Maxillary Sinus and Surrounding Bone Anatomy With Cone Beam Computed Tomography After Multiple Teeth Loss: A Retrospective Multicenter Clinical Study

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Purpose: *The aim of this multicenter study was to examine the residual alveolar bone anatomy and sinus mucosa pattern at maxillary sinus regions in multiple teeth loss.*

Materials and Methods: *This study was conducted with cone beam computed tomography images of 518 patients (267 females and 251 males) with multiple posterior maxillary teeth loss. Variables associated with sinus membrane (SM), sinus dimensions, ostium, septa, sinus neighborhood, alveolar bone height and ridge width, posterior superior alveolar artery, and adjacent roots were evaluated.*

Results: *No (58.2%) or flat (19.3%) thickening morphology was detected at most of the SMs. Membrane thickening and mucosal-like morphology was more prevalent for male patients ($P = 0.005$). The mean sinus width was relatively low (3.64 ± 3.33 mm) at the 5-mm level and showed an expected increase toward upper levels. Most of the sinus spaces were dimensionally average (39.5%) or wide (44.7%), and no effect of gender was observed in terms of sinus dimensions ($P > 0.05$).*

Conclusion: *Multiple teeth loss plays a role in creating an imaginary sinus anatomy constituted of a relatively narrow space compared with single-tooth loss cases, from 3.6-mm mean coronal width to 11.3 mm in the apical portion. (Implant Dent 2019;28:226–236)*

Key Words: dental implants, radiology, clinical, surgery, human

Various radiographic techniques, including panoramic images that provide a two-dimensional view of the region, are used to evaluate the maxillary posterior region. Besides their advantages such as low radiation and cost, the images can be magnified or distorted and create difficulties in accuracy of the diagnosis. Cone beam computed tomography (CBCT) provides a 3-dimensional (3D) view that has a higher radiation dosage than conventional 2-dimensional radiography but a significantly lower dosage than medical computerized tomography.[1] CBCT assessment provides more accurate view of the regional anatomical structures, variations, and pathologies.[2] Combining 3D images with several newly developed software programs enable clinicians to have a more precise presurgical planning due to the above-mentioned advantages.[2]

Premature loss of posterior maxillary teeth often leads to a very limited available bone height for proper

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implant placement due to the combination of alveolar bone loss and expansion of maxillary sinus.[3] Sinus augmentation designed to overcome these deficiencies has been accepted as the procedure to overcome these deficiencies.[3] However, there are several potential complications involving membrane perforation, bleeding, and severe postoperative infection that may happen during or after surgery. Hence, a careful advanced diagnosis is important for predicting and avoiding such complications before treatment. Several anatomic or pathologic factors such as compromised residual ridge, thin sinus membrane (SM), tooth- or sinus-related pathologies, posterior superior alveolar artery (PSAA) location (PSAA-L), presence and location of septa, and obstruction of the ostium play an important role in the risk of these complications.[4,5]

A presurgery CBCT imaging allows clinicians to recognize these anatomical structures and variations around the maxillary sinus. However, majority of these clinical imaging studies have small sample sizes, and most of them have been designed as clinical series. Hence, further studies evaluating the volumetric pattern of the maxillary sinus are needed. In a recent article, our research group published the findings of a comprehensive examination of the anatomical structure of the posterior maxillary region exhibiting single-tooth loss from CBCT images.[4] The findings of the study defined formation of an approximate sinus anatomy showing 16-mm apical and 11-mm coronal width after single-tooth loss. In most cases, SM had flat or semispherical membrane thickening around 4 mm, and the possibility of anterior septum existence was 51%. A complementing ridge anatomy around 7.5-mm alveolar bone height (ABH) and 7.2- to 9.3-mm ridge width (RW) from coronal to apical was also present. From these results, it can be predicted that most of single-tooth loss cases can be clinically rehabilitated by using standardized implants in combination with sinus/crest management or, alternatively, with short implants. However, in multiple teeth loss cases, such a prediction is still lacking because of the absence of comprehensive data. Therefore, the specific aims of this multicenter study were to examine the residual alveolar bone anatomy and sinus mucosa pattern at the maxillary sinus regions in multiple teeth loss, to investigate the prevalence, diameter, and location of PSAA and its relationship to the alveolar ridge, to study the prevalence of the sinus pathology, ostium pattern/locations, and septum structures, and to further analyze the volumetric features of the maxillary sinus cavity using panoramic, sagittal, and coronal image sections.

MATERIALS AND METHODS

CBCT images of 518 patients (267 females and 251 males) obtained from 6 study centers (S.K.-Near East University, E.D.-Hacettepe University, M.K.-Lithuanian University of Health Sciences, M.V.T.-University of Granada, R.G.-University of Illinois at Chicago, and K.S.-University of Michigan) with multiple posterior maxillary teeth loss were used for the study. One calibrated clinician from each center executed all measurements with CBCT software programs. Before starting, the clinicians discussed about the study protocol by using schematic diagrams and agreed on the methods for achieving the associated data. The means of adjacent mesial and distal measurements or scores were calculated to determine the values of edentate and dentate region variables. The Institutional Review Board, University of Illinois at Chicago, Chicago, IL, with the protocol number 2014-1034, approved this retrospective study.

Variables Associated With SM, Sinus Dimensions, Ostium, Septa, and Sinus Neighborhood

These variables consisted of SM morphology (SMM),[6] SM thickness (SMT),[6] SMT classification,[7] morphology of SM thickening,[7] sinus width,[8] sinus augmentation classification,[9] ostium pattern,[7] number of septa,[10] septa height,[10] septa classification,[10] and sinus relation[2] with a lesion or foreign body.

SMM was classified as no thickening = 1, flat thickening without well-defined outlines = 2, semispherical thickening with well-defined outlines rising in an angle of greater than 30° from the walls of the sinus floor = 3, mucocele-like, complete opacification of the sinus = 4, and mixed flat and semispherical thickenings = 5. SM thickening was measured from the base to the apex of the SM residing in edentate and adjacent dentate regions.

