An Investigation of the Relationship Between Schneiderian Membrane Thickness and Sinus Floor Cortication through Cone-beam Computed Tomography

Schneiderian Membran Kalınlığı ile Sinüs Taban Kortikasyonu Arasındaki İlişkinin Konik Işınlı Bilgisayarlı Tomografi ile İncelenmesi

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Abstract

Aim: In this study, we aimed to investigate the relationship between sinus floor cortication (SFC) and Schneiderian membrane thickness (SMT) through cone-beam computed tomography (CBCT) images.

Materials and Methods: A total of 292 maxillary sinuses of 146 patients (61 males, 85 females) who underwent a CBCT scan for dental implant treatment were evaluated. SFC was classified as follows: type-1: sinus floor exhibiting similar or higher density than the surrounding cortical areas, type-2: sinus floor exhibiting lower density than the surrounding cortical areas, type-3: sinus floor exhibiting no cortical bone, and type-4: sinus floor exhibiting fusion of sinus floor bone and native crestal bone. We also investigated the relationship between the SFC types and SMTs measured from the highest border of the membrane to the sinus floor on cross-sectional images.

Results: Type-1, type-2, type-3, and type-4 SFC were seen in 114, 102, 48, and 28 cases, respectively. The Schneiderian membrane was found to be thinner in type-1 SFC than in type-2 SFC. No significant difference was found between type-3 and type-4 SFC in terms of SMT.

Discussion and Conclusion: Evaluation of SFC and SMT using CBCT can provide information about implant stability and survival in treatment after sinus grafting. Although type-1 SFC is favorable for implant placement, it may also be associated with an increased risk of membrane perforation.

Keywords: cone-beam computed tomography; cortication; dental implantation; Schneiderian membrane; sinus floor augmentation

Öz

Amaç: Bu çalışmada sinüs tabanı kortikasyonu (STK) ve Schneiderian membran kalınlığı (SMK) arasındaki ilişkiyi konik ışınlı bilgisayarlı tomografi (KIBT) görüntüleri üzerinden incelemek amaçlanmıştır.

Gereç ve Yöntemler: Dental implant tedavisi için KIBT çektirmiş 146 hastaya ait (61 erkek, 85 kadın) toplam 292 maksiller sinüs değerlendirildi. STK şu şekilde sınıflandırıldı: tip 1: çevre kortikal alanla benzer ya da daha yüksek dansite gösteren sinüs tabanı, tip 2: çevre kortikal alandan daha düşük dansite gösteren sinüs tabanı, tip 3: kortikal kemik içermeyen sinüs tabanı, tip 4: krestal kemikle kaynaşmış sinüs tabanı. Kesitsel görüntülerde membranın en üst noktası ile tabanı arasında ölçülen SMK ile STK tipleri arasındaki ilişki de incelendi.

Bulgular: Tip 1, tip 2, tip 3 ve tip 4 STK sırasıyla 114, 102, 48 ve 28 vakada görüldü. Schneiderian membran tip 1 STK'de tip 2 STK'ye kıyasla daha ince bulundu. Tip 3 STK ile tip 4 STK arasında SMK açısından anlamlı fark görülmedi.

Tartışma ve Sonuç: STK ve SMK'nin KIBT ile değerlendirilmesi sinüs greftleme sonrası tedavide implant stabilitesi ve sağkalımı hakkında bilgi sağlayabilir. Tip 1 STK, implant yerleştirme için elverişli iken, daha yüksek bir membran perforasyonu riski ile ilişkili olabilir.

Anahtar Sözcükler: dental implantasyon; konik ışınlı bilgisayarlı tomografi; kortikasyon; Schneiderian membran; sinüs taban ogmentasyonu

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INTRODUCTION

The maxillary sinus is a large pyramidal cavity surrounded by the orbital, alveolar, facial, and infratemporal parts of the maxilla. The dimension, form, size, and wall density of the maxillary antrum vary among individuals and even from one site to another in the same subject (1). The bone volume in the posterior the maxilla is often inadequate for implant placement due to alveolar atrophy and sinus pneumatization. However, the height of the alveolar process can be increased by sinus augmentation procedures (SAPs) (2,3).

