery. Our study used CBCT images with a voxel size of 0.25 mm. Thereby, the diameter of artery lower than 0.25 mm could not be detected. However, cadavers' studies revealed that the PSAA was present in 100% of the samples. (50, 71) This finding indicated that although PSAA was not found for every patient via CBCT analysis, there was an artery present. Because our study measured at peripheral artery with small diameter and might have been below the sensitivity of the CBCT. (39)

The prevalence of a PSAA in females was greater than that of males, however, the difference was not significant. In contrast, Kim et al. (33) and Yalcin & Akyol (39) found a significantly higher prevalence in males. This difference might be due to the different ratio of males and females in this study. Other studies (35, 39) demonstrated that older individuals were more likely to have a PSAA, whereas our study found no relationship between the PSAA prevalence and age. In dentate areas, a PSAA was detected more often compared with edentulous areas, with the detection in the first molar area being significantly higher. This result concurred with the study of Ilguy et al. (27)

The location of the PSAA was mostly intraosseous (52.85%), followed by intra-sinus (46.11%), and superficial (1.04%), which conformed with the results of prior studies. (20, 23, 26, 27, 31, 37, 39) However, Lozano-Carrascal et al. (36) found that the PSAA was most commonly located below the sinus membrane (53.85%). Other studies (27, 38) showed a significant relationship between the location of the artery and sex; however, our study did not find this relationship.

In the present study, the most common PSAA diameter (80.31%) was less than 1 mm. This result concurred with previous studies. (23, 27, 30, 36) Nonetheless, our results were different from other studies that found the most common diameter was between 1 and 2 mm and ranged from 55.8–74.8 %. (20, 26, 37, 38) Maridati et al. (57) reported that damaging an artery less than 2 mm did not affect the performance of the sinus surgical approach. We did not find PSAA’s with a diameter larger than 2 mm. Furthermore, most arteries were less than 1 mm. Therefore, these results suggest that this study population would have a low occurrence of severe bleeding during sinus surgery.

The PSAA diameter was significantly different between sexes, except in the first molar area. Males had a larger artery diameter compared with females, which was in accordance with other reports. (23, 35, 37, 38) The current study found no relationship between PSAA diameter and age or dental status that matched the findings of Guncu et al. (31) and Danesh-Sani et al. (37). Nevertheless, other studies demonstrated that older individuals had a greater artery diameter. (35, 43) Kang et al. found a thicker sinus lateral wall with a significant larger vessel diameter. (23) Our results showed this relation at the first molar area.

The mean distance from the PSAA to the alveolar crest was 16.75 ± 3.7 mm, which was similar to the findings of Mardinger et al. (30) (16.9 ± 4.4 mm), Tehranchi et al. (38) (16.7 ± 3.96 mm), Chitsazi et al. (26) (16.17 ± 1.63 mm), and Simsek Kaya et al. (20) (16.95 ± 1.9 mm). The present study revealed that dentate areas had a higher distance compared with edentulous areas. This finding was in concordance with Velasco-Torres et al., who reported that the distance from the alveolar crest reduced when teeth were lost. (43) This might be the effect of tooth loss that caused alveolar ridge resorption and decreased the distance between PSAA and alveolar crest. The sex and age of the subjects did not significantly affect this distance in our study. In contrast, Khojastehpour et al. (35) and Tehranchi et al. (38) reported that males had a significantly greater distance compared with females. Moreover, our results demonstrated that the course of the PSAA had the highest distance from the alveolar crest at the first premolar and decreased to its most inferior level in the first molar area. These results were concordant with Kim et al. (33), Jung et al. (32), and Aung et al. (40) who demonstrated that the PSAA was closer to the alveolar crest in the molar area. The course of the artery could be explained by it moves up toward the infraorbital artery that was higher at the anterior region. (37)

The lateral wall sinus lift technique uses a superior horizontal osteotomy line up to 15 mm from the alveolar crest, which is adequate for exposing the lateral wall of the sinus surgery and placing dental implants. (30, 72) We found that most PSAAs had a distance to the alveolar crest of more than 15 mm (65.28%) nearly with Kang et al. (69%). (23) A distance less than 15 mm was seen in only 5.95% of images in the first molar area and a lower prevalence in the first premolar and the second premolar area of 0.9% and 1.62%, respectively. These PSAAs could present a low occurrence of hemorrhage in sinus surgery. If the osteotomy line is more than 15 mm, the surgeon should be concerned about potential bleeding during surgery. Accordingly, the surgeon should plan the surgery using CBCT to avoid damaging the artery and be prepared to control bleeding if it occurs.

