Resolution Of Maxillary Sinus Mucositis After Non-Surgical Root Canal Treatment

BY

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This thesis is dedicated to my parents, Pakinam Toma and Riad Roman, who have always been and continue to be my support to pursue my goals and ambitions.
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List of Abbreviations

AP- APICAL PERIODONTITIS

CBCT- Cone Beam Computed Tomography

CT- Computed Tomography

FOV- Field Of View

Gp- Group

MRI- Magnetic Resonance Imaging

MSChange- Maxillary Sinus Change

MSM- Maxillary Sinus Mucositis

MS- Maxillary Sinus

NS-RCT- Non-Surgical Root Canal Treatment

PAI- Perapical Index

PAIchange- Periapical Index Change

PARL- Periapical Radiolucency

Perf- Perforation

Post-MSM- Post-treatment Maxillary Sinus Mucositis

Post-PAI- Post-treatment Periapical Index

Pre-MSM- Pre-treatment Maxillary Sinus Mucositis

Pre-PAI- Pre-treatment Periapical Index

RCT- Root Canal Treatment
SUMMARY

A prospective clinical study was carried out to study the pattern of maxillary sinus mucositis (MSM) changes after non-surgical root canal treatment (NS-RCT).

Cone beam computed tomography (CBCT) scans of thirty-nine patients who received non-surgical root canal treatment at a private dental practice limited to endodontology were reviewed for the presence or absence of MSM pre- and post-operatively.

Post-operative follow-up ranged from 6 months to 36 months and subjects were divided into two groups. Group 1 had follow-up examination and imaging done 6-12 months after NS-RCT whereas Group 2 had follow-up examination and imaging done 13-36 months after NS-RCT.

The overall maxillary sinus changes were assessed by comparing the prevalence and severity of MSM before treatment and at follow-up. In addition, the effect of the pre- and post-operative size of the periapical lesion, presence or absence of a maxillary sinus floor perforation, shape of the maxillary sinus pathology, recall interval and tooth type (first versus second maxillary molar) on the changes to the maxillary sinus were explored.
I. INTRODUCTION

A. Background:

Apical periodontitis has been observed to affect the mucosal lining of the maxillary sinus even in the absence of cortical sinus floor perforation (1-6). These changes have been reported as early as the 1960’s with the aid of conventional radiographic imaging of the MS using contrast media (1,7-9). The results of those studies were verified in later reports using computed tomography (CT) as well as CBCT (4,5,10-12).

Studies have reported a high prevalence of maxillary sinus mucositis (77-83%) and maxillary sinusitis (>35%) (5,12,13).

A few studies have been conducted to evaluate the extension of periapical inflammation into the maxillary sinus leading to maxillary sinus mucositis. One study found that more than 80% of maxillary posterior teeth with a periapical radiolucency were associated with mucosal thickening, with mean thickness ranging between 3.38 and 6.6mm (14). In a different study, the average amount of mucosal thickening among the mucositis cases was 7.4 mm. This study also found that maxillary first and second molars were 11 times more likely to be involved than maxillary premolars (15).

Mucositis is expected to resolve following the identification and the treatment of the etiology. Several case reports demonstrated resolution of sinus changes after endodontic treatment (2,3,16,17).

To our knowledge, only one CBCT study has been published that assessed healing in 10 subjects with maxillary sinusitis. On the CBCT scan taken 3 months after
the NS-RCT, mucositis resolved completely in 3 cases, resolved partially in 3 cases, remained unchanged in 3 cases, and deteriorated in one case. The PAI was assessed 6 months post-operatively and 4 cases demonstrated complete healing of the periapical radiolucency, 2 cases were healing and 4 cases had a persistent radiolucency (18).

B. **Statement of the Problem and its Significance:**

While modern imaging has been able to establish evidence of resolution of periapical lesions after addressing the odontogenic etiology, there is scant research on the resolution of MSM.

Ericson et al and Nenzen et al conducted two different studies in the 1960’s using conventional radiography with contrast media to assess the resolution of MSM after addressing the etiologic tooth by either endodontic treatment or extraction (8,9). MSM was completely resolved in 11/14 cases (78%) on the 11-20 months follow-up after extraction (8). Nenzen et al demonstrated similar results with 5/7 cases (71%) completely healed, while 2/7 (29%) showed partial resolution approximately one year after endodontic treatment (9).

Several case reports and case series have also demonstrated healing of MSM after conventional root canal therapy (2,3,16,17). However, cases showing persisting MSM occasionally required additional surgical intervention (2,3).

In some cases, maxillary sinus mucositis may linger despite successful treatment of the dental etiology (3). In these cases, chronic MSM may then lead to chronic sinusitis and irreversible changes in the sinus mucosa (17).
Therefore, a thorough understanding of the pattern of the resolution of odontogenic MSM after endodontic treatment is necessary to establish a framework for follow-up and possible referral of cases not showing amelioration in the sinus involvement.

C. **Purpose of the Study:**

The purpose of this retrospective study was to investigate the resolution of maxillary sinus mucositis using CBCT imaging after non-surgical root canal treatment on a larger sample size than previously studied.