According to the measurements, SMT classification was divided into class 1: 0 to 5.0 mm, class 2: 5.1 to 10 mm, class 3: 10.1 to 15 mm, class 4: 15.1 to 20 mm, and class 5: >20 mm. Morphology of SM thickening was evaluated by scoring as no thickening = 1, round shaped = 2, irregular = 3, circumferential = 4, and complete thickening = 5. The dimensions of the sinus were calculated from sinus width and sinus augmentation classification variables. Sinus width was measured at 5-, 7-, 10-, 13-, and 15-mm levels from its buccal to palatal boundaries by drawing an imaginary line between these 2 points and classified as narrow = 1: upper boundary <14 mm and lower boundary <8 mm; average = 2: upper boundary 14 to 17 mm and lower boundary 8 to 10 mm; and wide = 3: upper boundary >17 mm and lower boundary >10 mm. Ostium pattern was scored as patent = 1 and obstructed = 2. Number of septa, septa height, and septa classification of the septa located anterior or posterior of the zygomatic process were identified. The presence of single septa anterior to the zygomatic process was scored as 1, whereas its posterior correspondent was 2, and 2 or more septa was classified as 3 in determining the septa classification,[10] and sinus relation was scored as N/A = 1, periapical lesion = 2, bone graft = 3, implant fenestration = 4, tooth extraction = 5, bone graft + implant = 6, endodontic filling material = 7, and foreign body = 8.

Variables Associated With Alveolar Ridge

These variables included ABH,[8] edentulous site classification,[8] sinus augmentation classification,[8] distance from the root tip to sinus floor,[6] and RW.[8] ABH was measured from the alveolar bone crest to the base of the sinus floor and edentulous site classification of the region. According to the ABH values, they were classified as

<4 mm = 1, 4 to 7 mm = 2, and 7.1 to 10 mm = 3. The cementoenamel junction (CEJ) and alveolar bone crest were taken as fixed reference points in SA-Class that was subdivided into 6 subclasses according to the distance between the CEJ to alveolar bone crest and ABH: abundant bone-1, from the CEJ to alveolar bone crest ≤3 mm + ABH > 10 mm = 1; abundant bone-2, from the CEJ to alveolar bone crest >3 mm + ABH > 10 mm = 2; barely sufficient bone-1, from the CEJ to alveolar bone crest ≤3 mm + 6- to 9-mm ABH = 3; barely sufficient bone-2, from the CEJ to alveolar bone crest >3 mm + 6- to 9-mm ABH = 4; compromised bone-1, from the CEJ to alveolar bone crest ≤3 mm + ABH ≤5 mm = 5; and compromised bone-2, from the CEJ to alveolar bone crest >3 mm + ABH ≤5 mm = 6. Distance from the root tip to sinus floor was measured from the tooth apex to sinus floor in vertical direction. RW included 3 measurements taken from the most coronal, middle, and apical (where the sinus floor is) thirds of each midmost alveolar ridge section.

Variables Associated With PSAA and Adjacent Roots

This variable group concerning with PSAA was listed as its location (PSAA-L),[11] diameter (PSAA-D),[11] distance to alveolar ridge (PSAA-ALV),[11] and its buccal bone thickness (PSAA-BBT).[11] Adjacent root length and vitality[6] values were also added to this group. PSAA-L was detected with the following scoring system: no PSAA = 1, intraosseous = 2, below SM = 3, and on the outer cortex of the sinus wall = 4. After measuring PSAA-D, it was classified according to its dimensions as no PSAA = 1, smaller than 1 mm = 2, 1 to 2 mm = 3, and higher or equal to 2 mm = 4. PSAA-ALV was the bone length between the lower border of PSAA and the alveolar ridge, whereas PSAA-BBT was the thickness of the buccal bone overlying the PSAA. Adjacent root length was measured from the CEJ to apex of each adjacent tooth. Vitality was determined according to the presence/absence of a root canal treatment in the neighboring teeth and scored as both vital = 1, mesial vital = 2, distal vital = 3, and both nonvital = 4.

Statistical Analysis

After completing the measurements, all data were sent to the principal investigator (T.F.T.). The data were studied as a whole, based on gender, according to age, status of edentulous sites, and the origin of data achieved. Normality assumption was checked by the Shapiro-Wilk test. Because data did not conform to normal distribution, nonparametric statistical tests were used. The Mann-Whitney *U* test is used to compare 2 groups in terms of quantitative variables. The distribution of the qualitative variables among gender groups was analyzed by the chi-squared test and the Bonferroni-adjusted z test for proportions. The quantitative measurements were given as mean ± SD (range), and the qualitative values were shown as frequency and percentage (%). A Spearman correlation analysis was also performed to find out a possible correlation between any variables by determining the coefficient rs. In the correlation analysis, only the correlations greater or equal to $|0.500|$ were defined as "clinically remarkable correlation" because very weak and clinically unimportant correlations tend to be statistically significant due to the high sample size. All statistical data analysis was performed using IBM SPSS version 23 for Windows (IBM Corp, Armonk, NY), and the statistical significance was set at $P < 0.05$.

RESULTS

One thousand one hundred ninety regions pertaining to CBCT scans of 518 patients were retrospectively evaluated in the study. Each edentulous tooth region was separately analyzed. The distribution of the centers, age, and edentulous regions is given in Table 1. The mean age of the participants was 52.06 ± 12.02 years. The distribution of edentulous areas was similar at female and male patients, and the first molar was the most frequently missing tooth (35.8%).

Comparison of the parameters regarding to SM, dimensions, ostium pattern, septa, and surrounding factors/materials is shown in Table 2. No (58.2%) or flat (19.3%) thickening morphology was detected at most of the SMs. More tendencies were seen at male patients to membrane thickening, and mucosal-like morphology was more prevalent for this gender (P = 0.005). Although SMT classification scores did not show intersexual difference ($P > 0.05$), membrane thickness measurements also supported this issue ($P = 0.003$ and $P = 0.006$).

