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Cone Beam Computed Tomography Evaluation of The Effect of Single Tooth Loss on Maxillary Sinus Mucosa Thickness

Tek Diş Eksikliğinin Maksiler Sinüs Mukoza Kalınlığı Üzerindeki Etkisinin Konik Işınlı Bilgisayarlı Tomografi ile Değerlendirilmesi

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ABSTRACT

Objective: The aim of this study was to evaluate maxillary sinus mucosal thickness in patients with a single missing tooth.

Material and Method: This retrospective, observational, radiographic study was performed on individuals using cone beam computer tomography who applied to Department of Oral and Maxillofacial Surgery for implantation between January 2012 and January 2019. The edentulous sides of the patients were determined as the study group and the symmetrically toothed sides of the patients were determined as the control group. Maxillary sinus mucosa thickness (MSMT) obtained at the sinus floor, medial sinus wall, and lateral sinus wall were compared between the two groups.

Results: Of the 105 patients included in the study, 51 were male and 54 were female. The ages of the patients ranged between 15 and 65 years, with a mean age of 32.92 ± 9.73 years. The MSMT of the lateral sinus wall on the toothed side were significantly higher in male patients than in female patients ($p = 0.001$ vs. $p < 0.01$, respectively). On the edentulous side, the MSMT of lateral sinus wall of men was significantly lower than that of women ($p = 0.001$ vs. $p < 0.01$).

Conclusion: Implant and bone augmentation planning at the sinus floor on the edentulous side should be considered in terms of maxillary sinus complications and implant failure. In conclusion, the absence of a single tooth as a local odontogenic factor is not a risk factor for maxillary sinus mucosal thickening.

Keywords: *Maxillary sinus mucosa thickness, Cone beam computed tomography, Tooth loss, Dental implant*

ÖZET

Giriş: Bu çalışmanın amacı tek diş eksikliği olan hastalarda maksiller sinüs mukozasının kalınlığını değerlendirmektir.

Materyal ve Metot: Bu retrospektif, gözlemsel, radyografik çalışma, Ocak 2012 ile Ocak 2019 tarihleri arasında Ağız Diş ve Çene Cerrahisi Anabilim Dalı'na implant tedavisi için başvuran bireylerden alınan konik ışınlı bilgisayarlı tomografi görüntüsü kullanılarak gerçekleştirildi. Hastaların dişsiz tarafları çalışma grubu, simetrik olarak dişli tarafları ise kontrol grubu olarak belirlendi. Sinüs tabanı, medial sinüs duvarı ve lateral sinüs duvarındaki elde edilen maksiller sinüs mukozası kalınlığı (MSMK) iki grup arasında karşılaştırıldı.

Bulgular: Çalışmaya dahil edilen 105 hastanın 51'i erkek, 54'ü kadındı. Hastaların yaşları 15 ile 65 arasında değişmekte olup ortalama yaş 32.92 ± 9.73 idi. Dişli taraftaki lateral sinüs duvarının MSMK'sı erkek hastalarda kadın hastalara göre anlamlı olarak daha yüksekti (sırasıyla $p = 0.001$ ve $p < 0.01$). Dişsiz tarafta, erkeklerin lateral sinüs duvarının MSMK'sı kadınlarınkinden anlamlı derecede düşüktü ($p = 0.001$ vs. $p < 0.01$).

Sonuç: Dişsiz tarafta sinüs tabanında implant ve kemik augmentasyonu planlaması maksiller sinüs komplikasyonları ve implant başarısızlığı açısından dikkate alınmalıdır. Sonuç olarak, lokal odontojenik bir faktör olarak tek diş eksikliği maksiller sinüs mukozal kalınlaşması için bir risk faktörü değildir.