D. **Significance of the Study:**

This study aims to aid in understanding the changes that occur after NS-RCT in cases originally presenting with maxillary sinus mucositis. Establishing how many months most cases require to resolve may aid in making the decision of when to rule out odontogenic etiology and when to refer the patient to an otolaryngologist for further evaluation.

E. **Hypothesis:**

We hypothesize that odontogenic maxillary sinus mucositis resolves after non-surgical root canal treatment.
II. CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

A. Anatomy and Physiology of the Normal Maxillary Sinus:

Being the largest of the four paired sets of paranasal sinuses, the maxillary sinuses are pyramid-shaped and are located in the body of the maxilla (19).

The maxillary sinus is bounded superiorly by the floor of the orbit, in which the infraorbital neurovascular bundle is located. Inferiorly, the floor of the MS is formed by the alveolar process of the maxilla and the hard palate. The MS is separated posteriorly from the infratemporal and pterygomaxillary fossae by the posterior wall. The anterior wall or the base of the sinus is formed by the nasal wall (19,20).

The sinus communicates with the nasal cavity via the ostiomeatal complex, which serves as a common pathway for drainage and ventilation of the maxillary sinus along with the ethmoid and frontal sinuses (21). The MS drains into the nasal cavity through the semilunar hiatus, which is located superiorly on the lateral nasal wall.

The MS is lined with the Schneiderian membrane, a bilaminar membrane made of mucoperisosteum that is 0-2mm in thickness. The Schneiderian membrane is composed of periosteum on the osseous side and of ciliated pseudo-stratified columnar epithelium on the internal surface. In addition, goblet, basal and intermediate cells are found within the epithelium. Cilia serve to move mucous toward the ostium for drainage while goblet cells secrete mucous when irritated. Finally, serous and mucous glands are found underneath the basement membrane and release mucous upon stimulation by the autonomic nervous system (21-23).
The function of the MS is still not fully understood (19,22). Theories suggest that the MS serves a role as a reservoir that warms, humidifies and filters inspired air, reduces the weight of the skull, controls the intranasal pressure, increases the surface area for olfaction, vocal resonance, shock absorbance and protection for the brain, and last but not least, contributes to facial growth (19,21,22).

B. Inflammatory Diseases of the Maxillary Sinus:

Inflammatory disease of the maxillary sinus may be caused by different factors such as trauma, infection, allergic reactions, foreign body reactions and chemical irritation.

Inflammation may manifest itself in different forms. Those include mucositis, sinusitis, retention pseudocysts, polyps and periostitis (19).

Sinus mucositis is a localized thickening of the sinus mucosal lining more than 2 mm and can reach up to 10 to 12 times its original thickness (24,19). Mucositis may not necessarily be associated with any signs or symptoms. On imaging, mucositis is found as a band of non-corticated tissue on the bony floor of the maxillary sinus (19,25). When mucositis is due to an allergic reaction, it tends to have a lobulated outline; whereas the outline tends to be more smooth in case of an infection (19).

Maxillary sinusitis is the generalized inflammation of the maxillary sinus. Cases of maxillary sinusitis may be associated with impaired ciliary function leading to accumulation of sinus secretions. In addition, drainage through the ostiomeatal complex may be impaired due to its blockage (19).
Maxillary sinusitis presents with thickening of the sinus mucosa (sinus mucositis) in addition to accumulated sinus secretions. On imaging, sinusitis may present as complete opacification of the MS. Maxillary sinusitis is further classified into acute and chronic sinusitis. Acute maxillary sinusitis presents with pain, swelling or tenderness to pressure over the involved area. Cases of bacterial acute sinusitis are often associated with a discolored discharge (3,19).

On the other hand, chronic sinusitis may not be associated with any signs or symptoms. It is a common sequela of acute sinusitis that has persisted for more than 3 months. Chronic sinusitis may be associated with allergic rhinitis, asthma, cystic fibrosis, odontogenic infections or anatomic variations leading to impaired mucous drainage such as a deviated nasal septum or pneumatization of the middle nasal turbinate, known as concha bullosa (19).

Polyps usually present one or multiple irregular folds within a thickened mucosal membrane in a chronically inflamed sinus and can be associated with bone displacement or bone destruction. Polyps can be solitary or appear in multiple sites. Most studies suggest that they develop from an inflammatory process caused by mucosal injury on a microscopic level. On radiographic imaging, polyps appear as uniform polypoid masses associated with a thickened sinus mucosa and smooth expansion, displacement or even destruction of the adjacent sinus floor (3,19,26).

Retention pseudocysts are cyst-like lesions where the cavity lacks an epithelial lining. To this day, the development of retention pseudocysts is not fully understood. One theory suggests that they may arise from submucosal accumulation of secretions due to blockage of the secretory ducts of seromucous glands in the sinus mucosa.
(3,19,25). Another explanation states that they may arise from cystic deterioration within an inflamed area of the sinus mucosa (19). Pseudocysts do not have an effect on the surrounding structures within the sinus. The sinus floor is usually intact and does not show signs of MSM. It has been suggested that an association between retention pseudocysts and seasonal or temperature changes may exist. Radiographically, pseudocysts are often an incidental finding that presents as a well defined dome shaped non-corticated structure with an internally homogenous radiopaque appearance (3,19).

