Original Study

RADIOGRAPHIC EVALUATION OF MAXILLARY SINUS SURGICAL RISKS IN SINUS LIFTING SURGERY CANDIDATES USING CONE BEAM COMPUTED TOMOGRAPHY (CBCT)

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ABSTRACT

Introduction: Dental implant placement in the maxillary posterior edentulous area can be an indication for sinus lifting surgery in case of inadequate residual bone between the sinus floor and crestal ridge. In the present study, we aimed to conduct a radiological assessment of maxillary sinus surgical risks in sinus lifting surgery candidates, using cone beam computed tomography (CBCT).

Methods: In this cross-sectional study, a total of 350 cases (100 premolar, 130 first molar, and 120 second molar edentulous areas) were extracted from the records of two private radiology clinics in Babol, Iran. The residual ridge height (RRH), mucosal thickness (MT), ostial patency, sinus width (SW), lateral wall thickness (LWT), angle formed between the medial and lateral walls of sinus (angle A), sinus floor thickness (FT), alveolar crest distance (ACD), presence of vertical septa, and correlation between these variables were evaluated using NNT software. The data were analyzed by t-test, ANOVA, and Mann-Whitney tests using SPSS version 22.

Results: The minimum RRH and LWT were observed in the second molar area, whereas minimum SW and angle A were found in the second premolar area. A correlation was found between increased MT and the presence of septa, ostium obstruction, decreased angle A, and FT. However, there was no significant association between other variables.

Conclusion: Based on the results of this study, it can be concluded that the first molar area is the highest risk area in sinus lifting surgery. Therefore, morphological sinus assessment seems to be essential in addition to routine CBCT evaluations.

Key words: Maxillary Sinus, Cone beam Computed tomography, Sinus augmentation.

Introduction

Dental implant placement in the maxillary posterior edentulous area can be an indication for sinus lifting surgery in case of inadequate residual bone between the sinus floor and crestal ridge [1]. Generally, there are two surgical techniques for sinus lifting surgery, including the lateral window and crestal approaches. In the first approach, surgical access is provided by making a lateral window in the outer wall of the maxillary sinus, while in the crestal approach, sinus floor elevation is achieved by performing minor osteotomy through the edentulous alveolar crest at the inferior border of the sinus [2].

It is very important to consider various anatomical and pathological findings in order to reduce surgical and postsurgical risks in the sinus. Cone beam computed tomography (CBCT) images can identify maxillary sinus variations, as well as the potential causes of sinusitis [2]. In addition, bone quantity and quality should be evaluated radiographically prior to sinus lifting surgery. CBCT images can provide precise information about various implant placement sites [3]. In fact, these images exhibit anatomical structures and provide valuable data regarding bone dimensions and morphology [3].

In a previous study, the prevalence of incidental findings in the maxillary sinus was estimated at 73% [4], and increased thickness of mucosa was reported as the most common anomaly with a prevalence of 54%. In addition, the incidence of mucous retention cyst was 5.14%, and sinus floor involvement was observed in 62% of these cases [5]. Evidence suggests that sinus anomalies are most common among females in the second decade of life [6]. Also, the greatest increase in mucosal thickness (MT) was found in the first molar area. Other affected sites include the second molar, second premolar, and third molar, respectively [7].

In addition to residual bone width and height, there are other criteria which should be considered in CBCT images:

I. Maxillary sinus lateral wall thickness (LWT): A thin lateral wall with a thickness of less than 1 mm is desirable in CBCT images, while a thickness of more than 2.5 mm is more time-consuming for membrane exposure [8]. Therefore, a thicker wall makes the surgical procedure more complicated [1].

II. Presence and diameter of the posterior-superior alveolar artery: Rupture of the artery during the surgical procedure leads to decreased visibility and increases the risk of sinus membrane perforation [1].

III. Maxillary sinus width (SW): The distance between the lateral and medial sinus walls is of utmost importance [1]. SW is considered a critical anatomical criterion in sinus surgery. Width of 12.1 mm is generally considered as the threshold limit [2]. On the other hand, very wide or very narrow sinuses may be challenging in sinus augmentation procedures [8].