Sinus dimensions were determined with sinus width and sinus augmentation

Table 1. Distribution of Centers, Age, and Tooth Regions According to Gender

Center/Age/Area	Female, n (%)	Male, n (%)	Total, n (%)
Near East University	48 (18.0)	68 (27.1)	116 (22.4)
Hacettepe University	68 (25.5)	45 (17.9)	113 (21.8)
Lithuanian University of Health Sciences	19 (7.1)	14 (5.6)	33 (6.4)
University of Granada	78 (29.2)	75 (29.9)	153 (29.5)
University of Illinois	37 (13.9)	35 (13.9)	72 (13.9)
University of Michigan	17 (6.4)	14 (5.6)	31 (6.0)
Total	267 (100)	251 (100)	518 (100)
Age, mean ± SD (min–max)	52.36 ± 12.53 (21–90)	51.77 ± 11.53 (23–77)	52.06 ± 12.02 (21–90)
Area			
1st premolar	75 (12.6)	69 (11.6)	144 (12.1)
2nd premolar	194 (32.6)	122 (20.5)	316 (26.6)
1st molar	185 (31.1)	241 (40.5)	426 (35.8)
2nd molar	141 (23.7)	163 (27.4)	304 (25.5)
Total	595 (100)	595 (100)	1190 (100)

Maxillary sinus–associated teeth regions (the upper premolar and molar area) and the mean age of study participants in different genders.
Min, minimum value; Max, maximum value.

Table 2. Variables Associated With SM, Dimensions, Ostium, Septa, and Relations

	Variable	Female	Male	Total	*P*
Membrane	SMM				**0.005**
	No thickening = 1	169 (63.5%)[a]	132 (52.5%)[b]	301 (58.2%)	
	Flat = 2	43 (16.2%)[a]	57 (22.7%)[a]	100 (19.3%)	
	Semispherical = 3	34 (12.8%)[a]	28 (11.2%)[a]	62 (12%)	
	Mucocele-like = 4	2 (0.8%)[a]	13 (5.2%)[b]	15 (2.9%)	
	Flat + semispherical = 5	18 (6.8%)[a]	21 (8.4%)[a]	39 (7.5%)	
	Total	266 (100%)	251 (100%)	517 (100%)	
	SMT (dentate) (SMT-D)	2.83 ± 3.53 (0–20)	4.13 ± 5.52 (0–31.6)	3.47 ± 4.66 (0–31.6)	**0.003**
	SMT (edentate) (SMT-E)	3.30 ± 4.60 (0–30)	4.71 ± 6.66 (0–33.2)	3.98 ± 5.73 (0–33.2)	**0.006**
	SMT classification (SMT-Class)				0.202
	0–5 mm = 1	200 (75.5%)	184 (73.3%)	384 (74.4%)	
	5–10 mm = 2	40 (15.1%)	28 (11.2%)	68 (13.2%)	
	10–15 mm = 3	9 (3.4%)	11 (4.4%)	20 (3.9%)	
	15–20 mm = 4	5 (1.9%)	10 (4.0%)	15 (2.9%)	
	>20 mm = 5	11 (4.2%)	18 (7.2%)	29 (5.6%)	
	Total	265 (100%)	251 (100%)	516 (100%)	
	SM thickening (SM-Thickening)				0.053
	No thickening = 1	164 (61.9%)	128 (51.0%)	292 (56.6%)	
	Rounded = 2	31 (11.7%)	43 (17.1%)	74 (14.3%)	
	Irregular = 3	38 (14.3%)	37 (14.7%)	75 (14.5%)	
	Circumferential thickening = 4	24 (9.1%)	26 (10.4%)	50 (9.7%)	
	Complete thickening = 5	8 (3.0%)	17 (6.8%)	25 (4.8%)	
	Total	265 (100%)	251 (100%)	516 (100%)	
Dimensions	Sinus width (SW)				
	At 5th mm	3.51 ± 3.30 (0.0–19.5)	3.78 ± 3.36 (0.0–17.1)	3.64 ± 3.33 (0.0–19.5)	0.403
	At 7th mm	4.45 ± 3.72 (0.0–20.2)	4.72 ± 3.54 (0.0–17.3)	4.58 ± 3.63 (0.0–20.2)	0.437
	At 10th mm	5.75 ± 3.86 (0.0–21.0)	6.00 ± 3.70 (0.0–17.9)	5.87 ± 3.78 (0.0–21.0)	0.472
	At 13th mm	6.96 ± 4.03 (0.0–21.9)	7.11 ± 3.68 (0.0–19.3)	7.03 ± 3.86 (0.0–21.9)	0.684
	At 15th mm	7.85 ± 4.27 (0.0–22.3)	7.92 ± 3.80 (0.0–19.8)	7.89 ± 4.04 (0.0–22.3)	0.852
	Mean	10.88 ± 6.27 (0–42.0)	11.68 ± 6.11 (0–36.3)	11.27 ± 6.20 (0–42.0)	0.151
	Sinus augmentation classification (SA-Class-1)				0.230
	Narrow = 1	30 (19.1%)	19 (12.5%)	49 (15.9%)	
	Average = 2	57 (36.3%)	65 (42.8%)	122 (39.5%)	
	Wide = 3	70 (44.6%)	68 (44.7%)	138 (44.7%)	
	Total	157 (100%)	152 (100%)	309 (100%)	

(continued on next page)

Table 2. (Continued)

