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ORIGINAL ARTICLE

# Vertical relationships between the divergence angle of maxillary molar roots and the maxillary sinus floor: A cone-beam computed tomography (CBCT) study

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**KEYWORD**

Maxillary sinus;
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**Abstract** *Aim:* To assess the relations between the divergence angle of the maxillary molar roots and their proximity to the maxillary sinus floor using CBCT.

*Method:* This study comprised CBCT scans of the maxilla, including at least the inferior one-third of the maxillary sinus and at least one molar present in any quadrant with complete eruption and root formation. Evaluation included the vertical relations between the maxillary molar root apices and the maxillary sinus floor (MSF), and the root divergence was measured from the root apices to the floor of the pulp chamber. The chi-square test was used for the associations between the study parameters. For the correlation between root divergence angles and MSF vertical relationship types, the Spearman test was used. A P-value $< 0.05$ was considered significant.

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*Results:* A total of 100 scans were analyzed, including 316 permanent maxillary first and second molars. The MSF Type II vertical relationship was the most prevalent (39.6%), followed by Type I (31.3%). The highest divergence angle was found between the distobuccal and palatal roots (mean = 44.9 ± 10.5°). For the mesiobuccal-distobuccal angle groups, there were higher percentages of the MSF Type I and II relationships among the angle groups < 1° and 21-45°. For the mesiobuccal-palatal angle groups, a higher prevalence of the MSF Type II relationship was found in the $<21^{0}$ and $>45^{0}$ angle groups, and a higher prevalence of the Type I relationship was found in the 21-$45^{0}$ angle group. For the distobuccal-palatal angle groups, higher percentages of the MSF Type II relationship were found in the three angle groups. For all teeth, there was a significant positive correlation between the MSF vertical relationship and the mesiobuccal-palatal angle (r = 0.116; P = 0.039).

*Conclusion:* There was a positive correlation between the divergence angle of the roots and their vertical relationship with the MSF. Clinicians should assess the divergence between the roots before performing extraction or endodontic treatments.



## 1. Introduction

The proximity of maxillary molar roots to the maxillary sinus floor (MSF) should be considered before any dental procedure involving maxillary molar roots that may push a foreign body inside the maxillary sinus and increase the possibility of spreading an infection in the sinus (Obayashi et al., 2004; Fry et al., 2016). Procedures such as periapical endodontic surgical procedures may lead to complications if the relationship between the root tips and MSF was not evaluated prior to the procedure. It is well known that the complications following extraction of the maxillary molars are root tip fracture, oroantral communication, root displacement in the maxillary sinus, etc. Furthermore, some studies have revealed an increase in the maxillary sinus dimensions and pneumatization and a decrease in the alveolar bone height and width following molar tooth extraction (Schropp et al., 2003; Sharan and Madjar, 2008; Levi et al., 2017).

The maxillary sinus (MS) is the largest paranasal sinus with a pyramid shape. The extent and form of the sinus vary from person to person (van den Bergh et al., 2000). The diagnosis of maxillary sinus diseases, whether from odontogenic or non-odontogenic origin or a result of periapical infection or direct trauma following tooth extraction, is a challenge in dental practice (Mehra and Jeong, 2008).

Panoramic radiographs are commonly used to study the relationship between maxillary molar root apices and the MSF. However, several drawbacks, such as superimposition, two dimensions and magnification of the anatomical structure, have limited its use. Currently, CBCT is considered the gold standard for sinus diagnosis since CBCT avoids structural overlapping, enlargement of images, and false reading and measurement of dental and maxillofacial structures. It also has a lower radiation dose than computed tomography (CT) (Shankar et al., 2013; Lopes et al., 2016; Tian et al., 2016).

Several studies have assessed the vertical relationships between maxillary molar teeth and the MSF and concluded varying results. Kwak et al. (Kwak et al., 2004) and Xi Zhang et al. (Zhang et al., 2019) found that the most common relationship was Type I. Estrela (Estrela et al., 2016) found that Type II was the most prevalent type. A study performed by Haghanifar et al. (Haghanifar et al., 2018) reported that maxillary first molar teeth had the greatest divergence angle of roots, and their relationship with the maxillary sinus floor was MSF Type II.

A better understanding of root divergence and its relation to the MSF prior to endodontics or surgical procedures involving maxillary molars is necessary along with 3D radiographs and will be more beneficial than 2D radiographs alone. In addition, ethnicity may impact the anatomical relationship between maxillary molars and the maxillary sinus. To the best of our knowledge, there are no available data among the Saudi population concerning the correlation between divergence angles of the maxillary roots and their vertical relationships with the maxillary sinus floor. The present study aimed to assess the relationships between the divergence angle of the maxillary molar roots and their proximity to the MSF using CBCT.

