ORIGINAL ARTICLE

Revisited maxillary sinus pneumatization narrative of observation in Al-Madinah Al-Munawwarah, Saudi Arabia: A retrospective cross-sectional study

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Abstract *Objectives:* Maxillary sinus pneumatization (MSP), is linked worldwide to number of factors. MSP measurements and assessment alongside potential correlates in Al-Madinah Al-Munawwarah, Saudi Arabia (SA) awaits identification.

Materials and methods: A retrospective cross-sectional study was conducted at Taibah University Dental-College and Hospital, Al-Madinah Al-Munawwarah; SA. The analysis included 700 female patients digital Orthopantomogram (OPG), of which 535 (76%) OPGs were usable. MSP was established according to the distance between the maxillary sinus floor and posterior teeth apices number 15, 16, 17, 18, 25, 26, 27 and 28. MSP categorized as followed: Sever MSP (Category I), Moderate MSP (Category II) and No MSP/normal (Category III). Descriptive statistics, and inferential analysis were carried out.

Results: Mean age of the patients was 30.11 ($\pm$10.26) and 290 (54.5%) were Saudi nationals. Severe pneumatization (category I) was prominent in the right and left first and second molars, 16, 26, 17, 27 (66%, 64%, 63% and 62%, respectively). A statistically significant difference (P < 0.0005) was observed between pneumatization categories in all sites. Furthermore, the impact

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of young age on levels of MSP was statistically significant (P < 0.05) on most teeth. However, nationality was non-significantly (P > 0.05) associated with MSP levels.

Conclusion: High percentages of female patients showed bilateral sever MSP in the upper molar area, specifically, young age group.

Clinical significance: The oro-antral communication during extraction and surgical cases of female patients' maxillary teeth is possible. This should be considered during dentists' daily practice in this geographic area of SA.

1. Introduction

Maxillary sinus is the nearest skull sinus to the oral cavity. Tremendous procedures in oral cavity involve modification to the sinus floor. This includes open or closed sinus lift, sinus obliteration, sinus exploration for removal of remaining roots or closure of iatrogenic oro-antral communications, besides, other sinus tumor and cyst removal surgical procedures (Ellis and Mahadevean, 2013; Sharan and Madjar, 2008). The maxillary first and second molars roots are the nearest to the sinus (Thomas von Arx and Scott Lozanoff, 2017). Non-pathogenic pneumatization of the sinus toward the alveolar ridge occurs physiologically till ridge development completion nearly at 20 years old (Misch, 2008).

Normally pneumatization of the sinus complete with the full eruption of the permanent teeth when the sinus floor extends below the hard palate level 4–5 mm below the floor of the nasal cavity at the age of 12 (Scuderi et al., 1993). Also, asymmetry between both sides is a normal finding, the first one of the paranasal sinuses appear in a radiological study is the maxillary sinus at 2 years old followed by the sphenoid at 4 years old then the frontal (7 years old). It is well known that the development of the sinus is complete or stabilized by early adulthood. Maxillary sinus dilatation diseases in adults and children are very rare although the frontal sinus is the most common site (Kalavagunta and Reddy, 2003; Wagner et al., 2017).

There are no understandable reasons for Maxillary Sinus Pneumatization (MSP) after full alveolar development unless teeth loss occurred, which gave appearance of protrusive neighboring teeth into sinus with a thin cortical bone lining, therefore, it may pose a hazard of oro-antral communications following extraction (Kantarci et al., 2004). Thus, oral cavity microbes might have a way to the sinus, and if this connection persists, subsequently the sinus membrane becomes inflamed and chronic epithelization of the oro-antral fistula may happen, increasing the risk of sinusitis (del Rey-Santamaría et al., 2006).

