



ORIGINAL ARTICLE

A COMPARATIVE ANALYTICAL RADIOGRAPHIC STUDY OF MAXILLARY SINUS PNEUMATIZATION IN EGYPTIAN AND SPANISH POPULATIONS

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ABSTRACT

Purpose: This study aimed to examine how age, sex, and race affect maxillary sinus pneumatization. Additionally, it aimed to determine which tooth on each side caused greater sinus pneumatization following extraction among Spanish and Egyptian patients.

Materials and Methods: Two protocols were used to assess maxillary sinus pneumatization digitally in 440 panoramic X-rays. The sample included 220 Spanish and 220 Egyptian patients, both male and female, aged 20 years or older. All patients had one or more maxillary posterior teeth extracted (from the first premolar to the third molar) on one side, with the contra lateral side fully dentate.

Results: Younger patients have a higher likelihood of sinus penetration with roots. The distance between the maxillary sinus and teeth is smaller in men than in women. No significant differences were observed between the right and left sides. In Spanish patients, the greatest pneumatization occurs after the second molar extraction, followed by the first molar. In Egyptian patients, the highest pneumatization is associated with extracting the second premolar, followed by the first molar. The distance to the maxillary sinus was significant in both populations. Univariate analyses showed non-significant extraction effects with varying effect sizes. The highest adjusted R² values were observed at the first molar in Egyptian and the second molar in Spanish patients.

Conclusion: Maxillary sinus volume changes with age; as age increases, the volume decreases. There is no significant difference in gender regarding the tooth-sinus-floor distance, but males show larger sinuses. No significant difference is seen between the right and left sides.

Keywords: Maxillary Sinus, Teeth Extraction, Pneumatization, Radiographic

INTRODUCTION

The maxillary sinus is the earliest of the paranasal sinuses to undergo development. It is found at birth and expands by normal physiological pneumatization during development until the eruption of the upper third molar or the age of twenty^{1,2}. Its normal extension is from the canine's distal side to the maxilla's posterior wall³. The function of the maxillary sinus is not entirely known. However, it is known to lighten the weight of the skull, play a role in resonance and voice, and regulate the pressure of the nasal cavity. It was also suggested that it contributes to the defense of the nasal cavity due to the nitrogen monoxide it produces, which humidifies and warms the inhaled air^{4,5}.

Dental procedures in the upper maxilla highly affect the maxillary sinus, as it is nearby. Interventions including tooth extraction, implant placement, endodontic and orthodontic treatment. If procedures are not done respecting the maxillary sinus extension, this can cause Schneiderian membrane perforation, displacement of the extracted tooth into the sinus, or sinusitis⁶⁻⁸. Aside from the physiologic pneumatization of the maxillary sinus during development, scientists agreed that other pneumatization might take place after the extraction of one or more maxillary posterior teeth, causing a decrease in the bone height and thus complicating the placement of dental implants^{9,10}. Another theory states that the reduction of bone volume is due to the normal process of bone reabsorption after extraction and not to the sinus pneumatization^{11,12}.

Numerous studies have explored the anatomical relationship between the maxillary sinus and the adjacent dentition, with the majority concluding that maxillary molars are positioned in closer proximity to the sinus floor compared to premolars^{13,14}. Some studies have identified the maxillary second molar as the tooth most closely approximated to the floor of the maxillary sinus^{13,14}. Other investigations deduced that the first molar is the closest maxillary to the sinus^{15,16}. Other researchers have placed greater emphasis on examining the relationship and spatial distance between the various roots of the maxillary molars and the maxillary sinus. However, there is no definitive conclusion could be reached likely due to anatomical variations among different populations^{16,17}. This relation can be explored using different imaging techniques but orthopantomography is still most frequent extraoral technique. It provides professional information about many anatomic structures, including teeth, maxillary sinus, and temporomandibular joints, all at a relatively low radiation dose and cost^{18,19}.