## 2. Methodology

Data were recruited retrospectively from a pool of patients who visited the College of Dentistry at Prince Sattam bin Abdulaziz University, Al-Kharj, Saudi Arabia, between March and October 2019. The CBCT radiographs were acquired using Carestream CS 9300 (CS 9300C Select; Carestream Health Inc., France) with the following parameters: voxel size 0.18 mm; tube voltage 90 kV; tube current 4 mA; and exposure time 8 s; with an adjustable field of view. Add-on software (CS 3D Imaging Software) was used for image analysis. The study was approved by the Research Ethics Review Board of Prince Sattam Bin Abdulaziz University (Ref#: PSAU2020005) and was conducted in accordance with the Helsinki Declaration of 1975, as revised in 2013.

### 2.1. Inclusion and exclusion criteria

Inclusion criteria included the following: age 21 years and above, at least one molar present in any quadrant, healthy, no maxillary sinus diseases, CBCT scan that included the entire maxilla and at least the inferior one-third of the maxillary sinus, and complete eruption and root formation of the first and second maxillary molars.

Exclusion criteria included missing all first and second maxillary molars, extensive caries in maxillary first or second molars in which the caries invaded the pulpal tissue, bone resorption due to periodontal disease in which the bone loss was 2 mm or greater, history of endodontic treatment or endodontic surgery involving maxillary first and second molars, history of maxillary sinus surgery or any surgery to the maxillofacial area, history of trauma in the posterior maxillary region, presence of periapical pathology or root resorption, bony changes due to systemic conditions, benign or malignant tumors in the posterior region of maxilla, history of or current orthodontic treatment, and unclear or degraded CBCT image quality due to the presence of metal or motion artifacts. Evaluation of the eligibility criteria was performed on the basis of careful medical and/or dental history aided by radiographic evaluation of the study sample prior to study commencement. For most criteria, the data were taken from the history or assessed during CBCT case assessment or both.

### 2.2. Data screening and measurements

The selected study sample received CBCT for different purposes, including evaluation of complex root canal anatomy, presence of pathological lesion and implant planning. The vertical relationship of the maxillary root apices with the MSF was evaluated using Kwak's classification system (Kwak et al., 2004), as shown in Fig. 1A. The Kwak classification system (Kwak et al., 2004) comprises five categories: Type I: the inferior wall of the sinus is located above the level connecting the buccal and palatal root apices; Type II: the inferior wall of the sinus is located below the level connecting the buccal and palatal root apices, without an apical protrusion over the inferior wall of sinus; Type III: an apical protrusion of the buccal root apex is observed over the inferior wall of the sinus; Type IV: an apical protrusion of the palatal root apex is observed over the inferior wall of the sinus; and Type V: apical protrusions of the buccal and palatal root apices are observed over the inferior wall of the sinus. The Kwak classification system (Kwak et al., 2004) was used in this study since it can offer more detailed data. The data interpretation was conducted by two calibrated examiners, where intra- and inter-examiner reliability was assessed using the kappa test. The examiners were general practitioners with 3 years of experience in which they were trained and supervised by oral and maxillofacial radiologists with > 10 years of experience.

Root divergence was measured between two buccal roots, mesial and palatal roots, and distal and palatal roots. The measurement was performed from root apices to the floor of the pulp chamber in a triangular shape (Fig. 1B). A line was drawn from the pulpal floor and then centralized in the apex of the selected root. Evident root apex is required for such measurement. Thus, fused roots and severely curved non-marked roots were not included in the measurements.

### 2.3. Statistical analysis

A software program (SPSS version 25, Chicago, IL, USA) was used to perform statistical comparisons. Data are presented descriptively as frequencies and percentages for the categorical variables (sex, tooth types, and MSF relationship types) and means ± standard deviations for the continuous variables (age and divergence angles). Age variable was also categorized into two sub-categories based on the median (median = 28 y ears). The chi-square test was used for the associations