The results showed that overall mean sinus membrane thickness was 1.3 ± 2.05 mm and the first premolar area only had mean MT < 1 mm. Yilmaz et al. reported a significant correlation between MT < 1 mm and membrane perforation. A reason for these results was that the thin membrane might not be tolerated by the force of membrane elevation. (65) The study in cadavers showed that thicker membrane had significantly higher load limits and it had more resistance to perforation during detachment membrane. (73) Male had statistically significant thicker sinus membrane than female that conformed with other studies. (29, 59, 74)This might be the reason of their lifestyle such as smoking. (74) Older had a greater membrane thickness in the present study. These results conformed with other studies. (29, 59, 75) These results might be affected by exposed with more chronic inflammatory diseases in older patients such as periodontitis. (75) Although, our population had low risk of membrane perforation, the surgeon should pre-operatively evaluate with CBCT before performing the sinus surgery.

Yeung et al. (76) found that females had a significant higher incidence of ostium patency than males, but our study did not find this. We found the most location of ostium was middle (95.98%) and mean distance of ostium from the sinus floor was 30.03 ± 5.08 mm nearly with Simsek Kaya et al.'s study (28.2 ± 2.89 mm). (20) Male had significantly higher ostium distance than female. Our finding conformed with A.B.G. de Carvalho et al.'s results. They reported that male had a higher ostium height and had a significant association with the presence of mucous thickening and the antral pseudocyst. (61) Fully dentate had longer ostium distance than partially edentulous and edentulous area. Elderly had significantly shorter ostium distance. This affirmed with previous study which found negative relationship between age and distance to the meatus. Moreover, they demonstrated indirect correlation between distance to the meatus and tooth loss. Their explanation was the loss of tooth that lack of masticatory function, promote more ridge resorption and result in a reduction in all measurements of sinus. (77) Besides, lower ostium presented a greater correlation with normal sinusal content, while higher ostium presented mucous thickening. These supported the effect of ostium height on accommodation the sinus drainage. The high ostium could make difficulty empty the sinusal content and caused the mucous thickening or antral pseudocyst. (61)

In current study, the obstruct ostium showed significant sinus membrane thicker than patent ostium. These concurred with Dobele et al. who found a relationship between membrane thickening and ostium obstruction. (11) Besides, Carmeli et al. reported that an increasing risk for ostium obstruction following sinus grafting is related with sinus membrane thickening > 5 mm. (60) Furthermore, Shanbhag et al. concluded sinus floor membrane thickening could be reliable predictor of ostium obstruction. (10)

A limitation of our study was no clinical data about patients' sinusitis history and symptoms, thereby the relationship between sinus membrane thickening or ostium obstruction and the clinical sinus disease could not made. Some CBCT images presented the anterior wall of the maxillary sinus that did not extend to the first premolar area (40.27%). These images might affect the PSAA prevalence in the first premolar area where only 4 arteries were found. These limited samples could not be statistically analyzed. Moreover, the lower number of males compared with females might not have been enough to identify a significant difference based on sex. Accordingly, further studies should have equal number of females and males and the maxillary sinus that extend to all posterior maxillary teeth.

Chapter VI Conclusion

Based on our findings:

- Mean RRH were 11.17 ± 3.31 mm.
- LWT tended to increase from anterior to posterior region but decrease in second molar.
- Prevalence of septa was 22.43%. The presence of septa was mostly in the first molar to second molar area. The most common orientation of the septa was mediolateral.
- Most of the PSAAs had a diameter ≤1 mm and the distance of the artery from the alveolar crest was > 15 mm that should have a low chance of severe bleeding during surgery.
- Mean of sinus membrane thickness was 1.3 ± 2.05 mm.
- Mean height of ostium from the sinus floor was 30.03 ± 5.08 mm.

Even though, the anatomical characteristics of maxillary sinus related to sex, age, tooth area and dental status and our population had low risk of complication. Due to variation on the anatomical characteristics of maxillary sinus, it should be evaluated case by case prior to the surgery. We recommend using CBCT for planning surgery, in order to minimize the risk of complications related to sinus surgery.

Appendix

Table A Residual ridge height divided by age group in each tooth area

Area	Age (years)	N	%	Residual ridge height (mm) (Mean ± SD)
First premolar	**20-29**	57	15.41	20.49 ± 6.51
	30-39	26	7.03	15.29 ± 5.62
	40-49	25	6.76	15.73 ± 6.67
	50-59	47	12.70	18.41 ± 7.12
	≥60	66	17.84	19.01 ± 7.84
Second premolar	**20-29**	78	21.08	13.49 ± 4.69
	30-39	36	9.73	11.83 ± 5.23
	40-49	56	15.14	14.73 ± 5.79
	50-59	82	22.16	13.40 ± 5.42
	≥60	118	31.89	15.06 ± 6.55
First molar	**20-29**	78	21.08	8.72 ± 2.66
	30-39	36	9.73	7.50 ± 2.84
	40-49	56	15.14	10.08 ± 4.41
	50-59	82	22.16	7.79 ± 3.52
	≥60	118	31.89	9.22 ± 4.00
Second molar	**20-29**	78	21.08	10.36 ± 2.37
	30-39	36	9.73	9.31 ± 2.61
	40-49	56	15.14	10.37 ± 3.51
	50-59	82	22.16	8.67 ± 2.66
	≥60	118	31.89	9.49 ± 3.36
Overall mean residual ridge height	**20-29**	78	21.08	12.72 ± 2.93
	30-39	36	9.73	10.75 ± 3.05
	40-49	56	15.14	12.45 ± 3.90
	50-59	82	22.16	11.28 ± 3.43
	≥60	118	31.89	12.57 ± 4.06