Although some studies stated that the relationship between maxillary posterior teeth and sinus could not be interpreted through panoramic X-ray^{20,21}, Malina Altzinger et al.²² demonstrated that panoramic X-rays identified all findings like cone-beam computed tomography (CBCT) except the protrusion of the maxillary bone cyst into the sinus. Concurrently, other studies have suggested that root projection into the maxillary sinus, radiographic darkening of the apical region within the sinus, and discontinuity of the sinus floor are strong indicators of true root protrusion into the sinus cavity^{23,24}. The significance of implementing maxillary sinus pneumatization following tooth extractions is that we can assume that the loss of teeth causes maxillary sinus pneumatization, which in severe situations may result in a union between the sinus floor and the alveolar bone crest. According to studies comparing pre and post-extraction radiographs, pneumatization of the maxillary sinus may occur following the extraction of a posterior maxillary tooth⁹. Moreover, extractions of posterior maxillary teeth may lead to maxillary sinus pneumatization, crestal bone loss, and alterations in the alveolar ridge, with or without the implementation of socket preservation techniques²⁵. Therefore, the current study had various objectives. The primary one aimed to relate age, sex, and racial characteristics to the sinus size and proximity of the root apices to the sinus floor (Protocol 1). The secondary goal was to identify the tooth that provokes more pneumatization to the sinus after extraction in each population, (Protocol 2).

MATERIALS AND METHODS

Ethical approval

The study received ethical approval from the Bioethics Committee of the Faculty of Medicine and Dentistry at the University of Santiago de Compostela, Spain (Approval no. USC 64/2024). After analyzing the reports from the corresponding working groups, which assessed the research project's methodological, ethical, and legal aspects and its feasibility under current legislation. The Committee of Ethics in Research of the USC AGREED issued a favorable report.

Study design

A pre-experimental study (One-Shot Case Design) was conducted at the Department of Oral Surgery at Santiago de Compostela University in Spain, at geospatial coordinates (3.7492°W, 40.4637° N).

Sample size

The necessary sample sizes for a study on maxillary sinus pneumatization after dental extractions were calculated using the G*Power program.

Egypt

It was determined that 90 participants were needed

to extract the first molar. The calculation was based on an effect size of 0.1778563, two predictors (gender and age), an alpha error of 0.05, and a study power of 0.95.

Spain

For the extraction of the second molar, it was determined that 67 Spanish patients were needed. The calculation was based on an effect size of 0.2437811, two predictors (gender and age), an alpha error of 0.05, and a study power of 0.95. In summary, the calculations helped to determine the minimum number of participants needed for the study to have sufficient statistical power in both populations.

Sample

In this study, 440 panoramic radiographs were selected: 220 selected from the archive of the Department of Oral Surgery in the Faculty of Medicine and Dentistry in Santiago de Compostela University of Spanish subjects who had attended the department seeking dental treatment and 220 panoramic radiographs from different radiographic centers in Alexandria, Egypt, of Egyptian citizens.

Inclusion criteria

1. Radiographs of patients older than 20 years old.
2. Radiographs clearly show the roots of the maxillary posterior teeth, the outline of the floor of the maxillary sinuses, the inferior orbital margin and the zygomatic process.
3. Radiographs of patients fully dentate or with one or more maxillary posterior teeth extracted.
4. Teeth, with fully formed roots, and without any pathology or lesion.
5. Patients who have signed and provided informed consent.

Exclusion criteria

1. Radiographs of patients under 20 years of age.
2. Radiographs of bad quality or showing artifacts.
3. Radiographs with pathologies, tumors, or malformations of the maxillary sinuses, patients who have undergone bone regeneration procedures or implant placement in the posterior maxillary sinus area, or who have nasal or sinus disease.
4. Radiographs of patients with a completely edentulous maxilla.
5. **Image acquisition and measurements**
6. All radiographs in Spain and Egypt were obtained by using SIRONA Orthophos PlusDS (Sirona Dental Systems GmbH, Germany) for capturing of panoramic and cephalometric radiographs; normal panorama mode was used (p1) with a voltage of 66 kVp, intensity of 16 mA, and exposure time of 14.1 s.
7. The measurements in both populations were done digitally using the SDEXIS XG software provided

by Sirona. Two previously established protocols (26, 9) were utilized to evaluate the relationship between the maxillary sinus and the posterior maxillary teeth.

