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Examining the relationship between the roots of the maxillary teeth and the maxillary sinus in both horizontal and vertical dimensions using cone beam computed tomography in both sexes

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Abstract

Knowledge of the anatomical and pathological relationship between the posterior teeth of Maxilla or edentulous area with the maxillary sinus is critical for diagnosis and treatment planning. The purpose of this study was to determine the relationship between the floor of the maxillary sinus and the teeth in both sexes using CBCT in Ahvaz. This study was conducted by reviewing the archive of cone beam computed tomography (CBCT) images of patients referred to a private maxillofacial radiology clinic in Ahvaz city in 2019. In order to investigate the position of the floor of the maxillary sinus in relation to the roots of the molar teeth, Reconstructed images in the cross-sectional dimension were prepared from volumetric information. The position of the floor of the maxillary sinus in relation to the roots of the molar teeth was divided into 4 types in the vertical dimension and 3 types in the horizontal dimension. All patient information, including the gender and position of the molar roots in relation to the maxillary sinus, were collected and analyzed. The results of our study showed that in the vertical dimension to examine the root of the molar teeth with the maxillary sinus in men and women, in the mesiobuccal, distobuccal and palatal roots, the highest frequency was related to the state where the root was far from the sinus floor, and in the horizontal dimension to Examining the root of the molar teeth with the floor of the maxillary sinus in women, the most frequency is related to the situation where the lowest position of the sinus floor is between the buccal and palatal roots. In addition, the results of our study also show that there is no significance between the position of the floor of the maxillary sinus in relation to the mesiobuccal and distobuccal roots in the vertical dimension between women and men, but there is in relation to the palatal root in the vertical dimension between women and men. In the vertical dimension, the position where the root is far from the sinus floor has the highest frequency, and in the horizontal dimension, the position where the lowest position of the sinus floor is between the buccal and palatal roots has the highest frequency. There is also a significance between the position of the floor of the maxillary sinus in relation to the palatal root in the vertical dimension between women and men.

Keywords: Maxillary teeth roots, maxillary sinus, horizontal and vertical dimensions, cone beam computed tomography.

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1. Introduction

Paranasal sinuses are a set of four air-filled cavities located in the maxillofacial complex. These cavities include the maxillary, frontal, sphenoid, and ethmoid air cells. The maxillary sinus is the first paranasal sinus to develop, and its growth reaches completion around the age of 20, coinciding with the eruption of the third molar. The floor of the sinus is formed by the alveolar process of the maxillary bone. The maxillary sinus is situated in close proximity to the teeth and dental structures, making it particularly relevant in dentistry. Abnormalities originating from the maxillary sinus can exhibit symptoms resembling odontogenic diseases, while conversely, irregularities originating from the vicinity of the teeth can impact the sinus or present a similar appearance to sinus-related conditions [1]. The expansion of the sinus in adults varies in relation to the alveolar ridge. In approximately 50% of cases, the sinus floor extends between the adjacent teeth or their roots, manifesting as either a protrusion of the sinus floor or the apex of the roots within the sinus [2]. Histological sections reveal that the majority of roots that appear to extend into the sinus through radiographic images are actually separated from the sinus by a thin cortical layer, and perforation occurs in 14-28% of cases [3]. Approximately 10-12% of cases of maxillary sinusitis can be attributed to odontogenic causes [4]. The maxillary sinus is positioned between the nasal cavity and the oral cavity, making it a vulnerable area for pathogen invasion from either

the nasal cavity or oral cavity. Sinusitis resulting from odontogenic factors occurs when the infection of maxillary teeth disrupts Schneiderian's membrane [5]. Due to its composition of cortical bone, the sinus floor acts as an effective barrier, preventing the penetration of odontogenic infections. However, in patients with tooth roots located in close proximity to the sinus floor, odontogenic infections may still drain into the sinus [4,5]. To properly diagnose and plan treatments, it is crucial to have a thorough understanding of the anatomical and pathological connection between the posterior teeth, edentulous areas, and the maxillary sinus [6]. The close proximity between the maxillary sinus and the roots of the posterior teeth can result in undesirable communication between the oral and sinus cavities during the extraction of these teeth [7,8]. The roots of the maxillary premolar and molar teeth are situated beneath the sinus floor, with the second molar roots being the closest to the floor. These roots are adjacent to the sinus floor, as well as the first molar, third molar, second premolar, first premolar, and canine [7,8].