The maxillary SAP is a safe procedure associated with reduced complication incidences and implant survival rates up to 92% (4–6). The outcome of the procedure depends on various anatomic factors, including the sinus width and membrane thickness, amount of residual crestal bone, and angle between the medial and lateral walls (7).

The Schneiderian membrane covers all internal walls of the maxillary sinus and contains multilayered cylindrical epithelium with a thickness of approximately 1 mm (8). Its perforation may affect the physiological functions of the sinus, leading to postsurgical sinusitis, including sinus congestion compromising the graft prognosis and implant survival (9–11). Higher perforation rates have been reported in thicker (≥3 mm) and thinner (≤0,5mm) membranes (12).

Primary implant stability with the surrounding bone is a necessary condition for implant osseointegration after SAPs (13). The amount of residual alveolar bone and cortical stability have been reported to be effective on both primer stability and final implant performance (7). Efficacy of maxillary sinus floor cortication has been investigated in the literature (13,14). Cortication level of the sinus floor can help determine if the implant can be placed at the same time, with or without SAP (7).

Cone-beam computed tomography (CBCT) is the current method of choice to assess the quality and amount of the alveolar bone before implant placement. CBCT has proven to be a useful tool in evaluating the anatomical and pathological structures of the maxillofacial field, with its advantages of good image quality with high resolution and delivering remarkably low radiation doses (15).

In this study, we aimed to investigate the relationship between the sinus floor cortication (SFC) types and Schneiderian membrane thickness (SMT) by using CBCT images. Although there have been studies evaluating SFC and SMT separately, to our knowledge, no study has assessed the relation between SFC and SMT by using CBCT.

MATERIALS AND METHODS

Case selection

The study protocol was approved by the Ethics Committee of the Faculty of Dentistry, Bolu Abant İzzet Baysal University (2017/40). Preoperative CBCT scans of 146 dental implant patients (61 males, 85 females; age range: 21–70 years) were evaluated retrospectively; volumes were selected from the radiology archive at the Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Bolu Abant İzzet Baysal University. The scans were collected from January 2015 to December 2017.

Patients with a history of maxillary sinus surgery, smoking, dental implant treatment in the posterior maxilla, and antral cysts and/or other sinus pathologies were excluded.

CBCT evaluation

The CBCT images were obtained using the I-CAT 3D Imaging System (Imaging Sciences International, Hatfield, PA, USA) with the following parameters: 5 mA,120 kVp, 16 x 9-12 FOV, and 0.3 mm voxel size.

A total of 292 maxillary sinuses were evaluated by a maxillofacial radiologist with an experience of seven years. Image analyses were performed using the I-CAT Vision software (Imaging Science International), which provides coronal, sagittal, and cross sectional views of 0.3 mm slice thickness.

Data analysis

The SFC assessment and categorization were made according to the classification proposed by Choucroun et al. (7) (Table 1 and Figure 1). For SMT measurement, the CBCT images were first reformatted to place the posterior maxillary region (from the first premolar to the second molar) of the alveolar bone crest in a vertical position in axial views, and the hard palate/floor of the nasal cavity in a horizontal position in coronal views. Then, measurements were performed on the