Protocol 1

It was used to achieve the primary goal of study. The outline of the maxillary sinus and the midline were traced digitally. Two horizontal reference lines were delineated to measure the distance between the root apices and the maxillary sinus floor: one at the apices of the roots and another at the inferior border of the sinus floor anterior to the root. A vertical line parallel joined these two horizontal lines to the midline

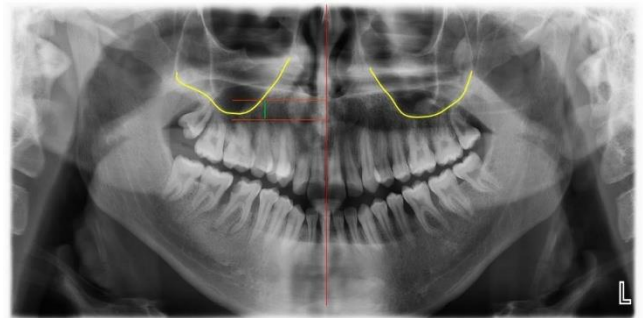


Figure1. Measurement of the distance between the floor of the maxillary sinus and the apices of the posterior upper teeth.

The distance between the maxillary sinus floor and each root apex was determined by measuring the vertical line (Fig 1). The resulted measurements were classified into 3 classes as follows:

Class 1: <0 mm (excessive pneumatization).

Class 2: 0-3 mm (sinus approximation).

Class 3: >3 mm (no sinus approximation).

Patients were also classified according again according to age range into 3 groups:

Group 1: ≤ 30 years (young age).

Group2: 31-50 years (middle age).

Group3: ≥51 years (older age).

All teeth classified as Class I clearly showed an interruption in the sinus floor, darkening of the apical part of the root involved in the sinus, or both findings²⁶.

Protocol 2

This protocol was applied to radiographs of patients with one or more upper posterior teeth extracted on one side with the contra-lateral side fully dentate to identify the maxillary posterior tooth that provoked the most extensive pneumatization after extraction. Three reference horizontal lines were drawn, one joining the inferior border of the two orbits and the other marking the inferior border of the zygomatic arch on each side.

Two measurements were performed on each side:

1. The distance between the inter-orbital line and

the zygomatic line.

2. The distance between the inter-orbital line and the inferior border of the sinus at the site of the studied tooth.

The null hypothesis is $IS_x / IZ_x = IS_t / IZ_t$

where

IS: vertical distance between the inter-orbital line and the most inferior point of the maxillary sinus at the area of the extracted tooth.

IZ: vertical distance between the interorbital line and the zygomatic arch line.

X: The side of extracted teeth.

T: The side of existing teeth.

The sinus floor position is expressed as the following relation:

IS distance / IZ distance.

From the null hypothesis, it's concluded that the value $IS_x - (IS_t * IZ_x / IZ_t)$ expresses the difference in the distance between the inter-orbital line and the sinus floor between both sides. If positive, it indicates that the sinus floor was inferior on the side of the extracted teeth⁹ (Figure 2).

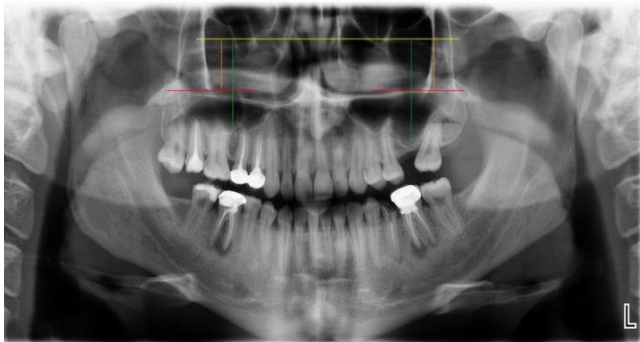


Figure 2. Reference lines used: Yellow line joins the inferior border of the two orbits. The two red lines mark the inferior border of the zygomatic arch on each side. The two orange lines are the distance between the inter-orbital line and the zygomatic line on each side (IZ). The two green lines are the distance between the inter-orbital line and the inferior border of the sinus at the site of the studied tooth (IS).