IV. Angle formed between the sinus medial and lateral walls (angle A): The low angle forward between the lateral and medial sinus walls is correlated with the prevalence of membrane perforation [2]. Angles exceeding 60° are regarded as optimal, while angles less than 30° increase the risk of perforation [8].

V. The close relation of the Schneiderian membrane with the roots of adjacent teeth: This leads to an increased risk of perforation [1] and complications during and after surgery. Also, particles may move into the sinus and result in sinus inflammation [9].

VI. Presence of septa in the maxillary sinus: The presence of intra-sinus septum increases the risk of sinus membrane rupture [4]. In the case of septa with low height (< 2 mm), no intervention is necessary; however, septa with an intermediate height need to be taken into account. Also, high septa, which partially or completely divide the sinus cavity, may cause some changes in the surgical method [4], while complete transverse septa do not affect the surgery; incomplete vertical septa compromise the surgical procedure [8].

VII. The thickness of the mucosal membrane (MT): A normal MT (1 mm) is not visible on radiographic images. However, in the case of inflammation, the thickness of mucosa may increase 10 to 15 times, which is noticeable in radiographic images [10]. More than 2 mm increase of MT is considered a pathological condition. Also, MT > 5 mm is associated with an increased risk of ostium obstruction [11].

VIII. Ostial patency: Ostium patency should be appraised before maxillary sinus surgery [1]. It is categorized as either "patent" or "obstructed" [11]. There is a strong correlation between radiographic signs of ostial obstruction and increased MT. Moreover, sinus drainage problems are associated with a higher risk of postsurgical sinusitis [3].

IX. Pathological lesions of the maxillary sinus (e.g., cysts and tumors): They should be treated prior to sinus lifting surgery [1].

In previous studies, the risk factors for sinus lifting surgery have been distinctly evaluated. Nevertheless, some of these studies have not compared the risks in different edentulous sites. Therefore, considering the local risks and surgical/postsurgical complications, in this study, we aimed to determine maxillary sinus surgical risks among candidates for posterior maxillary surgery.

Materials and Methods

In this cross-sectional study, a total of 350 cases were evaluated, including 100 second premolar, 130 first molar, and 120 second molar edentulous areas. The cases were extracted from the records of two private maxillofacial radiology clinics in Babol, Iran. The inclusion criteria were as follows: 1) large field of view (FOV) which includes the maxillary sinus bilaterally to the orbital floor; 2) no history of sinus lifting surgery or orthognathic surgeries; 3) no sign of destructive pathological lesions in sinus walls affecting the measurements (e.g., cysts and tumors); and 4) detection of at least one edentulous site in the posterior maxilla, with a residual ridge height (RRH) less than 5 mm.

NewTom 5G (Verona, Italy) and NewTom Giano (Verona, Italy) machines, along with the NNT software, were used in the oral and maxillofacial radiology centers. In the NNT viewer, after adjusting contrast and brightness to improve and match the quality of images, measurements were done in millimeters. A maxillofacial radiologist and a maxillofacial radiology resident evaluated the images simultaneously in a room with subdued light. In case of any controversies, a second opinion was sought from the second maxillofacial radiologist. Data were recorded in a checklist designed specifically for this survey [2, 12, 13].

The second premolar, first molar, and second molar edentulous sites were evaluated in this study. For each variable, the area with the highest surgical risk was determined. Moreover, images were assessed using a DELL personal computer (Inspiron N5110, 15.6 TFT LED backlit LCD display with full-HD 1366×768 resolution). The evaluation criteria were as follows:

Increase in the thickness of the maxillary sinus floor (MT): Any noticeable change in MT was measured at constant

contrast and density. In this study, MT was classified as follows: less than 2 mm, 2-5 mm, and more than 5 mm. Increased thickness was measured at three points in each site, including the deepest point of the sinus floor and 3-mm and 5-mm distances from the first point toward the lateral sinus wall. Measurements were performed vertically, and the mean values were recorded. MT more than 2 mm was considered to be a risk factor (Figure 1).