Many authors studied the oro-antral sinus communication (OSC) incidence as Del Rey et al. in 2006 who reported 5.1% incidence of OSC after third molar extraction (del Rey-Santamaría et al., 2006). Sharan et al. in 2008 compared MSP between dentate and edentulous sides of the patients in panoramic radiographs and found a larger expansion after extractions of the second molar compared to first molars and in multiple extractions of the posterior region (Sharan and Madjar, 2008). Also, Hamdy et al. in 2013 studied the sinus pneumatization in three dimensional aspects and found that maximum extension of the sinus was around the second molar

(Hamdy and Abdel-Wahed, 2013). In contrast, Von et al. found that premolars present more risk of sinus floor violation (Von Arx et al., 2014). Notably, MSP is found linked to number of factors including age, gender and ethnicity (del Rey-Santamaría et al., 2006; Hamdy and Abdel-Wahed, 2013; Hu et al., 2014).

Our current literature search showed no data available or study regarding the assessment of the degree of MSP specifically among the Al-Madinah Al-Munawwarah, Saudi Arabia (SA) population. This city is comprised of multi-ethnic pilgrims who settle from different regions of the world. As such the influence of risk factors including ethnicity on MSP is plausible. Investigating MSP and pattern among the Al-Madinah Al-Munawwarah population is paramount as it will raise the awareness and caution among oral and maxillofacial surgeons and dental implantologists to minimize the number of surgical complications i.e. decrease the incidence of oro-antral sinus communication.

The aim of the current study was to measure the degree of MSP among female patients attending Dental College & Hospital, Al-Madinah Al-Munawwarah, SA and to assess the possible risk factors for MSP (e.g. Age, tooth site and nationality).

2. Materials and methods

2.1. Study design and setting

This retrospective cross-sectional study was conducted at the department of Oral & Maxillofacial Surgery, Taibah University, Dental College & Hospital, (TUDCH) Al-Madinah Al-Munawwarah, SA. This is an emergence university situated at the west of SA which was established in 2003 and comprises of 28 different colleges over three campuses in the holy city of Al-Madinah Al-Munawwarah, SA (Al Nozha, 2017).

2.2. Sampling and sample size calculation

A convenience sample of dental x-rays digital Orthopantomogram (OPGs) was retrieved from the (TUDCH, R4 Carestream [CS]) Clinical and Practice Management Software database archives, (CS Health, Inc. Rochester, NY, USA). These OPG records taken during patients' diagnosis were selected using a simple random selection of cases in the Statistical Package of Social Sciences (SPSS). The OPG records for 700 female patients that attended TUDCH, between 2015 and 2017 had undergone analyses. This period was chosen on the basis that TUDCH established its R4 system.

The sample was calculated using Open Epi, Version3; open source calculator. The aforementioned sample size estimation (700 OPGs) for this study was calculated on the basis of 7748 OPGs for the period 2015–2017 and a prevalence of 50%. The latter was adopted on the basis of absence of the prevalence of MSP in the region. A 700 OPGs included 15% oversampling to compensate for OPGs that were not meeting the inclusion criteria mentioned in the following section.

2.3. Inclusion and exclusion criteria

The inclusion criteria for OPG records were as follows: Good quality OPG records (not pale, not dark, no artifact and no overlap) in both fully dentate and partially edentulous adult patients with an age range from 16 to 55 years. The exclusion criteria included those: Children below 16 years, presence of intra-sinus lesion, complex skeletal alterations, relevant skeletal asymmetries; chronic systemic disease and bone tumors.

2.4. Study variables measurements and intra-examiner reproducibility

The primary data retrieved from the Carestream (CS) R4 beside the OPGs included the patient's age, and nationality. Data for studied teeth, sides and sites were extracted from OPGs.

The dependent variable for this study was MSP category in relation to the measurements of the distance between the floor of the maxillary sinus and the apices of teeth; 15, 16, 17, 18, 25, 26, 27 and 28. The readings of the distance between floor of the sinus and the apex of the root in each defined position was classified to three different categories as follow: less than zero mm was considered as excessive MSP (Category I), from 0 to 3 mm was considered as sinus approximation (MSP Category II) and finally > 3 mm was considered as no Sinus Approximation (MSP Category III). These Categories which will be used onward in this paper were modified from the basic surgical classification for impacted maxillary wisdom teeth (Hupp et al. 2014).

