RESEARCH PAPER

Morphometric Assessment of Maxillary Posterior Teeth and Sinus Floor Relationships Using Cone Beam Computed Tomography (CBCT): Implications for Immediate Implant Placement

Dr. Divita Naik[1*], Dr. Somil Mathur[2], Dr. Vilas Patel[3], Dr. Meena Shah[4], Dr. Manan Shah[5], Dr. Thanmai Taduri[6]

[1*-6]Department of Prosthodontics, Crown & Bridgework and Oral Implantology, Faculty of Dental Science, Dharmsinh Desai University, Nadiad, Gujarat, India.

Email: divitanaik77@gmail.com[1*]

ABSTRACT

Objectives: The objective of this study was to validate the classification given by Yun-Hoa Jung in the population of Kheda district (Gujarat, India) and evaluate bone available for immediate implant placement in the maxillary posterior teeth (1st pre molar ,2nd premolar and 1st molar) region.

Materials and Method: This observational study evaluated a total of 59 maxillary posterior CBCTs, each having maxillary posterior teeth. CARESTREAM 3D version 3.10.27 and CARESTREAM 3D lite version 3.10.23 was used to view data. All the CBCTs were taken by a qualified specialist and DICOM files were evaluated. Orthogonal slicing and curved slicing views were used to measure the bone available.

Results: This study observed that the distobuccal (DB) roots of the maxillary first molar were closest to the sinus floor followed by the mesiobuccal (MB) and palatal roots. The palatal roots of maxillary first premolar were closer than the buccal roots. Type 2 and Type 3 relationships were found to be highly prevalent (67.8% combined) in the first molar region.

Conclusion: Preoperative CBCT analysis using the Jung's classification is essential for identifying patients with low available bone height (Types 2 and 3). For these patients, immediate implant placement may require adjunctive procedures like sinus floor elevation to ensure long-term success.

Clinical Relevance: Preoperative cone-beam computed tomography (CBCT) analysis using the Jung's classification is crucial in the maxillary posterior region to identify the vertical relationship of the tooth apex and the floor of the maxillary sinus. Recognizing these anatomical variations allow clinicians to anticipate limited bone height and strategically plan adjunctive procedures, such as sinus floor elevation, bone grafting etc. to ensure primary stability and long-term implant success. Consequently, integrating this classification system into diagnostic workflows optimizes treatment predictability and mitigates the risk of Schneiderian membrane perforation during immediate implant placement.

Keywords: Jung's classification, immediate implant placement, Maxillary sinus Cone-beam computed tomography, Maxillary posterior teeth, Sinus lift procedures.

How to cite this article: Dr. Divita Naik, Dr. Somil Mathur, Dr. Vilas Patel, Dr. Meena Shah, Dr. Manan Shah, Dr. Thanmai Taduri, Morphometric Assessment of Maxillary Posterior Teeth and Sinus Floor Relationships Using Cone Beam Computed Tomography (CBCT): Implications for Immediate Implant Placement, Int J Drug Deliv Technol. 2026;16(80s): 1185-1193; DOI: 10.25258/ijddt.16.80s.150

INTRODUCTION

The maxillary sinus is a bilateral structure located in the midfacial region of the skull and is the largest of the paranasal sinuses, representing a paired pyramidal cavity within the body of the maxilla. [1]. Considerable anatomical variation exists in the size, shape, and extension of the sinus, particularly in relation to the posterior maxillary dentition, and its dental implications have been well documented [2]. In nearly half of the population, the floor of the maxillary sinus extends between adjacent teeth or individual roots, producing elevations or "hillocks" on the sinus floor and occasionally resulting in radiographic projection of root apices into the sinus cavity. Histological and imaging studies have demonstrated that roots appearing to protrude into the sinus are often separated from the sinus membrane only by a thin cortical layer, with actual perforations reported in 14 – 28% of cases [3]. These close anatomical relationships are of significant clinical importance during extraction, implant placement, and sinus augmentation procedures, particularly in relation to post-extraction sinus pneumatization changes [4].

Following extraction of posterior maxillary teeth, progressive pneumatization of the maxillary sinus combined with alveolar ridge resorption frequently results in a reduction in residual bone height. Wehrbein and Diedrich demonstrated a positive correlation between the degree of root projection into the maxillary sinus and the extent of sinus pneumatization following tooth extraction.[5] Consequently, insufficient vertical bone height in the posterior maxilla remains a major limitation for achieving primary implant stability and long-term implant success [6]. The cortical floor of the maxillary sinus often lies in close proximity to the roots of maxillary premolars and molars, making precise preoperative assessment essential to avoid complications such as Schneiderian membrane perforation, inadequate implant anchorage, or sinus involvement during surgical procedures [7]. These anatomical variations and surgical risk factors are further compounded by sinus-related pathology and anatomical considerations that influence complications during lateral window sinus augmentation procedures [8].