Anahtar Kelimeler: *Maksiller sinüs mukozası kalınlığı, Konik ışınlı bilgisayarlı tomografi, Diş eksikliği, Dental implant*

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INTRODUCTION

Dental implants are currently the first treatment option for the rehabilitation of missing teeth. In implant planning, the patient's occlusion, the length of the tooth space, the condition of the soft tissues, the width, height, architecture and quality of the bone and the relationship with anatomical structures should be evaluated. In implant planning, clinicians focus on evaluating the bone width and height in the edentulous area. The condition, relationship and health of neighboring anatomical structures generally remain in the background. The health of the teeth and anatomical structures adjacent to the implant(s) will affect the success of the implant in the long term, and therefore they should be carefully evaluated during implant planning (Çakır and Karaca, 2015; Orhan et al, 2024). When planning implants in the upper jaw posterior region, the most important structure that concerns the surgical area is the maxillary sinus, when planning implants in this region, maxillary sinus lifting procedures are frequently performed in cases where the bone height is insufficient (Yamaguchi et al., 2022). Planning generally focuses on surgical techniques such as open or closed sinus lifting or the selection of graft materials to be used. However, one of the most important issues to be evaluated in sinus lifting procedures is the health of the maxillary sinus and sinus mucosa (Kim et al., 2016). In the literature, the health of the maxillary sinus mucosa is generally evaluated by mucosal thickness, and if maxillary sinus surgery is considered in the area where the implant is planned, the sinus mucosa should definitely be evaluated (Naitah et al., 2009). Patients may not have any complaints or disease history regarding the maxillary sinus, but during cone beam computer tomography (CBCT) evaluations, asymptomatic maxillary sinus pathologies are revealed and implant planning is made accordingly (Rafferty et al., 2009). Therefore, evaluation of the maxillary sinus mucosa with CBCT is critical for the success of the treatments, both during routine implant surgeries in the maxillary posterior region and in implant applications along with the repair of the maxillary sinus (Whyte and Boeddinghaus, 2019). Although the success of implantation and sinus lifting procedures performed in sinuses with pathological mucosal thickening has not been demonstrated in the literature, pathological changes noticed during implant planning are important in warning the patient about the risk of treatment failure (Amid et al., 2021).

The maxillary sinus (MS) develops during the 12th week of intrauterine life from the embryonic infundibulum of the middle meatus, between the concha nasalis media and the concha nasalis inferior. Sinus development is a highly active process. The volume of the sinus cavity can vary from 3 cm3 to 12 cm3 (Vereanu et al., 2015). The MS, the largest of all paranasal sinuses, is shaped like a pyramid, approximately 2.5-cm wide, 3.75-cm high, and 3-cm deep in adults (Pjetursson and Lang, 2014). The MS mucosa is covered with pseudostratified columnar ciliated epithelium and continues with the nasal cavity mucosa. The MS mucosa is an adherent to the underlying periosteum, and this mucoperiosteum is called the Schneiderian membrane (Whyte and Boeddinghaus, 2019). There is no consensus on the healthy maxillary sinus mucosal thickness (MSMT). Mucosal thickening is a common finding in asymptomatic patients, and mucosal changes up to 4 mm in these individuals are not considered pathological (Rancitelli et al., 2015). According to another view, healthy MSMT is between 0 and 2 mm, and mucosal thickening >2 mm is considered pathological (Capelli and Gatti, 2016). MSMT decreases as one moves from anterior to posterior (Kalyvas et al., 2018). Mucosal thickening is a general defense response to the inflammatory process resulting in hypertrophy of MS epithelial cells. This process can be triggered by many factors, such as odontogenic infection, paranasal sinusitis, chronic or acute rhinosinusitis, chemicals, allergies, and bronchial asthma (Arias-Irimia et al., 2010). Inflammation of MS mucosa (MSM) caused by various predisposing factors, including upper respiratory tract infections, immunodeficiency, asthma, inhalation of foreign bodies and irritants, increases the risk of developing maxillary sinusitis (Haskison et al., 2012). Pathologies such as pseudocyst, retention cysts, and mucoceles may also be the cause of MSM thickening (Penarrocha- Oltra et al., 2022).