Statistical analysis

The data were collected in spread excel sheet then data entry in SPSS version was performed. Firstly,

the test of normality for quantitative variables such as patient age and maxillary sinus distance (mm) was applied by using Kolmogorov-Smirnov test, then testing the assumption of homogeneity of variances through Levene Statistical test. Followed by the selection of the suitable test according to level of significance of Levene statistical test. If insignificant, ANOVA test was used to compare between dependent variable such as maxillary sinus distance (mm) and multiple extraction (EXO) groups from EXO 4 to EXO 8 followed by Multiple Pairwise comparisons by Tukey test. On the other hand, if Levene Statistical test was significant, Welch test was used, followed by Multiple Pairwise comparisons by Games-Howell test. Then multivariate analysis was applied to study the effect of multiple independent factors on the mean distance (mm) of maxillary sinus at once. Finally, the chi square test was used to predicate the association between the independent variables as gender with the level of EXO from EXO4 to EXO 8. All tests are considered significant at the level of 5%.

RESULTS

Protocol 1

Spanish population

In the Spanish population, age was seen to have a significant impact on the maxillary posterior teeth—sinus distance, as it affected the distance between all maxillary posterior teeth in female and male subjects except for the 2nd premolar in male subjects. Class I was found to decrease by age in both sexes, and consequently, the distance between teeth and sinuses increased. It was observed that sex significantly affected the distance between the upper wisdom tooth and the sinus in the young age group ($p < 0.001$) while affecting the distance to the sinus in the case of the upper 2nd molar ($p = 0.045$) in the middle age group, and the distance between all maxillary posterior molars and the sinus in the older age group (1st molar: $p = 0.015$, 2nd molar: $p = 0.037$, 3rd molar: $p = 0.006$), with males showing higher percentage of Class I in all age groups than females (Figure 3). The right and left sides didn't show any significant differences in any tooth, neither in males nor in females ($p > 0.05$).

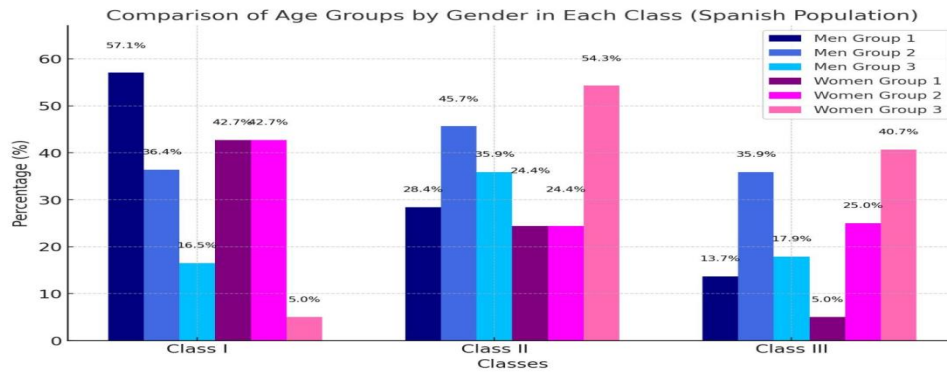


Figure 3. Percentage of Spanish participants based on both age and gender factors at different classes.

Egyptian population

It was concluded that age significantly affected the distance between upper posterior teeth and the sinus, as was seen in the maxillary 2nd molar, first molar, and 2nd premolar in males and females, in addition to the 1st premolar in females. As age increases, the percentage of finding a root penetrating the sinus (Class I) decreases, and the distance between the upper posterior teeth and the sinus tends to increase with age. The results showed that sex affected the distance between the sinus and the second molar ($p = 0.013$), 1st molar ($p = 0.007$), and 2nd premolar ($p = 0.039$) in the young age group (≤ 30 years). In contrast, the relation between the sinus and the 3rd molar was affected by sex in the middle age group ($p = 0.038$) (31-50 years). Additionally, males showed a higher percentage of class I than females in all age groups, indicating that males present larger maxillary sinuses than females. And finally, by comparing the distance between different teeth and the sinus floor, in the right and left side it was concluded that there is no statistical difference neither in males nor in females ($p > 0.05$) (Figure 4).