	Variable	Female	Male	Total	*P*
Ostium	Ostium pattern (OP)				0.100
	Patent = 1	235 (91.4%)	212 (86.9%)	447 (89.2%)	
	Obstructed = 2	22 (8.6%)	32 (13.1%)	54 (10.8%)	
	Total	257 (100%)	244 (100%)	501 (100%)	
Septa	Number of septa (NS)				
	Anterior to the zyg process	0.28 ± 0.58 (0–3)	0.35 ± 0.52 (0–2)	0.32 ± 0.55 (0–3)	0.187
	Posterior to the zyg process	0.15 ± 0.37 (0–2)	0.16 ± 0.38 (0–2)	0.15 ± 0.37 (0–2)	0.748
	Anterior septa height (SH-A)	7.06 ± 3.53 (2.1–22.0)	9.18 ± 5.64 (1.4–22.0)	8.38 ± 5.04 (1.4–22.0)	<**0.001**
	Posterior septa height (SH-P)	5.36 ± 2.27 (1.5–8.3)	6.87 ± 5.19 (1.0–24.7)	6.12 ± 4.02 (1.0–24.7)	0.068
	Septa classification (S-Class)				0.159
	Anterior single septum = 1	30 (44.8%)	62 (60.8%)	92 (54.4%)	
	Posterior single septum = 1	26 (38.8%)	28 (27.5%)	54 (32.0%)	
	Anterior/posterior multiple septa = 2	11 (16.4%)	11 (10.8%)	22 (13.0%)	
	Total	67 (100%)	102 (100%)	169 (100%)	
Relations	Sinus relation to (S-Relation)				**0.010**
	Nothing = 1	222 (83.5%)[a]	210 (83.7%)[a]	432 (83.6%)	
	Periapical lesion = 2	23 (8.6%)[a]	7 (2.8%)[b]	30 (5.8%)	
	Bone graft = 3	2 (0.8%)[a]	3 (1.2%)[a]	5 (1.0%)	
	Implant fenestration = 4	0 (0.0%)[a]	0 (0.0%)[a]	0 (0.0%)	
	Tooth extraction = 5	17 (6.4%)[a]	26 (10.4%)[a]	43 (8.3%)	
	Bone graft + implant = 6	0 (0.0%)[a]	1 (0.4%)[a]	1 (0.2%)	
	Endodontic filling material = 7	2 (0.8%)[a]	1 (0.4%)[a]	3 (0.6%)	
	Foreign body = 8	0 (0.0%)[a]	3 (1.2%)[a]	3 (0.6%)	
	Total	266 (100%)	251 (100%)	517 (100%)	

Gender distribution of the SMM, SMT at dentate and edentate regions, sinus width at different sinus heights and accordingly sinus augmentation classification, ostium pattern, septa classification, and sinus relations (bone graft, tooth extraction, endodontic material, etc). Quantitative variables were shown as mean ± SD (min–max). Qualitative variables were shown as n (%). Bold numbers indicate significant differences.

a, b: different letters indicate statistically different column proportions ($P < 0.05$) according to the Bonferroni-adjusted z test for proportions.

Table 3. Variables Associated With Alveolar Ridge

	Variable	Female	Male	Total	P
Height	ABH	7.52 ± 4.75 (0–26.0)	6.73 ± 3.90 (1–24.2)	7.13 ± 4.37 (0–26.0)	**0.041**
	Edentulous site classification (ES-Class)				**0.010**
	<4 mm = 1	81 (31.3%)[a]	91 (36.8%)[a]	172 (34.0%)	
	4 mm ≤ x < 7 mm = 2	75 (29.0%)[a]	89 (36.0%)[a]	164 (32.4%)	
	7 mm ≤ x < 10 mm = 3	103 (39.8%)[a]	67 (27.1%)[b]	170 (33.6%)	
	Total	259 (100%)	247 (100%)	506 (100%)	
	Sinus augmentation classification (SA-Class-2)				**0.015**
	Abundant bone-1	29 (11.6%)[a]	16 (7.0%)[a]	45 (9.4%)	
	Abundant bone-2	38 (15.2%)[a]	23 (10.1%)[a]	61 (12.8%)	
	Barely sufficient bone-1	23 (9.2%)[a]	12 (5.3%)[a]	35 (7.3%)	
	Barely sufficient bone-2	51 (20.4%)[a]	49 (21.5%)[a]	100 (20.9%)	
	Compromised bone-1	31 (12.4%)[a]	25 (11.0%)[a]	56 (11.7%)	
	Compromised bone-2	78 (31.2%)[a]	103 (45.2%)[b]	181 (37.9%)	
	Total	250 (100%)	228 (100%)	478 (100%)	
	Distance from the root tip to sinus floor (RT-SF)	4.23 ± 3.66 (0–15.6)	3.69 ± 3.23 (0–13.7)	3.96 ± 3.46 (0–15.6)	0.103
Width	RW				
	Coronal	3.33 ± 1.47 (0.8–8.5)	3.41 ± 1.49 (0.7–9.9)	3.37 ± 1.47 (0.7–9.9)	0.531
	Middle	4.06 ± 1.81 (0.9–10.5)	4.30 ± 1.89 (1.5–10.1)	4.18 ± 1.85 (0.9–10.5)	0.157
	Apical	5.27 ± 2.17 (1.1–13.4)	5.11 ± 2.23 (1.5–15.6)	5.19 ± 2.20 (1.1–15.6)	0.448
	Mean	7.99 ± 2.23 (2.5–15.2)	8.34 ± 2.07 (3.8–15.1)	8.16 ± 2.16 (2.5–15.2)	0.066

Measuring ABH and accordingly sinus augmentation classification, mean distance from the root tip to sinus floor, and RW in different genders. Quantitative variables were shown as mean ± SD (min-max). Qualitative variables were shown as n (%). Bold numbers indicate significant differences.
a, b: different superscripts indicate statistically different column proportions ($P < 0.05$) according to the Bonferroni-adjusted z test for proportions.

class measurements. The mean sinus width was relatively low (3.64 ± 3.33 mm) at a 5-mm level and showed an expected increase toward upper levels. Most of the sinus spaces were dimensionally average (39.5%) or wide (44.7%), and gender has no influence on sinus dimensions ($P > 0.05$). Ostium was patent at 89.2% of the patients, and gender did not influence its values ($P > 0.05$) (Table 2).

Nearly one-third of the patients revealed at least one sinus septum at the anterior of the zygomatic process with 8.38 ± 5.04 mm of mean septum height. However, its prevalence decreased to 15% when septa were located at the posterior of the zygomatic process with 6.12 ± 4.02 mm of mean septum height. Interestingly, anterior septa height was significantly higher at male patients ($P < 0.001$). Septa classification scores also supported these results. Again, gender did not affect classification scores ($P > 0.05$) (Table 2).

Despite high number of patients demonstrating no relationship between maxillary sinus and surrounding factors/materials (83.6%), the presence of tooth extraction (8.3%) and periapical lesion (5.8%) were the mostly encountered conditions. Furthermore, female patients had a significantly higher adjacent periapical lesion than male patients ($P = 0.010$) (Table 2).