Because the maxillary posterior teeth are closely associated with the MS, MSM thickening can also be seen due to odontogenic causes. In asymptomatic patients, MSM thickening may be seen on cone beam computed tomography (CBCT) scans taken during dental diagnosis and/or treatment planning. It is not possible to diagnose whether this thickening is directly due to inflammation and/or infection of odontogenic origin or whether it is caused by sinusitis that developed due to odontogenic origin. The presence of MSM thickening and the identification of odontogenic causes of this thickening are important. Periapical inflammatory diseases, advanced periodontitis, oroantral openings/fistulas, and surgical procedures are the risk factors for MSM thickening. MSM thickening caused by odontogenic factors is usually asymptomatic, and therefore MS should be evaluated, particularly when planning surgical procedures and dental treatments associated with MS (Whyte and Boeddinghaus 2019).

CBCT is the best and most accurate imaging method for three-dimensional evaluation and planning prior to implant and augmentation procedures. Compared to conventional imaging techniques, CBCT provides superior diagnostic accuracy regarding MS

morphology and mucosal structure. MS pathologies can adversely affect the success of MS-related surgeries. During the planning of augmentations involving MS, in addition to bone height and width, MSM should also be examined with CBCT (Çınarsoy Ciğerim et al, 2023; Tavelli et al, 2017). We suggest that tooth loss is one of the factors that may affect MS and MSMT. In the literature, there is no study evaluating MSM thickening in patients with a single missing tooth. The aim of this study was to evaluate maxillary sinus mucosal thickness in patients with a single missing tooth.

MATERIAL and METHOD

This retrospective, observational, radiographic measurement study was conducted between January 2012 and January 2019 on people using CBCT who applied to Van Yüzüncü Yıl University Faculty of Dentistry, Department of Oral and Maxillofacial Surgery for implantation. CBCT images were obtained for implant planning and evaluation. Approval for the study was obtained from Van Yüzüncü Yıl University Rectorate Non-Interventional Clinical Research Ethics Committee (Decision no: 2019/02-04).

Individuals aged ≥18 years, who are ASA1 healthy according to ASA classification and who have unilateral single tooth loss associated with the MS with a minimum of one year and a maximum of 2 years since tooth extraction and who had simple tooth extraction were included in the study. Individuals who smoked, those with skeletal asymmetry, those who underwent MS surgery, those with teeth with periodontal and periapical problems on the toothed and edentulous side, those with pathology of the oral region were excluded from the study. In addition, images with poor quality, inadequate visualization of bone margins, or artifacts were excluded. The sample size was calculated using the G*Power program (version 3.1.7), and it was determined that a minimum of 105 patients should be included in the study (power accepted as 95%; effect size as 0.5).

CBCT images of the patients were obtained using KaVo 3D eXam (Biberach, Germany) tomography device. The parameters of the images were 120 kVp, 5 mA, 0.2–0.4 mm voxels, 120 kVp, 5 mA, 16×4 and 16×8 cm field of view to include the maxillary anatomy. CBCT images were captured by the same technician. The eXamVision software (KaVo Dental GmbH, Biberach, Germany) was used for image analysis. All measurements were performed by an oral and maxillofacial radiologist at two different times, and investigator reliability was calculated as p = 0.902. The CBCT images were analyzed in coronal, sagittal, and axial sections. The MSM thicknesses were measured on the both edentulous and symmetrically toothed sides in the sinus floor, medial sinus wall, and lateral sinus wall, where the thickness was the highest in coronal view (Figure 1-2).