Table B Lateral wall thickness divided by age groups in each tooth area

Area	Age (years)	N	%	Lateral wall thickness (mm) (Mean ± SD)
First premolar	**20-29**	57	15.41	1.65 ± 0.49
	30-39	26	7.03	1.82 ± 0.61
	40-49	25	6.76	1.93 ± 0.75
	50-59	47	12.70	1.72 ± 0.68
	≥60	66	17.84	1.78 ± 0.78
Second premolar	**20-29**	78	21.08	2.34 ± 0.98
	30-39	36	9.73	2.16 ± 1.09
	40-49	56	15.14	2.34 ± 1.13
	50-59	82	22.16	1.97 ± 0.75
	≥60	118	31.89	1.88 ± 0.87
First molar	**20-29**	78	21.08	2.90 ± 1.26
	30-39	36	9.73	2.54 ± 1.37
	40-49	56	15.14	3.74 ± 3.39
	50-59	82	22.16	2.47 ± 1.24
	≥60	118	31.89	2.19 ± 1.09
Second molar	**20-29**	78	21.08	2.26 ± 1.47
	30-39	36	9.73	1.93 ± 0.85
	40-49	56	15.14	2.75 ± 1.85
	50-59	82	22.16	2.06 ± 1.32
	≥60	118	31.89	1.94 ± 0.97
Overall mean lateral wall thickness	**20-29**	78	21.08	2.34 ± 0.73
	30-39	36	9.73	2.14 ± 0.72
	40-49	56	15.14	2.89 ± 1.66
	50-59	82	22.16	2.11 ± 0.74
	≥60	118	31.89	1.97 ± 0.61

Table C Prevalence of posterior superior alveolar artery divided by age groups in each tooth area

Area	Age (years)	Posterior superior alveolar artery			
		Detection	%	No detection	%
First premolar	**20-29**	0	0.00	57	15.41
	30-39	0	0.00	26	7.03
	40-49	0	0.00	25	6.76
	50-59	0	0.00	47	12.70
	≥60	4	1.08	62	16.76
Second premolar	**20-29**	8	2.16	70	18.92
	30-39	1	0.27	35	9.46
	40-49	3	0.81	53	14.32
	50-59	10	2.70	72	19.46
	≥60	11	2.97	107	28.92
First molar	**20-29**	10	2.70	68	18.38
	30-39	3	0.81	33	8.92
	40-49	8	2.16	48	12.97
	50-59	11	2.97	71	19.19
	≥60	22	5.95	96	25.95
Second molar	**20-29**	16	4.32	62	16.76
	30-39	12	3.24	24	6.49
	40-49	16	4.32	40	10.81
	50-59	21	5.68	61	16.49
	≥60	81	21.89	81	21.89
Full mouth	**20-29**	23	6.22	55	14.86
	30-39	13	3.51	23	6.22
	40-49	16	4.32	40	10.81
	50-59	26	7.03	56	15.14
	≥60	41	11.08	77	20.81

Table D Location of posterior superior alveolar artery divided by age groups in each tooth area

Area	Age (years)	Location of posterior superior alveolar artery					
		Intrasinus	%	Intraosseous	%	Superficial	%
First premolar	**20-29**	0	0.00	0	0.00	0	0.00
	30-39	0	0.00	0	0.00	0	0.00
	40-49	0	0.00	0	0.00	0	0.00
	50-59	0	0.00	0	0.00	0	0.00
	≥60	0	0.00	4	100.00	0	0.00
Second premolar	**20-29**	2	6.06	5	15.15	1	3.03
	30-39	1	3.03	0	0.00	0	0.00
	40-49	0	0.00	3	9.09	0	0.00
	50-59	2	6.06	8	24.24	0	0.00
	≥60	2	6.06	9	27.27	0	0.00
First molar	**20-29**	6	11.11	4	7.41	0	0.00
	30-39	3	5.56	0	0.00	0	0.00
	40-49	5	9.26	3	5.56	0	0.00
	50-59	6	11.11	5	9.26	0	0.00
	≥60	13	24.07	9	16.67	0	0.00
Second molar	**20-29**	7	6.86	9	8.82	0	0.00
	30-39	8	7.84	4	3.92	0	0.00
	40-49	8	7.84	8	7.84	0	0.00
	50-59	14	13.73	7	6.86	0	0.00
	≥60	12	11.76	24	23.53	1	0.98

Table E Mean diameter of posterior superior alveolar artery divided by age groups in each tooth area