The topography of the inferior wall of the sinus plays a significant role in determining the path of infection. Understanding the horizontal and vertical relationships between the lower wall of the maxillary sinus and the tooth root apices is essential for identifying the routes of odontogenic infections and establishing diagnoses and treatment plans for sinus pathologies [9]. Sinusitis refers to the viral or bacterial inflammation of the mucous membrane in the paranasal sinuses and can occur concurrently with or as a secondary condition to acute rhinitis [10,11]. Viral infections of the upper respiratory system are the primary cause of maxillary sinusitis, with dental issues accounting for approximately 10% of cases. Sinusitis can be triggered by tooth extractions, facial trauma, and upper jaw osteotomy resulting in damage to the sinus membrane [10]. In the diagnosis of odontogenic sinusitis, radiographic findings play a significant role. Computed tomography (CT) is considered the gold standard diagnostic method for evaluating sinus pathologies. However, cone beam computed tomography (CBCT), which offers higher image resolution and lower radiation exposure, is particularly useful for identifying maxillary sinusitis of dental origin [12]. Cone beam computed tomography (CBCT) is a three-dimensional imaging method that has been developed in recent years [13].

This imaging technique offers numerous advantages, including high image accuracy, fast scan time, unique modes, and reduced image errors [14]. Moreover, CBCT has found significant applications in dentistry, such as assessing facial structures for dental implant placement, evaluating hard tissues in temporomandibular bone, examining facial structures for orthodontic treatments, assessing the position of the mandibular third molar in relation to the mandibular canal, and identifying signs of infection, cysts, and tumors [15]. One limitation of CBCT is its low contrast in soft tissue. The CBCT scanner operates by directing a cone-shaped X-ray beam onto a two-dimensional sensor, which rotates approximately 360 degrees around the patient's head [16]. During this dental imaging process, the scanner revolves around the patient, capturing cone-shaped image beams that result in approximately 600 distinct images. By rotating (360°) around the specific area of interest, a set of volumetric data is obtained. The device's software collects this information, reconstructs it, and prepares a digital image [18,17]. While numerous CBCT studies have been conducted across various dental fields, only a few have specifically focused on odontogenic maxillary sinusitis [12,9]. As a result, this study aims to determine the relationship between the maxillary sinus floor and teeth in both males and females using CBCT in the city of Ahvaz.

2. Materials and methods

This research is a descriptive and analytical epidemiological study that involved examining the archive of cone beam computed tomography (CBCT) images of patients referred to a private maxillofacial radiology clinic in Ahvaz city in 2019. These patients were referred to the clinic for various reasons related to their imaging needs. The study was specifically conducted at a private maxillofacial radiology clinic located in Ahvaz city during the year 2019. Based on specific objectives, previous studies [19], and the sampling formula, a sample size of 62 was determined, with an additional 10% attrition rate calculated for each group. Therefore, the total sample size for this study was estimated to be 140 individuals. This study involved the examination of cone beam computed tomography (CBCT) images from the archives of a private maxillofacial radiology clinic in Ahvaz city in 2019. The images were obtained from patients who had been referred for various reasons to undergo imaging. The QR device (Verona, Italy) with the NewTom, VGi model and a field of view (FOV) of 8*8, high resolution, and exposure conditions of KVP=90 in 9 seconds was used to capture all the images. The samples were selected based on criteria that included optimal image quality, availability of gender information, and coverage of the posterior area of the maxilla (maxillary sinus area). Patients with a history of surgery, pathology, midfacial trauma, or sinusitis were excluded from the study. All images were evaluated using NNT viewer software (NewTom, QR, Verona, Italy), version 10. To determine the positioning of the maxillary sinus floor in relation to the roots of the molar teeth, cross-sectional reconstructed images were generated from volumetric data. According to a study conducted by Mr. Jang et al. [20], the vertical dimension categorizes the position of the maxillary sinus floor relative to the molar tooth roots into four types: 1) the root is distant from the sinus floor, 2) the root makes contact with the sinus floor, 3) the root of the tooth is located laterally along the sinus cavity, and 4) the root has penetrated into the sinus. In the horizontal dimension, the positioning of the maxillary sinus floor in relation to the molar tooth roots is classified into three types:

1. The lowest point of the sinus floor is positioned more towards the outer side (buccal) compared to the buccal roots of the molar teeth.
2. The lowest point of the sinus floor is situated between the buccal and palatal roots of the molar teeth.
3. The lowest point of the sinus floor is situated more towards the inner side (palatal) compared to the palatal roots of the molar teeth.