The Carestream (CS) R4 Software was used to trace the digitalized panoramic view (Fig. 1) as follows: drawing of the maxillary sinus floor tracing Vertical Reference line (parallel to the midline); Horizontal Reference line (perpendicular to the midline); linear measurements of Bisector of Horizontal
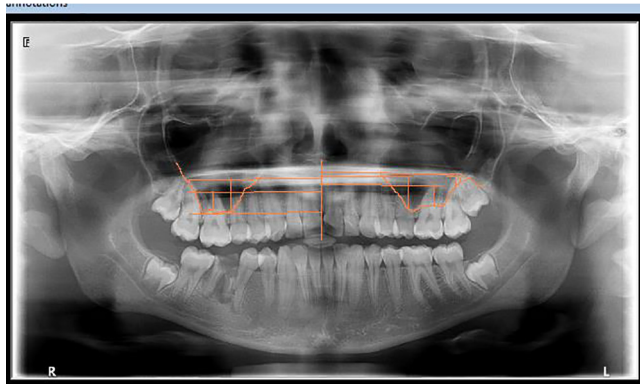

Fig. 1 Measurements of the distance between the maxillary sinus floor and posterior teeth apices in R4 dental imaging software.

and Vertical Reference lines - The measurements were taken from Line 1 from sinus floor cortex to the apical end of the second premolar; Line 2 from sinus floor to the apical end of the first molar; Line 3 from floor of the sinus to the apical end of the second molar; Line 4 from sinus floor to the apical end of the maxillary wisdom tooth; and tracing of the Long Axis (AX) of the tooth crown structure.

One observer was assigned to do the measurements after being trained and calibrated. This included the test re-test consistency of measurement for five OPGs. The researcher had undertaken the same measurements for each OPG twice at different following days (see Fig. 2).

2.5. Ethical considerations

This study was approved by Research Ethical Committee of Taibah University (TUCDREC20170326Allahmadi). All patients' personal information was not identified and only the researchers had access to the records.

2.6. Statistical analyses

Data was collected and entered into Microsoft Office Excel and imported into the Statistical Package for Social Science (SPSS) version 16.0 for analysis. Intra-examiner reproducibility (test re-test) was checked using intra-class coefficient. Descriptive statistics were used to report sample characteristics. Categorical variables e.g. gender were reported as frequency and percentages and continuous variables e.g. age were reported as mean/ ± Standard deviation (SD). Inferential parametric analysis was performed that included the one-way analysis of variance (ANOVA) to determine whether there were any significant differences between the means of Category I, II and III, MSP in each tooth position, groups and age. Significant overall ANOVA tests were followed by a series of post hoc multiple comparison (Bonferroni method) to determine which of these groups differ from each other. Non parametric Chi-square tests was used to explore the association between categorical variables (e.g. nationality) and MSP Categories. The level of significance was set at ≤0.05.

3. Results

3.1. Sample characteristics

Of the 700 OPGs 535 (76%) met the inclusion criteria to undergo measurements and MSP assessment. The mean age of participating female patients attending to the TUCDH was 30.11 (SD ± 10.26 years) and 290 (54.5%) were Saudis. Table 1 shows that the maximum MSP distance was related to the right wisdom tooth (−10.40 mm) and the least approximation distance was related to the right second premolar (18 mm). The most extracted tooth in our population sample was the right second premolar (35.9%) followed by the left second premolar (35.7%).