Finally, periostitis is the deposition of new layers of bone as a direct result of exudate from odontogenic infections. The exudate can diffuse through cancellous bone towards the cortical bone of the MS leading to elevation of the sinus floor. This causes pluripotent oste progenitor cells to differentiate into osteoblasts, which in turn deposit new bone along the elevated periosteum adjacent to the site of infection. On radiographic images, these layers of bone display a characteristic halo-like appearance (19).

C. Literature Review of Radiography:

Different imaging modalities have been and continue to be employed for dental diagnosis and procedures. These include conventional radiography, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasound and Cone Beam Computed Tomography (CBCT).

C.1. Conventional Radiography

The most commonly used imaging technique for endodontic treatment continues to be conventional radiography. This is due to a variety of factors such as being readily available, ease of use and emission of a low radiation dose (3,27).
Periapical radiographs of maxillary posterior teeth can provide a detailed yet limited view of the exposed teeth and the adjacent floor of the maxillary sinus (19).

Panoramic films have also been used to explore the maxillary sinus. The panoramic film offers the advantage of capturing both sinuses on one film, which facilitates direct comparison between them. This view is useful for evaluating the relationship of the maxillary dentition to the maxillary sinus, pneumatization and diseases of the sinus. However, the overlap of the hard palate limits the usefulness of panoramic images for thorough evaluation of the sinuses (28).

Other two-dimensional radiographic modalities of the skull, such as the Occipito-mental (Water’s), Lateral and Submentovortex skull views have been explored to capture and compare both maxillary sinuses. Nevertheless, lateral skull views make comparison more difficult due to the overlap of both sinuses on the image (19).

In general, two-dimensional imaging is not ideal for assessment of maxillary sinus anomalies. First, compressing three-dimensional anatomy into a two-dimensional film creates dimensional distortion and anatomical noise. In addition, the overlapping of roots on anatomical structures may render the interpretation more difficult. Also, dental materials such as crowns and posts may add to the difficulty in interpreting the image (29). Two-dimensional images do not accurately depict information in a bucco-lingual dimension and their sensitivity does not demonstrate pathology unless a significant amount of hard tissue loss has taken place. Last but not least, they have a limited ability to yield accurate measurements and information on anatomy and location of key structures (30). Therefore, additional imaging modalities have been explored for endodontic diagnosis.
Despite the shortcomings of conventional radiography, it still serves as an excellent modality for screening of the maxillary sinus and for aiding the clinician in deciding if any additional diagnostic measures are needed (3).

C.2. **MRI and CT**

Both of these modalities are extensively used in the medical field and are reliably employed in the examination of the paranasal sinuses. Their main advantage is offering three-dimensional information which enables precise evaluation of the captured area by assessing the acquired sections in all three orthogonal planes (axial, sagittal and coronal) (19).

CT is used primarily to examine the hard tissues while MRI offers excellent soft tissue depiction that allows the examination of any soft tissue changes including neoplasms. These modalities have enabled the evaluation of the true extent of lesions and their spatial relationships to important anatomical structures (31).

CT offers superior visualization of the ostiomeatal complex, nasal cavities and paranasal sinuses compared to conventional radiography (3,11,29). CT scans offer the advantage of being able to visualize both bone and soft tissues in thin sections and in multiple views. Axial and coronal views of the maxillary sinus may show diseased sinus tissue and demonstrate the relationship of odontogenic periapical disease to a sinus floor defect (28).

However, CT and MRI have many shortcomings which make them impractical for dental use. Firstly, these devices require a long scanning time and are associated with high costs. In addition, CT scanning requires a high radiation dose (28). For those reasons, CT devices are of limited availability in the dental field.
C.3. CBCT

In contrast to CT, CBCT yields comparable diagnostic quality with a significantly lower radiation dose. Cone-Beam Computed Tomography (CBCT) has only recently become a commonly used imaging modality for the assessment of dental and periapical tissues (32,33).

Invented in the late 1990s by Italian and Japanese groups working independently, the original CBCT machines were developed from CT scanners that had been modified to decrease the field of view (FOV), increase the resolution and decrease the necessary radiation exposure to the patient (34). Since then, the CBCT technology has witnessed a dramatic evolution and the FDA approved the first CBCT for dental use in the United States in 2001. The machine used in this study— the Kodak 9000 3D was subsequently approved in 2003 (35).

C.3.a. Advantages of CBCT

CBCT machines distinctively capture highly contrasting structures, which makes them well-suited for the examination of dental and osseous structures in the maxillofacial area (35).

Compared to conventional medical CT, the size of the CBCT machines is significantly smaller rendering them more practical for the use in dental offices. In addition, these machines are significantly less costly, require a shorter scan time and produce significantly less radiation than medical CT (34).
Unlike the medical CT machine, which emits constant radiation with multiple rotations throughout the length of the scan, CBCT utilizes sequential planar projections in a single rotation, which significantly reduces the exposure time as well as the exposure dose to the patient. These projection images are considered raw data and require computer software to assemble and reconstruct a three-dimensional image (34,35).

The CBCT scanner produces a cone-shaped x-ray beam directed from the source to the x-ray detector which passes through the center of the area of interest. This produces a cylindrical volume of data, namely, the field of view (FOV). The dimensions of the FOV depend on various factors such as the size and shape of the detector, beam collimation and its projection geometry. In general, the smaller the FOV, the smaller the radiation exposure and the greater the spatial resolution. FOV types run from limited/localized with FOV 5 cm or less, single arch (FOV 5-7 cm), inter-arch (FOV 7-10 cm), maxillofacial (FOV 10-15 cm) and finally, craniofacial, which has a FOV>15 cm (35).