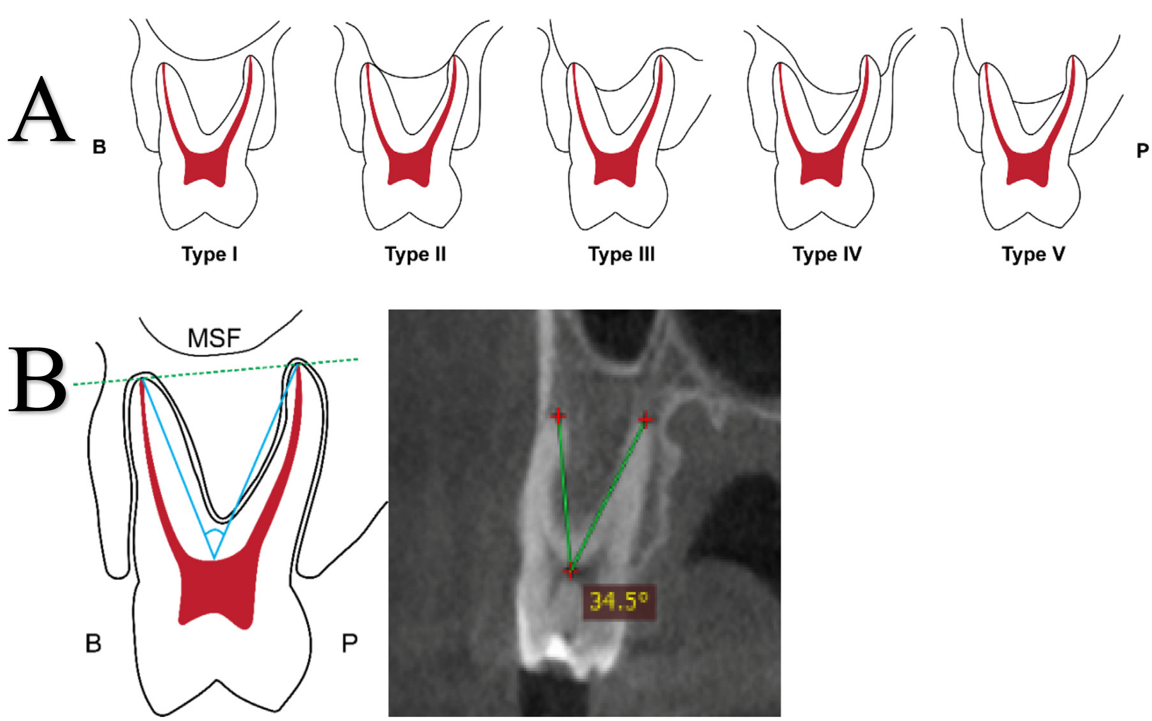


**Fig. 1** Shows the vertical relationship of the maxillary root apices with the MSF according to Kwak's classification (A); and the measurement of the divergence angle between the roots (B).

**Table 1** Characteristics of the study sample.

| | | Frequency | | Percent | |
|---|---|---|---|---|---|
| Gender (N = 100) | | | | | |
| | Male | 66 | | 66.0 | |
| | Female | 34 | | 34.0 | |
| Number of teeth according to location (N = 316) | | | | | |
| | Tooth #16 | 81 | | 25.6 | |
| | Tooth #17 | 75 | | 23.7 | |
| | Tooth #26 | 85 | | 26.9 | |
| | Tooth #27 | 75 | | 23.7 | |
| | Mean | SD | Median | Minimum | Maximum |
| Age (years) | 30.2 | 8.9 | 28 | 20 | 60 |

between the divergence angle groups and the different types of MSF vertical relationships. The Spearman correlation coefficient test was used to analyze the correlations between the root divergence angles and MSF vertical relationship types. The level of significance was set at P < 0.05 for all tests.

## 3. Results

The level of agreement between the examiners was > 95% with a high significance level (P < 0.001), demonstrating a high degree of reliability. Initially, CBCT radiographs from 271 individuals were assessed. Based upon the inclusion and exclusion criteria, 171 CBCT radiographs were excluded, and 100 CBCTs were included. Those CBCT radiographs belonged to 100 patients (66% males, 34% females) with ages ranging from 20 to 60 years (mean = 30.2°8.9 years). A total of 316 permanent maxillary first and second molars were analyzed (166 first molars and 150 s molars) (Table 1). The result of the vertical relationship between the root apex and MSF types revealed a higher prevalence of the MSF Type II relationship (39.6%), followed by the MSF Type I relationship (31.3%). Considering the difference between the sexes, in general, except type I, all other MSF relationship types were found to be more in males than in females (Table 2). Regarding the age groups, generally, the prevalence of Type I, II and V MSF relationships was higher in the ≥ 28-year-old group than in the < 28-year-old group. The measurements of the angles between the different roots revealed the highest divergence angle between the DB and P roots (mean = 44.9°10.5°), followed by the angle between the MB and P roots, while the angle between the MB and DB roots was two times lower (mean = 21.3°8.5°). The angles of the maxillary roots were more divergent in females than in males for all three divergence angles. Among the age groups, the MB-DB and MB-P angles were higher in the elderly group, while the DB-P angle was higher in the younger group. More details are presented in Table 2.

