Correlation Between Gingival Phenotype and Schneiderian Membrane Thickness

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Purpose: *The most common complication during sinus graft surgery is tearing or perforation of the Schneiderian membrane. Perforations are most likely to occur if the sinus membrane is thin. Preoperative prediction of the antral membrane thickness may be of practical importance during maxillary sinus augmentation procedures. The purpose of this investigation was to analyze a possible association between gingival phenotypes and thickness of the healthy sinus mucosa.* ***Materials and Methods:*** *Twenty consecutive patients without preoperative anamnestic, clinical, or radiologic signs of maxillary sinus pathologies were enrolled in the study. During otorhinolaringologic surgical interventions, maxillary mucosal biopsy specimens were endoscopically obtained from the sinus floor, and gingival thickness was measured at the maxillary anterior teeth.* ***Results:*** *Eleven out of 20 individuals had thick gingival tissues, and the remaining 9 presented with thin gingival phenotype. The average thickness of the Schneiderian membrane was 0.97 ± 0.36 mm with a wide inter-individual variability. Thickness of the sinus mucosa amounted to 1.26 ± 0.14 mm in individuals with thick gingival architecture and 0.61 ± 0.15 mm in subjects with thin gingival tissues. The association between thickness of the antral mucosa and periodontal phenotypes was statistically significant (*P < *.0001).* ***Conclusions:*** *Gingival thickness seems to represent a reliable parameter to predict sinus membrane thickness. Further investigations are needed to support these preliminary data.* Int J Oral Maxillofac Implants 2008;23:1128–1132

Key words: *gingival phenotypes, human histology, maxillary sinus, Schneiderian membrane, sinus mucosal thickness*

Maxillary sinus augmentation offers a predictable treatment modality to increase the bone volume available for posteriorly placed oral implants.[1] During sinus lifting, the elevation of the Schneiderian membrane is a delicate procedure. This membrane constitutes an important barrier for the protection of the sinus cavity. To reduce the risk of infections and optimize clinical outcomes in term of bone regeneration, its integrity should be preserved as much as possible.[2,3] Sinus membrane perforation is the most common complication during sinus graft surgery and may occur when access to the sinus floor is through the lateral wall as well as through the ridge crest.[4–6] The crestal approach presents additional technical difficulties compared to the lateral approach, as no direct surgical undermining of the Schneiderian membrane is performed.[7] At single-implant sites it is particularly important to correlate the extension of the sinus lifting with sinus membrane deformation capacity as well as thickness.[8] Clinical observations suggest a correlation between the sinus membrane thickness and the risk of perforations.[8,9]

In the literature few data are available on the thickness of healthy sinus membranes. Previous investigations report that normal mucosa is on average 1 mm thick with a considerable variation from

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subject to subject.[9,10] Preoperative prediction of the antral membrane thickness may provide additional information for consideration in the surgical planning. Whereas it has long been suggested that the thickness of the marginal periodontium is genetically determined,[11] no knowledge is yet available concerning the sinus mucosa. Gingival phenotypes may assist the clinician in addressing the features of the Schneiderian mucosa.[12]

Therefore, the aim of this preliminary study was to investigate whether a relationship exists between gingival tissue phenotypes and antral membrane thickness.

MATERIALS AND METHODS

Twenty consecutive systemically healthy patients (9 women and 11 men), with a mean age of 43.55 ± 6.50 years (range 35 to 55 years), were included in this study. All patients were referred to the Otorhinolaringology Department (Molinette Hospital Torino) for ethmoidonasal pathologies. During enrollment, the following inclusion criteria were considered: clinically healthy gingiva, absence of bleeding of probing, no periodontal probing depth in excess of 3 mm, and presence of all maxillary anterior teeth. The exclusion criteria were[13]: *(1)* maxillary sinus pathologies (sinusitis, cysts, polypi, neoplasms, allergies) or history of sinus surgery; *(2)* any medication and systemic disease that could affect the thickness of the periodontal soft tissues (cyclosporin A, calcium channel blockers, phenytoin, diabetes, immunologic diseases); *(3)* extensive restorations or previous mucogingival or periodontal surgery in the maxillary anterior region; *(4)* periapical radiolucency on maxillary posterior teeth; *(5)* previous orthodontic treatment that could affect the thickness of the labial gingival (such as arch expansion); *(6)* smoking habits; *(7)* pregnancy or lactation. Preoperative computed tomography (CT) scans and serial periapical radiographs were obtained to confirm the absence of maxillary sinus mucosal thickening and to evaluate dental as well as periodontal conditions.[14]

All patients participating in the study signed an informed-consent form approved by the Ethics Committee of the Medical Faculty, University of Torino.

During otorhinolaryngologic surgical intervention, all patients were subjected to unilateral endoscopic examination of the maxillary sinus, sinus mucosa biopsy, and gingival thickness measurements. Under general anesthesia, after decongestion of the nasal cavity, endoscopy of the middle meatus was performed. After medialization of the inferior turbinate, a trocar was inserted via the inferior meatus into the antral cavity. Endoscopic examination was performed with a rigid endoscopic optic (30, 70, and 120 degrees, Storz, Tuttlingen, Germany) linked to a Panasonic CCD camera. Assessment of the mucosal aspect of the maxillary sinus was based on criteria proposed by Petruson[15] and modified by Westergen et al.[16] Subsequently, a biopsy specimen of the mucosal lining of the maxillary sinus floor was excised with a small forceps via the introduced cannula and immediately placed in 10% buffered formalin before sending it to the Department of Histopathology for histologic processing. All endoscopic procedures were performed by the same experienced surgeon.

