Reliability of A Low Dose CBCT Protocol In Evaluating Sinus Pathology Associated with Potential Implant Sites: An Ex-Vivo Imaging Study

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Master of Dental Science Thesis
Reliability of a Low Dose CBCT Protocol in Evaluating Sinus Pathology
Associated with Potential Implant Sites: An Ex-Vivo Imaging Study

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University of Connecticut
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Introduction

The paranasal sinuses are group of air-filled spaces surrounding the nasal cavity; which start developing from the primitive choana at 25–28 weeks of gestation. Three projections arise from the lateral wall of the nose and serve as the beginning of the development of the paranasal sinuses.

The anterior projection forms the Agger nasi, the inferior or maxiloturbinate projection forms the inferior turbinate and maxillary sinus, while the superior or ethmoido-turbinate projection forms the ethmoidal air cells and their corresponding drainage channels. [1]

The sinuses are named from the facial bones in which they are located:

• Frontal sinuses
• Maxillary sinuses
• Ethmoid sinuses and
• Sphenoid sinuses

The maxillary and ethmoid sinuses are aerated at birth, while the sphenoid sinus and frontal sinuses are pneumatized at about the 2nd and 6th year of life respectively. [1] The sinuses reach the adult size at adolescent age. [1]

When there is any inflammation associated with the sinuses it is referred to as sinusitis. Sinusitis is most often due to an infection within these spaces. Rhinosinusitis (RS) is considered a more accurate term for sinusitis, because most infections begin with or are associated with rhinitis. In addition, the pathophysiology of the disease is thought to be more than just an abscess cavity of the sinus, and probably involves changes in the mucosa of both the nose and sinus cavities. Sinusitis can be categorized as follows:
1. Acute RS (ARS) most commonly presents as an acute upper respiratory infection (URI) that persists (without improvement) beyond 10 days, with the key signs and symptoms being nasal discharge, cough, and bad breath. The 10-day mark is somewhat subjective, because viral URIs can persist beyond 10 days. A less common presentation of ARS is that of a “severe” URI, with fever of 102°F plus concurrent purulent nasal discharge for 3 to 4 days. Conversely, acute rhinitis that is preceded by fever usually is viral in origin.

2. Chronic RS (CRS) is a more apathetic infection that lasts beyond 3 months, with the typical symptoms being nasal congestion, cough, and bad breath. Other signs and symptoms include: headache, and nasal discharge. Exacerbations are common.

3. Recurrent ARS (RARS) implies recurrent infections with relatively healthy intervals in between, although some element of CRS usually is present between acute infections.

Maxillary sinusitis is defined as a symptomatic inflammation of the maxillary sinus and is classified as chronic when it lasts longer than 12 weeks. [1] The origin of sinusitis is considered to be primarily rhinogenous, but in some cases dental infection is a major predisposing factor. The most common causes of odontogenic maxillary sinusitis include apical and marginal periodontitis, oroantral fistulas after tooth extraction and infection caused by intra-antral foreign bodies.

Maxillary sinusitis of odontogenic origin has been reported to account for approximately 10% to 12% of all cases of sinusitis. The maxillary sinus is susceptible to microbial infection via the nasal ostium or oral cavity. Sinus infections may originate from maxillary teeth infection, extractions, foreign bodies, or dental materials iatrogenically placed in the maxillary sinus. When
the Schneiderian membrane integrity is compromised, an odontogenic infection may result in sinusitis.

Patients may have diverse presentations ranging from isolated tooth pain, sinus congestion, respiratory complaints, and asymptomatic radiographic abnormalities. Sinus complaints may present before; concurrent with; or weeks, months, or years after dental symptoms occur. A differential diagnosis of dental or non-dental etiology is essential for the proper management of sinusitis.