The size of the FOV varies among scanners, with some machines offering the option to select the FOV depending on the practitioner’s needs.

Having a voxel size of 0.4mm and as low as 0.076 mm, these scans are spatially accurate and facilitate precise measurements and assessment (35).

The CBCT radiation dose produced by the Kodak 9000 limited FOV device, which is used in this study, is approximately equal to 1-5 days of background radiation. Comparatively, a posterior bitewing radiograph is equivalent to 3 days of background radiation (36).
C.3.b. Limitations of CBCT

First of all, despite its relatively lower radiation dose when compared with medical CT, CBCT still subjects the patient to higher radiation than conventional intraoral radiographs. For scans with a larger FOV, the radiation dose emitted by common CBCT machines is nearly equivalent to 5-33 panoramic radiographs. For limited FOV scans, the radiation dose is comparable to a single panoramic film (34).

Secondly, CBCT yields inferior spatial resolution when compared to conventional intraoral radiographs. Whilst conventional and digital radiography have a spatial resolution of 15-20 line pairs mm$^{-1}$, the spatial resolution of CBCT scans is only 2 line pairs mm$^{-1}$ (34).

Thirdly, compared to medical CT, CBCT shows inferior soft tissue resolution, which is why medical CT is still the highest diagnostic modality in three-dimensional medical radiography.

In addition, as with medical CT, the occasional presence of artifacts can compromise image quality and interpretation. Presence of metallic structures in the area scanned causes a cupping effect, which is produced by the differential absorption of x-ray photons. This leads to image distortion, which is known as beam hardening. Beam hardening can also cause streaks or dark bands to appear between two dense objects.

Lastly, minor patient movement during the scan can produce artifacts, which can render the scan of little diagnostic value (35).
C.4. **Application of CBCT in Endodontics**

CBCT allows the identification of the anatomical relationship of the root apices to important neighboring anatomical structures in any of the three orthogonal planes that the clinician wishes to view (12,34,37).

Due to the additional information provided on 3-D imaging, CBCT is recommended as an adjunct to intraoral imaging in the diagnosis of teeth which have been previously endodontically treated. CBCT may yield additional information such as presence and location of a perforation, separated instruments and assessment of the obturation and healing (30). When surgical treatment is indicated, CBCT clearly demonstrates the proximity of the tooth to vital structures as the maxillary sinus and, the mental foramen and the inferior alveolar canal. CBCT is also recommended in cases presenting with a complicated diagnosis, as non-specific signs and symptoms where the etiology cannot be determined. It can also aid in the negotiation of teeth with complex root canal configuration, obliterated canals and those with resorptive defects. Also, CBCT may demonstrate more information regarding presence, location and extent of root fractures, which underlines the significance of CBCT in cases of traumatic dental injuries and teeth where a vertical root fracture is suspected (30).

In one study, periapical lesions were detected in 20.3% of the roots on CBCT whereas only 2.4% could be detected on periapical radiographs (38). In another study, the higher sensitivity of CBCT in comparison to periapical radiographs was demonstrated when a periapical lesion was seen in 100% of the cases on CBCT, whereas only 25% of these lesions could be seen on the intraoral film (34).
In a study comparing CBCT with periapical radiographs, the authors found that of the 109 lesions detected with CBCT, 34% were not detected with periapical radiography. Periapical lesions on roots in close proximity to the floor of the sinus were more likely to be missed on periapical radiographs than those directly overlaying or further away from the sinus floor. In addition, periapical radiolucencies on molars, especially second molars, had a higher probability of being missed on periapical radiographs than those on premolars. Additional findings, like expansion of apical periodontitis into the sinus, sinus mucosal thickening and missed canals were more likely to be recognized on CBCT than on periapical films (5).

The same study also detected pathology in 35 maxillary sinuses on CBCT, while only 16 cases could be recognized on periapical films (5). A previous study had similar findings, where MSM was seen in 30 cases on CBCT but only 7 cases could be diagnosed on periapical radiographs (12).

C.5. Application of CBCT in Maxillary Sinus Examination

Numerous studies using CBCT have been conducted to investigate the prevalence of MSM. In a recent systematic review, the frequency of MSM ranged widely between 14.3% and 82%. Beside the wide range in the reported prevalence of mucosal thickening related to apical pathology, the degree of lumenal opacification, features of sinusitis and the presence of retention cysts and polyps varied among studies. A possible explanation could be differences in the classification of mucosal findings and criteria to diagnose sinus pathology (39).
A recent study conducted in 2013 looked at 485 CBCT scans and found that more than 80% of teeth with a periapical radiolucency were associated with mucosal thickening. The mean mucosal thickness ranged between 3.38 and 6.6mm (14).

A different study examined 508 CBCT scans and found MSM in 235 (46.2%) of the sinuses. There was a marked increase in the thickening of the sinus mucosa in cases with severe apical periodontitis (scans without AP had MSM in 41.5% of the cases, scans with AP had MSM up to 100%) (40).

