ORIGINAL ARTICLE

Analysis of Factors Affecting Implant Placement in Posterior Maxilla With Lateral Window Sinus Lift Technique; A CBCT Study

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ABSTRACT

Objective: To identify and analyse factors influencing lateral sinus augmentation for implant placement in the posterior maxillary region.

Study Design: Retrospective cross-sectional study.

Place and Duration of Study: The study was conducted in the Periodontology department at University College of Dentistry, The University of Lahore between January 2024 to June 2024.

Materials and Methods: The study was conducted at the Department of Periodontology, University College of Dentistry. Using CBCT (Cone Beam Computed Tomography) scans from 278 cases with missing posterior maxillary teeth, the study analysed factors like sinus angle, sinus septa presence, angle of sinus, posterior superior alveolar artery (PSAA) visibility and distance of PSAA from the superior and inferior border of the potential window.

Results: Key findings include a predominance of PSAA within the intra-osseous region (92.6%) and variations in distances from the PSAA to the superior and inferior borders of the planned lateral window. Additionally, the study highlighted a low incidence of maxillary sinus septa (5%). Schneiderian membrane thickness was less than 3mm in 79% of the cases, and variations in maxillary sinus shape were noted to be an angle greater than 30 degrees in 90.1% of the cases. The location of PSAA was intraosseous in 75 (92.6%) cases whereas in the remaining 6 (7.4%) cases it was not evident intraosseously.

Conclusion: In conclusion, CBCT proved crucial for treatment planning, and thorough evaluation of PSAA's relationship with sub-antral bone height was emphasized for safe lateral sinus augmentation procedures in posterior maxillary implant placements. The study contributes valuable insights for dental practitioners involved in implant planning and sinus surgeries.

Key Words: *CBCT, Sinus, Dentistry, Dental Implants.*

Introduction

The maxillary sinus, the largest of the paranasal sinuses with an average volume of 12.5 ml, plays a critical role in dental implant placement, particularly in the posterior maxilla. [1] Lined by the Schneiderian membrane—a thin, bilaminar mucoperiosteal layer—the sinus is closely related to several anatomical structures that must be considered during surgical procedures. Sinus pneumatization or depression of the sinus floor often reduces available bone height, complicating implant insertion and necessitating sinus augmentation or lift procedures.[2,3]

The sinus elevation technique, first introduced by Boyne and James in 1980, has since been refined.[4] When residual bone height is less than 5 mm, the open or lateral sinus lift approach is typically recommended, either for simultaneous or staged implant placement. In contrast, when bone height ranges from 5 to 8 mm, a less invasive crestal approach may suffice due to the reduced need for vertical bone augmentation. Literature indicates that sinus augmentation does not compromise implant survival rates.[5,6]

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Cone Beam Computed Tomography (CBCT) has become the preferred imaging modality for assessing the maxillary sinus, aiding clinicians in treatment planning. CBCT provides detailed insights into sinus anatomy, including variations in sinus shape and the location of critical structures like the posterior superior alveolar artery (PSAA).[7,8] While sinus shape variations such as V-shaped or U-shaped configurations are uncommon and usually of limited clinical consequence, they can influence surgical complexity. V-shaped sinuses pose a greater risk of Schneiderian membrane perforation during elevation, while U-shaped sinuses generally offer more space for graft material, facilitating easier procedures.[9]

Histological studies have demonstrated successful bone formation following sinus augmentation with simultaneous implant placement. Additionally, research conducted on the Indian sub-population using CBCT found the PSAA most commonly located within the intra-osseous region. The vessel's distance from the alveolar crest varied by gender but was unaffected by age.[10,11] These findings highlight the importance of identifying the PSAA's position preoperatively to prevent iatrogenic damage during the creation of a lateral window.[12,13]

While concerns have been raised about Schneiderian membrane thickness, a systematic review by Monje et. al.,[12] concluded that membrane thickness does not significantly impact the success of sinus lifts or implant placement. However, anatomical features like sinus septa have been linked to a higher incidence of membrane perforation, as shown in a study by Ghaida et. al.,[14] in Saudi Arabia.