The study focused on the maxillary first molar as it is frequently associated with odontogenic sinus infections. In the end, all relevant patient information, such as gender and the positioning of the molar roots in relation to the maxillary sinus, was gathered through an information form and subsequently submitted to a statistical consultant for analysis. The information was collected by reviewing the archive of images. For quantitative variables, the mean (and/or median) was employed to describe the central tendency of the data,

while the standard deviation (and/or interquartile range) was used to capture data dispersion. Qualitative variables were described using frequency and percentage. The relationship between qualitative variables was examined using Fisher's test or chi-square. The significance level for all tests was set at 0.5%. All analyses were conducted using SPSS version 23 software. Since the images from the archive were utilized, there was no need for an oxygenator for the patients. It is worth noting that the radiographs of the patients were prepared following protective protocols. Moreover, this research has received approval from the Research Council of Jundishapur University of Ahvaz under the ethics code IR.AJUMS.REC.1400.492.

3. Results

This study included 70 women (50% of the investigated subjects) and 70 men (50% of the investigated subjects). Tables 1 and 2 present the distribution of mesiobuccal, distobuccal, and palatal roots of molar teeth with maxillary sinus in the vertical dimension for both males and females. The analysis focuses on examining the vertical dimension of the root of molar teeth with maxillary sinus in women.

- In terms of the mesiobuccal root, the highest frequency was observed when the root was located far from the sinus floor, accounting for 42.9% (30 teeth), while the lowest observed frequency occurred when the root was in contact with the sinus floor, comprising only 12.9% (9 teeth).
- Regarding the distobuccal root, the highest frequency was recorded when the root was far from the sinus floor, accounting for 0.30% (21 teeth), whereas the lowest observed frequency was associated with the root in contact with the sinus floor, representing 18.6% (13 teeth).
- As for the palatal root, the highest frequency occurred when the root was far from the sinus floor, accounting for 45.7% (32 teeth), while the lowest observed frequency was recorded when the root was in contact with the sinus floor, comprising only 0.10% (7 teeth).

In the vertical dimension, when examining the root of molar teeth with maxillary sinus in men:

- Regarding the mesiobuccal root, the highest frequency was observed when the root was located far from the sinus floor, accounting for 47.15% (33 teeth), while the lowest observed frequency occurred when the root was in contact with the sinus floor, comprising only 15.7% (11 teeth).
- As for the distobuccal root, the highest frequency was recorded when the root was far from the sinus floor, accounting for 32.9% (23 teeth), whereas the lowest observed frequency was associated with the root being positioned laterally along the sinus cavity, with only 0.20% (14 teeth).
- In relation to the palatal root, the highest frequency occurred when the root was far from the sinus floor, accounting for 68.6% (48 teeth), while the lowest observed frequency was recorded when the root was in contact with the sinus floor, comprising only 6.8% (6 teeth).