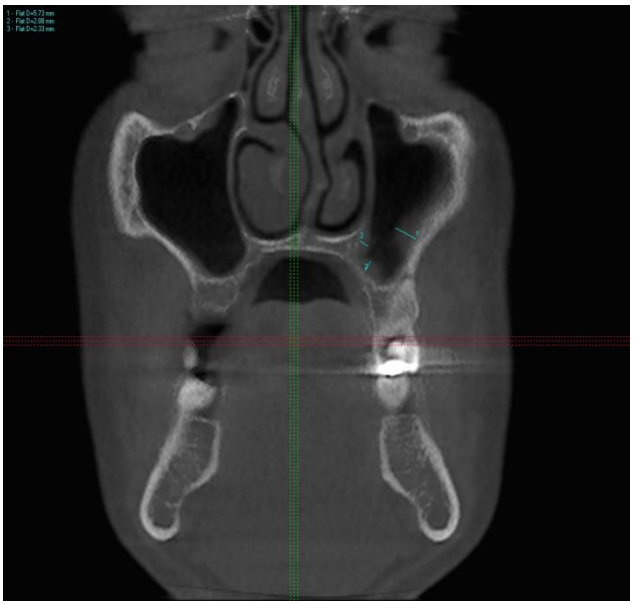

Figure 1. The maxillary sinus mucosal thickness measurements (MSMT) at the lateral wall of MS (1), MSMT at the base of the MS (2), and MSMT at the medial wall of the MS in coronal view (3)

Figure 2. The maxillary sinus mucosal thickness measurements (MSMT) at the base of the MS (1), and MSMT at the medial wall of the MS in coronal view (2)

The presence of polyps in the right and left sinuses was also evaluated, and the data were recorded (Figure 3). The edentulous sides of the patients were determined as the study group and the symmetrically toothed sides of the patients were determined as the control group. The MSMT obtained at the sinus floor, medial sinus wall, and lateral sinus wall were compared between the two groups. The aim of this study was to determine whether single tooth loss is a risk factor for maxillary sinus mucosal thickening.

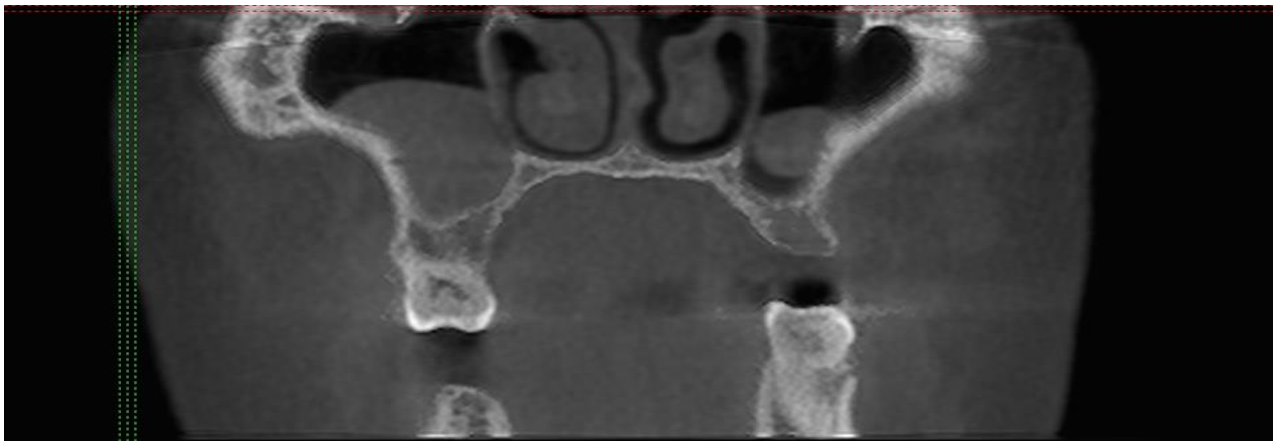

Figure 3. Polyps in the right and left maxillary sinus in coronal view.

Statistical Analysis

SPSS 26 (Statistical Package for the Social Sciences) program was used for statistical analyses. Descriptive statistical methods (mean, standard deviation, median, frequency, percentage, minimum, and maximum) were used to evaluate the study data. The conformity of the quantitative data to normal distribution was tested using Shapiro–Wilk test and graphical analyses. Mann–Whitney U test was used for comparisons of quantitative variables that did not show normal distribution between two groups. Wilcoxon signed-rank test was used for intra-group comparisons of quantitative variables that did not show normal distribution. Spearman's correlation analysis was used to evaluate the relationships between quantitative variables. Statistical significance was accepted at $p < 0.05$.