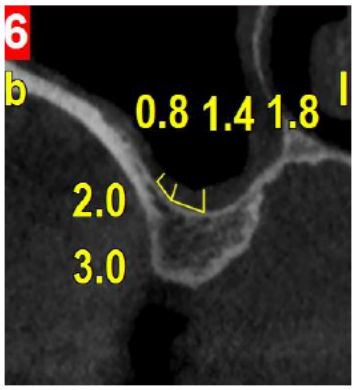

Figure 1: CBCT analysis and calculation of the average mucosal thickness in the cross-sectional image.

Patency of the maxillary sinus ostium: The sinus ostium may be patent (open) or obstructed in the event of blockade by mucosal or anatomical barriers, regardless of the edentulous site; therefore, no edentulous site in particular was assessed. RRH: This variable was measured as the distance between the alveolar crest and the deepest point of the sinus floor in each dental area. The site with minimum height was considered as high-risk (Figure 2).

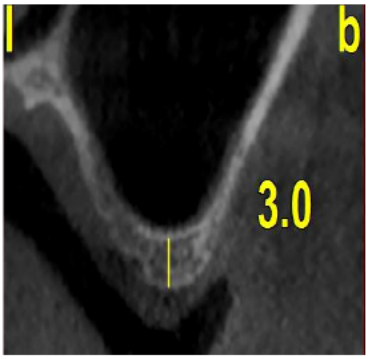

Figure 2: Measuring residual ridge height in CBCT cross-sectional image.

Maxillary sinus floor thickness (FT): FT was measured in each dental area in the most inferior part. The area with the lowest thickness was considered high-risk (Figure 3).

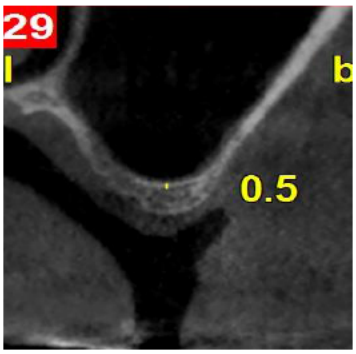

Figure 3: Measuring sinus floor thickness in CBCT cross-sectional image.

SW: The distance between the lateral and medial walls, measured at 5 mm superior to the sinus floor, was classified into more than 12.1 and less than 12.1 mm groups. The area with a width of more than 12.1 mm was considered high-risk (Figure 4).

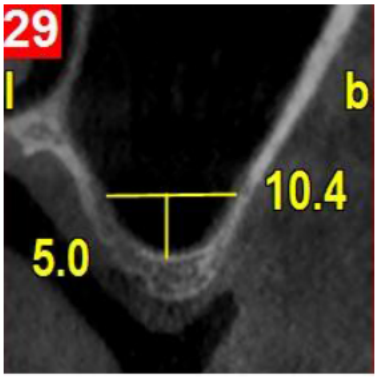

Figure 4: Measuring sinus width at 5 mm superior to the sinus floor in CBCT cross-sectional image.

LWT: Thickness of the lateral wall was measured at 10 mm superior to the sinus floor along the lateral wall. The thickest site was regarded as high-risk (Figure 5).

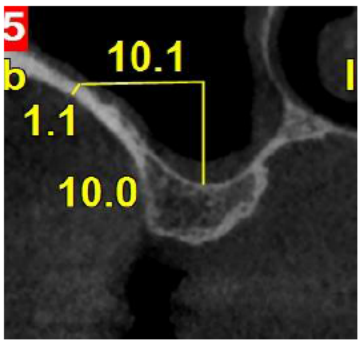

Figure 5: Measuring the lateral wall thickness at 10 mm superior to the sinus floor in CBCT cross-sectional image.

Angle formed between the lateral and medial walls (angle A): In order to measure angle A, two lines were drawn from

the lateral and medial walls toward the deepest point (most inferior point) of the sinus floor. The angle formed between these two lines was measured and categorized as less than 30°, 30-60°, and more than 60°. An angle of less than 30° indicated an increase in surgical risk (Figure 6).