Non-symptomatic abnormalities of the maxillary sinus such as mucosal thickening, retention cysts, are reported to occur in up to 74% of all cases. [1]

Mucous retention pseudocyst (MRP) is a benign and self-limiting lesion resulting from the outflow of mucus within the sinus mucosa due to ductal obstruction. It is suggested that MRP is of non-odontogenic origin since it may occur in both dentate and edentulous patients. Nevertheless, it is emphasized that periapical and periodontal diseases associated with maxillary molars, allergic reactions, trauma, smoking, and alteration of air temperature and humidity may be important etiological factors for sinusitis and mucous retention cyst.

As the pathogenesis of MRP seems to be based on hypothesis, many names have been attributed to this lesion including pseudocyst, the retention cyst of the maxillary sinus, serous cyst, mucous cyst, and benign maxillary mucous cyst. A pseudocyst has no epithelial lining and is surrounded by a fibrous connective tissue. [10]

The MRP is commonly found during radiographic examinations performed for other reasons. The lesion appears on panoramic and periapical radiographs of posterior maxillary teeth as a well-defined, homogeneous, dome-shaped, hemispherical or circular radiopacity of different dimensions, most commonly located on the floor of the maxillary sinus while preserving the
sinus walls. When the MRP completely fills the maxillary sinus, the radiographic interpretation becomes difficult since its appearance may mimic maxillary sinusitis.

Maxillary first molars are the teeth that are most lost to periodontal disease. [20] and are increasingly being restored with dental implants. Maxillary posterior edentulous ridges typically have compromised bone volume and sinus augmentation is typically indicated to gain adequate bone volume. Sinus pathology including marked mucosal thickening to mucus retention cysts are a major contraindication for performing sinus augmentation procedures.

For diagnosis of symptomatic pathologies of the maxillary sinus like retention cysts, polyps, and tumors, panoramic radiography is commonly used. Panoramic imaging does not adequately depict this anatomic area well and could lead to erroneous interpretation. Furthermore, small maxillary sinus lesions with diameter less than 3 mm show poor detection rates. [2-9]

To be able to diagnose the maxillary sinusitis, the appropriate imaging technique is needed. Diagnosing any sinus pathology is critical especially in case of placement of posterior implants in maxilla. Studies demonstrated that two-dimensional imaging provides insufficient information regarding the sinus pathology. Three-dimensional imaging using a multi slice CT has been proven to be excellent for evaluation of sinus pathology. When sinus pathology is associated with a posterior maxillary implant site, cone-beam computed tomography (CBCT) is increasingly being used.

Three-dimensional imaging is useful in the maxilla for a wide range of clinical settings, such as trauma, bone pathology, and neoplastic diseases, as well as in dental implantology. Often times when dental implants are being considered in the posterior maxilla, the lack of adequate
bone volume is a major challenge. Bone volume is compensated by doing a sinus augmentation and bone graft procedure.

Cone-beam computed tomography (CBCT) is a relatively new diagnostic tool that has revolutionized diagnosis and treatment planning in the medical and dental fields. CBCT was developed in the late 1970s and later adapted for dental applications in 1995 [12]. It is increasingly being used to image the maxillofacial area in three dimensions. CBCT provided an alternate option to other 3D imaging modalities like conventional CT, with less cost, better spatial resolution, higher-quality bone definition and most importantly lesser radiation exposure.

A CBCT scanner typically goes around the patient a 360-degrees and makes multiple basis projections and reconstructs the area of interest in 3D. While this is currently the routinely used method any effort to reduce the radiation dose without compromising image quality is always a desirable pursuit.

The evolution of a 180-degree CBCT protocol that images the patient by only going around the patient from ear to ear and only on the posterior/ventral aspect can reduce the radiation dose by approximately 40-60%. Lower dose associated with this modality is a major advantage in evaluating areas of interest when mild drop in the resolution is not a major concern. It may be useful in patients who may need radiographic evaluations at multiple time points.