Despite numerous individual studies on maxillary sinus anatomy and augmentation techniques, there remains a lack of comprehensive research evaluating all relevant factors in a single study. Our study aimed to bridge this gap by identifying and analyzing multiple anatomical and procedural variables that influence lateral sinus augmentation for implant placement in the posterior maxilla.

Materials and Methods

The study was conducted at the Department of Periodontology, University College of Dentistry, The University of Lahore during a period of 6 months. A retrospective cross-sectional study was conducted to include the CBCTs fulfilling the inclusion criteria. All CBCTs having one or more unilateral missing maxillary posterior tooth (2nd premolar, 1st molar and 2nd molar) available at the radiology department of University College of Dentistry were included in the study. Any CBCT scan with osseous pathology or defect in the area of interest was excluded from the study. The patient's age was more than 18 years. The sampling technique was non-probability convenience sampling. After approval from the Ethical Review Board of the institute (UCD/ERCA/6/4/23), CBCT images were obtained by Pro Max 3D Mid (Planmeca, Helsinki, Finland). Scanning was performed by fixing the patient's jaw and head support apparatus while the patient was standing. Amongst the total CBCTs gathered since 2018 till 2023, scans were evaluated according to the inclusion criteria. The scans had to have any one or more missing premolars or molars (excluding third molars) in the maxillary region. Cases having any pathology associated with maxillary jaw, incomplete bony healing after tooth extraction or presence of dental implants in the posterior maxilla were excluded.

After placement of a virtual implant of dimensions 5.0 x 8.0 at the selected 1st and 2nd Molar site and 4.5 x 8.0 at a premolar site in a restoratively driven position, following measurements were calculated using the methods explained ahead:

1. A horizontal line was drawn at the apex of the virtual implant and buccal and palatal end points are connected to the most concave part of the sinus floor. This angle is measured to identify the shape of sinus as less than 30 or more than 30-degree angle. [15]
2. Sub-antral bone height was measured starting from the floor of the maxillary sinus to the crest of alveolar bone. The bone height was divided into three groups: less than 5mm, 5 to 8mm and more than 8 mm.[14] Cases with bone height less than 5mm are discussed in this study.
3. A lateral window was planned in cases with sub-antral bone height less than 5mm. An imaginary lateral window was designed on the CBCT. The landmarks of the window were based on the respective sub-antral bone height. The superior window border was designed to be 12mm above the crestal bone level, whereas the inferior window was designed to be 3mm above the

sinus floor for lateral window technique. This design is in accordance with previous literature.[15,16]

Once the window borders were designed and marked on the CBCT, the distance from PSAA is measured by making a vertical line from PSAA to the crestal bone level in the coronal sections and then connecting these lines to the superior and inferior border points. The distance from PSAA to these points on the vertical line was calculated. If the distance from PSAA to the superior border was more than 2 mm or the vessel is not intraosseous it was considered not to affect the window design. On the other hand, if the vessel was within 2 mm of the superior border, it was assumed that the window dimensions would have to be changed and the vessel was affecting the treatment plan.

4. The location of the PSAA was determined either to be intra-osseous or intramembranous based on the CBCT at the given section. Similarly, on the coronal sections, the CBCT sections are analyzed from posterior to anterior to see at what point the PSAA is visible intraosseously, the site of tooth where this occurs is labeled as the first seen sight of the vessel. Similarly, the point where it merges in the soft tissue again on anterior sections is designated as the last seen site of the vessel. The sites were related to the adjacent tooth.
5. The thickness of the Schneiderian membrane was measured from the upper border of the membrane to the lower border and classified according to its thickness. It was divided into two groups namely less than 3mm and greater than 3mm.[14] Similarly, the Schneiderian membrane thickness was calculated on the buccal aspect of the bone as less than 1mm or more than 1mm where the window is to be prepared.
6. The angle formed between the palatal wall and buccal wall was then calculated by connecting the two walls at the level of apex of the implant and connecting both these points on each wall to the most concave point on the sinus floor and measuring this angle. The results were divided into two groups: less than 30^{o} or more than 30^{o}.[17]

Data entry and analysis was done with SPSS version 25. Quantitative variable (distance between PSAA and upper border for the lateral window) were presented with mean ±SD and qualitative variables were presented with frequency and percentage. Chi Square test was applied to see the association between qualitative variables (gender, sinus septa, sinus angle). P-value <0.05 was considered statistically significant.