To overcome the limitations posed by reduced bone availability in the posterior maxilla, sinus augmentation procedures have become an integral component of implant rehabilitation. Among these, crestal sinus lift techniques have gained popularity because of their minimally invasive nature, reduced postoperative morbidity, and the possibility of simultaneous implant placement. Summers first described the osteotome-mediated sinus floor elevation technique, which involves controlled fracture of the sinus floor and elevation of the Schneiderian membrane through the implant osteotomy site.[9] Subsequently, several modifications, including hydraulic sinus elevation and balloon-assisted techniques based on the osteotome approach, have enhanced the predictability and safety of indirect sinus augmentation procedures [10]. More recently, osseodensification-assisted sinus lifting has further improved implant primary stability and outcomes, particularly in cases with limited residual alveolar bone height [11].

The success of crestal sinus elevation procedures is highly dependent on precise radiographic assessment of the remaining alveolar bone as well as the spatial relationship between the maxillary sinus floor and the apices of posterior teeth roots [12]. Cone-beam computed tomography (CBCT) is widely regarded as the preferred imaging technique for evaluating sinus anatomy, available bone height, and root proximity to the sinus cavity, thereby aiding accurate implant treatment planning and reducing the likelihood of intraoperative and postoperative complications as compared to other imaging modalities [13]. Cone-beam computed tomography (CBCT) demonstrates a close anatomical relationship between the maxillary sinus floor and the root apices of posterior maxillary teeth, with frequent proximity or contact observed in this region [14].

Yun-Hoa Jung et al. proposed a classification system based on the spatial relationship between the posterior maxillary tooth roots and the maxillary sinus floor, categorizing these relationships into distinct types according to the degree of root approximation or protrusion into the sinus cavity. This classification provides valuable guidance for clinicians in predicting the risk of sinus membrane perforation, estimating residual bone availability after extraction, and determining the potential need for sinus augmentation procedures prior to implant placement [15]. In patients presenting with Jung's type 2 and type 3 relationships, where roots are either in close approximation to (Type 2) or protruding into the sinus floor(Type 3), preoperative morphometric analysis becomes particularly important for selecting appropriate implant protocols and determining the necessity of indirect sinus lift procedures to achieve favorable primary stability and long-term outcomes.

Although Jung's classification has been investigated in various populations, anatomical variations related to ethnicity and craniofacial morphology may influence the prevalence of different root-sinus relationships. Indian populations exhibit significant diversity in craniofacial anatomy, maxillary dimensions, and sinus morphology, which may affect the applicability of existing classification systems derived predominantly from non-Indian cohorts. Therefore, validating Jung's classification in the Indian population is clinically relevant for improving treatment planning accuracy, predicting sinus-related complications, and developing population-specific guidelines for implant placement and sinus augmentation procedures. The present study aims to evaluate and validate Jung's classification in a regional Indian population using CBCT-based morphometric analysis to aid clinicians in evidence-based decision-making during implant rehabilitation of the posterior maxilla.

MATERIALS AND METHOD

The present study "Morphometric analysis of available bone and proximity of maxillary sinus and posterior teeth for immediate implant placement-A cone beam computed tomography study" was conducted at the Department of Prosthodontics, Crown & Bridgework and Oral Implantology, Faculty of Dental Science, Dharmsinh Desai University, Nadiad. The study protocol and study design was approved by the Ethical Committee of Faculty of Dental Science Dharmsinh Desai University (Approval no-FDS/DDU/EC/12/2024).

The sample size for the present study was calculated using G*Power Software Version 3.1.9.4. This observational study evaluated a total of 59 cone-beam computed tomography (CBCT) scans of the maxillary posterior region, comprising maxillary first and second premolars along with maxillary first molars, resulting in the assessment of 177 roots of the maxillary first molars. The CBCT data were collected from a CBCT center at Dharmsinh Desai University, Nadiad. Adult patients with fully erupted maxillary premolars and first molars were included in the study. Teeth with previous apicectomy, periapical pathology, root fractures, root resorption, radicular bone resorption, or CBCT scans demonstrating Le Fort fractures, severe scattering, and/or distorted images were excluded to maintain image quality and diagnostic accuracy.

All CBCT scans were acquired using a CBCT unit (CS

8200 3D Neo Edition, Carestream, New York, USA) with a field of view of 12 cm × 10 cm and an ultra-high resolution of 75 µm. All scans were obtained by a single qualified operator to ensure standardization of image acquisition. The CBCT datasets were stored in DICOM format on DVDs, and either segmental or complete maxillary CBCT scans, as well as complete maxillary and mandibular DICOM datasets, were included for analysis.
The images were evaluated using CARESTREAM 3D Imaging Software version 3.10.27 and CARESTREAM 3D Lite version 3.10.23 on an HP laptop equipped with an Intel® Core™ i3-8130U processor. Orthogonal slicing and curved slicing views were employed to obtain accurate image sections for the assessment and measurement of the available bone. The acquired CBCT images were carefully analyzed using the software tools to facilitate detailed radiographic evaluation.