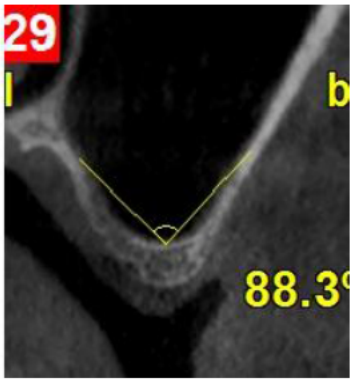

Figure 6: Measuring the angle of Mediolateral walls of the sinus in CBCT cross-sectional image.

Presence of intra-sinus septa: Vertical septa with a thickness of more than 2 mm were reported in all edentulous sites. The presence of septa was regarded as an indication of the increased surgical risk (Figure 7).

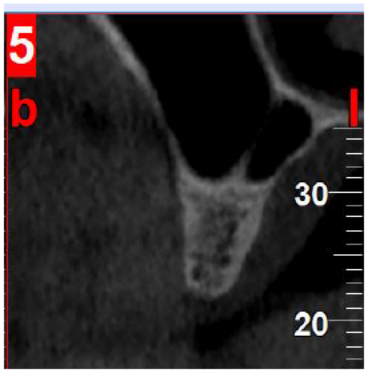

Figure 7: CBCT detection of a vertical sinus septum in the cross-sectional image.

Artery to alveolar crest distance (ACD): The artery site was specified by drawing a vertical line from the alveolar crest to the artery. Minimum ACD was indicative of high surgical risk (Figure 8).

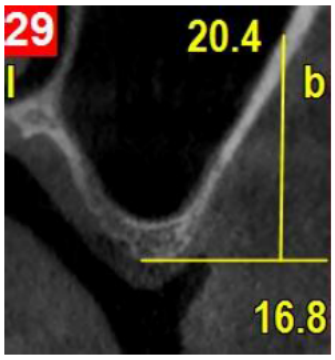

Figure 8: Measuring the artery to crest distance in CBCT cross-sectional image.

The collected data were analyzed using t-test, ANOVA, and Mann-Whitney tests in SPSS version 22. Data are presented as the range (maximum and minimum) and mean±standard deviation.

Results:

In this study, maxillary sinus was evaluated at 350 edentulous sites, in 183 patients in the age range of 23-78 years (mean 51.91±13.24)
Mean HR, SW, MT, FT, LWT, ACD, Angle A, differed by gender, are provided in table 1.

Study variables	Total (n=350)	Males (n=185)	Females (n=165)	P value
RH	3.229 ± 1.3270	3.158 ± 1.3910	3.308 ± 1.2509	0.283[a]
SW	10.835 ± 2.0364	10.826± 2.0696	10.845± 2.0047	0.437[a]
MT	3.897 ± 7.0084(1.1)	4.678± 7.7535(1.5)	3.022±5.9681(1)	0.003[b]
FT	0.478± 0.1917	0.512±0.2169	0.516±0.2242	0.253[a]
LWT	1.043± 0.4846	1.015±0.4943	1.075±0.4730	0.563[a]
Angle A	97.31± 20.05	95.65±21.61	99.17±18.02	0.1[a]
ACD	15.303 ± 3.8819	15.650±4.1550	14.913±3.5228	0.483[a]

Table 1- Mean value of studied items, differed by gender, in millimeters.

The provided data are mean values ± standard deviation
a: Independent t-test results
b: Mann-Whitney test results

MT was the only item that had significantly more values in males rather than females (P=0.003). In terms of other criteria, no significant difference was found between genders.

Areas / variables	Second Premolar (n=100)	First Molar (n=130)	Second Molar (n=120)	P value
RH	3.476±1.1579[a]	3.335±1.2508[a]	2.908±1.4784[b]	0.003
SW	10.035±2.0955[a]	11.099±1.9832[b]	11.217±1.8665[b]	<0.001
MT	3.793±6.2815(1.1)	4.195±7.7874(1.5)	3.662±6.7322(1.1)	0.823
FT	0.548±0.2272	0.515±0.1989	0.485±0.2332	0.107
LWT	1.056±0.4637[a]	1.172±0.5218[a]	**0.893** ±0.4168[b]	<0.001
Angle A	82.16±23.31[a]	98.74±12.07[b]	108.38±15.82[c]	<0.001
ACD	15.616±4.3622	15.132±3.8477	15.226±3.4921	0.624

Table 2- Mean values of studied items, based on different edentulous sites in millimeter.