The variables regarding alveolar bone dimensions are shown in Table 3. The mean ABH was 7.13 ± 4.37 mm and was significantly related to the study variables with the exception of the distance from the adjacent root tip to the above sinus floor. Accordingly, most patients had compromised bone (37.9%) and was significantly higher at male patients ($P = 0.015$). On the other hand, RW was clinically narrow (3.37 ± 1.47 mm) and slowly increased toward the apical region. However, no gender-related difference was detected for this variable ($P > 0.05$).

Variables associated with PSAA and adjacent roots were given in Table 4. When PSAA was considered, 63.0% of the patients did not reveal PSAA in their cross-sections, and most of the PSAA visible images showed intraosseous alignment of the artery. Moreover, significant effect of the gender was observed to the presence and location of PSAA. Although it was less visible in female patients, it showed a tendency of intraosseous localization in male patients ($P = 0.001$). When present, the diameter of PSAA did not go beyond 2 mm and was not influenced by the gender ($P > 0.05$). PSAA was localized 14.35 ± 4.99 mm away from the alveolar ridge with 1.24 ± 0.78 mm of mean overlying BBT. The mean length of the adjacent tooth roots was around 13 mm, and they were rarely devitalized. Although root length values were similar at different genders, only the number of devital teeth at the distal neighboring area was significantly higher at the male patient group ($P = 0.038$) (Table 4).

Table 4. Variables Associated With PSAA and Neighboring Teeth

	Variable	Female	Male	Total	*P*
Location	PSAA-L				**0.001**
	No PSAA = 1	169 (68.4%)[a]	133 (57.3%)[b]	302 (63.0%)	
	Intraosseous = 2	42 (17.0%)[a]	71 (30.6%)[b]	113 (23.6%)	
	Below SM = 3	34 (13.8%)[a]	22 (9.5%)[a]	56 (11.7%)	
	On the outer cortex of sinus wall = 4	2 (0.8%)[a]	6 (2.6%)[a]	8 (1.7%)	
	Total	247 (100%)	232 (100%)	479 (100%)	
Diameter	PSAA-D				0.533
	No PSAA = 1	58 (45.3)	55 (38.7%)	113 (41.9%)	
	<1 mm = 2	44 (34.4%)	57 (40.1%)	101 (37.4%)	
	1–2 mm = 3	26 (20.3%)	29 (20.4%)	55 (20.4%)	
	≥2 mm = 4	0 (0%)	1 (0.7%)	1 (0.4%)	
	Total	128 (100%)	142 (100%)	270 (100%)	
Bone	PSAA-ALV	14.46 ± 5.34 (0–24.7)	14.26 ± 4.72 (0–24.3)	14.35 ± 4.99 (0–24.7)	0.792
	BBT above PSAA (PSAA-BBT)	1.15 ± 0.65 (0–3.8)	1.32 ± 0.87 (0–4)	1.24 ± 0.78 (0–4)	0.162
Length and vitality	Root length (RL)	12.71 ± 2.62 (6.0–20.0)	13.21 ± 3.05 (6.0–20.7)	12.96 ± 2.85 (6.0–20.7)	0.066
	Neighboring teeth vitality (VIT)				**0.038**
	Both vital = 1	128 (58.2%)[a]	145 (66.5%)[a]	273 (62.3%)	
	Mesial vital = 2	23 (10.5%)[a]	10 (4.6%)[b]	33 (7.5%)	
	Distal vital = 3	58 (26.4%)[a]	58 (26.6%)[a]	116 (26.5%)	
	Both devital = 4	11 (5%)[a]	5 (2.3%)[a]	16 (3.7%)	
	Total	220 (100%)	218 (100%)	438 (100%)	

Analyzing PSAA parameters such as location, mean diameter and alveolar ridge distance, and neighboring tooth vitality in different genders. Quantitative variables were shown as mean ± SD (min-max). Qualitative variables were shown as n (%). Bold numbers indicate significant differences.
a, b: different superscripts indicate statistically different column proportions ($P < 0.05$) according to the Bonferroni-adjusted z test for proportions.

The results of the Spearman correlation analyses are given in Table 5. The correlations greater than or equal to |0.500| were defined as "clinically meaningful correlation" because very weak and clinically unimportant correlations tend to be statistically significant due to the high sample size. The sinus-related variables associated with thickness and morphology exhibited significant correlations within themselves. The variables representing the anatomy of edentulous ridge (ABH, sinus augmentation classification, and edentulous classification) also showed significant correlations among each other. Furthermore, sinus septa height at posterior of the zygomatic process was correlated with SMT, SMT classification, and bone thickness on the buccal surface of PSAA values. PSAA localization was also correlated with its diameter values.

Discussion

In the present multicenter study, the effect of multiple teeth loss to sinus-associated parameters was evaluated. According to SM thickening classification, no thickening (58.2%) or flat thickening (19.3%) morphology was detected at most of the SMs. Male patients had a thicker membrane thickening and mucosal-like morphology than female patients. Although SMT classification scores did not show intersexual difference ($P > 0.05$), membrane thickness measurements also supported this issue. SM thickening often emerges due to chronic sinusitis and when it becomes thicker than 2 mm, considered as "pathologic."[12] A high prevalence of thickening has been reported in the literature[13,14] even usually in asymptomatic cases. In 2011, Janner et al[15] detected 55% of sinus pathology frequency, according to the criterion defined by Cagici et al[16] in the patients referred to implant treatment for their maxillary posterior region. Moreover, the most reported pathology was flat thickening of the SM.[6] In this study, approximately 50% of the total cases showed thickening and the pathologic cases predominantly had flat morphology (Table 2), the proportion of the semispherical (SMM code 3) and mucocele-like (SMM code 4) morphology was similar with a previous reported study.[7] The difference between this study and the associated literature can be attributed to the ostium pattern of the sinus.