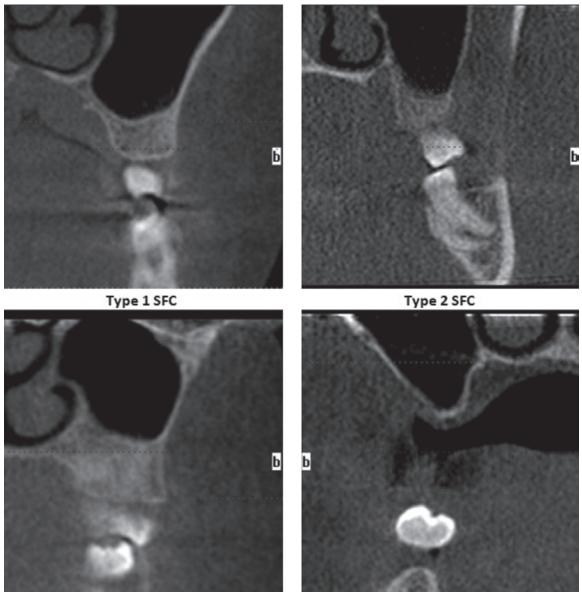

Figure 1. SFC classification

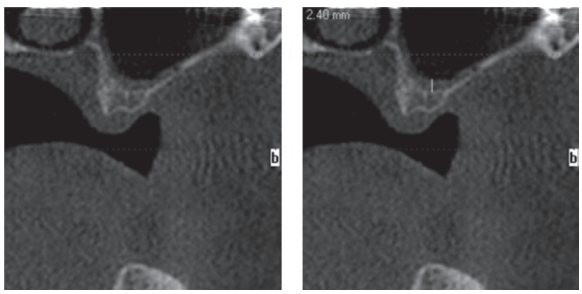

Figure 2. SMT measurement

thickest part of the Schneiderian membrane, from the floor of the sinus to the superior aspect of the membrane. In the literature, a SMT of 1 to 2 mm is considered healthy (16–18) (Figure 2).

For intraobserver reliability assessment, 15 CBCT images (30 maxillary sinuses) were randomly selected and re-evaluated after four weeks.

Statistical analysis

Statistical analysis was performed using the SPSS v. 18 (SPSS Inc., Chicago, IL) software. Descriptive statistics were performed. The independent samples t-test was used to determine the relationship between membrane thickness and sex. The difference of cortication types based on age and sex was assessed by the Fisher–Freeman–Halton test and the comparison of cortication type and sex according to age and SMT was made using ANOVA test. The Kappa test was used to determine intraobserver reliability.

RESULTS

Based on the repeated assessment of 30 maxillary sinuses separated by a 4-week interval, the Kappa test showed perfect intraobserver agreement (κ= 0.84).

The SMTs ranged from 0 to 8 mm, with a mean thickness of 0.991 mm. The mean SMT was found to be thicker in males (1.20 mm) than in females (0.782 mm) ($p<0.05$). No statistically significant relation was found between age and SMT ($r=0.069$, $p=0.239$).

In our study, a SMT >2 mm was considered pathological, and we found that 63 (21.6%) of the 292 maxillary sinuses fell into this category. Of the 63 pathological membranes, 33 (52.4%) were in males and 30 (47.6%) in females. The mean age of the patients who had a pathological SMT was 28.21 years.

Table 2 shows the relationship between SFC types, age, and SMT. SMT was significantly less in type-1 SFC than in type-2 SFC, but there was no significant difference between the other types. In addition, the mean patient age was significantly lower in type-1, type-2, and type-3 SFC than in type-4 SFC, but no significant difference was found between type-1, type-2, type-3 SFC and age. Type-1, type-2, type-3, and type-4 SFC were seen in 114, 102, 48, and 28 cases, respectively.

The distribution of SFC types by sex is shown in Table 3. Type-1 and type-4 SFC were significantly more common in females and males, respectively. Type-2 and type-3 SFC were almost equally distributed between males and females.

DISCUSSION AND CONCLUSION

The condition of the Schneiderian membrane has been shown to be an important factor affecting the sinus perforation risk during surgical procedures (19). There have been studies reporting diverse SMT results due to local and technique-related factors, such as presence of maxillary sinus disease, allergic conditions, neighboring periodontal inflammation and odontogenic infection, and use of different measurement methods. In our study, a SMT of ≤2 mm was considered healthy.

Rapani et al. reported a high perforation risk in patients with a SMT <1 mm (20). In our study, the mean female SMT (0.782 mm) was found to be significantly less than the mean male SMT (1.2 mm), indicating a higher perforation risk in female patients.

Table 1. Classification of the SFC cross-sectional CBCT images

SFC type	Description
1	Sinus floor exhibiting similar or higher density than the surrounding cortical areas; presence of less dense bone coronal to the sinus floor
2	Sinus floor exhibiting lower density than the surrounding cortical areas; presence of less dense bone coronal to the sinus floor
3	Sinus floor exhibiting no cortical bone
4	Sinus floor exhibiting fusion of sinus floor bone and native crestal bone; no bone is present coronal to the sinus floor.

Table 2. SFC type, age, and SMT relationship

		n	Mean	Standard deviation	p
Age	Type-1 SFC	114	24.7	11.89	**0.001**
	Type-2 SFC	102	25.3	13.17	
	Type-3 SFC	48	20.1	11.26	
	Type-4 SFC	28	44.4	15.58	
SMT	Type-1 SFC	113	0.527	1.25	**0.002**
	Type-2 SFC	102	1.391	1.94	
	Type-3 SFC	48	1.008	1.73	
	Type-4 SFC	28	1.011	1.75	

One-way ANOVA test was used.