The most affected teeth by severe MSP (Category I) were 16 and 26 (66.2% and 63.9%, respectively) followed by 17 and 27 (62.8% and 62.2%, respectively) (Table 2). In the present study, few percentages of teeth: 15, 16, 17, 18, 25, 26, 27 and 28 were away from the sinus floor i.e. Category III (4.7%, 4.5%, 6.7%, 18.5%, 5.2%, 4.3%, 9.3% and 20.7%, respectively). Category I percentages ranged from 40.6% to 66.2%, Category II percentages ranged from 17.2% to 26.9% while Category III percentages ranged from 4.3% to 20.7%.
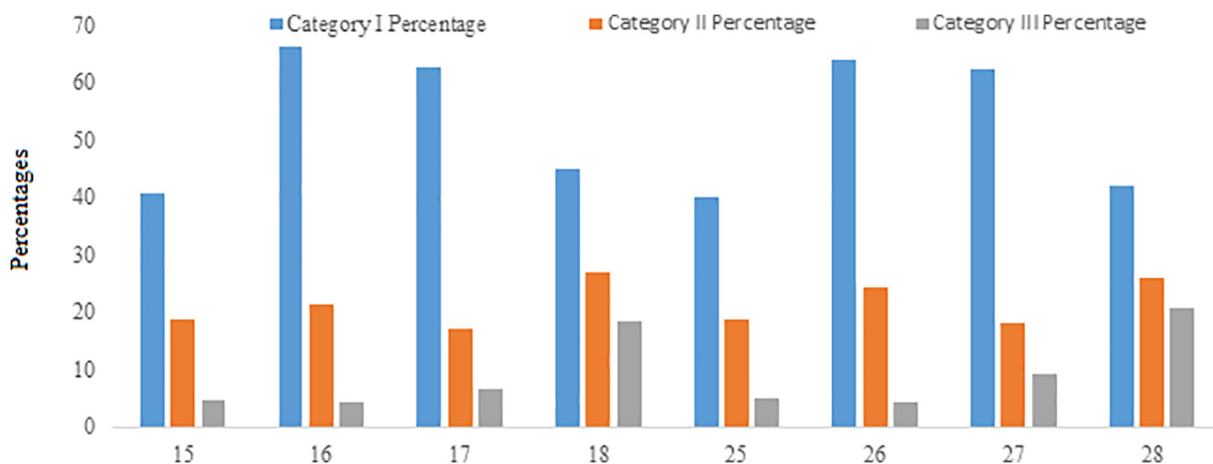
Fig. 2   Clustered bar chart of percentages of maxillary sinus pneumatization categories in each tooth site.

Table 1   Descriptive statistics of MSP frequency (%) and measurements of distance (in mm) between apices of upper second premolar, first, second and third molars and maxillary sinus.

Teeth number

Parameters	15	16	17	18	25	26	27	28
Frequency	343	493	464	483	344	495	481	475
Percentage	64.1	92.1	86.7	90.3	64.3	92.5	89.9	88.8
Min* distance in mm	−10.00	−8.80	−9.20	−10.40	−8.80	−9.00	−9.80	−8.80
Max‡ distance in mm	18.80	10.30	9.70	18.00	13.60	7.00	11.70	14.60
Missing teeth∞	192	42	71	52	191	40	54	60
Percentage	35.9	7.9	13.3	9.7	35.7	7.5	10.1	11.2

  * Min = Minimum.
‡ Max = maximum.
∞ Missing teeth = Extracted.

Table 2   Descriptive statistics of MSP categories frequency (%) and mean (SD) measurements of distance (mm) between apices of upper second premolar, first, second and third molars and maxillary sinus at both sides.

Variables	Teeth number								
Category I		15	16	17	18	25	26	27	28
	Frequency	217	354	336	240	215	342	333	225
	Mean	−2.84	−2.82	−3.08	−3.11	−2.90	−2.84	−3.22	−3.13
	Percentage	40.6	66.2	62.8	44.9	40.2	63.9	62.2	42.1
Category II	Frequency	101	115	92	144	101	130	98	139
	Mean	1.19	1.22	1.22	1.37	1.04	1.16	1.29	1.27
	Percentage	18.9	21.5	17.2	26.9	18.9	24.3	18.3	26.0
Category III	Frequency	25	24	36	99	28	23	50	111
	Mean	5.80	5.13	5.33	6.34	4.73	4.19	5.06	6.54
	Percentage	4.7	4.5	6.7	18.5	5.2	4.3	9.3	20.7

Excessive MSP (Category I) was considered if the readings of the distance between floor of the sinus and the apex of the root was less than zero mm, Sinus approximation (MSP Category II) considered from 0 to 3 mm and No Sinus Approximation (MSP Category III) considered when the distance was > 3 mm

The One Way ANOVA analysis revealed that there were statistically significant differences ($P < 0.05$) between the age means of Category I, II and III in each tooth position apart from tooth 27. As it shown in Table 3, age impacted significantly on the severity levels of MSP ($P < 0.05$) on most teeth, notably the impact was prominent among the young age groups.