MEASUREMENT

Root-sinus proximity was categorized using Jung's classification: The classification given by Yun Hoa Jung includes 4 descriptions: Type 0- The roots not in contact with the cortical borders of sinus, Type 1- The roots in contact with the cortical borders of sinus, Type 2 - The root projecting on the lateral border of the sinus, but its apex is outside the sinus borders, Type 3- The root apex projecting into the sinus cavity. In Types 2 and 3, the horizontal relationship between the roots of the teeth and the sinus floor was classified into three types: Type B, the lowest point of the sinus floor was located on the buccal side; Type BP, the lowest point of the sinus floor was located between the buccal and palatal roots; Type P, the lowest point of the sinus floor was located on the palatal side of the palatal root.[15]. The measurements were made from the root apex to the cortical inferior wall of the maxillary sinus along the long axis of the tooth as illustrated in Figure2.

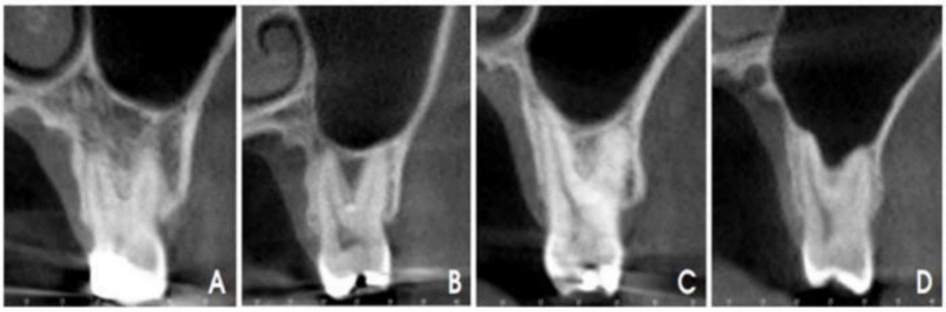


Fig. 1 a Type 0- The roots not in contact with the cortical borders of sinus
Fig. 1 b Type 1- The roots in contact with the cortical borders of sinus
Fig. 1 c Type 2 - The root projecting on the lateral border of the sinus, but its apex is outside the sinus borders
Fig. 1 d Type 3- The root apex projecting into the sinus cavity
Credit Note: Jung YH, Cho BH (2012) Assessment of the relationship between the maxillary molars and adjacent structures using cone beam computed tomography. Imaging Sci Dent 42(4):219–224. https://doi.org/10.5624/isd.2012.42.4.219

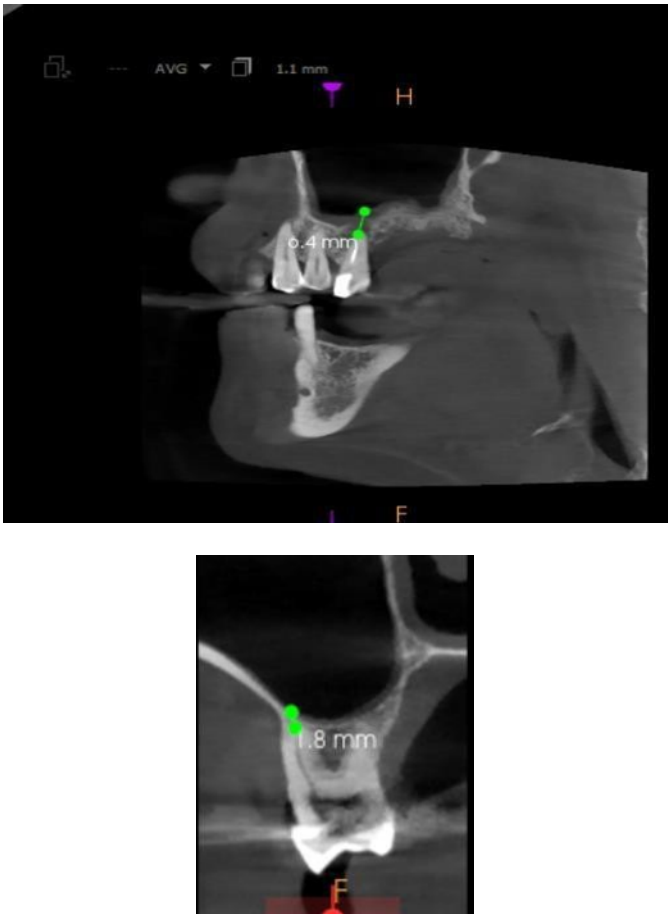


Fig. 2 Measurements made from apex of the root till the cortical floor of the sinus and classification according to horizontal relationships.