Area	Age (years)	Diameter of posterior superior alveolar artery (mm) (Mean ± SD)
First premolar	**20-29**	-
	30-39	-
	40-49	-
	50-59	-
	≥60	1.06 ± 0.51
Second premolar	**20-29**	0.85 ± 0.29
	30-39	0.91 ± 0.00
	40-49	0.68 ± 0.19
	50-59	0.84 ± 0.16
	≥60	0.94 ± 0.33
First molar	**20-29**	0.86 ± 0.98
	30-39	0.95 ± 0.58
	40-49	0.92 ± 0.18
	50-59	0.90 ± 0.16
	≥60	0.91 ± 0.26
Second molar	**20-29**	0.83 ± 0.22
	30-39	0.70 ± 0.13
	40-49	0.80 ± 0.22
	50-59	0.89 ± 0.19
	≥60	0.87 ± 0.28
Overall mean diameter	**20-29**	0.84 ± 0.21
	30-39	0.75 ± 0.12
	40-49	0.80 ± 0.19
	50-59	0.89± 0.15
	≥60	0.86 ± 0.24

Table F Mean distance of posterior superior alveolar artery divided by age groups in each tooth area

Area	Age (years)	Distance of posterior superior alveolar artery (mm) (Mean ± SD)
First premolar	20-29	-
	30-39	-
	40-49	-
	50-59	-
	≥60	20.22 ± 7.77
Second premolar	20-29	17.83 ± 1.39
	30-39	21.67 ± 0.00
	40-49	21.05 ± 3.76
	50-59	19.98 ± 4.32
	≥60	17.47 ± 5.04
First molar	20-29	16.83 ± 3.42
	30-39	13.80 ± 6.77
	40-49	16.37 ± 2.48
	50-59	15.46 ± 4.04
	≥60	15.14 ± 3.67
Second molar	20-29	16.71 ± 2.99
	30-39	16.16 ± 3.57
	40-49	16.28 ± 3.73
	50-59	15.48 ± 4.40
	≥60	17.00 ± 4.40
Overall mean distance	20-29	17.34 ± 2.72
	30-39	16.30 ± 3.79
	40-49	16.32 ± 3.74
	50-59	16.81 ± 4.16
	≥60	16.69 ± 3.97

Table G Mean membrane thickness divided by age groups in each tooth area

Area	Age (years)	Membrane thickness (mm) (Mean ± SD)
First premolar	**20-29**	0.08 ± 0.32
	30-39	0.54 ± 1.13
	40-49	0.81 ± 2.67
	50-59	0.36 ± 1.34
	≥60	1.31 ± 3.06
Second premolar	**20-29**	0.90 ± 1.45
	30-39	0.96 ± 2.21
	40-49	1.32 ± 2.85
	50-59	0.89 ± 2.16
	≥60	1.70 ± 2.95
First molar	**20-29**	1.19 ± 2.05
	30-39	1.77 ± 3.58
	40-49	1.95 ± 2.78
	50-59	1.78 ± 3.17
	≥60	1.82 ± 2.29
Second molar	**20-29**	0.69 ± 1.31
	30-39	1.23 ± 2.52
	40-49	1.43 ± 2.64
	50-59	1.22 ± 2.65
	≥60	1.52 ± 2.00
Mean	**20-29**	0.80 ± 1.20
	30-39	1.23 ± 2.27
	40-49	1.48 ± 2.46
	50-59	1.20 ± 2.16
	≥60	1.63 ± 2.10

Figure A Sinus hypoplasia caused the thickest lateral wall of maxillary sinus in our study

