PREVALENCE & IMPACT OF MAXILLARY SINUS INCIDENTAL FINDINGS IN CONE-BEAM COMPUTERIZED TOMOGRAPHY A SYSTEMATIC REVIEW

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by
Shadi Alzahrani, DDS, FRCD (C) May 2021

Examining Committee Members:

Louis DiPede, DMD, FACP Thesis Advisor, Department of Restorative Dentistry, Temple University School of Dentistry

Jie Yang, DMD, MS Department of Oral and Maxillofacial Pathology, Medicine and Surgery, Temple University School of Dentistry

Maobin Yang, DMD, MDS, PhD, Department of Endodontic, Temple University School of Dentistry

ABSTRACT

Objective: Applications of Cone-beam computerized tomography (CBCT) have increased dramatically in dentistry. Incidental findings (IFs) beyond the area of interest may be encountered. The maxillary sinus incidental findings in CBCT were considered the highest in the literature. This systematic review aims to analyze present literature on IFs in the maxillary sinus using CBCT

Methods: Electronic databases was searched for studies on the maxillary sinus incidental findings in CBCT to assess the prevalence and significance of the incidental findings.

Results: The initial search retrieved 239 abstracts, of which only 9 studies met the inclusion criteria. The sample size ranged from 34-1029 participants with a mean age of 35.4. The prevalence of incidental findings in the maxillary sinus was between 27 to 62.4%. Such findings in the maxillary sinus vary in importance and the need for intervention. The most common incidental findings were the thickening of the mucosal membrane followed by the polypoid lesion.

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CHAPTER 1

INTRODUCTION

Computerized tomography (CT) is the cornerstone for modern medical radiologists. An estimation of a 15-20% annual growth rate for medical CT is expected[1]. In 1998, cone-beam computerized tomography (CBCT) was introduced to provide a comprehensive three-dimensional view to overcome the drawbacks of 2-dimensional radiographs as well as decrease the radiation associated with the conventional CT [2].

The physics and mechanics behind the CBCT are fundamentally different from the conventional CT. As the name implies, a cone-shaped beam is a characteristic of CBCT, while conventional CT has a fan-shaped beam. Also, the source of the x-ray in CBCT makes less than 360-degree rotation, whereas the helical rotation around the area of interest is in the conventional CT. Due to horizontally collimated field of view (FOV) and lower tube output (kV,mAs), CBCT has a lower radiation dose than a conventional CT. [3,4,5]

The application of CBCT in dentistry and its use has dramatically increased for diagnosis and treatment planning especially for complex cases, including assessment of pathology, trauma, dental implants, and orthodontic treatment because of the high-quality 3-dimensional view for maxillofacial structures, no superimposition of the surrounding structure, and no gematric distortion.[2,6] There are different CBCT units on the market based on system, tube potential, current, and the field of view (FOV).[7,8,9]

FOV is the volume of the patient's tissue irradiated during exposure. Different parameters can determine FOV, such as beam projection geometry, and beam collimation, detector size, and shape. Hight of 10 cm or more is considered as large FOV, while less than 10 cm is small to medium FOV.[7] The ALARA (as low as reasonably achievable) should be followed to minimize the risk of radiation.[10] Also, CBCTs should be reserve when the lower dose radiograph fails to demonstrate the necessary diagnostic value.[7] Using the smallest FOV that achieves the image's interest is recommended to comply with the ALARA principle.[10]

While the CBCT has a significant advantage of a wide view and three-dimensional quality, one major effect of this technique are the incidental findings that may be encountered, and how to interpret those findings.[6] An incidental finding can be defined as a finding beyond the original area of interest. Incidental findings have been reviewed in other medical image modalities. The prevalence of IFs on the various image modalities can reach up to 31%.[6]