RESULTS

Of the 105 patients included in the study, 51 were male and 54 were female. The age of the patients who participated in the study ranged between 15 and 65 years, with a mean age of 32.92 ± 9.73 years. Analysis of the distribution of the tooth loss of the participants showed that 24.76% were premolars and 75.24% were molars. The distribution of patients' missing teeth according to sides was as follows: 47.62% on the right, 52% on the left, 9.52% unilaterally on the side with tooth loss, and 1.92% bilaterally with polyps on both sides (Table 1). The mean time elapsed since tooth extractions was found to be 17.34 ± 3,53 months.

Table 1. Distribution of descriptive characteristics

Age	*Mean ± standarddeviation*	32.92 ± 9.73
	(Minimum–Maximum)	(15-65)
Sex	**Male**	51 (%48.57)
	Female	54 (%51.43)
MissingToothType	**Premolar**	26 (%24.76)
	Molar	79 (%75.24)
Side of MissingTooth	**Right**	50 (%47.62)
	Left	55 (%52.38)
PolypStatus	**No**	89 (%84.76)
	Toothed Side	4 (%3.8)
	Edentulous Side	10 (%9.52)
	On bothsides	2 (%1.92)

Comparisons in Terms of MSMT at the Floor of the Maxillary Sinus

The difference between the sinus floor MSMT on the side with no tooth loss and the sinus floor MSMT value on the side with tooth loss was not statistically significant ($p > 0.05$). There was no statistical significance between the differences in the sinus floor MSMT values on the sides with and without tooth loss according to gender ($p > 0.05$). The difference between the MSMT of the sinus floor on the side with no tooth loss and the MSMT of the sinus floor on the side with tooth loss in male and female patients were not statistically significant ($p > 0.05$). The sinus floor MSMT values of male patients on the sides with and without tooth loss were significantly higher than those of female patients ($p = 0.001$ vs. $p < 0.01$, respectively) (Table 2).

Table 2. Evaluation of maxillary sinus floor, medial sinus wall, and lateral sinus wall msmt measurements according to gender and sides toothed and edentulous

		Gender			
		Male(n=51)	**Female(n=54)**	**Total(n=105)**	***p***
Toothed side sinus floor	*Mean ± SD*	2.99±4.89	1.93±4.41	2.45±4.67	[a]***0.001****
	(Minimum–Maximum)	(0.3-22.2)	(0.1-26.4)	(0.1-26.4)	
Edentulous side sinus floor	*Mean ± SD*	3.43±5.38	2.56±5.35	2.99±5.37	[a]***0.001****
	(Minimum–Maximum)	(0.3-33.7)	(0-35.4)	(0-35.4)	
	Difference	0.44±7.49	0.62±6.30	0.54±6.89	[a]***0.540***
	P	[b]***0.553***	[b]***0.059***	[b]***0.124***	
Toothed Side Medial Sinus Wall	*Mean ± SD*	1.29±1.48	0.95±2.2	1.12±1.88	[a]***0.001****
	(Minimum–Maximum)	(0.4-9.9)	(0.1-15.7)	(0.1-15.7)	
Edentulous Side Medial Sinus Wall	*Mean ± SD*	1.29±1.65	1.36±2.99	1.33±2.41	[a]***0.001****
	(Minimum–Maximum)	(0.4-9.5)	(0-18)	(0-18)	
	Difference	-0.001±2.25	0.41±3.68	0.21±3.06	[a]***0.198***
	P	[b]***0.723***	[b]***0.064***	[b]***0.372***	
Toothed Side Lateral Sinus Wall	*Mean ± SD*	1.34±1.48	1.19±2.3	1.26±1.93	[a]***0.001****
	(Minimum–Maximum)	(0.4-9.6)	(0.1-15.7)	(0.1-15.7)	
Edentulous Side Sinus Lateral Wall	*Mean ± SD*	1.48±1.81	1.57±3.08	1.52±2.53	[a]***0.001****
	(Minimum–Maximum)	(0.5-10.1)	(0-18)	(0-18)	
	Difference	0.14±2.36	0.38±3.64	0.26±3.07	[a]***0.406***
	P	[b]***0.946***	[b]***0.216***	[b]***0.394***	