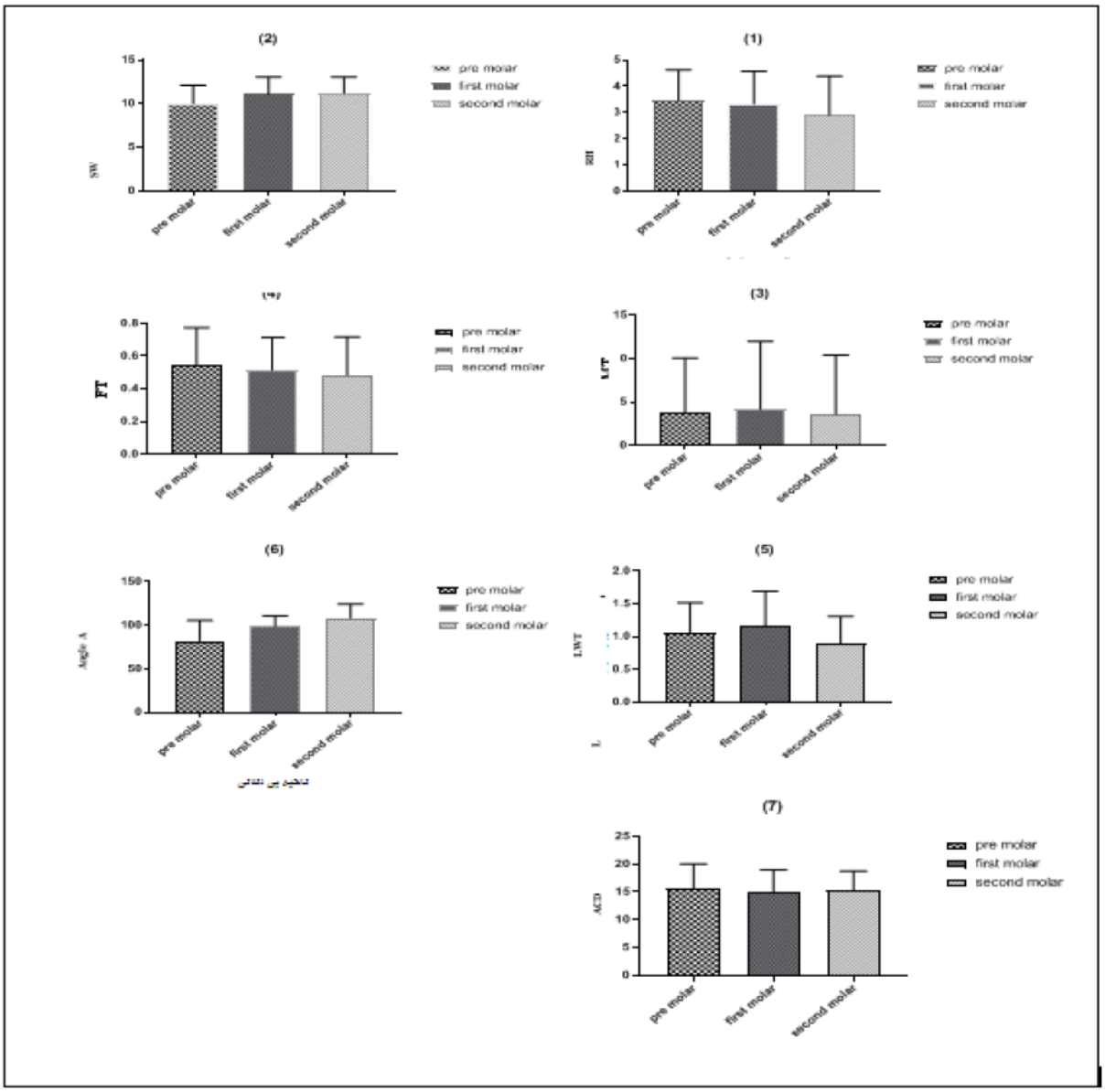

Figure 10- Mean values of studied items, based on different edentulous sites in millimeter.