The maxillary sinus is one of the four pairs paranasal sinuses in the skull. It is the largest and begins development in the second or third intrauterine month which is the first to develop of the paranasal sinuses. [6] The maxillary sinus has a pyramidal shape with a base adjacent to the nasal cavity apex toward the zygoma.[39] It lined by specialized epithelium named the Schneiderian membrane, which is essential for a filter, warming and humidifying the inspired air. The Schneiderian mucosal membrane thickness range between 0.3-0.8 mm. The superior boundary of the maxillary sinus is formed by the orbital floor, which separates the orbital contents from the maxillary sinus. The lateral

wall of the nasal cavity forms the medial wall of the maxillary sinus. The floor of the maxillary sinus is continuous with the dental alveolar process. The lateral wall is contiguous with the buccal aspect of the dental alveolar process.[39]

Medical CT is considered a gold standard for radiographic examination of the maxillary sinus. [13,16,17] Because of the proximity to the posterior maxillary teeth, maxillary sinuses are usually visualized in a diagnostic CBCT of the posterior maxillary teeth and alveolus.

Incidental findings are not uncommon across various dental disciplines. For instance, higher cysts were found in the maxillary sinuses floor when there is endodontics treatment or pathology. [11] It was reported by Lu et al. the association between apical periodontitis and mucosal thickening. The prevalence of mucosal thickening was found to be 100 % with severe periodontitis patients, more than 70 % with mild to moderate periodontitis compared to 41% without apical periodontitis disease. [12]

The most common incidental findings in CBCT showed in the maxillary sinus. [13] Also, the prevalence was greater in the magnetic resonance imaging (MRI) because of higher sensitivity in detecting soft tissue lesions in general. Those incidental findings were asymptomatic. [13,14] Benign lesions, anatomical variation, and malignancies have all been reported as maxillary sinus incidental findings.

In general, maxillary sinus pathology can divide into neoplastic and Non-neoplastic lesions. Non-neoplastic lesions commonly include mucous retention cyst, antrochoanal polyp, and mucocele. The incidence of cysts in the maxillary sinus detected

on CT is between 12.4 and 35.6%.[15] Classification of cysts in the maxillary sinus can be further divided according to the formation mechanism into secretory and non-secretory cysts. [15] Secretory cysts can form by obstruction of mucosal glands. The more common is the non-secretory cyst, which can form by an exudate formation and accumulation in the sinus mucosa, leading to lifting of the epithelium lining. [18,19] Dental disease has been associated with up to 50% of mucous retention cysts and are unilateral in 80-90% of cases. [20] Most mucous retention cysts are found on the floor of the maxillary sinus. Controversy exists in the literature on the clinical significance and management of mucous retention cyst. [20,21,22]

Mucocele on the other hand, is an epithelial lining mucus containing sac. Mucoceles can expand and cause bone resorption. [23] Trauma, inflammation, surgery, and neoplasm can contribute to forming a mucocele in the maxillary sinus. Mucoceles may cause nasal obstruction, check swelling, or orbital displacement. [24] Endoscopic treatment is the preferred treatment option for the management of a mucocele. [25]

An antrochoanal polyp is a benign lesion that arises from the mucosa of the maxillary sinus. They may grow into the nasal cavity to reach the choana. [25] Antrochoanal polyps are more common in children. [26,27] Surgical excision is accepted management of antrochoanal polyps. [26]

The comprehensive review of a CBCT also provides an opportunity to examine and inspect anatomical variations, such as accessory ostium and maxillary septum. [28] Those anatomical variations could be attributed to existing sinusitis and may interfere with a planned procedure. [29] A good understanding of the surrounding anatomical

structures is essential to conduct a comprehensive examination and interpretation of the entire radiograph view to avoid any negative consequences. [30] Not every practitioner has the skills and knowledge to review and interpret the findings in a CBCT. Therefore, the American Academy of Oral and Maxillofacial Radiology (AAOMR) and the European Academy of DentoMaxilloFacial Radiology (EADMFR) were outlined the necessity for referral to an Oral and Maxillofacial radiologist when the clinician is not experienced in the interpretation of CBCT beyond the initial area of interest of the 3-dimentional radiograph. [31,32]

Recognizing anatomical variations in the maxillary sinus can facilitate the proposed surgical procedure and help to avoid complications. For example, maxillary sinus septa are one of the anatomical variations associated with increasing the complication rate. The complications may include perforation of the sinus membrane and hemorrhage during a sinus graft procedure. [17,29,33] The presence of septae can range from 10-58% of sinuses. As such, CBCT can detect those septae before the procedure, which can decrease the incidence of perforation of the sinus membrane or other complications by altering the surgical technique. [33]

Other anatomical variations in the maxillary sinus are accessory ostium and ethmoidal pneumatization (Haller cells), which are associated with maxillary sinusitis. The presence of accessory ostium can be found in up to 19% of patients, and Haller cells may be seen more frequently in the maxillary sinus (14-43%). [29]

This systematic review aims to analyze and evaluate the frequency and risk of IFs in the maxillary sinus in CBCT.