The probability of sinus obstruction is increased with high SMT. It was reported that an irregular or circumferential SM thickening higher than 5 or 10 mm gradually associated with obstruction.[7,17] In this study, 10.8% of the cases with multiple teeth loss had an obstructed ostium pattern (Table 2); although not statistically significant, this finding was supported by the correlations between ostium pattern and membrane morphology variables. When SMT results were compared in terms of gender, female edentate and dentate patients showed lower SMT scores ($P < 0.05$) (Table 2). In clinical perspective, this result is similar to Schneider et al[6] that can be attributed to the higher tendency of males to have sinus pathology, which can be partially explained by their lifestyle (eg, smoking habits and ventilation dynamics). According to the Spearman correlation analysis, SMT, SMT classification, and SM thickening variables exhibited positive

Table 5. Results of the Spearman correlation analysis

Variable	SMM	SMT	SMT-Class	SM-Thickening	SW	SA-Class-1	OP	NS	SH-A	SH-P	S-Class
SMM	1,000										
SMT	**,742****	1,000									
SMT-Class	**,668****	**,732****	1,000								
SM-Thickening	**,884****	**,718****	**,616****	1,000							
SW	,017	,179**	,136**	,039	1,000						
SA-Class-1	,154**	,262**	,244**	,160**	,476**	1,000					
OP	,397**	,401**	,449**	,437**	,125**	,165**	1,000				
NS	-,096*	,031	-,012	-,105*	,073	-,069	-,021	1,000			
SH-A	-,170*	,110	-,081	-,110	-,026	,128	-,202*	,000	1,000		
SH-P	,375*	**,574****	**,641****	,268	-,276	,471**	-,092	,217	,499**	1,000	
S-Class	,100	,043	,026	,009	-,093	,303**	,101	-,102	-,183*	,284	1,000
S-Relation	,282**	,259**	,233**	,266**	,128**	,246**	,220**	-,010	-,195*	-,151	-,056
PSAA-L	-,048	-,087	-,098*	-,024	,150**	-,070	-,011	-,031	,140	-,385*	-,213**
PSAA-D	-,087	,050	-,061	-,061	,259**	,035	,024	,163*	,269*	,436	-,160
PSAA-ALV	-,091	-,113	-,163*	,015	-,251**	-,113	-,004	,117	,065	,091	-,144
PSAA-BBT	,056	-,017	-,116	,107	-,269**	-,054	-,015	,007	,044	**-,644***	-,269*
ABH-E	-,064	-,239**	-,192**	-,100*	-,451**	-,256**	-,125**	-,200**	,028	-,028	-,113
ES-Class	-,072	-,232**	-,145**	-,097*	-,414**	-,264**	-,112*	-,037	,009	,142	,156*
SA-Class-2	,129**	,276**	,156**	,159**	,255**	,201**	,162**	,172**	,115	,269	-,107
RT-SF	-,120**	-,241**	-,226**	-,129**	-,401**	-,188**	-,104*	-,115*	-,042	,231	,040
RW	,178**	,102*	,099*	,132**	,142**	,111	,066	-,177**	-,018	-,422**	-,288**
RL	,145**	-,155**	-,172**	,080	-,260**	-,067	-,048	-,097	-,366**	-,033	,162
VIT	,105*	-,048	-,070	,041	-,173**	-,265**	-,013	-,044	-,198*	,177	,403**

Variable	S-Relation	PSAA-L	PSAA-D	PSAA-ALV	PSAA-BBT	ABH-E	ES-Class	SA-Class-2	RT-SF	RW	RL	VIT
SMM												
SMT												
SMT-Class												
SM-Thickening												
SW												
SA-Class-1												
OP												
NS												
SH-A												
SH-P												
S-Class												
S-Relation	1,000											
PSAA-L	-,141**	1,000										
PSAA-D	-,113	**,725****	1,000									
PSAA-ALV	-,150*	,119	-,076	1,000								
PSAA-BBT	-,072	,038	,221**	,233**	1,000							
ABH-E	-,180**	,178**	-,106	,266**	-,015	1,000						
ES-Class	-,156**	,080	,009	,176*	-,095	**,823****	1,000					
SA-Class-2	,153**	-,059	,129*	-,093	,248**	**-,803****	**-,831****	1,000				
RT-SF	-,186**	,089	-,078	,234**	-,007	**,940****	**,847****	**-,823****	1,000			
RW	,099*	,158**	,074	-,131	,099	,251**	,174**	-,153**	,181**	1,000		
RL	,076	,118*	-,084	,116	,096	,305**	,197**	-,122*	,285**	,169**	1,000	
VIT	,011	,040	,029	-,074	-,101	,055	,092	,024	,010	,121*	,190**	1,000

Bold numbers indicate significant correlations
*p<0.05, **p<0.001

and significant correlation among each other ($P < 0.001$) (Table 5). When the sinus anatomy was considered, all those variables carry similar properties mainly based on the thickness of the SM.

Sinus width classification was proposed by Chan et al[8] as an adjunctive tool in sinus elevation planning and also recommended to test its implications with further trials. According to their findings, sinus width can be expected as 8.5 to 9 mm, 10.5 to 12 mm, 13 to 14 mm, 14.5 to 18 mm, and 15 to 19.5 mm from the measurements performed at 5-, 7-, 10-, 13-, and 15-mm levels, respectively[8] but may exhibit slight modifications in terms of single- or multiple tooth loss.[4] In this study, sinus width values at all levels were notably lower than the proposed classification. The lower sinus width value in this study could be derived from the different number of molar teeth in the study samples. The relevant literature showing the dimensions of the maxillary sinus reported lower sinus dimensions in females.[18,19] In this study, no significant differences were found between male and female patients ($P > 0.05$) according to sinus augmentation classification and sinus width values (Table 2).

The ABH >5 mm has been reported as the minimum required amount for primary implant stability.[20] Although it can have clinical variations, the mean ABH for first premolar, second premolar, first molar, and second molar locations was reported to be 10.6 to 13.4 mm, 5.9 to 9.0 mm, 3.3 to 5.5 mm, and 5.9 to 9.0 mm, respectively.[21–23] It was also reported that the probability of thinner SM increases with reduced ABH.[24,25] Although present ABH values for each location was compatible with the above-mentioned numbers, ABH and SMT did not show any significant correlation (Table 5) ($P > 0.05$).

In the previous report of the same group, male patients with single tooth loss showed wider RW values than female patients.[4] However, in the present multiple teeth loss, no difference was found between males and females ($P > 0.05$). Results from this study suggested a tendency of crestal bone resorption and sinus expansion after tooth loss. This observation was further supported by the reported literature.[26,27] However, a recent study, with large sample size, has highlighted that in older patients, the maxillary sinus decreases in volume and medial dimensions.[28] This controversial result can be explained by the resorptive phenomenon after tooth extraction. Alveolar bone remodeling after a single-tooth extraction could be conditioned by the presence of a tooth remnant, but after extraction of a posterior segment of teeth, the lack of masticatory function promotes more aggressive ridge resorption.