[a]*Mann–Whitney U Test* [b]*WilcoxonSigned-Rank Test* ***p < 0.01*

Comparisons in Terms of MSMT in the Medial Wall of the Maxillary Sinus

The difference between the MSMT of the medial sinus wall on the side with no tooth loss and the MSMT of the medial sinus wall on the side with tooth loss was not statistically significant ($p > 0.05$). The differences in the MSMT of the medial sinus wall on the sides with and without tooth loss according to gender ($p > 0.05$) were not statistically significant. The difference between the MSMT of the medial sinus wall on the side with no tooth loss and the MSMT of the medial sinus wall on the side with tooth loss was not significant ($p > 0.05$). The difference between the MSMT of the medial sinus wall on the side with no tooth loss and the MSMT of the medial sinus wall on the side with tooth loss was not significant ($p > 0.05$). The MSMT of the medial sinus wall on the side with no tooth loss in male patients were significantly higher than those of female patients ($p = 0.001$ vs. $p < 0.01$). The medial sinus wall values of male patients on the edentulous side were significantly lower than that of females ($p = 0.001$ vs. $p < 0.01$) (Table 2).

Comparisons in Terms of MSMT in the Lateral Wall of the Maxillary Sinus

The difference between the MSMT of the lateral sinus wall on the side with no tooth loss and the medial sinus wall on the side with tooth loss was not significant ($p > 0.05$). There was no significance between the differences in the MSMT of the lateral sinus wall on the sides with and without tooth loss according to gender ($p > 0.05$). The difference between the MSMT of the lateral sinus wall on the side with no tooth loss and the MSMT of the medial sinus wall on the side with tooth loss was not significant ($p > 0.05$). The difference between the MSMT of the lateral sinus wall on the side with no tooth loss and the MSMT of the medial sinus wall on the side with tooth loss was not significant ($p > 0.05$). The MSMT of the lateral wall of the sinus on the side with no tooth loss were significantly higher in male patients than in female patients ($p = 0.001$ vs. $p < 0.01$). The MSMT of the lateral sinus wall on the side with tooth loss were significantly lower in male patients than in female patients ($p = 0.001$ vs. $p < 0.01$) (Table 2).

DISCUSSION

The mean MSMT has been reported to range between 0.3 and 0.8 mm in ten unfixed fresh cadavers without signs of sinusitis (Kotas ve ark., 2023). Pommer et al. (2009) found the mean MSMT to be 0.09 ± 0.05 mm in a similar study using 20 fresh cadavers. In a study analyzing sinus biopsies from healthy individuals, Aimetti et al. (2008) measured a mean thickness of 0.97 ± 0.36 mm. As seen from the studies, the value of healthy MSMT varies. The clinical symptoms that may occur in MS thickening are controversial. There appears to be no consensus on the value of mucosal thickness that is considered pathologic. Literature review showed that the majority of studies have accepted a MSMT ≥2 mm as pathologic (Janner et al., 2011; Goller-Bulut et al., 2015). In this study, we accepted a MSMT ≥2 mm as pathologic. Further, the MSMT at the base of MS on the sides with and without tooth loss were >2 mm. The MSMT of the lateral and medial wall of the MS were <2 mm.

In the study conducted by Aksoy and Orhan (2019), which is among the few studies investigating the relationship between tooth loss and MSM thickening, the MSMT in MS with posterior tooth loss were significantly higher than the MSMT in MS without tooth loss, and the MSMT in MS with posterior tooth loss were more likely to be ≥2 mm.