Results

A total of 278 scans had one or more missing posterior maxillary teeth. Analysis of remaining sub-antral bone height resulted in 81 (29.1%) cases showing less than 5mm of remaining bone thickness, 105 (37.8%) cases showed bone height between 5 to 8 mm and remaining 92 (33.1%) cases had bone height of more than 8 mm. Amongst these, the results of the cases with sub-antral bone height less than 5mm requiring lateral sinus lift are discussed in this study. From the 81 cases evaluated, 41 (50.6%) participants were males and 40 (49.4%) were females. The site distribution showed that 11 (13.6%) sites were missing second premolars, 40 (49.4%) sites showed missing first molars and remaining 30 (37%) sites were related to second molars. Table 1 depicts the various factors along with their measurements. The location of PSAA was intraosseous in 75 (92.6%) cases whereas in the remaining 6 (7.4%) cases it was not evident intraosseously. When the distance of PSAA was calculated from the superior border of the potential window for lateral sinus lift technique, in 13.9% of the cases, presence of the artery hindered the making of ideal dimension window by being too close to the superior border. The mean distance in all the 75 cases was 5.83mm with a range of -2.2 mm to 12.3mm. The average distance of PSAA taken from the inferior border of the lateral window planned was 12.87mm ranging from 6.8mm to 19.3mm. Table 2 shows the relationship of Schneiderian membrane thickness, presence of septa and sinus angle with gender. There is no significant relationship of any of these factors with gender.

Discussion

This CBCT-based study analyzed anatomical factors influencing the lateral sinus lift procedure for dental implant placement in the posterior maxilla. Among cases with sub-antral bone height <5 mm (29.1% of total), we found that 92.6% showed intraosseous

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Table I: Distribution of Tooth No. With Sinus Angle, Presence of Septa and Thickness of Schneiderian Membrane with Chi Square Analysis

Tooth No.	Sinus Angle		Presence of septa		Thickness of Schneiderian membrane at sinus floor	
	Less than 30 degrees	More than 30 degrees	Present	Absent	Less than 3 mm	More than 3 mm
	1 (1.2%)	16 (17.9%)	2 (2.4%)	22 (27.1%)	15 (18.5%)	8 (9.8%)
	3 (3.7%)	30 (45.7%)	1 (1.2%)	21 (25.9%)	19 (23.4%)	11 (13.5%)
	4 (4.9%)	27 (33.3%)	3 (3.7%)	33 (40.7%)	16 (19.7%)	12 (14.8%)
p-value	0.479		0.665		0.752	

Table II: Descriptive Frequencies of Various Factors

Parameters	Categories	N (%)
Sinus angle	<30°	8 (9.9)
	≥30°	73 (90.1)
Sinus septa	Absence of septa	93.7
	Presence of septa	6.3
Schneiderian membrane thickness (at sinus floor)	<3mm	64 (79)
	≥3mm	17 (21)
Schneiderian membrane thickness (at buccal aspect)	≤1mm	70 (86.4)
	>1mm	11 (13.6)
PSAA visibility (origin point)	Not identified (intra-membranous throughout)	6 (7.4)
	Origin at 2nd Molar or posterior to it	65 (80.2)
	Origin at 1st Molar	10 (12.4)
PSAA visibility (termination point)	Not identified (intra-membranous throughout)	6 (7.4)
	Termination at 2nd Pre-molar	12 (14.8)
	Termination at 1st Pre-molar or anterior to it	63 (77.8)
Buccal Bone thickness	Less than 1 mm	60 (74.1)
	More than 1mm	21 (25.9%)