In the present retrospective study, the mean distance to the septa anterior and posterior to the zygomatic process was around 8.5 and 6 mm, respectively. This means the probability to encounter a septum was between 1/6 and 1/3. Septa anterior to the zygomatic process were higher in male patients ($P < 0.001$). This is different from our previous single-tooth loss study.[4] Septa anterior to the zygomatic process were slightly lower and have no correlation with septa height and number of septa. Moreover, Keceli et al[4] (2017) found the increasing number of septa posterior to the zygomatic process correlated with the decreasing amount of ABH and attributed that finding to the concordant relationship between bone resorption with sinus expansion.bib4 Nevertheless, according to the present findings, septa posterior to the zygomatic process showed a negative correlation with PSAA-BBT that may indicate the possible relationship of septa formation with buccal bone remodeling instead of sinus expansion. Consequently, both consecutive trials remark a complex but associated remodeling processes of those anatomical regions that need to be highlighted with further investigations.

The relevant information regarding the approximate location of PSAA has been given as 18 mm above the alveolar crest.[11,29] Despite some marginal values extending to 24.7 mm, our results indicated 14.4-mm mean distance and was comparable with other similar studies.[4,30] The average diameter of PSAA was also similar with previous findings (≤2 mm).[31] As shown by some other investigators,[11,32] neither its location nor diameter of PSAA showed difference between male and female patients.

The spreading potential of the periapical pathologies to the sinus region may increase the risk of sinus-related infections.[33] In our previous study, the absence of correlation between sinus relation and adjacent tooth vitality with other parameters has been attributed to the low number of nonvital adjacent teeth having periapical pathology (around 7%).[4] In this study, almost one-third of the neighboring teeth had at least one devital root, but still no correlation existed between the above-mentioned variables. Furthermore, the percentage of periapical lesion incidence was also quite low (5.8%). As an implication, although its complications might cause headache in many cases, the rate of the spreading pathology risk can be considered as a lower possibility.

This study has some limitations, which should be carefully evaluated before interpreting the results. Although CBCT should be considered as an important diagnostic image modality in dental practice, it is important to realize its main limitations, such as specific artifacts, limited volume, and the lack of soft-tissue information.[34] Another limitation to be highlighted is that the reported anatomical variations of this study should not be applied to the general population, as the examined sample of CBCT scans in all centers belongs to dental implant patients showing specific characteristics, such as high median age and maxillary tooth loss.

CONCLUSION

Within the limitations of this trial, it can be concluded that multiple teeth loss plays a role in creating an imaginary sinus anatomy constituted of a relatively narrow space compared with single-tooth loss cases, from 3.6-mm mean coronal width to 11.3 mm in the apical portion. An alveolar bone with 7.1-mm ABH and 8.3-mm RW form the complementary surrounding anatomy of this region. The main variations in genders were septa located anterior to the zygomatic process, sinus relation, ABH, edentulous site classification, sinus augmentation classification-2, location of PSAA, adjacent teeth vitality that can be based on the less tendency of bone resorption, and adjacent tooth pathology in female patients. Further studies are needed to clarify the rationale behind those variations.

Roles/Contributions by Authors

E. Dursun: Making CBCT measurements and data preparation at Hacettepe University. H. G. Keceli: Manuscript preparation and literature review. A. Dolgun: Editing the results. M. Velasco-Torres: Making CBCT measurements and data preparation at University of Granada. M. Olculer: Making CBCT measurements and data preparation at Near East University. R. Ghoreishi: Making CBCT measurements and data preparation at University of Illinois at Chicago. K. Sinjab: Making CBCT measurements and data preparation at University of Michigan. R. S. Sinacola: CBCT archive management at University of Michigan. M. Kubilius: Making CBCT measurements and data preparation at Lithuanian University of Health Sciences. M. D. Tözüm: Literature review. P. Galindo-Moreno: Preparation of the study at University of Granada. H. G. Yilmaz: Preparation of the study at Near East University. H. -L. Wang: Preparation of the study at University of Michigan. G. Juodzbalys: Preparation of the study at Lithuanian University of Health Sciences. T. F. Tözüm: Preparation of the study, coordination of the study centers, analysis of data, and application to ICOI grant.

Disclosure

The authors claim to have no financial interest, either directly or indirectly, in the products or information listed in the article.

Approval

The Institutional Review Board, University of Illinois at Chicago, Chicago, IL, with the protocol number 2014-1034, approved this retrospective study.

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References

1. Yang SM, Park SI, Kye SB, et al. Computed tomographic assessment of maxillary sinus wall thickness in edentulous patients. *J Oral Rehabil.* 2012;39:421–428.

2. Lana JP, Carneiro PM, Machado Vde C, et al. Anatomic variations and lesions of the maxillary sinus detected in cone beam computed tomography for dental implants. *Clin Oral Implants Res.* 2012;23:1398–1403.

3. Tatum H Jr. Maxillary and sinus implant reconstructions. *Dent Clin North Am.* 1986;30:207–229.

4. Keceli HG, Dursun E, Dolgun A, et al. Evaluation of single tooth loss to maxillary sinus and surrounding bone anatomy with cone-beam computed tomography: A multicenter study. *Implant Dent.* 2017;26:690–699.

5. Talo Yildirim T, Guncu GN, Colak M, et al. Evaluation of maxillary sinus septa: A retrospective clinical study with cone beam computerized tomography (CBCT). *Eur Rev Med Pharmacol Sci.* 2017;21:5306–5314.

6. Schneider AC, Bragger U, Sendi P, et al. Characteristics and dimensions of the sinus membrane in patients referred for single-implant treatment in the posterior maxilla: A cone beam computed tomographic analysis. *Int J Oral Maxillofac Implants.* 2013;28:587–596.

7. Carmeli G, Artzi Z, Kozlovsky A, et al. Antral computerized tomography pre-operative evaluation: Relationship between mucosal thickening and maxillary sinus function. *Clin Oral Implants Res.* 2011;22:78–82.