In the study by Block and Dastoury (2014), it was showed that extraction of unhealthy teeth reduced sinus membrane thickening but did not completely eliminate it. This may be one of the reasons for the high prevalence of MSM thickening in maxillae with tooth loss. Apart from odontogenic factors, there are many other causes that predispose to sinus membrane inflammation such as upper respiratory tract infection, allergy, asthma, smoking, diabetes mellitus, history of previous trauma, some sportive activities (swimming and diving), anatomical variations, and nasal polyps (Whyte and Boeddinghaus, 2019). These factors should be considered along with tooth loss when evaluating MSM thickening. In this study, while investigating the effect of tooth loss on MSMT, we excluded possible factors that may affect MSMT, especially smoking. Kuligowski et al. (2021) reported that the mucosal thickening of MS in the area with tooth loss was higher than that on the side with healthy teeth. In this study, contrary to the studies conducted by Aksoy and Orhan (2019), Block and Dastoury (2014), and Kuligowski et al (2021) the MSMT of the sides with and without tooth loss were similar. One of the reasons for this difference could be that the pre-extraction periapical health status of the teeth extracted in this study is different from the periapical health status of the extracted teeth in the mentioned studies. Another reason is that the time elapsed after extraction may affect the MSMT, and this factor has been ignored in the mentioned studies. In the above studies, the higher rate of MSMT in the areas with tooth loss suggests that MSMT, which probably originated from an odontogenic source before tooth extraction, continues after extraction. However, the fact that the systemic conditions of the patients and factors directly affecting MSMT such as smoking were not eliminated in the mentioned studies may be another reason for the differences. These differences make it difficult to compare results.

Mahasneh et al. (2022) and Raghav et al. (2014) showed no difference in MSM thickening between male and female patients. On the other hand, Hsiao et al. (2019), Munakata et al. (2021), Dursun et al. (2019), and Aksoy and Orhan (2019) reported that MSM thickening was higher and more common in males. The authors reported that this difference in the direction of increase in MSMT in males may be related to environmental factors such as smoking and occupation. In our study, the MSMT of the sinus floor on the sides with and without tooth loss in males were higher than those of females. Although we excluded smokers in this study, it was possible that male and female individuals were exposed to different environmental influences. The limitation of this study was that the male and female patients included have different occupational and environmental conditions.

In conclusion, when single tooth loss was evaluated as a local odontogenic factor, it was not found to be a risk factor alone for MSMT. However, because MSMT is >2 mm at the base of the sinus on the side with tooth loss, it is obvious that implant and bone augmentation planning in this region should be considered carefully in terms of MS complications and implant failure. This also demonstrates the importance of obtaining a CBCT in every implant and/or MS surgery planning, even if only one tooth is missing.

Limitations

The limitations of this study include not knowing the maxillary sinus mucosa thickness of the patient before CBCT, and not knowing the perodontal health and periapical pathologies of the teeth before tooth extraction. In this study, the health status of the missing teeth at the time of extraction is not known. In addition, the thickness of the maxillary sinus on the extraction side at the time of extraction is not known. These are limitations of the study.

Conflicts of Interest

The authors declare no conflicts of interest.

Ethical Approval

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Van Yüzüncü Yıl University for Non-Interventional Clinical Research (decision no: 2019/02-04).

Author Contributions

Conceptualization, L.C. and A.G.Ö.T.; methodology, L.C., A.G.Ö.T. and A.K.; software, A.G.Ö.T and A.K.; validation, L.C., A.G.Ö.T. and

A.K.; formal analysis, L.C. and A.G.Ö.T.; investigation, L.C. and A.G.Ö.T.; resources, L.C and A.G.Ö.T.; data curation, L.C, A.G.Ö.T. and A.K.; writing—original draft preparation, L.C. and A.G.Ö.T.; writing—review and editing, L.C. and A.G.Ö.T.; visualization, L.C. and A.G.Ö.T..; supervision, L.C.; project administration, L.C. All authors have read and agreed to the published version of the manuscript

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