STATISTICAL ANALYSIS

All data were presented as mean values along with their corresponding standard deviations (mean ± SD). Group comparisons were carried out using one-way Analysis of Variance (ANOVA). The p-value was used to determine the level of statistical significance in hypothesis testing. Results with a p-value below 0.05 were considered to indicate a statistically significant difference.

RESULTS

The current study demonstrated a significant association between the roots of maxillary posterior teeth and the floor of the maxillary sinus. Variations in the root–sinus relationship were observed according to Jung's classification, with Type 2 being the most prevalent pattern and Type 1 being the least common. The distances between the roots of the maxillary first molars and the sinus floor differed significantly among the classification types, with Type 0 exhibiting the greatest separation and Type 3 showing the closest approximation to the sinus floor. Furthermore, statistically significant differences were identified in the relationship between maxillary premolar roots and the maxillary sinus, indicating anatomical variability among posterior maxillary teeth.

Table 1 and Figure 1 present the distribution of maxillary first molar roots according to Jung's classification. Type 2 was the predominant pattern, accounting for 40.7% of cases, followed by Type 3 (27.1%) and Type 0 (25.4%), whereas Type 1 was observed least frequently (6.8%).

Table 2 summarizes the mean distance between the roots of the maxillary first molar and the floor of the maxillary sinus. The mesiobuccal root demonstrated a mean distance of 2.11±1.82 mm, with the greatest distance observed in Type 0 (3.90±2.54 mm) and the shortest in Type 3 (1.04±0.68 mm). The distobuccal root showed a mean distance of 1.87±1.26 mm, ranging from 2.94±1.39 mm in Type 0 to 0.84±0.56 mm in Type 3. Similarly, the palatal root exhibited a mean distance of 1.97±1.35 mm, with the maximum value recorded in Type 0 (3.17±1.45 mm) and the minimum in Type 3 (0.90±0.86 mm). The observed differences amongst the classification groups were statistically significant.

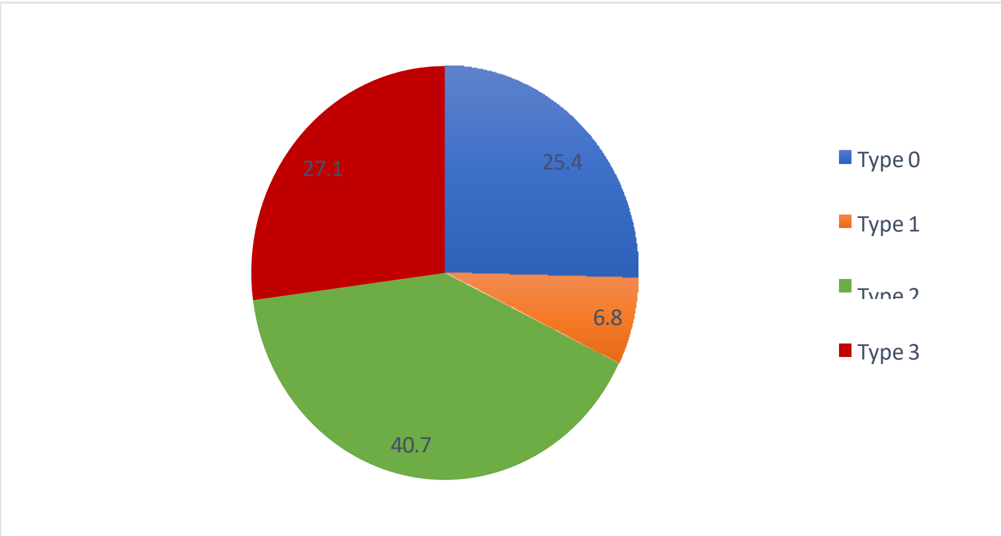
Table 3 and Figure 2 illustrate the relationship between the roots of the maxillary premolars and the floor of the maxillary sinus. The buccal root of the maxillary premolar demonstrated the greatest mean distance from the sinus floor (5.73±2.81 mm), followed by the palatal root (5.18±2.62 mm). In contrast, the maxillary second premolar showed the shortest mean distance (4.23±2.37

mm). These variations were also found to be statistically significant.