In another study where 82 CBCT scans were examined, the average amount of mucosal thickening among the cases was 7.4 mm. Maxillary first and second molars were eleven times more likely to be involved than premolars. MSM was most commonly associated with the palatal root of maxillary 1st molars followed by the mesiobuccal root of the 2nd molars (15).

To date, only one CBCT study has been published in 2011, which evaluated the healing of MSM after root canal therapy (18). A pilot study was conducted with 30 cases, which presented with apical periodontitis and MSM. After excluding 5 cases, the prevalence of pre-operative MSM was found to be 56%. 10 of these cases were reassessed using CBCT 3 months after treatment and the investigators found full resolution of MSM in 30% of the cases while 30% showed partial resolution. MSM on an additional 30% remained unchanged and the remaining 10% deteriorated. The authors also noted an inverse association between the thickness of the mucositis and the distance between the root apices to the sinus floor, which was not statistically significant (18).
III. MATERIALS & METHODS

A proposal of the research project “Resolution of Maxillary Sinus Mucositis After Non-Surgical Root Canal Treatment” was submitted to the University of Illinois at Chicago Institutional Review Board (IRB) for exemption. The IRB responded that the research did not involve human subjects and did not require IRB approval (see Appendix).

A. Case Selection:

CBCT scans previously taken at a local Endodontic specialty practice were reviewed to identify maxillary molars which received non-surgical endodontic treatment.

A.1. Inclusion Criteria

- CBCT scans of maxillary molars from patients who received non-surgical root canal treatment and who have at least 6 month recall scans.
- Pre- and post-operative CBCT of high diagnostic value in all three planes.

A.2. Exclusion Criteria

- Non-diagnostic CBCT scans.
- Teeth that have received surgical endodontic treatment before follow-up.
B. CBCT Analysis:

All images were obtained using a Kodak 9000 3D Extraoral Imaging System (Kodak Dental Systems, Atlanta, GA) using limited field of view (5 cm x 5 cm) with voxel size of 76 microns. Using the Kodak Imaging Software, the CBCT images were evaluated on coronal and sagittal sections (see Figure 1). An experienced endodontist and a second-year endodontic resident evaluated the scans.

Pre-operative scans were evaluated for the following: the number of the involved tooth (first or second maxillary molar), presence, dimensions and type of MSM and PARL and finally, presence or absence of sinus floor perforation. Post-operative scans were evaluated for any changes in MSM, PARL or the sinus floor.

The dimensions of the periapical lesion were measured on the CBCT by measuring the longest distance in length and in width of the periapical radiolucency. When more than one root had a PARL, the root with the largest PARL was selected.

The mucositis was measured depending on the shape. It was categorized as diffuse, dome shaped or a combination of the two.

Diffuse cases were measured at the highest point of the MSM adjacent to the involved tooth. When a periapical lesion was present, the mucositis was measured above the associated root. In cases presenting with a dome-shaped thickening, measurements were made from the MS floor to the highest point of the dome-shaped sinus pathology. In cases of combined diffuse and dome-shaped lesions, only the dome-shaped lesion was measured at its highest point as described above.
MSM was categorized using the classification developed by Lu et al into: Class 1: normal (no mucosal thickening), Class 2: 0-2 mm, Class 3: 2-4 mm (mild maxillary sinus mucosal thickening), Class 4: 4-10 mm (moderate), Class 5: >10 mm (severe) (see Figure 2) (40).

Presence of a periapical lesion was recorded and classified according to the CBCT-PAI scoring system developed by Estrela et al. (0): intact periapical tissues, (1): Diameter of periapical radiolucency >0.5–1 mm, (2): Diameter of periapical radiolucency >1–2 mm, (3): Diameter of periapical radiolucency >2–4 mm, (4): Diameter of periapical radiolucency >4–8 mm, (5): Diameter of periapical radiolucency >8 mm (see Figure 3) (41).

A total of 39 pre- and post-operative scans were evaluated in this study, which were further divided into two groups, Group 1 had recall 6 to 12 months (n=20) and Group 2 had recall 13 to 36 months (n=19) after NS-RCT.
Figure 1: Measurements for the mucositis, periapical radiolucency and bone height taken on a follow-up scan.

Figure 2: MSM Classification Classes 1-5 developed by Lu et al. A- Class 1 (normal), B- Class 2 (<2mm), C- Class 3 (2-4mm), D- Class 4 (4-10mm), E- Class 5 (>10mm).
C. **Outcome Measures**

The following information was recorded for each of the 39 subjects included in this study from the pre- and postoperative scans: tooth type (first or second molar), date of the preoperative scan, date of the postoperative scan, dimensions of the PARL if present, dimensions of any sinus opacification if present, the morphological presentation of sinus disease if present (diffuse, dome shaped or both) and the presence or absence of a sinus floor perforation. All patient identifiers and demographics were not recorded.
IV. STATISTICAL ANALYSIS

All statistical analyses were performed using the IBM SPSS Statistics software package (Version 21; IBM Corp, Armonk, NY). Descriptive statistics were first run, and associations between the dependent variable (MSChange) and the independent variables (Pre-operative PAI, post-operative PAI, PAIChange, Perf, recall group and shape) were evaluated using the Chi-square and Fisher’s exact tests.