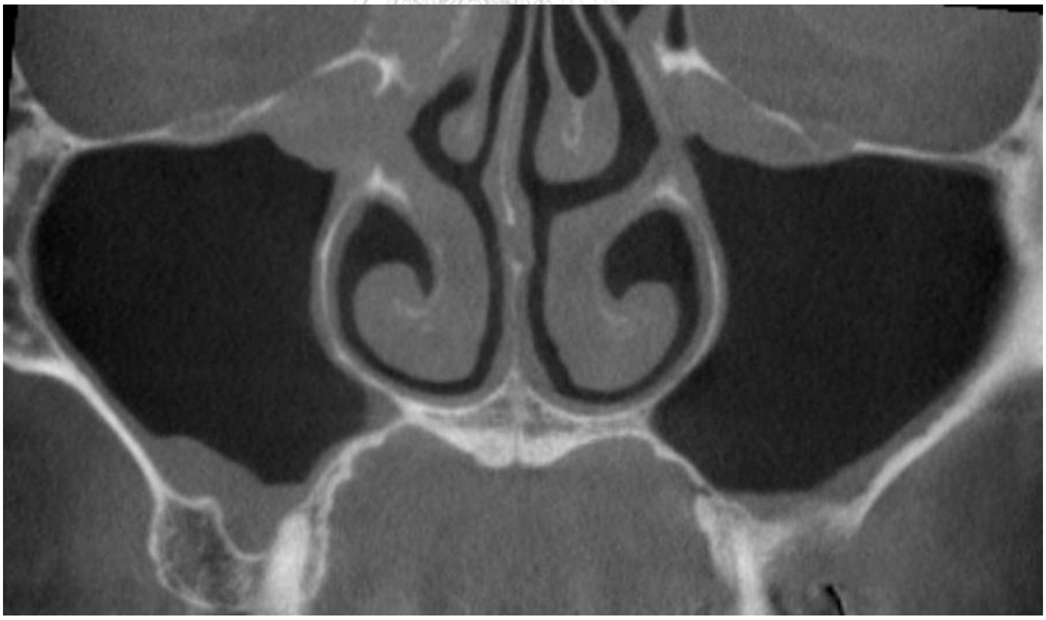

Figure B Mucosal thickening and ostium obstruction at left and right maxillary sinus in coronal view

Figure C Mucosal thickening at left and right maxillary sinus in coronal view

REFERENCES

1. Hupp JR, Tucker MR, Ellis E. Odontogenic diseases of the maxillary sinus. In: Tucker MR, editor. Contemporary oral and maxillofacial surgery. 6th ed. St. Louis: Elsevier Inc.; 2014. p. 382-93.

2. Mohan N, Wolf J, Dym H. Maxillary sinus augmentation. Dent Clin North Am. 2015;59(2):375-88.

3. Pjetursson BE, Tan WC, Zwahlen M, Lang NP. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. J Clin Periodontol. 2008;35(8 Suppl):216-40.

4. Betts NJ, Miloro M. Modification of the sinus lift procedure for septa in the maxillary antrum. J Oral Maxillofac Surg. 1994;52(3):332-3.

5. van den Bergh JP, ten Bruggenkate CM, Disch FJ, Tuinzing DB. Anatomical aspects of sinus floor elevations. Clin Oral Implants Res. 2000;11(3):256-65.

6. Lim EL, Ngeow WC, Lim D. The implications of different lateral wall thicknesses on surgical access to the maxillary sinus. Braz Oral Res. 2017;31:e97.

7. Ella B, Sédarat C, Noble Rda C, Normand E, Lauverjat Y, Siberchicot F, et al. Vascular connections of the lateral wall of the sinus: surgical effect in sinus augmentation. Int J Oral Maxillofac Implants. 2008;23(6):1047-52.

8. Timmenga NM, Raghoebar GM, Liem RS, van Weissenbruch R, Manson WL, Vissink A. Effects of maxillary sinus floor elevation surgery on maxillary sinus physiology. Eur J Oral Sci. 2003;111(3):189-97.

9. Garcia-Denche JT, Wu X, Martinez PP, Eimar H, Ikbal DJ, Hernandez G, et al. Membranes over the lateral window in sinus augmentation procedures: a two-arm and split-mouth randomized clinical trials. J Clin Periodontol. 2013;40(11):1043-51.

10. Shanbhag S, Karnik P, Shirke P, Shanbhag V. Cone-beam computed tomographic analysis of sinus membrane thickness, ostium patency, and residual ridge heights in the posterior maxilla: implications for sinus floor elevation. Clin Oral Implants Res. 2014;25(6):755-60.

11. Dobele I, Kise L, Apse P, Kragis G, Bigestans A. Radiographic assessment of

findings in the maxillary sinus using cone-beam computed tomography. Stomatologija. 2013;15(4):119-22.

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

13. Okano T, Harata Y, Sugihara Y, Sakaino R, Tsuchida R, Iwai K, et al. Absorbed and effective doses from cone beam volumetric imaging for implant planning. Dentomaxillofac Radiol. 2009;38(2):79-85.

14. Venkatesh E, Elluru SV. Cone beam computed tomography: basics and applications in dentistry. J Istanbul Univ Fac Dent. 2017;51(3 Suppl 1):S102-S21.

15. Qian L, Tian XM, Zeng L, Gong Y, Wei B. Analysis of the morphology of maxillary sinus septa on reconstructed cone-beam computed tomography images. J Oral Maxillofac Surg. 2016;74(4):729-37.

16. Talo Yildirim T, Guncu GN, Colak M, Nares S, Tozum TF. Evaluation of maxillary sinus septa: a retrospective clinical study with cone beam computerized tomography (CBCT). Eur Rev Med Pharmacol Sci. 2017;21(23):5306-14.

17. Sigaroudi AK, Kajan ZD, Rastgar S, Asli HN. Frequency of different maxillary sinus septal patterns found on cone-beam computed tomography and predicting the associated risk of sinus membrane perforation during sinus lifting. Imaging Sci Dent. 2017;47(4):261-7.

18. Hong KL, Wong RCW, Lim AAT, Loh FC, Yeo JF, Islam I. Cone beam computed tomographic evaluation of the maxillary sinus septa and location of blood vessels at the lateral maxillary sinus wall in a sample of the Singaporean population. J Oral Max Surg Med. 2017;29(1):39-44.