The distribution of the different MSF relationship types and divergence angles among the different types of teeth is shown in Table 3. Generally, the MSF Type I and II vertical relationships were found more among all teeth, the MSF Type III relationship was found higher in teeth #17 and #27, and the MSF Type IV and V relationships exhibited smaller percentages (10% or less). With regard to the divergence angles, the maxillary first molars had higher values for all three divergence angles than the maxillary second molars.

To better understand the relationship between MSF types and divergence angles, the latter was grouped as follows: < 21°, 21-45°, and > 45°. As shown in Table 4, no significant association (P = 0.546) was found between the MSF types and MB-DB angle groups, although there were higher percentages of MSF Type I and II relationships among the angle groups < 21° and 21°-45°. However, the association between the MSF types and MB-P angle groups was significant (P = 0.022), with a higher prevalence of the MSF Type II relationship in the < 21° and > 45° angle groups and the MSF Type I relationship in the 21-45° angle group. However, the association between the MSF relationship types and DB-P

**Table 2** Distribution of vertical relationship with MSF and divergence angles of root according to gender and age groups (N = 316).

| | ALL | Gender | | Age groups | |
|---|---|---|---|---|---|
| | | Male | Female | < 28 years | ≥ 28 years |
| Vertical relationship with MSF N(%) | | | | | |
| Type I | 99 (31.3) | 62 (29.1) | 37 (35.9) | 49 (29.7) | 50 (33.1) |
| Type II | 125 (39.6) | 85 (39.9) | 40 (38.8) | 60 (36.4) | 65 (43.0) |
| Type III | 47 (14.9) | 33 (15.5) | 14 (13.6) | 31 (18.8) | 16 (10.6) |
| Type IV | 22 (7) | 16 (7.5) | 6 (5.8) | 14 (8.5) | 8 (5.3) |
| Type V | 23 (7.3) | 17 (8.0) | 6 (5.8) | 11 (6.7) | 12 (8.0) |
| Divergence angles (Mean ± SD) | | | | | |
| MB-DB angle | 21.3 ± 8.5 | 20.8 ± 8.1 | 22.3 ± 9.5 | 20.7 ± 8.3 | 22.1 ± 8.8 |
| MB-P angle | 42.4 ± 9.9 | 42.0 ± 9.5 | 43.3 ± 10.8 | 42.3 ± 10.2 | 42.6 ± 9.7 |
| DB-P angle | 44.9 ± 10.5 | 44.3 ± 10.4 | 46.0 ± 10.6 | 44.9 ± 10.6 | 44.8 ± 10.4 |

**Table 3** Distribution of vertical relationship with MSF and divergence angles of root according to tooth type (N = 316).

| | Tooth #16 | Tooth #17 | Tooth #26 | Tooth #27 |
|---|---|---|---|---|
| Vertical relationship with MSF N (%) | | | | |
| Type I | 29 (35.8) | 22 (29.3) | 28 (32.9) | 20 (26.7) |
| Type II | 34 (42.0) | 30 (40.0) | 37 (43.5) | 24 (32.0) |
| Type III | 6 (7.4) | 18 (24.0) | 6 (7.1) | 17 (22.7) |
| Type IV | 8 (9.9) | 2 (2.7) | 5 (5.9) | 7 (9.3) |
| Type V | 4 (4.9) | 3 (4.0) | 9 (10.6) | 7 (9.3) |
| Divergence angles (Mean ± SD) | | | | |
| MB-DB angle | 25.1 ± 8.1 | 16.6 ± 6.7 | 25.5 ± 8.0 | 17.4 ± 7.0 |
| MB-P angle | 45.4 ± 8.1 | 37.4 ± 10.0 | 46.8 ± 8.0 | 39.3 ± 10.4 |
| DB-P angle | 46.7 ± 10.5 | 39.9 ± 9.5 | 49.5 ± 10.1 | 42.6 ± 9.1 |