Table 4 Illustrates the horizontal relationship between the maxillary first molar roots and the sinus floor for roots classified as Jung's Type 2 and Type 3 (N = 120), the anatomical distribution varied significantly across the different root types. For the mesiobuccal root (n = 40), a Type B relationship—where the lowest point of the sinus floor was located on the buccal side—was the predominant finding, occurring in 26 cases (65.0%), followed by a Type BP relationship in 11 cases (27.5%) and a Type P relationship in 3 cases (7.5%). Similarly, the distobuccal root (n = 27) was most frequently associated with a Type B relationship, accounting for 19 cases (70.4%), while a Type BP relationship was noted in 7 cases (25.9%) and a Type P relationship was observed in just 1 case (3.7%). In contrast, the palatal root (n = 53) exhibited a strong propensity for a Type P relationship, where the lowest point of the sinus floor was situated on the palatal side of the palatal root, representing 35 cases (66.0%); a Type BP relationship was identified in 16 cases (30.2%), whereas a Type B relationship was rarely seen, accounting for only 2 cases (3.8%). Cumulatively across all evaluated Type 2 and Type 3 roots, a Type B relationship was the most common overall presentation with 47 cases (39.2%), followed by a Type P relationship in 39 cases (32.5%) and a Type BP relationship in 34 cases (28.3%).(Table 4)

Table 1 Frequency distribution of distance between maxillary 1st molar roots and maxillary sinus based on the Jung's

Maxillary 1st molar roots	**Jung's classification**				**Total**
	Type 0	**Type 1**	**Type 2**	**Type 3**	
	N	**N**	**N**	**N**	**N**
Mesiobuccal root	10	9	24	16	59
Distobuccal root	31	20	1	7	59
Palatal root	4	2	28	25	59
Total	45(25.4)	12(6.8)	72(40.7)	48(27.1)	177(100.0)



PIECHART:1 Frequency distribution of distance between maxillary 1st molar roots and maxillary sinus based on the Jung's classification.

Table 2 Mean distance between roots of maxillary 1st molar and maxillary sinus based on the Jung's

Maxillary 1st molar roots	**Jung's Classification**	**Mean (SD)**	**Maximum**	**Minimum**	**F value**	**P value**
Mesiobuccal root	Type 0	3.90±2.54	0.70	9.00		
	Type 1	2.78±1.75	1.30	5.30		
	Type 2	1.60±0.70	0.50	3.30		
	Type 3	1.04±0.68	0.30	3.00		
	Total	2.11±1.82	0.30	9.00	11.57	≤0.05*
Distobuccal root	Type 0	2.94±1.39	1.10	5.70		

	Type 1	2.85±1.19	1.50	4.20		
	Type 2	1.73±0.89	0.60	4.20		
	Type 3	0.84±0.56	0.20	2.30		
	Total	1.87±1.26	0.20	5.70	13.05	≤0.05*
Palatal root	Type 0	3.17±1.45	1.20	5.50		
	Type 1	3.05±1.10	2.00	4.60		
	Type 2	1.75±0.80	0.20	3.20	14.25	≤0.05*
	Type 3	0.90±0.86	0.30	3.80		
	Total	1.97±1.35	0.20	5.50		

**-statistically significant, **- statistically non-significant*

Table 3 Frequency distribution of distance between maxillary premolar roots and maxillary sinus

Maxillary premolar roots	N (%)	Mean (SD)	P- value
Maxillary 1st premolar- Buccal root	59 (33.3)	5.73±2.81	≤0.05
Maxillary 1st premolar- Palatal root	59 (33.3)	5.18±2.62	≤0.05
Maxillary 2nd premolar root	59 (33.3)	4.23±2.37	≤0.05
Total	177(100.0)	5.05±2.60	≤0.05

**-statistically significant, **- statistically non-significant*

Table 4 Frequency distribution of Type B, Type BP and Type P.

Root Type	Type B(Buccal Side)	Type BP (Between Buccal and Palatal)	Type P (Palatal Side)	Total Cases (N)
Mesiobuccal Root	26 (65.0%)	11(27.5)	3(7.5%)	40 (100%)
Distobuccal Root	19 (70.4%)	7 (25.9%)	1(3.7%)	27 (100%)
Palatal Root	2 (3.8%)	16 (30.2%)	35(66.0%)	53 (100%)
Total	**47 (39.2%)**	**34 (28.3%)**	39(32.5%)	120 (100%)

DISCUSSION

The present study evaluated the anatomical relationship between the roots of maxillary posterior teeth and the maxillary sinus floor (MSF) using CBCT imaging and Jung's classification. The findings demonstrated that the maxillary first molar roots were frequently located in close proximity to the sinus floor, with significant variations according to root type and Jung's classification. This close anatomical relationship is clinically relevant because the posterior maxilla is regarded as a critical region during implant placement, endodontic therapy, extraction, sinus augmentation, and periapical surgery due to the increased risk of sinus perforation and odontogenic sinus complications [15].

In the current study, Jung's type 2 relationship was the most frequently encountered pattern, followed by type 3, indicating that a considerable proportion of maxillary posterior roots were either directly contacting the maxillary sinus floor or extending very close to it. These observations are in accordance with previously published CBCT investigations assessing posterior maxillary anatomy and root-sinus relationships. Shahbazian et al. demonstrated that sinus pneumatization and post-extraction changes significantly reduce the available bone height in the posterior maxilla, thereby influencing the proximity of roots to the sinus floor [16]. Similarly, Kilic et al. reported that maxillary molar roots, particularly those of second molars, often exhibit intimate anatomical relationships with the sinus floor [17]. Didilescu et al. also identified considerable morphometric variations in the relationship between maxillary first molars and the sinus floor depending on root anatomy and sinus morphology [18]. Tian et al. further observed that maxillary molars generally lie closer to the sinus floor than premolars, especially in younger individuals where sinus pneumatization is more evident [19]. Comparable findings were observed by Ragab et al. in an Egyptian population, where posterior tooth roots demonstrated significant proximity to the maxillary sinus floor [20].