Tables 3 and 4 present the results of investigating the relationship between the roots of molar teeth and the maxillary sinus in the horizontal dimension for both genders, male and female. Specifically, Table 3 focuses on the frequency distribution of molar roots with the maxillary sinus in the horizontal dimension for women. When examining the root of molar teeth in women in relation to the floor of the maxillary sinus in the horizontal dimension, the highest frequency was found in cases where the lowest position of the sinus floor was between the buccal and palatal roots, accounting for 94.3% (66 teeth). Conversely, the lowest observed frequency occurred in cases where the lowest point of the sinus floor was positioned more towards the palatal side than the palatal roots of the molar teeth, constituting only 1.4% (1 tooth). The frequency distribution of molar roots with the maxillary sinus in the horizontal dimension for men is presented in Table 4. When examining the root of the molar tooth in men in relation to the maxillary sinus in the horizontal dimension, the highest frequency of 92.9% (65 teeth) was found in cases where the lowest position of the sinus floor was between the buccal and palatal roots. On the other hand, the lowest observed frequency occurred when the lowest point of the sinus floor was positioned more towards the palatal side than the palatal roots of the molar teeth, accounting for 2.9%. The analysis of the mesiobuccal, distobuccal, and palatal roots of molar teeth in relation to the maxillary sinus in the vertical dimension for both males and females is presented in Table 5. The results show the connection between the molar tooth roots and the maxillary sinus floor, categorized by gender. In the vertical dimension, the majority of cases in women (42.9%; 30 teeth) and men (47.15%; 33 teeth) exhibited a scenario where the mesiobuccal root was distant from the floor of the sinus. Conversely, the lowest percentages were observed in women (12.9%; 9 teeth) and men (15.7%; 11 teeth) where the root was in contact with the sinus floor. However, according to the chi-square test, no statistically significant relationship was found between the position of the maxillary sinus floor and the mesiobuccal root in the vertical dimension between men and women (P=0.588). In most cases, the position of the floor of the maxillary sinus in relation to the distobuccal root of the molar tooth in the vertical dimension differed between women and men. Specifically, 0.30% (21 teeth) of women and 32.9% (23 teeth) of men had their roots far from the sinus floor. On the other hand, the lowest percentage among women was 18.6% (13 teeth), where the roots were in contact with the sinus floor. Among men, 0.20% (12 teeth) had their roots positioned laterally along the sinus cavity. However, according to the chi-square test, there was no statistically significant relationship observed between the position of the maxillary sinus floor and the distobuccal root in the vertical dimension between men and women (P=0.743). In terms of the palatal root of the molar tooth, the majority of cases showed a similar pattern. In women, 45.7% (32 teeth) had their roots far from the sinus floor, while in men, the percentage rose to 68.6% (48 teeth). The lowest numbers were 0.10% (7 teeth) for women and 6.8% (6 teeth) for men, where the root made contact with the sinus floor. According to the chi-square test, there was a statistically significant relationship between the position of the maxillary sinus floor and the palatal root in the vertical dimension between men and women (P=0.040). Table 6 provides an examination of the relationship between the root of the molar tooth and the maxillary sinus in the horizontal dimension, focusing on both male and female subjects.

Table 1. Frequency distribution of roots of molar teeth with maxillary sinus in the vertical dimension in women

Women (number = 70 teeth)	
The position of the floor of the maxillary sinus in relation to the mesiobuccal root of the molar teeth in the vertical dimension	
The root is far from the floor of the sinus.	30(42.9)
The root is in contact with the floor of the sinus.	9(12.9)
The root of the tooth is placed laterally along the sinus cavity.	10(14.2)
The root has sunk into the sinus.	21(30.0)
The position of the floor of the maxillary sinus in relation to the distobuccal root of the molar teeth in the vertical dimension	
The root is far from the floor of the sinus.	21(30.0)
The root is in contact with the floor of the sinus.	13(18.6)
The root of the tooth is placed laterally along the sinus cavity.	18(25.7)
The root has sunk into the sinus.	18(25.7)
The position of the floor of the maxillary sinus in relation to the palatal root of the molar teeth in the vertical dimension	
The root is far from the floor of the sinus.	32(45.7)
The root is in contact with the floor of the sinus.	7(10.0)
The root of the tooth is placed laterally along the sinus cavity.	20(28.6)
The root has sunk into the sinus.	11(15.7)

Table 2. Frequency distribution of the root of molar teeth with maxillary sinus in the vertical dimension in men

Men (number=70 teeth)	
The position of the floor of the maxillary sinus in relation to the mesiobuccal root of the molar teeth in the vertical dimension	
The root is far from the floor of the sinus.	33(47.15)
The root is in contact with the floor of the sinus.	11(15.7)
The root of the tooth is placed laterally along the sinus cavity.	12(17.15)
The root has sunk into the sinus.	14(20.0)
The position of the floor of the maxillary sinus in relation to the distobuccal root of the molar teeth in the vertical dimension	
The root is far from the floor of the sinus.	23(32.9)
The root is in contact with the floor of the sinus.	17(24.2)
The root of the tooth is placed laterally along the sinus cavity.	14(20.0)
The root has sunk into the sinus.	16(22.9)
The position of the floor of the maxillary sinus in relation to the palatal root of the molar teeth in the vertical dimension	
The root is far from the floor of the sinus.	48(68.6)
The root is in contact with the floor of the sinus.	6(8.6)
The root of the tooth is placed laterally along the sinus cavity.	9(12.8)
The root has sunk into the sinus.	7(10.0)