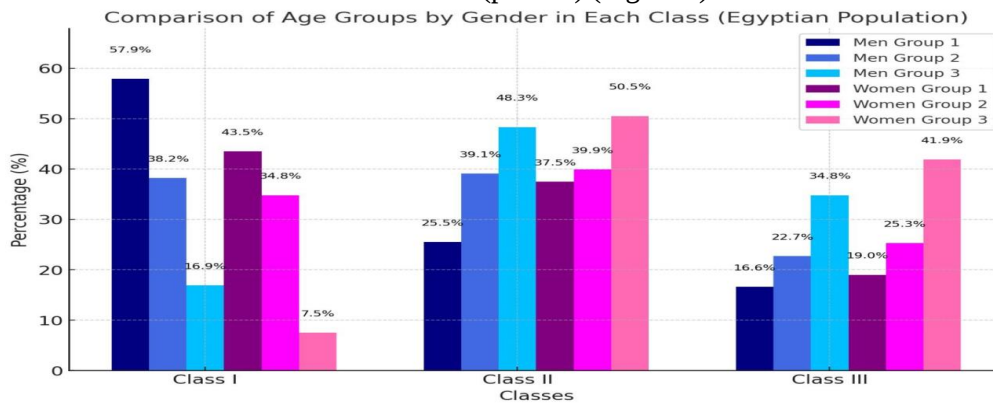


Figure 4. Percentage of Egyptian participants based on both age and gender factors at different classes.

Protocol 2

Spanish population

In the Spanish population, it was noticed that the amount of sinus pneumatization differed significantly after the extraction of different posterior teeth ($p < 0.001$). The major pneumatization occurred after the extraction of the maxillary 2nd molar with a mean distance of (1.12 ± 0.48 mm) followed by the 1st molar (0.81 ± 0.41 mm). No difference was seen in the amount of maxillary sinus pneumatization after different teeth were extracted in males and females ($p = 0.968$) (Figure 5).

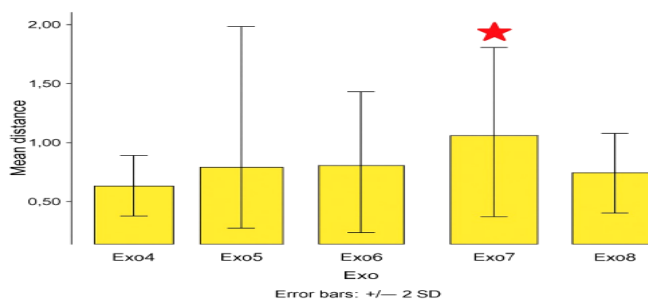


Figure 5. The data presented in the figure demonstrates that extraction of the upper second molar caused the largest degree of sinus pneumatization in relation to other posterior superior teeth in the Spanish population.

Egyptian population

In the Egyptian subjects, pneumatization differed significantly according to the extracted tooth ($p=0.002$). But in contrast to the Spanish study group, Egyptians showed greater pneumatization after the extraction of the maxillary 2nd premolar with a mean distance of 0.93 ± 0.48 mm followed by the 1st molar (0.75 ± 0.29 mm). No difference between male and female subjects was found in the pneumatization after extraction ($p=1.000$) (Figure 6).

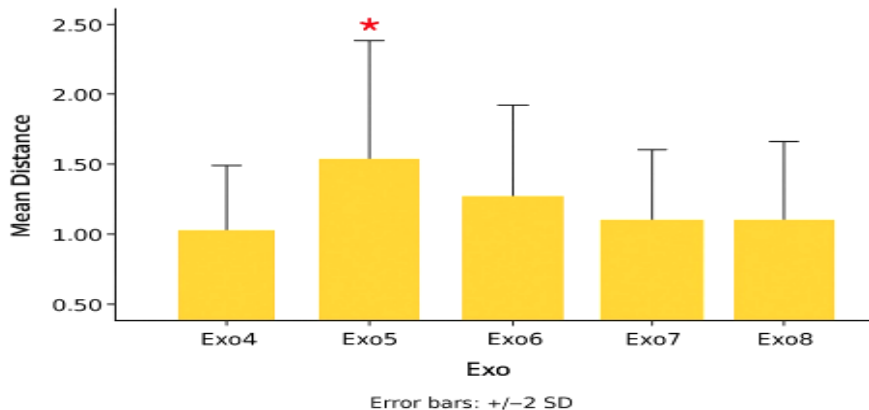


Figure 6. The data presented in the figure demonstrates that extraction of the upper second premolar caused the largest degree of sinus pneumatization in relation to other posterior superior teeth in the Egyptian population.