The close anatomical relationship identified in the present study has important pathological implications. Hauman et al. explained that the minimal thickness of bone separating posterior root apices from the Schneiderian membrane allows odontogenic infections to spread more easily into the maxillary sinus [21]. This relationship becomes clinically significant in cases involving apical periodontitis, periodontal disease, extraction procedures, and endodontic surgery. Fuhrmann et al. emphasized the importance of detailed radiographic evaluation for identifying sinus floor integrity and osseous defects prior to surgical procedures in the posterior maxilla [22]. Engström et al. demonstrated that periodontal treatment may influence the thickness of the sinus mucosa, thereby supporting the association between periodontal inflammation and sinus pathology [23]. Phothikhun et al. further reported a significant association between periodontal bone loss and mucosal thickening of the maxillary sinus on CBCT examination [24]. In addition, Ariji et al. observed that maxillary molar roots may extend toward both the sinus floor and cortical plates, facilitating the spread of odontogenic infection into surrounding anatomical structures [25].

The present study demonstrated significantly shorter distances between the sinus floor and roots classified under Jung's type 3 relationship, especially involving the distobuccal and palatal roots of maxillary molars. Similar findings were reported by Razumova et al., who observed that posterior tooth roots frequently approximate or protrude into the sinus cavity, increasing the possibility of sinus complications during dental procedures [26]. Jung et al. further demonstrated that CBCT imaging provides superior diagnostic re liability compared with panoramic radiography in identifying root protrusion into the sinus cavity [27]. This superiority is mainly attributed to the three-dimensional visualization provided by CBCT, which eliminates image distortion and superimposition. Lu et al. also demonstrated a strong association between apical periodontitis and maxillary sinus mucosal thickening identified on CBCT scans [28]. Likewise, Shokri et al. reported that roots extending into the sinus cavity exhibited significantly reduced distances from the sinus floor compared with roots remaining outside the sinus boundaries [29].

In the present study, premolar roots generally maintained greater distances from the sinus floor than molar roots, although the second premolar demonstrated relatively closer approximation compared with the first premolar. These findings are consistent with previous CBCT-based investigations. Von Arx et al. reported that second premolars tend to lie closer to the sinus floor than first premolars, although both remain anatomically safer than molars during surgical procedures [30]. Gu et al. also observed that first and second molars showed the highest frequency of root protrusion into the sinus cavity among all posterior teeth [31]. Kang et al. demonstrated that roots positioned close to the sinus floor are often associated with thinner buccal cortical bone, thereby increasing surgical complexity during implant placement and periapical procedures in the posterior maxilla [32]. Chand et al. further reported that chronic periodontitis patients demonstrated greater sinus involvement and closer approximation between posterior roots and the sinus floor compared with healthy individuals [33]. Yoshimine et al. emphasized that root morphology, alveolar bone morphology, and sinus pneumatization significantly influence the topographic relationship between posterior teeth and the sinus cavity [34].

The findings of the present study are also in agreement with observations reported in the Indian population. Gupta et al. demonstrated that maxillary first molars showed the closest anatomical relationship with the sinus floor among all posterior teeth evaluated using CBCT imaging [35]. Such anatomical proximity has considerable clinical relevance in implantology, oral surgery, endodontics, and periodontology. Procedures such as sinus floor elevation, extraction of maxillary posterior teeth, implant placement, and apical surgeries may carry an increased risk of sinus membrane perforation when roots are located in close contact with the sinus floor. Therefore, accurate preoperative assessment using CBCT imaging is essential for evaluating root-sinus relationships, estimating available bone height, and minimizing intraoperative as well as postoperative complications. A comprehensive understanding of these anatomical relationships may assist clinicians in improving treatment planning and achieving more predictable outcomes in the posterior maxillary region.

CONCLUSION

Preoperative CBCT analysis using the Jung classification is essential for identifying patients with low available bone height (Types 2 and 3). Based on the Jung's classification, highest prevalence was seen with type 2 in which the roots were in contact with the maxillary sinus floor. A statistically significant difference was observed in the distance between maxillary premolar roots and floor of maxillary sinus. The least distance was observed from maxillary 2nd premolar to floor of maxillary sinus. For these patients, immediate implant placement may require adjunctive procedures like sinus floor elevation to ensure long-term success.