CHAPTER 2

MATERIALS AND METHODS

A comprehensive electronic search was conducted in various electronic databases, including PubMed, Medline, and Google scholar electronic databases, for studies to evaluate the maxillary sinus incidental findings in CBCT scan from January 2000 to December 2020. Studies reported in other than English language were excluded. In order to increase reproductivity and transparency, this systematic review will be utilizing the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) reporting guidelines.

The following keywords were used in the search: “incidental findings” AND “maxillary sinus” AND “cone-beam computed tomography” OR “conebeam computed tomography.”

The selection of the articles was conducted in two phases. In phase 1, the study's title and abstract were reviewed using established inclusion criteria: studies of humans and reported in English peer-reviewed articles with incidental findings in the maxillary sinus in CBCT, reported prevalence, nature, or impact of those incidental findings. The following exclusion criteria were applied:

1. Case reports and case series
2. Studies with a focus on IFs in patients with syndromic patients
3. Studies that do not include IFs in the maxillary sinus
4. Clefts patients
5. Studies published in languages other than English

In phase 2, a full text was thoroughly reviewed and identified for final review using the established inclusion criteria.

Inclusion criteria:

1. Human studies of all ages
2. Reporting maxillary sinus incidental findings in CBCT
3. all FOVs (small and large)

Exclusion criteria:

1. language other than English
2. Not reporting the incidental findings in the maxillary sinus