DISCUSSION

There are number of causative factors that influence maxillary sinus pneumatization (MSP) following tooth extraction. Some of these factors are non-modifiable factors as patient's age and sex, while modifiable factors like tooth location, sinus floor morphology, sinus floor position relative to the root apices, and the number of extracted teeth has been reported^{27,28}. The current study recruited the panoramic radiographs of 220 Egyptian patients and 220 Spanish patients, both males and females, who were 20 years of age or older, to compare the change in the size of the maxillary sinus after the extraction of one or more of the posterior teeth either molar or premolar on one side either the left or the right side. The influence of gender on the size of the maxillary sinus concerning the site of tooth extraction from 1st premolar to the 3rd molar in both Egyptian and Spanish patients was evaluated. We demonstrated that there was no association between the patients' gender and the change in the size of the maxillary sinus post extraction (Protocol 2). In contrast to our findings, a cross-sectional study conducted by Alqahtani et al.¹⁰ to investigate MSP following posterior tooth extraction in a population from Riyadh, Saudi Arabia, reported that males exhibited more pronounced post extraction MSP compared to females. This study investigated the relationship between maxillary posterior teeth and the maxillary sinus using orthopantomograms in different age groups (Protocol 1). The results of the research suggested that the maxillary sinus volume is more prominent in younger subjects, and that the probability of finding a root in proximity or even penetrating the sinus is quite high when treating young patients. Our results agreed with many others, such as El Sayed et al.²⁶ who found that severe pneumatization took place in the younger age

groups, and Torres et al.²⁹ who found that the maxillary sinus volume is considerably smaller in older generations than in young age groups, independently of the edentulism status, and Bornstein et al.³⁰ who proved that younger subjects presented higher volume of the maxillary sinus than those older than the mean age of his sample. Furthermore, a controversy regarding the sex and sinus measurements was always present. Our study (Protocol 1) demonstrated the influence of gender on the size of maxillary sinus without any tooth extraction among both the Egyptian and Spanish populations. Najem et al.³¹ evaluated the potential of using cone beam computed tomography (CBCT) images to determine gender and age by measuring the maxillary sinus's linear dimensions in an Egyptian population. The study found no statistically significant differences in maxillary sinus measurements between males and females³¹. Our findings differ from the results of some other previous studies conducted in various populations. The controversial results are multifactorial and might be attributed to regional variations in morphometric characteristics among populations worldwide which may impact the outcomes of morphological studies. Another factor contributing to differences in studies' results may be variations in measurement methods, sample sizes, and the diversity of ethnic and racial groups even within the same population³¹. However, another study by Belgin et al.³² that used CBCT to evaluate the maxillary sinus volume in three dimensions across age and sex groups of 200 Turkish patients selected by a retrospective review of the archives of the Dicle University found that the males' maxillary sinus volume was considerably larger than the females³². Bornstein et al.,³³ reported that males had significantly larger

maxillary sinus than females. This is attributed to the fact that males tend to have a larger craniofacial dimension including maxillary sinuses in terms of volume, height, width and depth compared to females. These findings could be utilized and implemented in forensic medicine to aid in gender determination³³. Furthermore, knowledge and assessment of the dimensional and volumetric measurements of the maxillary sinus is crucial and should be performed before placing any devices like temporary anchorage devices (TADs) especially in the posterior region of maxilla to reduce the risk of sinus perforation^{34, 35}.