However, it is known that acquiring a scan with a lower number of basis projections would pose the challenge of mild reduction of image resolution. The key is to establish a balance between reduced radiation exposure and resolution so that there is no compromise in the diagnostic quality. Since there are studies that show that a 180° acquisition protocol has been found to be adequate for evaluating an implant site in the posterior maxilla, it is important to
evaluate if this lower resolution acquisition is adequate for evaluating any associated maxillary sinus pathology.

Currently there are no studies that evaluate the diagnostic efficacy of the 180° rotational acquisition for diagnosis of sinus pathology at potential dental implant sites.

**Materials and Methods**

A total of 25 dentate human skulls with no identifiable markers of age, sex, or ethnicity were acquired from the Educational Support Services (Anatomy Laboratory) at UCHC to provide fifty sample sites. (Figure 1)

![Dentate human skull](image)

**Fig 1.** Dentate human skull
Mucosal thickening was replicated in the maxillary sinus as close to a clinical situation as possible. Modeling wax was used to simulate mucosal thickening on the floor, roof, medial and lateral walls of the sinus. Severity of the mucosal thickening was replicated with the layers and amount of thickness of the wax. Vitamin-E capsules and gummies were used to simulate mucus retention cysts and were carefully placed on the floor, medial and lateral walls of the sinus. (Figure 2)

Fig 2. Vitamin E capsules and gummies used to replicate sinus pathologies
All the included skulls were imaged using two 3D acquisition protocols (180- and 360-degree rotation protocols. CBCT images were acquired using J Morita’s Accuitomo CBCT machine. The first scan was acquired with a 360° acquisition with standard exposure parameters (90 kV -10 mA). The scan had 80mm x 80mm focused field of view (FOV) and an exposure time of 17.5 seconds. The second scan was a low dose 180° protocol with exposure parameters (80kV -2mA), a 80x 80mm FOV and an exposure time of 9.0 seconds. (Figure 3).

Following image acquisition, three-dimensional image volumes were reconstructed using i-Dexel reconstruction software provided by the CBCT manufacturer (Accuitomo J,Morita,Kyoto,Japan).

Fig 3. CBCT imaging set up
One Oral and maxillofacial radiology resident and one board certified oral and maxillofacial radiologist analyzed all the images for comparing sinus pathology. All the skulls were assigned a coded number and a master list was created documenting the representative type and location of the simulated pathology. The creation of the master list was done by a research assistant (AE) who did not have any role in the study after the creation of the master list was created and the randomization of the scans was done. The scans were then randomly provided to the evaluators where the evaluators did not know the acquisition protocol while evaluating the scans.

The images were displayed on the radiology departmental image viewing workstation powered by a HP Pavillion ZE 2000 computer and 20-inch dual monitor display with a 1600 x 900-pixel resolution. The viewing conditions (room lighting and display monitor settings) were standardized.

Examiners were allowed to manipulate density, contrast and magnification to simulate actual radiological practices. Prior to the start of image analysis (Figure 4)

![Image](image_url)

**Fig 4.** Pseudo-retention cyst, 180-degree CBCT
Both examiners were calibrated using a set of six images selected from the experimental data set. Each examiner analyzed the images independently and a consensus was reached regarding the analyses and the nomenclature of the simulated pathology. (Figure 4-9)

**Fig 5.** Pseudo-retention cyst, 360-degree CBCT
Fig 6. No sinus pathology, 180-degree CBCT

Fig 7. No Sinus Pathology, 360-degree CBCT
**Fig 8.** Maxillary sinusitis, 180-degree CBCT

**Fig 9.** Maxillary sinusitis, 360-degree CBCT
Results

**Krippendorff’s alpha** (also called *Krippendorff’s Coefficient*) is an alternative to Cohen Kappa for determining inter-rater reliability was performed.

Krippendorff’s alpha Can handle various sample sizes, categories, and numbers of raters. It applies to any measurement level (nominal, ordinal, interval, ration). It commonly used in content analysis to quantify the extent of agreement between raters. (Fig 8) 50 total sample sites of Sinus pathologies were examined by two examiners for each imaging modality 360° CBCT, and 180° CBCT.