Table 3. Frequency distribution of molar tooth root with maxillary sinus in horizontal dimension in women

Women	
The position of the floor of the maxillary sinus in relation to the root of the molar teeth in the horizontal dimension	
The lowest point of the sinus floor is more towards the buccal side than the buccal roots of the molar teeth.	3(4.3)
The lowest point of the sinus floor is located between the buccal and palatal roots of the molar teeth.	66(94.3)
The lowest point of the sinus floor is more towards the palatal side than the palatal roots of the molar teeth.	1(1.4)

Table 4. Relationship between the roots of maxillary molar teeth and the maxillary sinus in the horizontal dimension in men

Men	
The position of the floor of the maxillary sinus in relation to the root of the molar teeth in the horizontal dimension	
The lowest point of the sinus floor is more towards the buccal side than the buccal roots of the molar teeth.	3(4.2)
The lowest point of the sinus floor is located between the buccal and palatal roots of the molar teeth.	65(92.9)
The lowest point of the sinus floor is more towards the palatal side than the palatal roots of the molar teeth.	2(2.9)

Table 5. Comparing the relationship between the root of the molar teeth and the maxillary sinus in the vertical dimension in women and men

	Women (number = 70 teeth)	Men (number=70 teeth)	P-value*
The position of the floor of the maxillary sinus in relation to the mesiobuccal root of the molar teeth in the vertical dimension			0.588
The root is far from the floor of the sinus.	30(42.9)	33(47.15)	
The root is in contact with the floor of the sinus.	9(12.9)	11(15.7)	
The root of the tooth is placed laterally along the sinus cavity.	10(14.2)	12(17.15)	
The root has sunk into the sinus.	21(30.0)	14(20.0)	
The position of the floor of the maxillary sinus in relation to the distobuccal root of the molar teeth in the vertical dimension			0.743
The root is far from the floor of the sinus.	21(30.0)	23(32.9)	
The root is in contact with the floor of the sinus.	13(18.6)	17(24.2)	
The root of the tooth is placed laterally along the sinus cavity.	18(25.7)	14920.0)	
The root has sunk into the sinus.	18(25.7)	16(22.9)	
The position of the floor of the maxillary sinus in relation to the palatal root of the molar teeth in the vertical dimension			0.040
The root is far from the floor of the sinus.	32(45.7)	48(68.6)	
The root is in contact with the floor of the sinus.	7(10.0)	6(8.6)	
The root of the tooth is placed laterally along the sinus cavity.	20(28.6)	9(12.8)	
The root has sunk into the sinus.	11(15.7)	7(10.0)	

* Chi-Square Test

Table 6. Comparing the relation between molar tooth root and maxillary sinus in horizontal dimension in men and women

	Women (number = 70 teeth)	Men (number=70 teeth)	P-value*
The position of the floor of the maxillary sinus in relation to the root of the molar teeth in the horizontal dimension			0.843
The lowest point of the sinus floor is more towards the buccal side than the buccal roots of the molar teeth.	3(4.3)	3(4.2)	
The lowest point of the sinus floor is located between the buccal and palatal roots of the molar teeth.	66(94.3)	65(92.9)	
The lowest point of the sinus floor is more towards the palatal side than the palatal roots of the molar teeth.	1(1.4)	2(2.9)	
* Chi-Square Test			

The table presents the results regarding the connection between the molar tooth root and the maxillary sinus in the horizontal dimension, categorized by gender. In most cases, the position of the maxillary sinus floor in relation to the molar tooth root in the horizontal dimension was observed to be at the lowest point between the buccal and palatal roots of the tooth. Specifically, 94.3% (66 teeth) of women and 92.9% (65 teeth) of men exhibited this pattern.

It is worth mentioning that the lowest percentage was 1.4% (1 tooth) for women and 2.9% (2 teeth) for men, where the sinus floor was situated more palatal than the palatal roots of the molar teeth. Assessed through the chi-square test, the research findings revealed that there was no statistically significant relationship between the position of the maxillary sinus floor in relation to the molar tooth root in the horizontal dimension among men and women (P=0.843).