As regards to the effect of tooth position on MSP, in the current study we confirmed that in the Egyptian patients there was a significant association between the means of maxillary sinus distance (mm) and the tooth type, especially between the 1st premolar and the 2nd premolar, and between the 2nd premolar and the 2nd molar. On the other hand, in Spanish patients, there was a significant association between the 1st premolar and the 2nd molar and the 2nd molar and 3rd molar. This may be due to alveolar ridge remodeling, which involves an increase in the size of the maxillary sinuses and may be triggered physiologically by extracting a posterior tooth in the maxilla. Clinically, post-extraction coronal ridge resorption, together with MSP, can compromise the vertical bone height necessary for optimal implant placement. MSP is occasionally regarded as a component of disuse atrophy, which is defined by a decline in the structural and mechanical properties of the bone adjacent to the extraction site^{25, 36}.

A study by Lim et al.,³⁶ utilized panoramic radiographs of Korean patients to assess the vertical change in sinus dimensions before and after single or multiple tooth extractions, showed that MSP was higher in the single tooth extraction (2.09 ± 3.11 mm) than in the multiple tooth extraction (0.89 ± 4.71 mm). Moreover, the teeth that induced the most extensive MSP were the second molars (2.25 ± 4.39 mm) followed by the first molars (1.90 ± 4.02 mm), second premolars (0.78 ± 3.07 mm), and first premolars (0.34 ± 3.88 mm) respectively. Regarding the history of the extracted teeth, out of all the causes of extraction, the extraction procedures conducted for endodontic issues resulted in the largest degree of sinus enlargement (2.28 ± 2.37 mm). In multiple teeth extractions models, compared to first premolars, second molars showed a statistically significant impact on MSP (estimate: -2.35 mm, $P=0.0177$). Statistically significant differences were found between extractions for "unknown" and "periodontally compromised" reasons for extraction³⁶. These results partly align with our findings regarding the specific tooth, which is the second molar, that triggered the most extensive MSP in Spanish population.

Regarding the number of extracted teeth and their influence on the extent of downward MSP. It was reported that higher level of MSP was noticed in multiple tooth extraction cases in previous research (0.54 ± 1.7 mm vs. 2.22 ± 2.54 mm and 1.11 ± 1.81 mm vs. 2.14 ± 2.47 mm, respectively)^{9, 24}. In contrast, other studies demonstrated a more extensive MSP following single tooth extraction as compared to multiple tooth extraction (2.09 ± 3.11 mm vs. 0.89 ± 4.71 mm)³⁶. It has been proposed that the roots of adjacent teeth may confer a protective effect limiting MSP²⁷. Conversely, certain studies have restricted their analysis to single-tooth extractions, while others did not address the distinction between single and multiple extractions due to methodological constraints, as their primary objective was to compare non-grafted sockets with those treated using alveolar ridge preservation techniques in the posterior part of maxilla^{25, 28}.

In the current study, we have evaluated the panoramic radiographs after unilateral single or multiple posterior tooth extraction with a minimal duration of six months post-extraction as our main objective in Protocol 2 was to identify the tooth that caused the most extensive MSP in both populations without comparing the significance of single or multiple tooth extraction on MSP. Other studies have evaluated the impact of the relationship between the sinus floor and the root apices on MSP and reported extensive pneumatization in class V in which the maxillary tooth root was enveloped by the upwardly curved contour of the maxillary sinus floor⁹. On the contrary, Jung et al.³⁷ reported that the spatial relationship between the maxillary sinus floor and the root apex did not demonstrate a statistically significant influence on the extent of MSP. Such inconsistencies may stem from challenges in accurately delineating the sinus floor on panoramic radiographs, particularly due to variations in the positioning of the root apex on the buccal or palatal aspects, as well as in the furcation region³⁶.