The height and width of any sinus pathology was measured by two examiners twice. The intra-rater width is 0.938 and the intra-rater height is 0.952 for 180-degree protocol. (Table 1) The inter-rater width is 0.967 and the inter-rater height is 0.943 for 360-degree protocol.

The Inter-rater and intra-rater agreement was 100 % for identification of Pathology, and mean opinion score was 100% comparing the 180-degree Vs 360-degree protocol. (Fig 7) The intra-rater agreement for mean opinion score for measurement of pathology was 96%and the inter-rater agreement for mean measurement of pathology was 82% comparing 180-degree scans protocol to 360-degree protocol. (Table 2)

The subjective evaluations of the diagnostic quality of the protocols, the ability to make and read measurements of the sinus pathologies, and preferences for the specified diagnosis were comparable. The 360° imaging protocol for this specific diagnosis was not found to be superior to the 180° rotational acquisition.
<table>
<thead>
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<th>Width</th>
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<td>0.938</td>
<td>0.952</td>
<td>0.967</td>
<td>0.943</td>
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Table 1) Intra-rater and Inter-rater agreements for width and height

<table>
<thead>
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<th>Percentage of Agreement</th>
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<tr>
<td></td>
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<td>Identification of Pathology</td>
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<tr>
<td>MOS for identification of Pathology</td>
<td>100</td>
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<tr>
<td>Location of Pathology</td>
<td>100</td>
</tr>
<tr>
<td>MOS for measurement of Pathology</td>
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</table>

Table 2) Inter-rater and intra-rater agreements
Fig 8. Krippendorff’s Alpha
Discussion

Three-dimensional visualization of the area of interest is advantageous for performing many surgical procedures in areas close to important structures, the perforation of which may lead to unwanted complications.

Sinus pathology and maxillary sinusitis in particular is a major concern when placing implants in the posterior maxilla especially when sinus augmentation procedures are required to gain bone volume. Estimating the amount of inter-radicular distance, the quality of bone and pathology of sinus is very important, especially if the procedure is performed without any preoperative imaging or using a 2-dimensional imaging method. [22]

Three-dimensional imaging can solve this issue to a large extent, but the radiation dose remains a concern. A critical balance is to reduce the dose while not compromising the quality of the image for the diagnostic task at hand.

CBCT machines deliver a significantly lower radiation dose than conventional multi-slice medical CT. [14,15] While CBCT is considered a low-dose imaging modality amongst the 3-D imaging modalities available; it delivers a dose higher than that of two dimensional intraoral periapical or panoramic imaging. While this statement is not a reasonable comparison, it is one that is often made. This is largely because, traditionally Panoramic images and periapical images or a combination of these images has traditionally been used to evaluate dentoalveolar structures. Any newer evaluation method is often compared to the existing or widely used methods. Along the lines of that discussion, CBCT delivers a higher radiation dose than 2D imaging modalities.
The comparative dose delivery is constantly changing because of the evolution of newer and more effective CBCT machines.

CBCT scanners traditionally acquire the scan with a 360° sweep around the patient. Newer-generation scanners now offer the ability to scan using a 180° rotation. The evolution of newer acquisition protocols allowed for imaging the entire head with only a 180° rotation, because during post-processing, advanced algorithms reconstruct the scanned volume, [16]

The 180° acquisitions have a significantly lower number of basis projections, which helps in dose reduction. [16-18] Furthermore, the 180° sweep focuses on the back of the head, thus sparing the more radiosensitive organs in the front, such as the eyes and the thyroid gland. [14]

Typically, when there are fewer basis projections, the image quality is slightly poorer, so our study evaluated whether this drop in the number of basis projections with this modified protocol had any effect on the observers' ability to reliably evaluate the presence and extent of sinus pathology.