Janner et al. (19), Bornstein et al. (21), and Shahidi et al. (22) reported SMTs ranging between 0.2 and 34.6 mm, 0.25 and 13.98 mm, and 1 and 31.9 mm, respectively. In our study, we found that the SMT ranged between 0 and 8 mm. The differences between the studies may be related to etiological factors or use of different measurement methods.

Janner et al. (19) and Shahidi et al. (22) reported a pathological SMT rate of 37% and 40.3%, respectively. In our study we observed a pathological SMT in 21.57% of the study population.

Some studies reported that the SMT could vary between the two sexes, being thicker in males (23–25), and our findings were consistent with these reports as we found that the mean SMT of our male patients was significantly greater ($p<0.05$). The SMT has also been reported to change with age; Phothikhun et al. (26) found a higher rate of pathological SMT among individuals aged ≥49 years and Shahidi et al. (22) reported that the mean patient age was significantly higher in patients with pathological SMTs than in those with non-pathological SMTs (46.6±15.9 years vs 42.5±14.8 years), and that 58.3% of patients aged >60 years had a pathological SMT. However, in our study, we observed no link between age and SMT. The cortication level of the sinus floor is important for primary implant stability and osseointegration. Choucroun et al. (7) evaluated 100 CT scans and found 31 cases of type-1 SFC, 41 type-2 SFC, 18 type-3 SFC, and 10 type-4 SFC. In our study, the most frequent type was type-1 SFC (114 cases), followed by type-2 (102), type-3 (48), and type-4 (28) SFC. Type-1 SFC yields the highest primary implant stability, increasing the chances of osseointegration. Type-2, type-3, and type-4 SFC may complicate the initial implant stability, and thus require the use of various surgical approaches, such as sinus augmentation and/or delayed implant placement. However, in type 1 SFC a sufficient amount of residual crestal bone could provide bicortical implant stability without performing SAP.

In our study, type-1 SFC was more common in young and female patients, indicating a high rate of successful osseointegration and implant stability. Conversely, type-4 SFC was more common in older and male patients, suggesting a low success rate. These re-

Table 3. Distribution of SFC types by sex

		Male		Female		p
		n	%	n	%	
SFC	Type-1	36	29.5	78	45.9	0.002
	Type-2	46	37.7	56	32.9	
	Type-3	20	16.4	28	16.5	
	Type-4	20	16.4	8	4.7	
Total		122		170		

* The Fisher–Freeman–Halton test was used.

sults show that SFC type may change with age and sex.

We found that the SMT was significantly lower in type-1 SFC than in type-2 SFC, and therefore we think that although type-1 SFC yields good implant stability and osseointegration there is also a high risk of sinus membrane perforation.

Evaluations of SFC and SMT can provide information about implant stability and survival in treatment after sinus grafting. While an accurate evaluation is not possible with conventional radiography, CBCT can be helpful with a lower radiation dose compared to CT. Finally, although type-1 SFC is favorable for SAP, it should be kept in mind that it may also be associated with an increased risk of membrane perforation.

Conflict of Interest and Financial Disclosure

The authors declare that they have no conflict of interest to disclose. The authors also declare that they did not receive any financial support for the study.