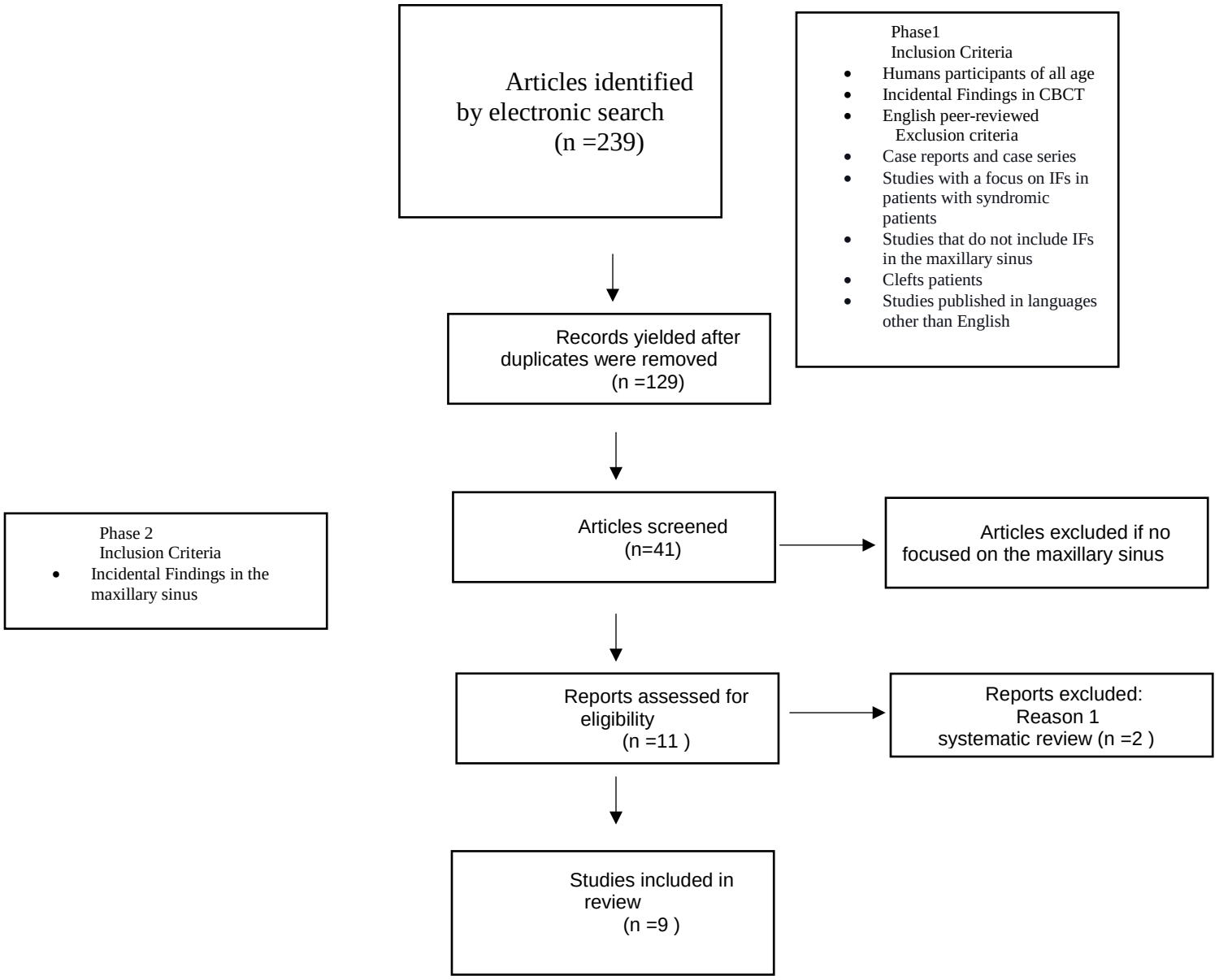
Data extraction

The following data were extracted from the studies included in the final analysis: author names, year of publication, design of the study, number of patients, mean age, M/F ratio, FOV size, type of CBCT, the prevalence of incidental findings in maxillary sinus, type of reviewers, definition of each incidental findings, voxels size, kVp, mA, and findings.

Quality assessment & Risks of bias

The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) was used to assess the quality and the risk of bias. Studies were categorized into three groups. 1-20 % considered low risk of bias, while 20-50 % is moderate risk and more than 50% has a high risk of bias.

Figure 1 PRISMA Flowchart.



CHAPTER 3

RESULTS

Study selection

Two hundred thirty-nine studies were reported in the initial search. The title and abstract were reviewed in phase 1, which resulted in 129 studies remaining after removing the duplication with incidental findings in the maxillary sinus. In phase 2, 9 full-text studies were reviewed and analyzed, which meet our inclusion criteria.

Study Characteristics

Nine Studies were deemed eligible and included, which were published from 2011 through 2019. The sample size ranged from 34 to 1029. The mean age of participants is 35.4, and the range of participants was from 3 to 107 years.

Studies have been conducted globally, including the United States, Germany, Turkey, Hong Kong, Switzerland, and Lativa. All the studies were conducted in a university setting except one study, which was based on private practice.

Regarding field of view size, one study only used a small FOV; the rest of the studies used either a large FOV or a combination of both. Voxels of the images were between 0.09 to 0.5 mm. Kilovolts were between 80 to 129. Milliamps (mA) in the CBCT machines were between 5 to 20, with 5 was the most dominant settings. Different types of CBCT were used from different companies (KaVo, Galileos, I-Cat, Verona, Kodak).

Regarding the reviewers, certified oral and maxillofacial radiologists (OMFR) were involved in the interpretation of five studies. One study did not mention the type of the reviewer. Two studies were reviewed by experienced oral surgeons, general dentists, and postgraduate periodontology residents, one by an orthodontist and medical radiologist. When the postgraduate residents reviewed the CBCT, the oral and maxillofacial radiologist was consulted when doubts were present.

In general, the maxillary sinus incidental findings in CBCT were range from 27% to 62.4%. There was variability in the definition and parameters of the incidental findings throughout the studies. Two studies included the dental findings, such as impacted tooth or tooth in the maxillary sinus in the incidental findings, two studies did not include anatomical variations as an incidental finding. One study discussed only the radiopacity incidental findings in the maxillary sinus. Mucosal thickening was the most common incidental findings in the maxillary sinus, ranging between 14.93 -48.5%. Although, the variability of the thickness between 1-3 mm which considered normal.