Finally, Wilcoxon Signed-Rank test was run to compare Pre-MSM with Post-MSM and Pre-PAI with Post-PAI for significant changes before and after treatment.

A significance level of $p \leq 0.05$ was set for all tests.
V. RESULTS

A. **Frequencies:**

Overall, 39 CBCT cases were included in this study. 20 pre- and post-operative CBCT were categorized under Group 1 and 19 scans were categorized under Group 2.

A Total of 23 maxillary first molars and 16 maxillary second molars were included in this study. For Group 1, the mean follow-up time was 9 months and for Group 2, the mean follow-up time was 20 months. (See Figures 4 and 5).

![Gp 1 Recall](image)

Figure 4: Group 1 Recall Frequency
When the shape of MSM was explored, the majority (69%) presented with diffuse uniform mucosal thickening followed by 21% with the combined appearance of both diffuse mucosal thickening and a localized dome-shaped area. The remaining 10% presented only in the form of a localized dome shape lesion without any increase in the lining on the floor of the sinus. The distribution among Groups 1 and 2 were similar (65% vs 74%, 20% vs 21% and 15% vs 5% for each of the types, accordingly).

Presence of a sinus floor perforation varied widely between Groups 1 and 2. The majority of Group 1 presented with a sinus floor perforation (60%), whereas only 26% of the cases in Group 2 had one. Combined, 44% of the cases presented with a sinus floor perforation.
B. **Periapical Index:**

The pre-operative PAI ranged between class 0 and class 5. The majority of the cases fell under Class 3 (28%), followed by Class 4 (26%), Class 0 (18%), Class 2 (15%), Class 1 (8%) and finally Class 5 (5%).

The post-operative PAI ranged only between Class 0 and Class 3. 59% of the cases were categorized under PAI Class 0, followed by 18% under Class 2, 13% under Class 3 and 10% under Class 1.

All in all, 78% of the cases had a decrease in the PAI at follow-up, 13% remained unchanged and 9% had an increase in the PAI. For more information, please refer to Table I. The changes in PAI before and after treatment were statistically significant for Group 1, Group 2 and both groups combined (p<0.05).

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
<th>Both Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-PAI &lt; Pre-PAI</td>
<td>77.8%</td>
<td>78.6%</td>
<td>78.1%</td>
</tr>
<tr>
<td>Post-PAI = Pre-PAI</td>
<td>11.1%</td>
<td>14.3%</td>
<td>12.5%</td>
</tr>
<tr>
<td>Post-PAI &gt; Pre-PAI</td>
<td>11.1%</td>
<td>7.1%</td>
<td>9.4%</td>
</tr>
</tbody>
</table>

**TABLE I: COMPARISON OF PERIAPICAL INDICES BEFORE AND AFTER TREATMENT FOR GROUPS 1 AND 2 ALONE AND THE AVERAGE OF BOTH.**
C. **Maxillary Sinus Mucositis:**

In this study, MSM was present when the sinus mucosal thickness was more than 2 mm. Therefore, Classes 3-5 represented different severities of maxillary sinus mucositis, whereas Classes 1 and 2 represented a normal maxillary sinus.

The overall prevalence of pre-operative sinus mucositis was 56.4%. The pre-operative MSM ranged between Classes 1-5 with the majority falling under Class 4 (36%), followed by Class 2 (28%), Classes 1 and 3 (15% each) and the least subjects were categorized under Class 5 (5%). This distribution was not similar among Groups 1 and 2. 60% of the cases in Group 1 presented with MSM (Classes 3-5), while 52.6% from Group 2 presented with MSM (Classes 3 and 4; none of the cases had MSM Class 5) (see Figure 6 for more information).

The overall post-operative prevalence of MSM was 30.8%. The post-operative MSM also ranged between Classes 1-5. The majority of the cases fell under Class 2 (41%) followed by Class 1 (28%), Classes 3 and 4 (13% each) and finally Class 5 (5%). Like the pre-operative MSM classification, the distribution was not similar among Groups 1 and 2 either. For instance, 25% of the cases from Group 1 still fell under Classes 3 and 4, whereas 36.5% of the cases in Group 2 were categorized under Classes 3,4 and 5 (see Figure 7).

Overall, 63.6% of the cases had a decrease in the MSM Class at follow-up, 22.8% remained unchanged and 13.6% had an increase in the MSM class. For more information, please refer to Table II.
The changes in MSM before and after treatment were statistically significant for Group 1 (p=0.004) but not for Group 2 (p=0.660). The changes in both groups combined were also statistically significant (p=0.009).

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
<th>Both Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-MSM &lt; Pre-MSM</td>
<td>83.3%</td>
<td>40%</td>
<td>63.6%</td>
</tr>
<tr>
<td>Post-MSM = Pre-MSM</td>
<td>16.7%</td>
<td>30%</td>
<td>22.8%</td>
</tr>
<tr>
<td>Post-MSM &gt; Pre-MSM</td>
<td>0%</td>
<td>30%</td>
<td>13.6%</td>
</tr>
</tbody>
</table>

**TABLE II: COMPARISON OF MSM CLASSES BEFORE AND AFTER TREATMENT FOR GROUPS 1 AND 2 ALONE AND THE AVERAGE OF BOTH.**
Figure 6: Distribution of Pre-operative MSM in Groups 1 and 2 and both Groups Combined.