REFERENCES

1. Misch CE (1999) Contemporary implant dentistry. 2nd edn. CV Mosby Co, St Louis, pp 76–194.
2. McGowan DA, Baxter PW, James J (1993) The maxillary sinus and its dental implications. 1st edn. Wright Co, London, pp 1–25.
3. Whyte A, Boeddinghaus R (2019) The maxillary sinus: physiology, development and imaging anatomy. Dentomaxillofac Radiol 48(8):20190205. https://doi.org/10.1259/dmfr.20190205
4. Sharan A, Madjar D (2008) Maxillary sinus pneumatization following extractions: a radiographic study. Int J Oral Maxillofac Implants 23(1):48–56. https://doi.org/10.11607/jomi.2008.23.1.e48
5. Eberhardt JA, Torabinejad M, Christiansen EL (1992) A computed tomographic study of the distances between the maxillary sinus floor and the apices of the maxillary posterior teeth. Oral Surg Oral Med Oral Pathol 73(3):345–346. https://doi.org/10.1016/0030-4220(92)90177-B
6. Kwak HH, Park HD, Yoon HR, Kang MK, Koh KS, Kim HJ et al (2004) Topographic anatomy of the inferior wall of the maxillary

sinus in Koreans. Int J Oral Maxillofac Surg 33(4):382–387. https://doi.org/10.1006/ijom.2003.0503
7. Wehrbein H, Diedrich P (1992) Progressive pneumatization of the basal maxillary sinus after extraction and space closure. Fortschr Kieferorthop 53(2):77–83. https://doi.org/10.1007/BF02143255
8. Chan HL, Wang HL (2011) Sinus pathology and anatomy in relation to complications in lateral window sinus augmentation. Implant Dent 20(6):406–412. https://doi.org/10.1097/ID.0b013e318233c4c5
9. Nunes LS, Bornstein MM, Sendi P, Buser D (2013) Anatomical characteristics and dimensions of edentulous sites in the posterior maxillae referred for implant treatment: a cone beam computed tomographic analysis. Clin Oral Implants Res 24(3):348–354. https://doi.org/10.1111/j.1600-0501.2011.02380.x
10. Summers RB (1994) A new concept in maxillary implant surgery: the osteotome technique. Compendium 15(2):152–160. https://doi.org/10.1111/j.1708-8208.1994.tb00244.x
11. Chen L, Cha J (2005) An 8-year retrospective study: 1,100 patients receiving 1,557 implants using the minimally invasive hydraulic sinus condensing technique. J Periodontol 76(3):482–491. https://doi.org/10.1902/jop.2005.76.3.482
12. Huwais S, Meyer EG (2017) A novel osseous densification approach in implant osteotomy preparation to increase biomechanical primary stability, bone mineral density, and bone-to-implant contact. Int J Oral Maxillofac Implants 32(1):27–36. https://doi.org/10.11607/jomi.2017.32.1.e27
13. Bornstein MM, Scarfe WC, Vaughn VM, Jacobs R (2014) Cone beam computed tomography in implant dentistry: a systematic review focusing on guidelines, indications, and radiation dose risks. Int J Oral Maxillofac Implants 29(Suppl):55–77. https://doi.org/10.11607/jomi.2014suppl.g1.2
14. Tadinada A, Jalali E, Al-Salman W, Jambhekar S, Katechia B (2015) The relationship between maxillary sinus floor and maxillary posterior tooth root apices using cone beam computed tomography. Quintessence Int 46(1):69–73. https://doi.org/10.3290/j.qi.a33188
15. Jung YH, Cho BH (2012) Assessment of the relationship between the maxillary molars and adjacent structures using cone beam computed tomography. Imaging Sci Dent 42(4):219–224. https://doi.org/10.5624/isd.2012.42.4.219
16. Shahbazian M, Xue D, Hu Y, Van Cleynenbreugel J, Jacobs R (2010) Spiral computed tomography based maxillary sinus imaging in relation to tooth loss, implant placement and potential grafting procedure. J Oral Maxillofac Res 1(1):e7. https://doi.org/10.5037/jomr.2010.11007
17. Kilic C, Kamburoglu K, Yuksel SP, Ozen T (2010) An assessment of the relationship between the maxillary sinus floor and the maxillary posterior teeth root tips using dental cone-beam computerized tomography. Eur J Dent 4(4):462–467. https://doi.org/10.1055/s-0039-1697866
18. Didilescu AC, Rusu MC, Săndulescu M, Georgescu CE, Ciuluvică RC (2012) Morphometric analysis of the relationships between the maxillary first molar and maxillary sinus floor. Open J Stomatol 2(4):352–357.https://doi.org/10.4236/ojst.2012.24062
19. Tian XM, Qian L, Xin XZ, Wei B, Gong Y (2016) An analysis of the proximity of maxillary posterior teeth to the maxillary sinus using cone-beam computed tomography. J Endod 42(3):371–377. https://doi.org/10.1016/j.joen.2015.11.010
20. Ragab MH, Abdalla AY, Sharaan ME (2022) Location of the maxillary posterior tooth apices to the sinus floor in an Egyptian subpopulation using cone-beam computed tomography. Iran Endod J 17(1):7–12. https://doi.org/10.22037/iej.v17i1.34295
21. Hauman CHJ, Chandler NP, Tong DC (2002) Endodontic implications of the maxillary sinus: a review. Int Endod J 35(2):127–141. https://doi.org/10.1046/j.1365-2591.2002.00470.x
22. Fuhrmann R, Bücker A, Diedrich P (1997) Radiological assessment of artificial bone defects in the floor of the maxillary sinus. Dentomaxillofac Radiol 26(2):112–116. https://doi.org/10.1038/sj.dmfr.4600212
23. Engström H, Chamberlain D, Kiger R, Egelberg J (1988) Radiographic evaluation of the effect of initial periodontal therapy on thickness of the maxillary sinus mucosa. J