Risk of bias

Bias assessment was conducted by using STROBE guidelines to evaluate the quality of the nine selected papers. The overall risk of bias ranged from low to moderate, with only one article only having a high risk of bias. The detailed methodological scores are presented in table 2. For the objectives, 8 out of 9 articles state a specific objective and hypothesis. All of the nine studies described a study design early on. 7 studies met the methodological setting criteria and described the relevant dates and location. Stating a

clear eligibility criterion was described in 7 papers. Only one study did not describe all relevant statistical methods. For the results section, the numbers at each group, outcomes, and the main result were described and stated in all the nine studies. 4 papers were missing the limitations and potential bias discussion.

Table 1 Studies characteristic

Author	year	Study Design	Sample Size	age range	mean age	M/F	FOV Size	Type of CBCT	Maxillary Sinus IF	Type of Reviewers	Voxels Size	kVp
Ritter	2011	RS	1029	8 to 107	44.19	52-48 %	Large	Galileos	53.3	OS,2GD	0.30/0.15	85
Hsiao	2019	RS	680	3 to 90	48.53	48-52 %	All	i-CAT	37.21	Resident, OMFR	0.3	120
Drage	2013	RS	329	N/M	14.5	44.1-55.9 %	All	i-CAT	37	OMFR	0.2-0.4	120
Dedeoğlu	2019	RS	258	20–79	45.17	N/M	Large	NewTom 5G	41.90%	OMFR	0.3, 0.25, and 0.2	110
Pazera	2010	RS	139	N/M	17.5	45.3-54.7 %	small	3 DX Accuitomo	45.80%	orthodontist,OMFR	0.125	N/M
Kawai	2019	RS	169	7 to 82	28.7	36-64 %	Large	ProMax 3D Mid	just radiopacity 20%	2 OMFR	N/M	N/M
Raghav	2014	RS	201	10 to 69	32.09	55.3-44.7	All	Kodak 9300	76.10%	2 OMFR	0.09-0.5	80-90
Dobele	2013	RS	34	31-64	52.53	53-47 %	N/A	I-CAT	MT 55.9 OB 20.5,	N/M	025-0.4	129
Avsever	2018	RS	999	5to 84	N/A	61.2-38.8	Large	3D Accuitomo 170	62.4	2 OMFR	N/M	N/M

TABLE 2 STROBE CHECKLIST

Authors	Ritter	Hsiao	Drage	Pazera	Kawai	Kurtuldu	Raghav	Dobele	Avsever
Criteria									
Introduction									
Objectives (states specific objectives and hypothesis?)	✓	✓	✓	✓	✓	✓	✓	X	✓
Methods									
Study design (presents key elements of study design early on?)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Setting (describes in term of location ✓ and relvant dates ✓?)	X	✓	✓	✓	✓	✓	X	✓	✓
Participants (gives eligibility criteria ✓ and methods of selection ✓?)	X	✓	✓	✓	✓	✓	✓	X	✓
Bias (efforts to address potential bias described?)	X	X	X	X	✓	X	✓	X	✓
Study size (method to retrieve study size explained? Was it adequate?) ✓.✓	X. ✓	✓. ✓	X. ✓	✓. ✓	✓. ✓	X. ✓	X. ✓	X. ✓	✓. ✓
Statistical methods (all statistical methods described? Appropriate for data?) ✓.✓	✓ ✓	✓. ✓	✓. ✓	✓. ✓	✓. ✓	✓. ✓	✓. ✓	X	✓. ✓
Results									
Participants (numbers at each stage described?)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Outcome data (numbers of outcome events reported?)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Main results (estimates given?)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Discussion									
Limitations (were limitations including potential bias discussed?)	✓	X	✓	X	✓	✓	✓	X	X
Interpretation (were cautious interpretations discussed?)	✓	✓	✓	✓	✓	✓	x	X	✓
Generalizability (study has external validity?)	X	✓	✓	✓	✓	✓	✓	✓	✓
Other Information									