REFERENCES

1. Arman C, Ergur I, Atabey A, Guvencer M, Kiray A, Korman E, et al. The thickness and the lengths of the anterior wall of adult maxilla of the West Anatolian Turkish people. Surg Radiol Anat. 2006;28(6):553–8.
2. Sharan A, Madjar D. Maxillary sinus pneumatization following extractions: a radiographic study. Int J Oral Maxillofac Implants. 2008;23(1):48–55.
3. Tan WL, Wong TL, Wong M, Lang NP. A systematic review of postextractional alveolar hard and soft tissue dimensional changes in humans. Clin Oral Implants Res. 2012;23(s5):1–21.
4. Aghaloo TL, Moy PK. Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? Int J Oral Maxillofac Implants. 2007;22(Suppl.):49–70.
5. Del Fabbro M, Testori T, Francetti L, Weinstein R. Systematic review of survival rates for implants placed in the grafted maxillary sinus. Int J Periodontics Restorative Dent. 2004;24(6):565–77.
6. Wallace SS FS. Effect of maxillary sinus augmentationon the survival of endosseous dental implants. A systematic review. Ann Periodontol. 2003;8:328–43.
7. Choucroun G, Mourlaas J, Kamar Affendi NH, Froum SJ, Cho SC. Sinus floor cortication: classification and prevalence. Clin Implant Dent Relat Res. 2017;19(1):69–73.
8. Cakur B, Sumbullu MA, Durna D. Relationship among Schneiderian membrane, Underwood's septa, and the maxillary sinus inferior border. Clin Implant Dent Relat Res. 2013;15(1):83–7.
9. Hernandez-Alfaro F, Torradeflot MM, Marti C. Prevalence and management of Schneiderian membrane perforations during sinus-lift procedures. Clin Oral Implants Res. 2008;19(1):91–8.
10. Pommer B, Unger E, Suto D, Hack N, Watzek G. Mechanical properties of the Schneiderian membrane in vitro. Clin Oral Implants Res. 2009;20(6):633–7.
11. Oh E, Kraut RA. Effect of sinus membrane perforation on dental implant integration: a retrospective study on 128 patients. Implant Dent. 2011;20(1):13–9.
12. Wen SC, Lin YH, Yang YC, Wang HL. The influence of sinus membrane thickness upon membrane perforation during transcrestal sinus lift procedure. Clin Oral Implants Res. 2015;26(10):1158–64.
13. Schatzker J, Horne JG, Sumner-Smith G. The effect of movement on the holding power of screws in bone. Clin Orthop Relat Res. 1975(111):257–62.
14. Bidez MW, Misch CE. Force transfer in implant dentistry: basic concepts and principles. J Oral Implantol. 1992;18(3):264–74.
15. White SC, Pharoah MJ. The evolution and application of dental maxillofacial imaging modalities. Dent Clin North Am. 2008;52(4):689–705.
16. Guo ZZ, Liu Y, Qin L, Song YL, Xie C, Li DH. Longitudinal response of membrane thickness and ostium patency following sinus floor elevation: a prospective cohort study. Clin Oral Implants Res. 2016;27(6):724–9.
17. Ren S, Zhao H, Liu J, Wang Q, Pan Y. Significance of maxillary sinus mucosal thickening in patients with periodontal disease. Int Dent J. 2015;65(6):303–10.
18. Insua A, Monje A, Chan HL, Zimmo N, Shaikh L, Wang HL. Accuracy of Schneiderian membrane thickness: a cone-beam computed tomography analysis with histological validation. Clin Oral Implants Res. 2016;28(6), 654–61.
19. Janner SF, Caversaccio MD, Dubach P, Sendi P, Buser D, Bornstein MM. 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(12):1446–53.
20. Rapani M, Rapani C, Ricci L. Schneider membrane thickness classification evaluated by cone-beam computed tomography and its importance in the predictability of perforation. Retrospective analysis of 200 patients. Br J Oral Maxillofac Surg. 2016;54(10):1106–10.

21. Bornstein MM, Wasmer J, Sendi P, Janner SF, Buser D, von Arx T. 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(1):51–7.
22. Shahidi S, Zamiri B, Momeni Danaei S, Salehi S, Hamedani S. Evaluation of anatomic variations in maxillary sinus with the aid of cone beam computed tomography (CBCT) in a population in south of Iran. J Dent (Shiraz). 2016;17(1):7–15.
23. Yoo JY, Pi SH, Kim YS, Jeong SN, You HK. Healing pattern of the mucous membrane after tooth extraction in the maxillary sinus. J Periodontal Implant Sci. 2011;41(1):23–9.
24. Shanbhag S, Karnik P, Shirke P, Shanbhag V. 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(6):755–60.
25. Engström H, Chamberlain D, Kiger R, Egelberg J. Radiographic evaluation of the effect of initial periodontal therapy on thickness of the maxillary sinus mucosa. J Periodontol. 1988;59(9):604–8.
26. Phothikhun S, Suphanantachat S, Chuenchompoonut V, Nisapakultorn K. Cone-beam computed tomographic evidence of the association between periodontal bone loss and mucosal thickening of the maxillary sinus. J Periodontol. 2012;83(5):557–64.