4. Discussion

Due to the superior quality of CBCT in comparison to panoramic radiography when it comes to detecting the vertical distance between the tooth root and the maxillary sinus, we opted for CBCT radiography as our preferred method for this study. Our focus in this research lies primarily on the maxillary first molar, as this particular tooth is known to often result in odontogenic sinus infections [21,22]. Recognizing the significance of the first molar, we also examined the roots of this tooth in both the horizontal and vertical dimensions in relation to the maxillary sinus. In conducting our study, we assessed the outcomes concerning the mesiobuccal, distobuccal, and palatal roots of the molar teeth, alongside the maxillary sinus, considering both vertical and horizontal dimensions among males and females. Similar to our own investigation, Gu [23] et al. conducted a study titled "Evaluation of the Relationship between Maxillary Posterior Teeth and Maxillary Sinus Floor Using Cone Beam Computed Tomography," where they collected cone beam computed tomography images from 1011 Chinese patients.

The findings from this study revealed that the OS type exhibited the highest prevalence among all posterior root epics, demonstrating statistical significance (P<0.05). Additionally, the IS type was observed in the palatal roots (PRs) of maxillary first molars (MFMs) and the mesiobuccal roots (MBRs) of maxillary second molars (MSMs) at rates of 24.8% and 21.6% respectively (P<0.05). Notably, the frequency of the IS type decreased with age, although there were exceptions for premolar roots and PRs in MSMs (P<0.05). Age was identified as a significant factor influencing the mean distance, whereas gender had minimal impact. Moreover, when adjacent teeth were absent, a decrease in the distance between the apices of the maxillary second premolar root and the maxillary sinus floor (MSF) was observed (P<0.05). Furthermore, our study yielded similar results in terms of gender, as no significant differences were observed in both vertical and horizontal dimensions.

Furthermore, in the research conducted by Jung and Cho (24), CBCT was utilized to assess the correlation between the roots of maxillary molar teeth and the maxillary sinus in a cohort of 83 patients. Notably, the mean distance between the sinus floor and the root apex was found to be the greatest for M2 palatal roots, while it was the shortest for M2 mesiobuccal roots. Additionally, M1 mesiobuccal roots demonstrated the closest proximity to M2 mesiobuccal roots. The study also reported a statistically significant variation in the thickness of the bone covering the roots, except for the M2 buccal roots, across the four vertical relationships (p<0.01). Specifically, type 2 exhibited the thinnest bone coverage (p<0.01). Unlike our study, which differs in terms of the types of vertical connections studied, Jung and Cho's research identified penetration of the root apex into the sinus cavity as the most prevalent type. It is plausible that these disparities arose due to discrepancies in the study populations.

Nevertheless, their findings revealed that root protrusion into the maxillary sinus floor (MSF) predominantly occurred in the vertical dimension within their sample population. The variations observed in linear and near-MSF measurements across different populations further substantiate the hypothesis that conducting CBCT cross-sectional radiographic studies at three distinct levels assists in

accurately determining the initial radiographic position of the root and MSF radiographs.

In a separate study, Ananda et al. (2015) carefully selected sixty CBCT scans, consisting of 30 Malay and 30 Chinese subjects, from a database of over 300 archived images. Their objective was to investigate the correlation between the maxillary sinus and the maxillary first molar. The results indicated that among the subjects, 95% exhibited a sinus floor that extended anteriorly to the first molar, while 72% had a depressed floor between the roots. In terms of interradicular bone presence, 75% of the patients displayed this bone structure, with approximately 50% of the root apex penetrating into the floor of the maxillary sinus. Furthermore, the study revealed that only 6 cavities (10.0%) were located adjacent to the buccal roots, while 43 (71.7%) were positioned between the buccal and palatal roots. Interestingly, no cavities were identified inside the palatal roots. In addition, eleven individuals (18.3%) demonstrated that the maxillary sinus floor positioned above the tip of the root.

Overall, within their study, the researchers categorized the vertical relationship between the root apices of premolar and molar teeth and the lower wall of the maxillary sinus into four categories. They observed the occurrence of these four types in relation to the maxillary first molar. Consistent with previous findings, our study also revealed that, when examining the vertical dimension of molar teeth in relation to the maxillary sinus in both males and females, the highest frequency was observed in cases where the root was distant from the sinus floor in the mesiobuccal, distobuccal, and palatal roots. In contrast, the lowest frequency was observed in cases where the root made contact with the sinus floor. Additionally, we noted that when examining the root of molar teeth in relation to the floor of the maxillary sinus in both women and men, the highest frequency was observed when the lowest position of the sinus floor rested between the buccal and palatal roots. On the other hand, the lowest observed frequency occurred when the lowest point of the sinus floor was positioned further towards the palatal side compared to the palatal roots of the molar teeth.