The examiners examined the pathology in the sinus, mean opinion score of pathology, location of pathology, measurement of thickening, and mean opinion score for measurement twice with the intervals of two weeks.

Krippendorff’s alpha was performed for determining inter-rater reliability and intra-rater reliability. Krippendorff’s alpha is a reliability coefficient developed to measure the agreement among observers and examiners. In statistics, inter-rater reliability is the degree of agreement among examiners. It is a score of how much homogeneity exists in the ratings given by various
raters. In contrast, intra-rater reliability is a score of the consistency in ratings given by the same person across multiple instances. [21]

Inter-rater and intra-rater reliability are aspects of test validity. Assessments of them are useful in refining the tools given to examiners.

In this study the inter-rater and intra-rater percentage for identification of sinus pathology was 100% means agreement. It means there was 100% agreement in identification of pathology in 50 scans between the two examiners. The intra-rater reliability for identification of sinus pathology was also 100%. It means there was 100% agreement of identification of pathology when each examiner, re-examine the scans for the second time.

The inter-rater and intra-rater percentage of mean opinion score for identification of sinus pathology was 100%. The mean opinion score represents overall quality of a scan. It is the mean over all individual values on a predefined scale that a subject assign to his opinion of the performance. The MOS is expressed as a single rational number, typically in the range 1–5, where 1 is lowest perceived quality, and 5 is the highest perceived quality. In our study we used the scale of 1-3, where 1 was bad, 2 was fair and 3 was good.

The inter-rater and intra-rater percentage of mean opinion score for identification of sinus pathology was 100% in our study. It means there was 100% agreement in mean opinion score of sinus pathology in 50 scans between the two examiners. The intra-rater reliability of MOS for identification of sinus pathology was also 100%. It means there was 100% agreement in scale of identification of pathology when each examiner, re-examine the scans for the second time.
The inter-rater and intra-rater percentage for location of sinus pathology was 100%. Some sinus pathology was located on floor of sinus, some in lateral wall of maxillary sinus, some in right maxillary sinus and some in left maxillary sinus. In our study it shows there was 100% agreement in location of sinus pathology in 50 scans between the two examiners. The intra-rater reliability for identification of sinus pathology was also 100%. It means there was 100% agreement of location of sinus pathology when each examiner, re-examine the scans for the second time.

The inter-rater of MOS for measurements of sinus pathology was 96.42%. It shows there was 96.4% agreement in measurements of sinus pathology in 50 scans between the two examiners.

The intra-rater percentage for measurement of sinus pathology was 82.14%. It shows there was 82.14% agreement for measurement of sinus pathology when each examiner, re-examine the scans for the second time.

An additional advantage to having a fewer number of basis projections is that it also slightly reduces the amount of scatter artifacts that come from metallic structures in the field of view, such as metallic restorations, implants, and orthodontic wires and brackets.

While optimizing the field of view and reducing the number of basis projections reduce the radiation dose delivered, another advantage of this acquisition technique is that it reduces the total acquisition time to 9 seconds, as compared to 17.5 seconds with a traditional 360° acquisition format. Furthermore, it also reduces the total reconstruction time and file size.
As discussed earlier in this study, 50 total sample sites of Sinus pathologies were examined by two examiners for each imaging modality 360° CBCT, and 180° CBCT.

**Conclusion**

In conclusion, this *ex vivo* study using dry human skulls demonstrates that the 180° rotational CBCT acquisition protocol is able to accurately evaluate the location, measurements, and diagnosis of sinus pathology with very high reliability and is comparable to a 360° rotational CBCT acquisition.

This finding is particularly important in case of placing implant in posterior maxilla. By choosing 180-degree technique, the radiation dose can be reduced by 40%. Lower dose associated with 180-degree is a major advantage in evaluating patients who may need radiographic evaluations at multiple time points, this is important, as it would limit the exposure of radiologically sensitive organs in the head and neck region.

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