Figure 7: Distribution of Post-operative MSM in Groups 1 and 2 and both Groups Combined.
D. **Chi-square and Fisher’s Exact Test:**

Correlation between healing of the maxillary sinus mucositis and the independent variables (tooth type, recall group, pre-operative periapical index, post-operative periapical index, healing of the periapical lesion, shape of the mucositis and sinus floor perforation) was explored and none of the results were statistically significant (p>0.05).
VI. DISCUSSION

The overall prevalence of pre-operative MSM was 56.4%, which was close to the number reported by Maillet et al (51.8%), Nurbakhsh et al (56%), Ritter et al (56.3%) and Janner et al (55%) (15,16,40,41). Nevertheless, it is lower than the range commonly documented in the literature (71-88%) (4,5,11,12,42,43).

This may be due to a number of reasons. First, the sample size used in our study was small and the distribution of maxillary sinus mucositis classes varied widely. Second, as stated in the systematic review published by Vogiatzi et al in 2014, there are differences in the classification of mucosal findings and in the criteria to diagnose sinus pathology (39). According to Ruprecht and Lam, sinus polyps may arise due to a tooth infection, while maxillary sinus pseudocysts are not odontogenic in origin (19). On the other hand, Mehra and Murad’s paper states the opposite about MS polyps and pseudocysts (28).

According to Vogiatzi, the mucosal thickening noted on published CBCT studies varied widely between 14.3% and 82%. These studies were conducted on different group samples that included patients receiving endodontic treatment, patients under orthodontic treatment, edentulous patients, patients receiving implants or samples from the population. Studies on endodontic, implant patients and the general population had a higher prevalence of MSM whereas lower prevalence was recorded on orthodontic patients, where MSM was more of an incidental finding due the decreased likelihood of presence of an odontogenic infection. Last but not least, Vogiatzi’s study also reported different thresholds and criteria among the studies in diagnosing mucosal thickening of
the MS (39). This threshold ranged from 1 mm to 3.54 mm (18, 39, 44, 45). In addition, some of the studies in the systematic review did not give information on the sample and did not specify the criteria for diagnosing sinus pathology (39, 43, 46).

In our study, the majority of the cases with mucosal thickening presented as a flat diffuse increase in the mucosal lining (69%). This is similar to the finding reported by Shanbhag et al (73.5%) (14). In their study, mucositis was only categorized as flat or polypoid, and the polypoid shape comprised 26% of their cases. In our study, 10% were polypoid or dome-shaped and 21% were a combination of flat diffuse with a localized polypoid thickening.

At the time of follow-up in this study, a normal maxillary sinus mucosa (MSM Classes 1 and 2) was observed in 70% of the cases. Therefore, we accept the null hypothesis that MSM resolves after NS-RCT. In general, 63.6% demonstrated improvement, 22.8% stayed unchanged and 13.6% deteriorated. Our numbers are very similar to those reported by Nurbakhsh et al, who found improvement in 60% of MSM cases 3 months after treatment. In addition, 30% remained unchanged and 10% worsened (18).

Our tests did not show an association between the healing of the PARL and the MSM. In fact, all of the MSM cases that showed deterioration had a post-operative PAI 0.

Of the three cases that demonstrated worsening of the MSM, two teeth were first molars and one tooth was a second molar. All of these teeth were from Group 2, with recalls at 15, 16 and 28 months after treatment.
More MSM healing was seen in Group 1, the group with the shorter recall time, which ranged from 6 to 12 months after NS-RCT than in Group 2 (with recall 13 to 36 months after treatment). The changes in MSM before and after treatment were statistically significant for Group 1 (p=0.005) but not for Group 2 (p=0.293).

There are a few explanations for this finding. First, Groups 1 and 2 did not have a similar distribution of MSM severity pre-operatively. For instance, 40% of the cases in Group 1 presented with a normal MS whereas the remaining 60% presented with MSM, which ranged between Classes 3-5. On the other hand, 47.4% of the cases in Group 2 had a normal MS and only 52.6% presented with MSM, which ranged between Classes 3 and 4, without any cases classified under Class 5 (please refer to Fig. 6).

Another reason may be the lack of control of other factors, which may contribute to MSM. Maxillary sinus pathology can arise due to different etiologies. Pathology can be odontogenic, originating from teeth with endodontic or periodontal disease. It can also emerge due to an infection (e.g., upper respiratory tract infection, influenza, etc.). Alternatively, MSM may be due to an allergic reaction to pollen or seasonal changes, as well as anatomical variations like a deviated nasal septum, concha bullosa or nasal and sinus polyps (19). Although cases of MSM with an existing endodontic infection is more likely to be odontogenic in origin (14,40), pre- and post-operative MSM may also be due to a different and unrelated or an additional etiology like the ones mentioned above.
VII. LIMITATIONS

Our study had several weaknesses. Firstly, our sample size of 39 cases was small, which gave the study a low statistical power. This may be a reason why no statistically significant associations could be established between the MS changes after treatment and the variables studied. A sample size calculation was not feasible due to the lack of previous research in this subject with only one existing pilot study using 10 cases (18).