**Table 4** Association between MSF types and different types of root divergence angles for the whole sample (N = 316).

| | MSF classification | | | | | P |
|---|---|---|---|---|---|---|
| | Type I | Type II | Type III | Type IV | Type V | |
| MB-DB angle | | | | | | |
| < $21^{o}$ | 49 (31.0) | 56 (35.4) | 29 (18.4) | 12 (7.6) | 12 (7.6) | 0.546 |
| 21-$45^{o}$ | 50 (32.3) | 67 (43.2) | 17 (11.0) | 10 (6.5) | 11 (7.1) | |
| > $45^{o}$ | 0 (0.0) | 2 (66.7) | 1 (33.3) | 0 (0.0) | 0 (0.0) | |
| MB-P angle | | | | | | |
| < $21^{o}$ | 1 (12.5) | 5 (62.5) | 1 (12.5) | 1 (12.5) | 0 (0.0) | 0.002 |
| 21-$45^{o}$ | 69 (38.3) | 52 (28.9) | 33 (18.3) | 14 (7.8) | 12 (6.7) | |
| > $45^{o}$ | 29 (22.7) | 68 (53.1) | 13 (10.2) | 7 (5.5) | 11 (8.6) | |
| DB-P angle | | | | | | |
| < $21^{o}$ | 4 (44.5) | 3 (33.3) | 2 (22.2) | 0 (0.0) | 0 (0.0) | 0.058 |
| 21-$45^{o}$ | 54 (34.6) | 49 (31.4) | 31 (19.9) | 11 (7.1) | 11 (7.1) | |
| > $45^{o}$ | 41 (27.2) | 73 (48.3) | 14 (9.3) | 11 (7.3) | 12 (7.9) | |

angle groups was not significant (P = 0.058), although higher percentages of the MSF Type II relationship were found in the three angle groups. The MSF Type V relationship was not found in the > 45° MB-DB, < 21° MB-P or < 21° DB-P angle groups.

The correlations between the MSF types and the different divergence angles are presented in Table 5. For all teeth, the correlation was positive but weak and significant with the MB-P angle (r = 0.116; P = 0.039). Similarly, at the tooth level, a positive but not strong and significant correlation (r = 0.264; P = 0.017) was found with the MB-P angle in tooth #16. All other correlations were not significant (P > 0.05). Noticeably, although not significant, the correlation with the MB-DB angle was negative in tooth #17.

## 4. Discussion

This study aimed to assess the relationships between the divergence angle of the maxillary molar roots and their proximity to

**Table 5** Correlation between MSF types and different types of root divergence angles for the whole sample and according to tooth type (N = 316).

| | | MB-DB angle | MB-P angle | DB-P angle |
|---|---|---|---|---|
| All teeth | Correlation Coefficient | −0.020 | 0.116* | 0.080 |
| | Sig. (2-tailed) | 0.729 | 0.039 | 0.156 |
| | N | 316 | 316 | 316 |
| Tooth #16 | Correlation Coefficient | 0.022 | 0.264* | 0.210 |
| | Sig. (2-tailed) | 0.849 | 0.017 | 0.060 |
| | N | 81 | 81 | 81 |
| Tooth #17 | Correlation Coefficient | −0.034 | 0.070 | 0.019 |
| | Sig. (2-tailed) | 0.773 | 0.551 | 0.869 |
| | N | 75 | 75 | 75 |
| Tooth #26 | Correlation Coefficient | 0.099 | 0.194 | 0.127 |
| | Sig. (2-tailed) | 0.366 | 0.075 | 0.247 |
| | N | 85 | 85 | 85 |
| Tooth #27 | Correlation Coefficient | 0.068 | 0.135 | 0.175 |
| | Sig. (2-tailed) | 0.562 | 0.250 | 0.134 |
| | N | 75 | 75 | 75 |