PSAA Posterior Superior Alveolar Artery

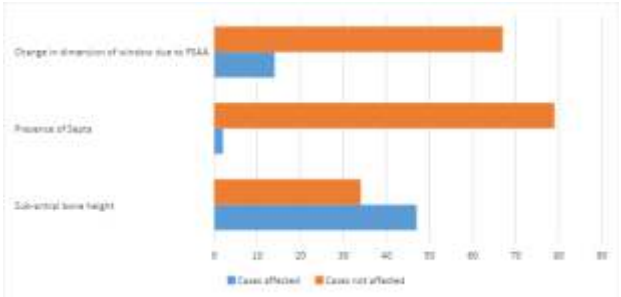

Figure 1: Factors Affecting Implant Placement in Cases With Lateral Sinus Lift

presence of the PSAA, 90.1% had sinus angles ≥30°, Schneiderian membrane thickness was <3 mm in 79% of cases, and septa were present in only 6.3%. These results highlight critical anatomical variables

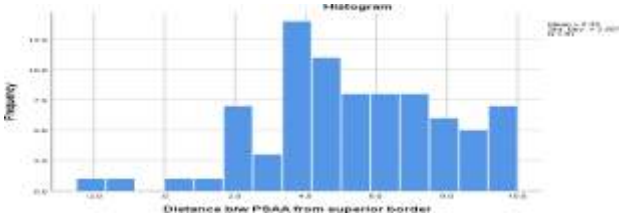

Figure 2: Histogram Showing the Distance of PSAA from the Superior Border of Planned Lateral Window

that can affect sinus augmentation planning.[18]

Sub-antral bone height was found to be <5 mm in 29.1% of cases, necessitating a lateral window approach. Our results reinforce prior findings by Valentini and Atiq et al. who suggested lateral sinus augmentation as a reliable technique when bone height is <8 mm.[19,20,21] However, our study showed a higher frequency of deficient bone height compared to De Souza et al., who reported that 83% of sites had sufficient bone for implant placement.[22] This discrepancy could be attributed to differences in timing post-extraction or population-based variations.

Septa were observed in only 6.3% of cases, significantly lower than the 33% reported in Henriques et al.'s meta-analysis.[23] The low frequency in our sample could reflect population-specific anatomical patterns or a smaller sample size. Despite this low incidence, septa remain clinically significant, as their presence is associated with an increased risk of Schneiderian membrane perforation and complications during sinus elevation, as supported by Ghaida et al.[12] Careful CBCT evaluation remains essential when planning lateral window access.

The PSAA was identified intraosseously in 92.6% of cases, consistent with Godil et. al.,[12] 's findings in the Indian sub-population. Notably, in 13.9% of cases, the artery was within 2 mm of the superior border of the planned lateral window, potentially impacting

the window design. These results emphasize the need for individualized surgical planning. Literature by Iwanaga et al.[24] recommends limiting the superior window border to avoid vessel injury, which aligns with our findings.

Most cases (79%) had membrane thickness <3 mm, similar to results from Monje et. al.,[12] who concluded that Schneiderian membrane thickness does not significantly impact implant success. Our study further confirms that membrane thickness did not vary significantly by gender and posed no procedural limitation in lateral sinus augmentation.

The sinus angle was ≥30° in 90.1% of cases, indicating a predominantly U-shaped sinus morphology, which is generally favorable for graft placement. This supports Cho et. al.,[16] assertion that V-shaped sinuses carry higher perforation risk. The prevalence of wide sinus angles in our cohort reduces intraoperative complications during membrane elevation.

This study is limited by its retrospective design, potential selection bias due to convenience sampling, and lack of surgical outcome correlation. The analysis did not account for time since tooth extraction or sinus pathologies that may affect anatomy.

Prospective studies incorporating surgical outcomes, post-operative CBCT follow-ups, and diverse ethnic populations would strengthen evidence for planning sinus augmentation. Additionally, integrating artificial intelligence in CBCT assessment may improve predictive accuracy for complication risks.

Conclusion

CBCT is an invaluable tool for treatment planning of implant cases requiring sinus augmentation. There are multiple factors that have to be analyzed before placing an implant in the posterior maxillary region. Location of PSAA, height of sub-antral bone, presence or absence of septa and thickness of Schneiderian membrane are some of the more important factors that must be analyzed through CBCT. Each case has variations and must be planned separately but it is suggested that careful evaluation of the relationship of PSAA with sub-antral bone height is necessary for performing a safe procedure.

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CONFLICT OF INTEREST

Authors declared no conflicts of Interest.

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DATA SHARING STATEMENT

The data that support the findings of this study are available from the corresponding author upon request.