Our study design did not permit drawing direct conclusions about when to expect healing of MSM because Groups 1 and 2 were two unrelated samples. To be able to observe the reaction of MSM after treatment, the same patient sample should have been followed up at specified time intervals throughout the study to be able to compare their healing at varying recall times.

Secondly, MSM diagnosis was only based on CBCT findings. Information about the patients’ medical history, dental history, clinical signs and symptoms, allergies, local pollen count at the time of the CBCT imaging was not included in the study. Therefore, we could not differentiate between odontogenic and non-odontogenic maxillary sinus mucositis. In addition, longer recall intervals are more likely to be associated with new etiologies like a different tooth, seasonal allergies, sinus infections, etc.

The MSM and PAI classification may not clearly show healing since each class comprises a wide range. To elucidate, a case that has presented with 10 mm thickness of mucositis pre-operatively and decreased to a thickness of 4.5 mm post-operatively,
would be classified as Class 4 MSM pre- and post-operatively and therefore be considered unchanged.

In addition, cases presenting with a combination of both diffuse and dome-shaped sinus opacifications could either be due to a sinus polyp, which presents as localized thickening of the sinus mucosa (mucositis) with one or more folds which form the polyps. A maxillary sinus with diffuse mucositis and an unrelated sinus pseudocyst may also look the same on the CBCT scans. Therefore, solely measuring the distance between the sinus floor and the highest point of the dome-shaped mass without recording any information about the flat and diffuse mucositis may give conflicting data. We suggest measuring both entities separately, since one of the two may be absent on the pre- or post-operative scans and therefore, help establish if healing has taken place. To explain further, a case may have presented pre-operatively with a combined lesion (diffuse and dome shaped) and based on the height of the measurement on the dome, was classified as Class 3. On the post-operative scan, the dome may have persisted at the same height, and despite the absence of diffuse MSM, it would have still been classified as Class 3. A case with this presentation may be more consistent with complete MSM healing and an unrelated pseudocyst rather than a non-resolving odontogenic mucositis case.

Last but not least, there was no calibration prior to the CBCT analysis. In addition, CBCT scans were reviewed by two unblinded operators- an experienced endodontist and a second year endodontic resident. Routinely in radiographic studies, multiple highly qualified endodontists and / or dental radiologists have evaluated CBCT
scans and inter-evaluator agreement was calculated. This may decrease bias and increase the validity of the study.
VIII. FUTURE RESEARCH

Future research is still needed for understanding the healing of odontogenic maxillary sinus involvement and should include prospective longitudinal clinical trials. Previous images, a thorough medical history, dental history, clinical exam and the local pollen count at the time of each radiograph may aid in establishing if the MSM observed is a new finding or is rather an unrelated non-odontogenic finding.
IX. CONCLUSIONS

Cases presenting with MSM showed overall improvement after NS-RCT. However, we were not able to demonstrate when complete healing would take place and we were not able to demonstrate a significant effect of any of the independent variables recorded on the healing of MSM. Future research is needed to further investigate factors which may impact maxillary sinus healing and to better understand the pattern of sinus healing.
IX. CITED LITERATURE


APPENDIX

Determination Notice
Research Activity Does Not Involve “Human Subjects” at UIC

April 2, 2015

Mary Roman, DDS
Endodontics
801 S. Paulina Street
304D ENDO, M/C 642
Chicago, IL 60612
Phone: (312) 996-7514 / Fax: (312) 996-9500

RE: Research Protocol # 2015-0298
“Resolution of maxillary sinus mucositis after non-surgical endodontic treatment”

Sponsor: None

Dear Dr. Roman:

The above proposal was reviewed on April 2, 2015. From the information you have provided, the proposal does not appear to involve “human subjects” at UIC as defined in 45 CFR 46.102(f).

The specific definition of human subject under 45 CFR 46.102(f) is:

*Human subject* means a living individual about whom an investigator (whether professional or student) conducting research obtains

1. data through intervention or interaction with the individual, or
2. identifiable private information.

*Intervention* includes both physical procedures by which data are gathered (for example, venipuncture) and manipulations of the subject or the subject’s environment that are performed for research purposes. *Interaction* includes communication or interpersonal contact between investigator and subject. *Private information* includes information about behavior that occurs in a context in which an individual can reasonably expect that no observation or recording is taking place, and information which has been provided for specific purposes by an individual and which the individual can reasonably expect will not be made public (for example, a medical record). Private information must be individually identifiable (i.e., the identity of the subject is or may readily be ascertained by the investigator or associated with the information) in order for obtaining the information to constitute research involving human subjects.

All the documents associated with this proposal will be kept on file in the OPRS and a copy of this
letter is being provided to your Department Head for the department's research files.

If you have any questions or need further help, please contact the OPRS office at (312) 996-1711 or me at (312) 355-2908. Please send any correspondence about this protocol to OPRS at 203 AOB, M/C 672.

Sincerely,

Charles W. Hoehne, B.S., C.I.P.
Assistant Director
Office for the Protection of Research Subjects

cc: Christopher Wenckus, Endodontics, M/C 642
Mohamed I. Fayad, Endodontics, M/C 642
VITA

NAME: Mary Roman

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Professional Memberships: Edgar D Coolidge Endodontic Study Club
American Association of Endodontists
American Dental Association
Chicago Dental Society