Funding (was source of funding outlined? If so, bias with funders?)	X	✓	X	X	✓	✓	X	X	✓
Total score	10 out 16	14 out of 16	13 out of 16	13 out of 16	15/ 16	14 out of 16	11 out of 16	7 out of 16	15 out of 16
Total percentage	63	88	81	81	94	88	68	44	94

CHAPTER 4

DISCUSSION

The prevalence of maxillary sinus incidental findings in CBCT in our systematic review ranged from 37 to 62.4%. Failure to identify those incidental findings may cause potential negative medical consequences and medicolegal issues. There was variability in the nine selected studies' results because there was no standardization of the population characteristics. Compared to the previous systematic reviews, our overall prevalence was less than the systematic reviews of Khalifa et al., Edward et al., and Dief et al. The difference primarily because of the inclusion criteria and limited to one anatomical area instead of investigating the maxillofacial area.[34,35,36]

A wide mean age range of the participants was observed (3-107 years) in the included studies. The age was reviewed to investigate the correlation with the incidental findings in many studies. Studies show an increase in the incidental findings with an advanced age population. [34] The same trend was observed in our review in four studies by Ritter, Hsiao, Pazera, and Kawai wt. al when participants were grouped based on age. Nevertheless, it was statistically significant for age over 60 in only one study (P=0.01), when Lutz Ritter et al. reviewed the maxillary sinus incidental findings in CBCT in 1029 patients. [2]

Dedeoğlu et al. evaluated the maxillary sinus anatomical variation and pathologies in young, and elderly 140 patients with the age range were 20–79 years.

More pathologies were found in elderly patients in contrast to young patients, but the finding was not statistically significant (P=0.077). In contrast, the accessory ostium presence, which is one of the anatomical variations, was statistically significant in the elderly patients (P= 0.009), according to Dedeoğlu et al.[29]

Besides a wide range of mean age, the indications of CBCT are different between the age group. Implant procedures and sinus grafts usually occur in the older population when compared to orthodontic treatment. So, we have different indications for different age groups, which may skew our results higher or lower.

Another characteristic that may explain the variability in the prevalence is the size of FOV. Increasing the FOV will provide a larger area of an anatomical structure that can increase the chances of detecting incidental findings. One study used small FOV while the rest used a combination between large or both sizes. However, even with small FOV, incidental findings were 45.8%.

There was a variability thorough the studies for defining the incidental findings' parameters which increase the resulting variability and explains the difference in the prevalence. One study investigated the presence of radiopaque lesions in the maxillary sinus. In general, incidental findings in the maxillary sinus can be categorized into anatomical variations or pathological findings. The pathological findings can be categorized differently, but the more common conditions throughout the literature result from inflammation, cystic condition, developmental abnormalities, calcifications, neoplasms, or trauma. [2,6]

Inflammatory conditions have the highest prevalence in the maxillary sinus. Those can be categorized into acute or chronic rhinosinusitis. The cystic lesion can be further divided into secretory and non-secretory. The cystic lesions are considered benign in nature and found to be the second most common after the inflammatory conditions. [2]

The Schneiderian membrane thickening is an inflammatory reaction to an insult such as infection, trauma, neoplasm, etc. [6] Mucosal thickening was found to be the most common maxillary sinus incidental findings in CBCT. [37] The normal thickness of the Schneiderian membrane is 0.8-1 mm. [14] Although, there is a variability thorough the literature for defining the mucosal thickness of the Schneiderian membrane. Most of the literature uses the range between 1 to 3 mm as the limits for a diagnosis of mucosal thickening with no consensus on the mucosal membrane's normal thickness. [37,38] Acceptance of certain limit can increase or decrease the overall incidental findings prevalence in the maxillary sinus throughout the literature. Especially since that mucosal thickening is the most common incidental finding. [13,37] However, Rak et al. showed no clinical significance for a mucosal membrane equal to or less than 3 mm, which was concluded to be a normal variant. [6]