19. Hungerbuhler A, Rostetter C, Lubbers HT, Rucker M, Stadlinger B. Anatomical characteristics of maxillary sinus septa visualized by cone beam computed tomography. Int J Oral Maxillofac Surg. 2019;48(3):382-7.

20. Simsek Kaya G, Daltaban O, Kaya M, Kocabalkan B, Sindel A, Akdag M. The potential clinical relevance of anatomical structures and variations of the maxillary sinus for planned sinus floor elevation procedures: A retrospective cone beam computed tomography study. Clin Implant Dent Relat Res. 2019;21(1):114-21.

21. Rancitelli D, Borgonovo AE, Cicciu M, Re D, Rizza F, Frigo AC, et al. Maxillary sinus

septa and anatomic correlation with the schneiderian membrane. J Craniofac Surg. 2015;26(4):1394-8.

22. Orhan K, Kusakci Seker B, Aksoy S, Bayindir H, Berberoğlu A, Seker E. Cone beam CT evaluation of maxillary sinus septa prevalence, height, location and morphology in children and an adult population. Med Princ Pract. 2013;22(1):47-53.

23. Kang SJ, Shin SI, Herr Y, Kwon YH, Kim GT, Chung JH. Anatomical structures in the maxillary sinus related to lateral sinus elevation: a cone beam computed tomographic analysis. Clin Oral Implants Res. 2013;24 Suppl A100:75-81.

24. Taleghani F, Tehranchi M, Shahab S, Zohri Z. Prevalence, location, and size of maxillary sinus septa: computed tomography scan analysis. J Contemp Dent Pract. 2017;18(1):11-5.

25. Irinakis T, Dabuleanu V, Aldahlawi S. Complications during maxillary sinus augmentation associated with interfering septa: a new classification of septa. Open Dent J. 2017;11:140-50.

26. Chitsazi MT, Shirmohammadi A, Faramarzi M, Esmaieli F, Chitsazi S. Evaluation of the position of the posterior superior alveolar artery in relation to the maxillary sinus using the cone-beam computed tomography scans. J Clin Exp Dent. 2017;9(3):e394-e9.

27. Ilguy D, Ilguy M, Dolekoglu S, Fisekcioglu E. Evaluation of the posterior superior alveolar artery and the maxillary sinus with CBCT. Braz Oral Res. 2013;27(5):431-7.

28. Mudgade DK, Motghare PC, Kunjir GU, Darwade AD, Raut AS. Prevalence of anatomical variations in maxillary sinus using cone beam computed tomography. J Indian Acad Oral Med Radiol. 2018;30(1):18-23.

29. Shahidi S, Zamiri B, Momeni Danaei S, Salehi S, Hamedani S. Evaluation of anatomic variations in maxillary sinus with the aid of cone beam computed tomography (CBCT) in a population in south of Iran. J Dent (Shiraz). 2016;17(1):7-15.

30. Mardinger O, Abba M, Hirshberg A, Schwartz-Arad D. Prevalence, diameter and course of the maxillary intraosseous vascular canal with relation to sinus augmentation procedure: a radiographic study. Int J Oral Maxillofac Surg. 2007;36(8):735-8.

31. Guncu GN, Yildirim YD, Wang HL, Tozum TF. Location of posterior superior alveolar artery and evaluation of maxillary sinus anatomy with computerized tomography: a clinical study. Clin Oral Implants Res. 2011;22(10):1164-7.

32. Jung J, Yim JH, Kwon YD, Al-Nawas B, Kim GT, Choi BJ, et al. A radiographic study of the position and prevalence of the maxillary arterial endosseous anastomosis using cone beam computed tomography. Int J Oral Maxillofac Implants. 2011;26(6):1273-8.

33. Kim JH, Ryu JS, Kim KD, Hwang SH, Moon HS. A radiographic study of the posterior superior alveolar artery. Implant Dent. 2011;20(4):306-10.

34. Anamali S, Avila-Ortiz G, Elangovan S, Qian F, Ruprecht A, Finkelstein M, et al. Prevalence of the posterior superior alveolar canal in cone beam computed tomography scans. Clin Oral Implants Res. 2015;26(1):e8-12.

35. Khojastehpour L, Dehbozorgi M, Tabrizi R, Esfandnia S. Evaluating the anatomical location of the posterior superior alveolar artery in cone beam computed tomography images. Int J Oral Maxillofac Surg. 2016;45(3):354-8.

36. Lozano-Carrascal N, Salomo-Coll O, Gehrke SA, Calvo-Guirado JL, Hernandez-Alfaro F, Gargallo-Albiol J. Radiological evaluation of maxillary sinus anatomy: A cross-sectional study of 300 patients. Ann Anat. 2017;214:1-8.

37. Danesh-Sani SA, Movahed A, ElChaar ES, Chong Chan K, Amintavakoli N. Radiographic evaluation of maxillary sinus lateral wall and posterior superior alveolar artery anatomy: a cone-beam computed tomographic study. Clin Implant Dent Relat Res. 2017;19(1):151-60.