Post Hoc multiple comparisons demonstrated the differences in means was highly significant toward Category I in all sites, (Supplement 1). However, the results of bivariate analysis (Table 4) showed that there was a non-significant difference ($p > 0.05$) between the nationality and the degree of any MSP categories in all teeth apart from tooth 17.

Table 3 Comparison of mean values of age/years with different MSP categories (n-535).

Teeth number	MSP Cat I Mean ± SD	MSP Cat II Mean ± SD	MSP Cat III Mean ± SD	F[*]	p-value
18	27.01 ± 8.256	30.19 ± 10.488	31.41 ± 10.062	9.851	0.000
17	28.36 ± 9.620	31.36 ± 10.257	31.42 ± 8.965	4.477	0.012
16	28.18 ± 9.209	31.37 ± 10.394	30.71 ± 7.363	5.366	0.0005
15	26.24 ± 7.298	28.52 ± 9.283	33.64 ± 8.981	10.750	0.000
25	26.74 ± 7.923	27.78 ± 8.379	32.64 ± 10.775	6.308	0.002
26	28.45 ± 9.362	31.33 ± 10.700	29.87 ± 10.248	4.130	0.017
27	29.04 ± 9.686	29.51 ± 9.759	31.56 ± 10.742	1.446	0.237
28	27.60 ± 8.897	29.27 ± 10.227	31.63 ± 10.533	6.484	0.002

[*] F = One-way ANOVA analysis.

Table 4 Chi-squared analysis between nationality and MSP categories (n = 535).

Teeth number	MSP Category I		MSP Category II		MSP Category III		p-value
	Saudi F (%)	Non Saudi F (%)	Saudi F (%)	Non Saudi F (%)	Saudi F (%)	Non Saudi F (%)	
18	139 (52.3)	100 (46.5)	73 (27.4)	70 (32.6)	54 (20.3)	45 (20.9)	0.395
17	192 (73.6)	142 (70.6)	56 (21.5)	36 (17.9)	13 (5.0)	23 (11.4)	*0.031*
16	202 (74.5)	151 (68.6)	59 (21.8)	55 (25.0)	10 (3.7)	14 (6.4)	0.233
15	125 (65.4)	91 (60.7)	56 (29.3)	44 (29.3)	10 (5.2)	15 (10.0)	0.234
28	129 (50.2)	94 (43.5)	70 (27.2)	69 (31.9)	58 (22.6)	53 (24.5)	0.335
27	186 (71.0)	145 (66.8)	51 (19.5)	47 (21.7)	25 (9.5)	25 (11.5)	0.600
26	195 (72.0)	145 (65.3)	64 (23.6)	66 (29.7)	12 (4.4)	11 (5.0)	0.275
25	124 (64.2)	90 (60.0)	54 (28.0)	47 (31.3)	15 (7.8)	13 (8.7)	0.723

Italic indicates the level of significance was set at 0.05.

4. Discussion

The aim of the present descriptive study was to measure MSP degree among female patients attending the Dental College & Hospital, Al-Madinah Al-Munawwarah, Saudi Arabia and to assess the possible risk factors for MSP (e.g. Age, tooth site and nationality). Our key findings demonstrated that small percentages of the measured sites were away from the floor of the maxillary sinus and the largest percentages of all measured teeth appeared in Category I, (i.e. sever maxillary pneumatization (40.2–66.2%) with a statistically significant value (P = 0.005)). Therefore, the likelihood of post-extraction sinus complication in our population is expected daily. These results aligned with other studies showing that the Saudi population have a high risk of sinus communication due to extensive teeth approximation (Al-Zoubi et al., 2017; Mattar et al., 2010).