Mean RRH was significantly different in 3 areas (P=0.003). Also, the height of the ridge was significantly less in the second molar area (P<0.001). Mean SW was significantly different at various sites (P<0.001), and the least value of SW was seen at the second premolar area (P<0.001). LWT was significantly different at different sites, (P<0.001) and

had significantly less value at the second molar area (P<0.001). There was a significant difference among mean values of the angle A, at various sites (P<0.001), and the most and least values were seen in second molar and second premolar areas, respectively (P<0.001). There was no significant difference in the mean values of FT, MT, and ACD in different edentulous sites. The mean values of studied variables are shown in Table 3, classified by age range groups, as over and under 40 years of age.

variable	Age group	Second premolar	First molar	Second molar	P value
RH	Under 40	3.213±1.40	3.422±1.31	2.638±1.61	0.199
	Over 40	3.589±1.02	3.306±1.23	2.950±1.46	0.005
SW	Under 40	10.327±1.66	11.584±2.02	10.687±1.28	0.020
	Over 40	9.910±2.25	10.941±1.95	11.298±1.93	<0.001
MT	Under 40	2.65±3.81(1.5)	5.58±8.47(2.1)	4.39±5.77(2.2)	0.141
	Over 40	4.28±7.05(1.2)	3.74±7.54(1.3)	3.54±6.88(0.95)	0.199
FT	Under 40	0.593±0.24	0.547±0.18	0.481±0.16	0.224
	Over 40	0.529±0.21	0.504±0.20	0.486±0.24	0.458
LWT	Under 40	0.907±0.30*	1.175±0.46	0.763±0.35	0.002
	Over 40	1.120±0.50	1.171±0.54	0.913±0.42	0.001
Angle A	Under 40	85.35±20.53*	99.09±12.8*	122.581±18.12*	<0.001
	Over 40	80.8±24.42	98.63±11.89	107.64±15.4	<0.001
ACD	Under 40	13.533±3.47	14.906±2.68*	16.506±2.40	0.007
	Over 40	16.509±4.41	15.206±4.16	15.029±3.59	0.044

Table 3- Mean values of the studied items, classified by age group at various edentulous areas in millimeter.

***Significant difference between two age groups at each edentulous site to the level of α=0.05**

The mean value of RRH was significant in over 40-year age group at different edentulous sites (P=0.005). As shown in table 3, there was a significant difference between both age groups in terms of SW, LWT, angle A, and ACD (P<0.05). There was no significant difference in FT between two age groups at various edentulous areas (P>0.05). The incidence of sagittal septa, with a height of more than 2 millimeters was 4.11%. Septa were most frequently found at the first molar area, whereas the least frequency was observed at the second molar site, and the difference was significant (P=0.023). In the current study, the incidence of obstructed sinus ostium was 19.1%. There has been a significant correlation between septum existence and the increase in MT (P=0.017). The correlation between obstruction of ostium and the increase in MT was significant (P<0.001).

Variable / Variable	**Angle A**	**ACD**	**LWT**	**FT**	**MT**	**SW**
RH	r=0.002 p=0.967	0.064 0.235	0.256* 0.00	-0.032 0.545	-0.023 0.674	0.104 0.052
SW	r=0.203* p=0.00	0.029 0.586	0.044 0.411	0.066 0.218	0.025 0.635	
MT	r= -0.119* p= 0.026	0.224* 0.00	0.021 0.699	0.279* 0.00		
FT	r= 0.057 p= 0.286	0.052 0.328	0.032 0.549			
LWT	r= -0.033 p= 0.541	-0.107* 0.046				
ACD	r= 0.072 p= 0.176					

Table 4: Table of correlation among measured variables.