Regarding the relationship between MSP and Schneiderian membrane thickening (SMT), Jung et al.³⁷ reported that tooth extraction in cases where the SMT exceeded 10 mm, the extent of MSP averaged 2.84 ± 5.74 mm. This observation may be attributed to inflammatory changes affecting the sinus floor and surrounding alveolar bone, particularly given that most teeth with SMT >10 mm were endodontically compromised, despite the limited sample size. Among the various indications for extraction, teeth with endodontic pathology exhibited the highest degree of MSP, with a mean value of 2.28 ± 2.37 mm³⁶. In a recent systematic review and meta-analysis involving maxillary sinuses affected by periapical lesions, findings indicated that the presence of these lesions was associated with up to a 2.43- fold increased likelihood of SMT exceeding 2 mm³⁸. Research has

suggested that a periapical lesion located in proximity to the maxillary sinus may act as a reservoir for the propagation of odontogenic bacteria, potentially leading to an increase in SMT³⁹. Particularly in cases where the alveolar bone apical to the root apex is thin, the extraction of a tooth with an apical lesion and pronounced SMT may amplify the resorption of the surrounding alveolar bone, accompanied by concurrent resorption of the bundle bone³⁶. In contrast, other studies reported that SMT did not affect MSP. Nevertheless, details regarding the extent of SMT or the underlying reasons for the tooth extraction were not clarified²⁷. In the present study, we haven't examined the relationship between SMT and extent of MSP as the panoramic radiographs selected were those which had no previous pathologies, tumors, or malformations of the maxillary sinuses, and free of any nasal or sinus diseases with no probability of SMT. Moreover, the patient's radiographs selected were those that haven't undergone either bone regeneration procedures or implant placement in the posterior maxillary sinus area.

In the current study there was a significant provoke of MSP following the extraction of maxillary 2nd premolar in Egyptian population and 2nd molar in Spanish population. It is noteworthy that there is a significant correlation between MSP and second molar extraction, likely due to the region's proximity to the sinus floor and low bone density. The second molar's distal location makes it challenging to access, suggesting that strategies like alveolar ridge preservation (ARP) could be helpful in the prevention of MSP in this area. Some studies support ARP in the posterior maxilla⁴⁰. The change in sinus floor height was measured at -0.30 ± 0.10 mm in sockets with ARP and -1.30 ± 0.27 mm in those without ARP respectively²⁵. Cha et al. also provided evidence in favor of ARP, observing a change in sinus floor level of -1.16 mm in sockets without ARP and -0.14 mm in those with ARP²⁸. The positive influence of ARP may improve the prospects for successful implant placement in the second molar region⁴¹. Several limitations should be emphasized in this study. First, it was crucial to have pre-extraction panoramic radiographs for the selected subjects and to evaluate the condition of bone and the level of the sinus floor. Second, the use of two-dimensional radiographic analysis may lead to overlapping of buccal and palatal sinus floor alterations, potentially reducing the precision of the findings. Furthermore, 2D imaging may not adequately capture or distinguish sinus pathology. Although obtaining a 3D CBCT scans before and after extraction for many patients is inherently difficult, future research should emphasize the use of three-dimensional radiographic methods to improve diagnostic accuracy and reliability³⁶. The greatest

extent of MSP was observed following maxillary second premolar and second molar extraction in Egyptian and Spanish population, respectively underscoring its relevance in site-specific treatment planning and deciding the most convenient treatment modalities. Future studies employing three-dimensional radiographic techniques are necessary to further substantiate these results.

CONCLUSION

The current study's findings show that the maxillary sinus volume varies with age, decreasing with increasing age. In both Egyptian and Spanish populations, males exhibited larger maxillary sinuses compared to females. In the Spanish population, extraction of the maxillary second molar, followed by the first molar, was associated with greater sinus pneumatization, while in the Egyptian population, extraction of the second premolar followed by the first molar showed distinct patterns of pneumatization. This suggests that sinus pneumatization following tooth extraction may vary across populations. Additionally, our sample revealed no significant difference between the right and left sides.

DECLARATION

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Conflict of interest: The authors have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

Ethical approval: This study was conducted in accordance with the principles of the Declaration of Helsinki and was also approved by the Committee of ethics in research of the Faculty of Medicine and Dentistry, University of Santiago de Compostela, Santiago de Compostela, Spain (Approval No. USC 64/2024)

Consent to participate

All panoramic radiographs were captured as part of routine care. Informed consent was waived by the ethical board due to the retrospective nature of the study. All patient information was kept confidential and anonymized to protect their privacy. The study was strictly conducted in compliance with ethical regulations.

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