Mucocele and retention cyst are from cystic secretory conditions. A mucocele is benign, expansile, and cyst-like and containing mucus lined with epithelium, while a retention cyst is a dome-shaped radiopacity that forms as a result of a blockage of mucus glands. [6,29]

The other limitations to the current review were that all nine studies were retrospective cross-sectional-based design studies that have inherent risk for potential

bias. However, more robust evidence is generally unavailable; it seems to offer the best evidence. On the other hand, the review methodology for CBCT was not standardized, with wide visibility in the review technique, type of reviewer, and reliability measurements between the reviewers. Certified oral and maxillofacial radiologists were involved in reviewing the image in 5 studies. While in one study, CBCT was reviewed by an orthodontist and medical radiologist. The rest are reviewed by an oral surgeon, general dentists, senior periodontology residents, and questionable findings were discussed with the radiologist. Single reviewers evaluated two studies, which can increase reporter bias. Two independent observers have reviewed the data in 5 studies, which will decrease the reporter bias. One study did not mention the type of reviewer or the method of reviewing the image. In Addition, calibration of the final findings was conducted differently and was mentioned in 4 studies out of 9. In one study, calibration of reviewers was performed by using five examples for each finding. Another one reviewed 10% of the cases at least six months after initial reviewing.

Significant of those findings and those requiring intervention or follow-up. This is one of the limitations of those types of studies which are based purely on reviewing the scans without associated clinical investigation. The clinically significant incidental findings were discussed only by Drage et al. They investigated the impact of the incidental findings on orthodontic treatment decisions by reviewing 455 cases. 168 incidental findings were significant and required clinical examination, but that did not change the intended treatment plan. In contrast, 200 incidental findings did not require further examination. They concluded that less than 1 % of incidental findings influenced

the orthodontic treatment. [7] In another study, 187 CBCTs were reviewed by Dogramaci et al., who reported that 28.8% of the incidental findings required clinical examination and follow-up, 16% required intervention, and 15.6% monitoring.[15] Also, Nguyen et al. reviewed 300 CBCT and showed that 12% of the incidental findings required abortion or amendment of an intended treatment plan, and 37% required at least an addition examination without change on an intended plan. [39] There is lack of unanimity in managing specific incidental findings, and therefore no slandered protocol to help the clinician reach the best outcomes. A systematic review by Khalifa concluded that the majority of the incidental findings in the maxillofacial area in CBCT do not require referral or treatment. [6]

The current review narrows the focus on the maxillary sinus, which is one of the limitations. Incidental findings can be found in any anatomical area and should be reported. Khalifa and Felemban reported in a recent systematic review that the overall frequency of incidental findings ranged from 77 to 92% in the maxillofacial region. There were 1.63 to 3.73 incidental findings per scan, and between 0.3 to 31.4 were highly significant findings. [35] For example, Degenerative joint disease (DJD) of temporomandibular joint (TMJ) was the most common pathological incidental findings. Intracranial calcification may also be found in CBCT, which can be physiologic or vascular calcifications. Most calcifications are considered low significance, but there was a reported association between some calcifications and other conditions and disease.

Future research that combined the radiographic and clinical examination of incidental findings is warranted to determine the actual significance of those incidental

findings and formulate a protocol to deal with those findings. This study also emphasizes the importance of careful interpretation of CBCT with a high prevalence of incidental findings to avoid negative consequences for patients or legal liability to clinicians.

CHAPTER 5

CONCLUSION

In conclusion, the increasing popularity of CBCT because of the high-resolution 3D image and the ability for digital manipulation of anatomical structure in combination with computerized planning software. There is no denying that CBCT is a diagnostic technology that has taken outpatient imaging by storm. CBCT is now used for every aspect of diagnosis, treatment planning, and follow-up after procedures. Those precise images have increased the obtained view, which also increases the chance of incidental findings beyond the region of interest. The incidence of the maxillary sinus incidental findings in our review ranged from 37 to 62.4% from common benign lesion to significant pathology. Mucosal thickening of the Schneiderian membrane was the most common findings throughout the literature. Controversy exists about the significance of those incidental findings. Neoplasm findings were rare but cannot be excluded. Complete reviewing of CBCT is crucial to avoid negative consequences and medicolegal issue.

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