Statistical analysis showed that the height of the residual ridge is correlated to LWT, (P<0.001, r=0.256). So, as the height of the ridge is increased, the LWT will be increased, as well. Also, the angle A was significantly correlated with SW. A decrease in the ACD was correlated to an increase in LWT (P=0.046, r=107). The increase in the MT is correlated with the value of the angle A. So, with a decrease in angle value, there would be more increase is the MT (P=0.026, r=0.119). There is a significant correlation between the increase in MT and FT; in case of any increase in MT, the FT would be increased, as well (P<0.001, r=0.279). The SW at the second premolar area is less than other edentulous areas, and the difference is statistically significant (P=0.005). The incident of angles lower than 60 degrees, at premolar area is significantly more excessive in comparison to other edentulous sites (p<0.001), and no significant correlation was observed with gender (P=0.08), and age group (p=0.379).

Discussion

In this study, evaluation of the correlation between surgical risks and edentulous sites revealed that the first molar teeth were exposed to the highest risk in sinus lifting surgery. There was a significant correlation between different edentulous sites and RRH, LWT, presence of vertical septa, SW, and angle A. However, no significant correlation was found between other variables. Previous studies have investigated these variables independently, while in the present study, all surgical risk factors in sinus lifting surgery were studied simultaneously, and their correlation was examined.

In our study, independent evaluation of variables showed the lowest RRH in the second molar area; which is in accordance with the study of Monje et al. [14]. Moreover, in studies of Tavelli et al. [8] and Schwarz et al. [15], reduction in RRH increased the risk of sinus membrane perforation; therefore, the second molar area may be also a very risky site. Also, minimum LWT was observed in the second molar area, which is in accordance with studies of Kiakojori et al. [16] and Khajehahmadi et al. [13] but in contrast to the study of Monje et al. [14]. It should be noted that in the present study, LWT was evaluated at a 10-mm distance from the sinus floor; also, ethnic differences might explain the observed discrepancy. Overall, an increase in LWT leads to a more time-consuming and complicated sinus lifting surgery, especially in the lateral window approach and increases the surgical risk.

In this study, the incidence of vertical septa with a height of more than 2 mm was reported to be 11.4% in second premolar, first molar, and second molar edentulous site cross-sections. However, this rate was estimated as 38% in the study of Tavelli et al. [8], 45.4% in the study of Shahidi et al. [11], and 44% in the study of Kang et al. [17]. In these studies, all types of septa were assessed in different sections. In our study, septa were found more commonly in the first molar area, which is in line with the study of Neugebauer et al. [4], indicating major surgical risks in this area.

In the present study, minimum SW was observed in the second premolar area at 5 mm superior to the deepest point of the sinus. This finding was expectable due to tooth and sinus anatomy. Other studies, including the one conducted by Zheng et al. [2], have not considered different dental sites. In our study, the lowest angle A was observed in the second premolar area, which is consistent with the findings reported by Velloso et al. [18]. Also, in accordance with the study of Wagner et al. [19], angle A was not correlated with gender or age. Moreover, based on the study by Tavelli et al. [8], an angle exceeding 60° was associated with the minimum risk of sinus membrane perforation. In the present study, the minimum risk was observed in the second molar area.

Additionally, the correlation between the risk factors was evaluated in this study. A significant association was found between ostium obstruction and increased MT, which is in accordance with studies by Shanbhag et al. [20] and Dobele et al. [3]. Furthermore, the presence of vertical septa had a significant correlation with increased MT, which is similar to the findings reported by Rancitelli et al. [21] and Schwarz et al. [15].

A significant correlation was also observed between LWT and RRH, which is similar to studies of Kiakojori et al. [16] and Monje et al. [14]. Moreover, with an increase in LWT, ACD significantly decreased. Nevertheless, this correlation has not been examined in other surveys. Besides, a significant correlation was found between SW and angle A, which was highly expected regarding bone morphology. Similarly, a significant correlation was found between the increase in MT and FT and the increase in ACD and angle A, which was not examined in other studies. Overall, based on our findings, in addition to anatomical evaluation of the surgical site, sinus morphometric measurements can have a significant effect on the treatment plan and prognosis assessment.

Conclusion

The results of this study revealed that the first molar area is exposed to the highest surgical risk during sinus lifting surgery. Therefore, in presurgical CBCT evaluations, morphometric assessment of the sinus seems to be essential, besides conventional measurements.

Acknowledgments

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