In a separate study conducted in Turkey, Yildirim [26] et.al classified the relationship between the maxillary first molar and the maxillary sinus. The most frequently observed relationship was categorized as type 2, followed by types 1 and 3. Although the distribution of type 2 and 3 relationships was balanced between the control and case groups, the overall findings of this study differed from ours. Specifically, the highest percentage in their classifications indicated that the floor of the maxillary sinus positioned itself above the buccal and palatal roots of the maxillary molar teeth. The reason for this contrast could be attributed to variations in the statistical population, age, gender, or race. They reported that the floor of the maxillary sinus was situated above the buccal and palatal roots of the maxillary molars. However, our study yielded different results in the vertical dimension, suggesting that factors such as age, gender, and descent may have a lesser impact on the horizontal dimension compared to the vertical dimension.

In a study titled "Radiographic Assessment of the Anatomical Relationship between the Floor of the Maxillary Sinus and the Maxillary Posterior Teeth in Saudi Arabia," Hameed [27] and colleagues utilized cone beam computed tomography to collect data from 200 patients (100 men and 100 women) retrieved from the archives. They measured the mean distance between the tips of the maxillary second premolar, ranging from 4.63 mm to 6.49 mm. Additionally, the mean distance between the tip of the posterior teeth and the floor of the maxillary sinus varied from 0.68 ± 0.39 mm in the disto-buccal root of the upper right second molar to 3.93 ± 1.26 mm in the palatal root of the upper maxillary first molar.

Both the male group (0.68 ± 1.17 mm) and the female group (0.69 ± 1.17 mm) exhibited a similar result in the distobuccal root (DBR) of the maxillary second molar. The researchers observed that the apex of the root, along with the alveolar depression of the maxillary sinus floor, had a greater inclination towards the buccal side compared to the buccal root. This particular observation accounted for 62-70% of the population, making it the most prevalent finding [23]. Interestingly, these findings differed from our own study's results. Furthermore, Haghanifar [28] and colleagues conducted a study on a specific subset of the Iranian population, investigating the vertical relationship between molar roots and the sinus floor, and their results also varied from our own findings and those of other studies. The vertical relationship between each root and the maxillary sinus in cross-sectional images was assessed and categorized into four classes. The researchers reached the conclusion that class 2, which accounted for 39.1% of cases, was the most frequently observed class among maxillary molar teeth. They also found that class 0 was significantly more prevalent in men (31.7%) compared to women (18.7%). Additionally, the highest angular divergence among the three molar roots was observed in the first molar, with the angle between the buccal and palatal roots being larger than that between the buccal roots. Notably, the maxillary first molar exhibited the greatest degree of divergence and was associated with class 2 of the maxillary sinus floor.

Razumova [29] and her colleagues conducted a study that investigated the correlation between the maxillary sinus floor and the root apex of posterior teeth using cone beam CT scans (CBCT). They measured the distance between the maxillary sinus floor and the root tip of each tooth in different groups. Additionally, Kwak's classification was utilized to record the relationship between the maxillary sinus and the posterior roots. In order to determine the vertical relationships between the root apices of maxillary premolars and molars, Kwak et al.'s classification was employed. For teeth with only one root, the horizontal relationship was categorized as follows: First class indicated that the lower wall of the maxillary sinus floor was positioned above the root apex. In the second class, the root apex makes contact with the lower wall of the sinus.

In the third class, the root tip protrudes into the lower wall of the sinus. Various types of vertical relationships were observed and documented on both sides in cross-sectional images. The distance between the root tips of maxillary molars and premolars was measured for each root. The second class was predominantly observed in the first and second molars, while class 1 was most frequently observed in premolars. The shortest distance to the maxillary sinus floor was found in the mesiobuccal root of the second molar, and the greatest distance was observed in the palatal root of the first and second molars. No statistically significant difference was found among age groups ($P < 0.01$). In terms of the vertical dimension, the prevalence of the lower wall of the

sinus being below the connecting line of the buccal and palatal root apices without penetration of the apex was highest in maxillary molars. The disparity in sample size, racial composition, mean age, and evaluation criteria contributes to the differences between the findings of these studies and our own results.