the MSF using CBCT. We focused on maxillary molars, while premolars were excluded from the study because most anatomical studies have revealed that the MSF is commonly nearest in the first and second molars (Roque-Torres et al., 2016; Pei et al., 2020). The growth rate of the maxillary sinus may differ significantly according to age, particularly at younger ages (Jun et al., 2005). Thus, in the current study, we excluded children and adolescents < 21 years even though they had fully matured maxillary first and second molars. In addition, teeth with extensive caries that exceed the pulp chamber with any pathological signs of apical periodontitis and teeth with chronic periodontitis were excluded because such teeth can cause mucosal thickening and other pathological changes in the maxillary sinus. Moreover, teeth with advanced periodontitis may result in tooth mobility and thus inaccurate vertical relation with MSF (Huang and Brunsvold, 2006; Arias-Irimia et al., 2010). Different classifications for the vertical relationship between the root apex and MSF have been presented in the dental literature. Lopes in 2016 (Lopes et al., 2016) studied the vertical relations between the MSF and maxillary molars and classified the relations into four types: Type 0 (MSF over root apex), Type 1 (root apex touches MSF), Type 2 (MSF placed between roots), and Type 3 (protrusion of apices into maxillary sinus). Additionally, Pagin et al. 2013 (Pagin et al., 2013), in a Brazilian population, used different methods to evaluate the vertical relationship of the MSF and maxillary first and second molars. In the current study, the Type II relationship was the most common type, followed by the Type I relationship, and the Type V relationship was the least common. This result is consistent with a study performed by Hameed et al. (Shaul Hameed et al., 2020). In contrast, Kilic et al. (Kilic et al., 2010) and Kwak et al. (Kwak et al., 2004) reported that a Type I vertical relationship was the most common finding in the Turkish population and Korean population, respectively. The explanation of the variation between studies in their findings could be explained by the difference in the sample size, range of age, sex distribution, method used, and ethnicity.

For the evaluation of the correlation between the divergence angle of the maxillary molar roots and their proximity to the maxillary sinus floor (MSF) in female and male patients, our results revealed that males had a significant inverse correlation between the right first molar MB-P angle and the left second molar MB-DP angle with proximity to the MSF. A possible explanation for these results is that the diversity in males and females of growth and that males have longer roots than females (Shokri et al., 2014). However, further research is needed to analyze the sex differences for a better understanding of the relation of the divergence angle to the MSF.

Regarding the correlation in different age groups, significant inverse correlations were observed between the right first molar MB-P (for age groups 30–39 and $\geq$ 40 years) and DP-P (for age group 30–39 years) angles with proximity to the maxillary sinus floor. This result may be explained by the anatomical structure in which the maxillary sinus increases in volume by pneumatization until the maxillary third molar completely erupts by age range from 21 to 30, after which it starts to decrease in volume size (Jun et al., 2005; Schriber et al., 2019). Nevertheless, pneumatization of the maxillary sinus is affected by many factors, such as hormones of growth, air pressure inside the maxillary sinus, hereditary factors and extraction of posterior teeth (Sharan and Madjar, 2008; Cho et al., 2010; Przystańska et al., 2018; Razumova et al., 2019).

Understanding the divergence and proximity of the root apices to the MSF is essential in clinical practice. Multiple cases of endodontic material displacement into the maxillary sinus have been reported in the literature (Orlay, 1966; Ehrich et al., 1993; Kavanagh and Taylor, 1998). All these materials in contact with the internal layer of the maxillary sinus will cause infection, and aspergillosis might also occur (Beck-Mannagetta and Necek, 1986; De Foer et al., 1990). Knowing the relation between the MSF and the apex of roots is also essential in dental implant treatment, e.g., for the selection of implant length or for the need for bone augmentation (Zhang et al., 2019). The current study could present a correlation between the divergence angles of the roots and their vertical relationship to the MSF.

The most important clinically relevant finding was the divergence angle of the maxillary molar roots in relation to the MSF. Hence, clinicians should assess the divergence of roots before tooth extraction. If the divergence angle is high, the extraction could be challenging, as a higher divergence angle increases the risk of MSF perforation during the extraction of the tooth (Haghanifar et al., 2018).

Some limitations of this study should be acknowledged. The sample size was collected from a single area over a short period of time, making the external validity limited. Further large-scale investigations are recommended to better understand the correlation between the divergence angles of the roots and the MSF.

## 5. Conclusion

Within the limitations of this study, it highlights the close proximity between MSF and roots of maxillary posterior teeth. The care must be taken during planning any surgical treatment in the maxillary posterior region. Proper understandings of maxillary posterior region anatomy will subsequently guide us to proper preoperative planning and minimize the chance for any complications.

## CRediT authorship contribution statement

**Ali Robaian:** Conceptualization, Methodology, Writing - review & editing. **Nasser Raqe Alqhtani:** Data curation, Writing - original draft. **Ziyad Ibrahim Alghomlas:** Data curation, Software. **Adel Alzahrani:** Visualization, Investigation. **Abdulrahman Khalid Almalki:** Data curation, Software. **Ali Al Rafedah:** Supervision. **Abdullatif Al Abdulsalam:** Data curation, Software. **Khaled M. Alzahrani:** Writing - review & editing.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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