Periodontol 59(9):604–608. https://doi.org/10.1902/jop.1988.59.9.604

24. Phothikhun S, Suphanantachat S, Chuenchompoonut V, Nisapakultorn K (2012) Cone-beam computed tomographic evidence of the association between periodontal bone loss and mucosal thickening of the maxillary sinus. J Periodontol 83(5):557–564. https://doi.org/10.1902/jop.2011.110376
25. Ariji Y, Obayashi N, Goto M, Izumi M, Naitoh M, Kurita K, et al (2006) Roots of the maxillary first and second molars in horizontal relation to alveolar cortical plates and maxillary sinus: computed tomography assessment for infection spread. Clin Oral Investig 10(1):35–41. https://doi.org/10.1007/s00784-005-0019-y
26. Razumova S, Brago A, Howijieh A, Manvelyan A, Barakat H, Baykulova M (2019) Evaluation of the relationship between the maxillary sinus floor and the root apices of the maxillary posterior teeth using cone- beam computed tomographic scanning. J Conserv Dent 22(2):139–143. https://doi.org/10.4103/JCD.JCD_367_18
27. Jung YH, Cho BH, Hwang JJ (2020) Comparison of panoramic radiography and cone-beam computed tomography for assessing radiographic signs indicating root protrusion into the maxillary sinus. Imaging Sci Dent 50(4):309–318. https://doi.org/10.5624/isd.2020.50.4.309
28. Lu Y, Liu Z, Zhang L, Zhou X, Zheng Q, Duan X, et al (2012) Associations between maxillary sinus mucosal thickening and apical periodontitis using cone-beam computed tomography scanning: a retrospective study. J Endod 38(8):1069–1074. https://doi.org/10.1016/j.joen.2012.04.016
29. Shokri A, Lari S, Yousef F, Hashemi L (2014) Assessment of the relationship between the maxillary sinus floor and maxillary posterior teeth roots using cone beam computed tomography. J Contemp Dent Pract 15(5):618– 622. https://doi.org/10.5005/jp-journals-10024-1588
30. von Arx T, Fodich I, Bornstein MM (2014) Proximity of premolar roots to maxillary sinus: a radiographic survey using cone-beam computed tomography. J Endod 40(10):1541–1548. https://doi.org/10.1016/j.joen.2014.06.022
31. Gu Y, Sun C, Wu D, Zhu Q, Leng D, Zhou Y (2018) Evaluation of the relationship between maxillary posterior teeth and the maxillary sinus floor using cone-beam computed tomography. BMC Oral Health 18(1):164. https://doi.org/10.1186/s12903-018-0626-9
32. Kang SH, Kim BS, Kim Y (2015) Proximity of posterior teeth to the maxillary sinus and buccal bone thickness: a biometric assessment using cone-beam computed tomography. J Endod 41(11):1839–1846. https://doi.org/10.1016/j.joen.2015.06.017
33. Chand A, Ronghe B, Byakod G, Lathi AA, Muglikar S (2017) Relationship between inferior wall of maxillary sinus and maxillary posterior teeth using cone-beam computed tomography in healthy and chronic periodontitis patients. J Indian Soc Periodontol 21(6):466–472. https://doi.org/10.4103/jisp.jisp_192_17
34. Yoshimine S, Nishihara K, Nozoe E, Yoshimine M, Nakamura N (2012) Topographic analysis of maxillary premolars and molars and maxillary sinus using cone beam computed tomography. Implant Dent 21(6):528–535. https://doi.org/10.1097/ID.0b013e3182745b94
35. Gupta N, Gupta ND, Maheshwari S et al (2014) Evaluation of maxillary sinus anatomy and its relationship with posterior teeth in Indian population using CBCT: a retrospective study. J
36. Clin Diagn Res 8(8):ZC71– ZC74. https://doi.org/10.7860/JCDR/2014/9027.4724