Our results also showed that there is no association between the nationality and the degree of MSP which may be attributed to other unexplored factors, e.g. epigenetic environmental etiology. Expansion of the maxillary sinus with severe thinning of the bony floor was obvious and appeared in the OPGs of large percentages of the present sample which will increase the demand of ridge augmentation and extensive bone regeneration before implant placement in the future.

Sharan et al, in 2008 measured MSP on panoramic radiographs following extraction in 152 views and compare these measurements with the dentate side and they found that MSP average was 2.18 mm in dentate versus 5.27 mm for the extraction site (Sharan and Madjar, 2008). However, in the present study, dentate sites related to all maxillary molars and second premolars showed a significant severe MSP outcomes.

Our result go in contrary to Tolstunov et al, who measured the available remaining bone in edentuolous maxilla for implant insertion in 30 edentulous patients and found that most of his patients (78.7%) were clear or moderately pneumatized and have enough maxillary bone beneath the maxillary sinus as well as finding of a negative correlation with age as maxillary bone decreases by age. This goes in contrary with our results which showed greater MSP in the young age group (Tolstunov et al., 2012). In the current study, we related MSP degree in respect to each tooth position however, Kalavagunta and Reddy, studied extensive MSP in 200 CT scans and classified them according to horizontal and vertical dimension in relation to the orbit but they don't relate this to the teeth-roots, apex position (Kalavagunta and Reddy, 2003). OPG is the standardized radiograph in all patient data filing systems in our faculty and therefore it allows us to use this huge archived data as well as measurements that were obtained through the R4 software. Additionally, a reliability test was conducted before collecting the data, in contrary to other studies which used CT scans which was difficult to us as this is not available for each patient in our cases.

Farina et al., 2011 in their radiographic study estimated that approximately 60% of the bone height loss is due to the decrease in alveolar ridge, and about 35% is because of MSP (Farina et al., 2011). Nevertheless, they found in one of their three dimensional radiographic studies that the bucco-palatal width of the residual alveolar ridge was related to the extrac-

tion or maintenance of adjacent teeth, not the height. Also, the aforementioned study concluded that the presence of a single posterior tooth appears to prevent major sinus expansion, but sometimes, even the loss of one single tooth can provoke a significant down growth of the sinus (Farina et al., 2011; Thomas von Arx and Scott Lozanoff, 2017).

The anatomic relation between sinus floor and dentition is a misunderstanding to some young dentists who may think that the teeth and alveolus is related to the nasal cavity which is a completely wrong concept. Actually, the posterior maxillary teeth are related to the sinus floor and the distance between them may vary from a good bony bridge to a very close approximation to the floor. In which cases, an impression of the root apices presents on the only separating thin lining mucosa (Shahbazian et al., 2010).

Environmental factors may play a role in the etiology of this condition, which lead to pushing of the Schnederian membrane (highly reactive membrane) against cavity sides of the sinus following every patient's breath. The ethnicity appeared not to have a role in our patients and this enforces the evidence towards environmental factors besides bone weakening disorders such as vitamin D deficiency and this is well known nowadays especially in young adult Saudi females which support our results(Al-Daghri, 2018; Al-Raddadi et al., 2018). Other risk factor of increasing MSP should be investigated in future studies. The strength of the current study is that it is the first one that describes the degree of MSP in our region but the study requires further supplemental study in a comparable male side.

5. Conclusion

High percentages of patients were with significant severe MSP on both sides of the measured molars sites. Notably, this significant was highly correlated with young age groups, irrespective of nationality, highlighting the need to replicate these findings and explore the role of other factors (e.g. environment and genetics) in MSP in this geographic area of SA.

6. Recommendation

Further investigational studies should be considered to investigate other associated significant predictive risk factor initiating this hidden epidemic condition.

7. Ethical considerations

The present study was carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki). The study was approved by Research Ethical Committee of Taibah University (TUCDREC20170326Allahmadi). All patients' personal information was not identified and only the researchers had access to the records.

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Conflicts of interest

The authors have no conflict of interest to declare.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sdentj.2018.11.002.

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