In their study conducted in South Korea, Kwak [30] categorized the horizontal relationship between the tooth root and the maxillary sinus. According to the observed relationships, it was noted that the highest frequency occurred in the lowest part of the sinus floor, situated between the buccal and palatal roots. The researchers measured the distance between each root apex and the lower wall of the maxillary sinus. In terms of the vertical dimension, type 1 (in which the inferior sinus wall was positioned above the surface connecting the buccal and lingual root apexes) was the most prevalent, accounting for 54.5% in the first molar area and 52.4% in the second molar area. Additionally, the horizontal relationship between the lower wall of the sinus and the root apex was classified into three types. Type 1: The alveolar depression of the lower sinus wall inclined more toward the buccal side than the buccal root. Type 2: The alveolar depression of the lower sinus wall was located between the buccal and palatal roots. Type 3: The alveolar depression of the lower sinus wall leaned more toward the palatal side than the palatal root. Type 2, which refers to the alveolar indentation of the lower sinus wall positioned between the buccal and lingual roots, emerged as the predominant category in the horizontal dimension, accounting for 80% in both the first and second molar regions. In summary, this study uncovered numerous anatomical characteristics and established connections between the maxillary sinus and its adjacent structures. Similarly, our own investigation delved into both the horizontal and vertical dimensions. While the vertical findings in our study exhibited similarities, the horizontal relationship differed.

In addition, Kilic [1] and their colleagues conducted a study on a Turkish population, revealing that the vertical relationship between the root tip and the sinus floor is more prevalent among the Korean population. The disparity in our respective study findings may stem from significant anatomical variations and racial diversity among the analyzed populations. Furthermore, our own results indicate that, in terms of the horizontal dimension, the most frequent occurrence in both women and men involves the sinus floor's lowest position being situated between the buccal and palatal roots of the molar teeth. Conversely, the least observed frequency pertains to cases where the lowest point of the sinus floor inclines more towards the palatal side relative to the palatal roots of the molar teeth.

Johari [31] et.al conducted an evaluation on the relationship between the root structures of the first and second molars in the upper jaw and the maxillary sinus floor using computed tomography images obtained through cone beam technology. The analysis included a total of 139 maxillary permanent molar teeth and 126 maxillary permanent second molar teeth, assessing their vertical and horizontal relationships with the sinus floor. The vertical connections between the roots of the maxillary molars and the floor of the maxillary sinus were classified into five groups based on reconstructed cone beam computed tomography (CBCT) images in the coronal section. Similarly, the horizontal connections between the roots of the maxillary molars and the sinus floor were classified into three groups within the reconstructed CBCT images in the coronal section. According to their findings, the majority of maxillary molar roots were observed to have vertical contact with the sinus floor without any penetration. In terms of the vertical dimension, their study yielded different results compared to ours. However, there have been fewer studies focusing on the horizontal dimension of communication. They reported that, concerning the horizontal relationship in the region of the maxillary first molar teeth, in most cases, it was situated in the lowermost part of the sinus floor between the buccal and palatal roots. This finding aligns with our own results in the horizontal dimension. Furthermore, our study's results indicate that there is no significant difference in the position of the maxillary sinus floor in relation to the mesiobuccal and distobuccal roots in the vertical dimension between women and men. However, a significant difference is observed in relation to the palatal root in the vertical dimension between women and men. This discrepancy could be attributed to anatomical variances between males and females.

5. Conclusion

The findings from our study revealed that, when examining the vertical dimension of maxillary molar roots in relation to the maxillary sinus in both men and women, the most frequent scenario for the mesiobuccal, distobuccal, and palatal roots was to be located at a distance from the sinus floor. In the horizontal dimension, when investigating the position of molar roots in women relative to the maxillary sinus floor, the highest occurrence was observed when the lowest part of the sinus floor was between the buccal and palatal roots. In addition, the results of the current study indicate that there is no significant difference between the position of the maxillary sinus floor and the mesiobuccal and distobuccal roots in the vertical dimension among women and men. However, a significant difference is observed with respect to the palatal root in the vertical dimension between women and men. This dissimilarity may be attributed to anatomical distinctions between males and females.

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