38. Tehranchi M, Taleghani F, Shahab S, Nouri A. Prevalence and location of the posterior superior alveolar artery using cone-beam computed tomography. Imaging Sci Dent. 2017;47(1):39-44.

39. Yalcin ED, Akyol S. Relationship between the posterior superior alveolar artery and maxillary sinus pathology: a cone-beam computed tomography study. J Oral Maxillofac Surg. 2019;77(12):2494-502.

40. Aung CMS, Panmekiat S, Pimkhaokham A. The study of the alveolar antral artery canal in a group of Thai population using cone beam computed tomography. Mahidol Dental Journal. 2017;37:63-9.

41. Neugebauer J, Ritter L, Mischkowski RA, Dreiseidler T, Scherer P, Ketterle M, et al. Evaluation of maxillary sinus anatomy by cone-beam CT prior to sinus floor elevation. Int J Oral Maxillofac Implants. 2010;25(2):258-65.

42. Visconti M, Ferreira L, Prado R, Sousa Melo S, Silvestre Verner F, Haiter-Neto F.

Evaluation of maxillary sinus septa prior to dental implant therapy: a cone beam computed tomography study. Int J Odontostomat. 2018;12(2):97-102.

43. Velasco-Torres M, Padial-Molina M, Alarcon JA, O'Valle F, Catena A, Galindo-Moreno P. Maxillary sinus dimensions with respect to the posterior superior alveolar artery decrease with tooth loss. Implant Dent. 2016;25(4):464-70.

44. Yang HM, Bae HE, Won SY, Hu KS, Song WC, Paik DJ, et al. The buccofacial wall of maxillary sinus: an anatomical consideration for sinus augmentation. Clin Implant Dent Relat Res. 2009;11 Suppl 1:e2-6.

45. Yang SM, Park SI, Kye SB, Shin SY. Computed tomographic assessment of maxillary sinus wall thickness in edentulous patients. J Oral Rehabil. 2012;39(6):421-8.

46. Monje A, Catena A, Monje F, Gonzalez-Garcia R, Galindo-Moreno P, Suarez F, et al. Maxillary sinus lateral wall thickness and morphologic patterns in the atrophic posterior maxilla. J Periodontol. 2014;85(5):676-82.

47. Pommer B, Ulm C, Lorenzoni M, Palmer R, Watzek G, Zechner W. Prevalence, location and morphology of maxillary sinus septa: systematic review and meta-analysis. J Clin Periodontol. 2012;39(8):769-73.

48. Kim MJ, Jung UW, Kim CS, Kim KD, Choi SH, Kim CK, et al. Maxillary sinus septa: prevalence, height, location, and morphology. A reformatted computed tomography scan analysis. J Periodontol. 2006;77(5):903-8.

49. Shen EC, Fu E, Chiu TJ, Chang V, Chiang CY, Tu HP. Prevalence and location of maxillary sinus septa in the Taiwanese population and relationship to the absence of molars. Clin Oral Implants Res. 2012;23(6):741-5.

50. Solar P, Geyerhofer U, Traxler H, Windisch A, Ulm C, Watzek G. Blood supply to the maxillary sinus relevant to sinus floor elevation procedures. Clin Oral Implants Res. 1999;10:34-44.

51. Traxler H, Windisch A, Geyerhofer U, Surd R, Solar P, Firbas W. Arterial blood supply of the maxillary sinus. Clin Anat. 1999;12(6):417-21.

52. Ariji Y, Kuroki T, Moriguchi S, Ariji E, Kanda S. Age changes in the volume of the human maxillary sinus: a study using computed tomography. Dentomaxillofac Radiol. 1994;23(3):163-8.

53. Przystanska A, Kulczyk T, Rewekant A, Sroka A, Jonczyk-Potoczna K, Gawriolek K,

et al. The association between maxillary sinus dimensions and midface parameters during human postnatal growth. Biomed Res Int. 2018:1-10.

54. Suzuki H, Yamaguchi T, Furukawa M. Maxillary sinus development and sinusitis in patients with cleft lip and palate. Auris Nasus Larynx. 2000;27(3):253-6.

55. Boyne PJ, James RA. Grafting of the maxillary sinus floor with autogenous marrow and bone. J Oral Surg. 1980;38(8):613-6.

56. Toraman Alkurt M, Peker I, Degerli S, Cebeci ARI, Sadik E. Comparison of cone-beam computed tomography and panoramic radiographs in detecting maxillary sinus septa. J Istanb Univ Fac Dent. 2016;50(3):8-14.

57. Maridati P, Stoffella E, Speroni S, Cicciu M, Maiorana C. Alveolar antral artery isolation during sinus lift procedure with the double window technique. Open Dent J. 2014;8:95-103.

58. Ata-Ali J, Diago-Vilalta JV, Melo M, Bagan L, Soldini MC, Di-Nardo C, et al. What is the frequency of anatomical variations and pathological findings in maxillary sinuses among patients subjected to maxillofacial cone beam computed tomography? A systematic review. Med Oral Patol Oral Cir Bucal. 2017;22(4):e400-e9.