8. Chan HL, Suarez F, Monje A, et al. Evaluation of maxillary sinus width on cone-beam computed tomography for sinus augmentation and new sinus classification based on sinus width. *Clin Oral Implants Res.* 2014;25:647–652.

9. Wang HL, Katranji A. ABC sinus augmentation classification. *Int J Periodontics Restorative Dent.* 2008;28:383–389.

10. Wen SC, Chan HL, Wang HL. Classification and management of antral septa for maxillary sinus augmentation. *Int J Periodontics Restorative Dent.* 2013;33:509–517.

11. Guncu GN, Yildirim YD, Wang HL, et al. Location of posterior superior alveolar artery and evaluation of maxillary sinus anatomy with computerized tomography: A clinical study. *Clin Oral Implants Res.* 2011;22:1164–1167.

12. Kolo ES. The role of plain radiographs in the diagnosis of chronic maxillary rhinosinusitis in adults. *Afr Health Sci.* 2012;12:459–463.

13. Vallo J, Suominen-Taipale L, Huumonen S, et al. Prevalence of mucosal abnormalities of the maxillary sinus and their relationship to dental disease in panoramic radiography: Results from the health 2000 health examination survey. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2010;109:e80–e87.

14. Maestre-Ferrin L, Galan-Gil S, Carrillo-Garcia C, et al. Radiographic findings in the maxillary sinus: Comparison of panoramic radiography with computed tomography. *Int J Oral Maxillofac Implants.* 2011;26:341–346.

15. Janner SF, Caversaccio MD, Dubach P, et al. Characteristics and dimensions of the Schneiderian membrane: A radiographic analysis using cone beam computed tomography in patients referred for dental implant surgery in the posterior maxilla. *Clin Oral Implants Res.* 2011;22:1446–1453.

16. Cagici CA, Yilmazer C, Hurcan C, et al. Appropriate interslice gap for screening coronal paranasal sinus tomography for mucosal thickening. *Eur Arch Otorhinolaryngol.* 2009;266:519–525.

17. Shanbhag S, Karnik P, Shirke P, et al. Cone-beam computed tomographic analysis of sinus membrane thickness, ostium patency, and residual ridge heights in the posterior maxilla: Implications for sinus floor elevation. *Clin Oral Implants Res.* 2014;25:755–760.

18. Uthman AT, Al-Rawi NH, Al-Naaimi AS, et al. Evaluation of maxillary sinus dimensions in gender determination using helical CT scanning. *J Forensic Sci.* 2011;56:403–408.

19. Lee MK, Sakai O, Spiegel JH. CT measurement of the frontal sinus - gender differences and implications for frontal cranioplasty. *J Craniomaxillofac Surg.* 2010;38:494–500.

20. Smiler DG, Johnson PW, Lozada JL, et al. Sinus lift grafts and endosseous implants. Treatment of the atrophic posterior maxilla. *Dent Clin North Am.* 1992;36:151–186; discussion 187–158.

21. Farina R, Pramstraller M, Franceschetti G, et al. Alveolar ridge dimensions in maxillary posterior sextants: A retrospective comparative study of

dentate and edentulous sites using computerized tomography data. *Clin Oral Implants Res.* 2011;22:1138–1144.

22. Pramstraller M, Farina R, Franceschetti G, et al. Ridge dimensions of the edentulous posterior maxilla: A retrospective analysis of a cohort of 127 patients using computerized tomography data. *Clin Oral Implants Res.* 2011;22: 54–61.

23. Kopecka D, Simunek A, Brazda T, et al. Relationship between subsinus bone height and bone volume requirements for dental implants: A human radiographic study. *Int J Oral Maxillofac Implants.* 2012;27:48–54.

24. Yilmaz HG, Tozum TF. Are gingival phenotype, residual ridge height, and membrane thickness critical for the perforation of maxillary sinus? *J Periodontol.* 2012;83:420–425.

25. Ardekian L, Oved-Peleg E, Mactei EE, et al. The clinical significance of sinus membrane perforation during augmentation of the maxillary sinus. *J Oral Maxillofac Surg.* 2006;64:277–282.

26. Acharya A, Hao J, Mattheos N, et al. Residual ridge dimensions at edentulous maxillary first molar sites and periodontal bone loss among two ethnic cohorts seeking tooth replacement. *Clin Oral Implants Res.* 2014;25:1386–1394.

27. Dursun CK, Dursun E, Eratalay K, et al. Effect of porous titanium granules on bone regeneration and primary stability in maxillary sinus: A human clinical, histomorphometric, and microcomputed tomography analyses. *J Craniofac Surg.* 2016;27:391–397.

28. Velasco-Torres M, Padial-Molina M, Avila-Ortiz G, et al. Maxillary sinus dimensions decrease as age and tooth loss increase. *Implant Dent.* 2017;26: 288–295.

29. Traxler H, Windisch A, Geyerhofer U, et al. Arterial blood supply of the maxillary sinus. *Clin Anat.* 1999;12:417–421.

30. Velasco-Torres M, Padial-Molina M, Alarcon JA, et al. Maxillary sinus dimensions with respect to the posterior superior alveolar artery decrease with tooth loss. *Implant Dent.* 2016;25:464–470.

31. Ella B, Sedarat C, Noble Rda C, et al. Vascular connections of the lateral wall of the sinus: Surgical effect in sinus augmentation. *Int J Oral Maxillofac Implants.* 2008;23:1047–1052.

32. Mardinger O, Abba M, Hirshberg A, et al. Prevalence, diameter and course of the maxillary intraosseous vascular canal with relation to sinus augmentation procedure: A radiographic study. *Int J Oral Maxillofac Surg.* 2007;36:735–738.

33. Bornstein MM, Wasmer J, Sendi P, et al. Characteristics and dimensions of the Schneiderian membrane and apical bone in maxillary molars referred for apical surgery: A comparative radiographic analysis using limited cone beam computed tomography. *J Endod.* 2012;38:51–57.

34. Watanabe H, Honda E, Tetsumura A, et al. A comparative study for spatial resolution and subjective image characteristics of a multi-slice CT and a cone-beam CT for dental use. *Eur J Radiol.* 2011;77:397–402.