59. Bayrak S, Ustaoglu G, Demiralp KO, Kursun Cakmak ES. Evaluation of the characteristics and association between schneiderian membrane thickness and nasal septum deviation. J Craniofac Surg. 2018;29(3):683-7.

60. Carmeli G, Artzi Z, Kozlovsky A, Segev Y, Landsberg R. Antral computerized tomography pre-operative evaluation: relationship between mucosal thickening and maxillary sinus function. Clin Oral Implants Res. 2011;22(1):78-82.

61. de Carvalho ABG, Ferreira Costa AL, Fuziy A, de Assis ACS, Castro Veloso JR, Coutinho Manhaes LRJ, et al. Investigation on the relationship of dimensions of the maxillary sinus drainage system with the presence of sinusopathies: a cone beam computed tomography study. Arch Oral Biol. 2018;94:78-83.

62. Wayne, D. W. Biostatistics. A foundations of analysis in the health sciences. 6th ed. New York: John Wiley & Sons; 1995. p. 180.

63. Sayin M, Türkkahraman H. Malocclusion and crowding in an orthodontically referred Turkish population. Angle Orthod. 2004;74(5):635-9.

64. Stern A, Green J. Sinus lift procedures: an overview of current techniques. Dent

Clin North Am. 2012;56(1):219-33.
65. Yilmaz HG, Tozum TF. Are gingival phenotype, residual ridge height, and membrane thickness critical for the perforation of maxillary sinus? J Periodontol. 2012;83(4):420-5.
66. Farina R, Pramstraller M, Franceschetti G, Pramstraller C, Trombelli L. Alveolar ridge dimensions in maxillary posterior sextants: a retrospective comparative study of dentate and edentulous sites using computerized tomography data. Clin Oral Implants Res. 2011;22(10):1138-44.
67. Sharan A, Madjar D. Maxillary sinus pneumatization following extractions: a radiographic study. Int J Oral Maxillofac Implants. 2008;23(1):48-56.
68. Cavalcanti MC, Guirado TE, Sapata VM, Costa C, Pannuti CM, Jung RE, et al. Maxillary sinus floor pneumatization and alveolar ridge resorption after tooth loss: a cross-sectional study. Braz Oral Res. 2018;32:e64.
69. Ardekian L, Oved-Peleg E, Mactei EE, Peled M. The clinical significance of sinus membrane perforation during augmentation of the maxillary sinus. J Oral Maxillofac Surg. 2006;64(2):277-82.
70. Neiva RF, Gapski R, Wang HL. Morphometric analysis of implant-related anatomy in Caucasian skulls. J Periodontol. 2004;75(8):1061-7.
71. Rosano G, Taschieri S, Gaudy JF, Del Fabbro M. Maxillary sinus vascularization: a cadaveric study. J Craniofac Surg. 2009;20(3):940-3.
72. Elian N, Wallace S, Cho SC, Jalbout ZN, Froum S. Distribution of the maxillary artery as it relates to sinus floor augmentation. Int J Oral Maxillofac Implants. 2005;20(5):784-7.
73. Pommer B, Unger E, Suto D, Hack N, Watzek G. Mechanical properties of the Schneiderian membrane in vitro. Clin Oral Implants Res. 2009;20(6):633-7.
74. Dursun E, Keceli HG, Dolgun A, Velasco-Torres M, Olculer M, Ghoreishi R, et al. Maxillary sinus and surrounding bone anatomy with cone beam computed tomography after multiple teeth loss: a retrospective multicenter clinical study. Implant Dent. 2019;28(3):226-36.
75. Monje A, Diaz KT, Aranda L, Insua A, Garcia-Nogales A, Wang H-L. Schneiderian membrane thickness and clinical implications for sinus augmentation: a systematic

review and meta-regression analyses. J Periodontol. 2016;87(8):888-99.

76. Yeung AWK, Colsoul N, Montalvao C, Hung K, Jacobs R, Bornstein MM. Visibility, location, and morphology of the primary maxillary sinus ostium and presence of accessory ostia: a retrospective analysis using cone beam computed tomography (CBCT). Clin Oral Investig. 2019;23(11):3977-86.

77. Velasco-Torres M, Padial-Molina M, Avila-Ortiz G, García-Delgado R, O'Valle F, Catena A, et al. Maxillary sinus dimensions decrease as age and tooth loss increase. Implant Dent. 2017;26(2):288-95.

VITA

NAME	Nutcha Benjaphalakron
DATE OF BIRTH	22 May 1992
PLACE OF BIRTH	Thailand
INSTITUTIONS ATTENDED	Doctor of dental surgery D.D.S.
HOME ADDRESS	505/238 Condo ideo mobi Phaya Thai , Si Ayutthaya Road, Khwaeng Thung Phaya Thai, Khet Ratchathewi, Bangkok 10400 Thailand