Gingival thickness was assessed at the facial aspect of the maxillary central incisors, lateral incisors, and canines by the same calibrated periodontist.[12] Thickness was determined at a midbuccal location approximately 1 mm apical to the probing depth level with a 15 endodontic reamer according to the method of Paolantonio.[17] The reamer was held perpendicularly to the mucosal surface and pierced through the soft tissue with light pressure until a hard surface was felt. A new silicone disk stop was placed in tight contact with the soft tissue surface and fixed by a drop of cyanoacrylate adhesive. Measurements were recorded by means of a caliper. Gingival phenotypes were evaluated on the basis of gingival thickness as previously reported by Müller et al.[18] They described a thin gingival phenotype characterized by gingival thickness < 1 mm and a flat-thick gingival morphotype with gingival tissues > 1 mm.

Histologic Evaluation

The processing and the histologic measurements were performed by a calibrated, blinded examiner. Samples were fixed in 4% buffered formalin for 24 hours, dehydrated using ascending grades of alcohol (80%, 95%, 100%) and xylol, and embedded in paraffin. Four to 7 serial sections, 2 µm thick, were made for each tissue specimen. The sections were treated with xylol and a series of decreasing concentrations of alcohol (100%, 95%, 80%), immersed in distilled water, stained in hematoxylin-eosin, and observed under a light microscope (Leica, Wetzlar, Germany) to assess morphologic aspects as well as determine the sinus membrane thickness.[19] Maxillary mucosal biopsy specimens were evaluated at a magnification of 100×. The sinus membrane thickness was measured in microns using a micrometric ocular, with 10 × 10-µm squares. All sections of each biopsy specimen were analyzed. The highest and lowest values obtained per tissue specimen were used for data analysis.

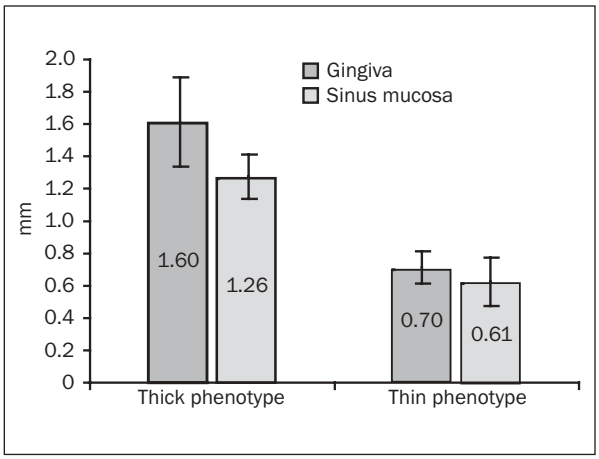

Fig 1 Sinus mucosal thickness in relation to gingival phenotypes. Data are reported as mean ± SD.

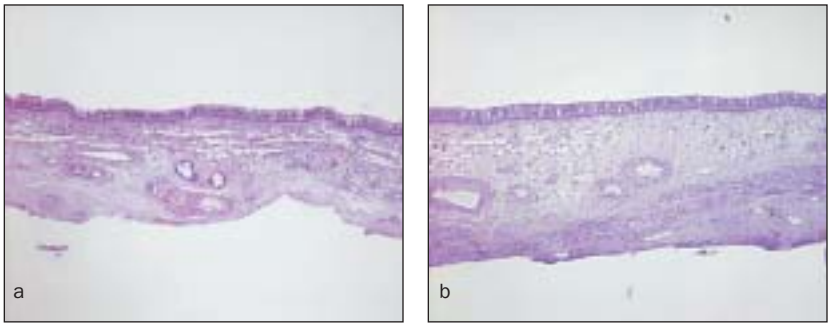

Fig 2 Light microscope images of the Schneiderian membrane thickness (original magnification × 100) in an individual with thin gingival phenotype *(a)* and an individual with thick gingival phenotype *(b)*.

Statistical analysis was expressed using mean values and standard deviations for each parameter. Pearson's correlation coefficient was calculated to examine the relationship between gingival phenotype and sinus membrane thickness. The power calculation was performed to determine the proper sample size. *P* values less than .05 were considered significant.

RESULTS

Gingival thickness was, on average, 1.19 ± 0.50 mm. Considerable intra-individual as well as inter-individual variations were observed. Buccal gingiva was thinnest at canines, with mean values of 1.07 ± 0.45 mm, and increased at central incisors to 1.30 ± 0.57 mm. Comparable thickness was found in the central and lateral incisor regions.

Subjects' means varied between 0.61 ± 0.11 mm and 2.09 ± 0.17 mm. Nine individuals presented thin gingival tissues with mean values of 0.70 ± 0.10 mm (range 0.61 to 0.85 mm), and the remaining 11 subjects had considerably thicker gingiva (mean 1.60 ± 0.27 mm, range 1.16 to 2.09 mm).

Endoscopic evaluation in all patients showed a normal mucosa without any sign of discharge or swelling (grade 0, endoscopic score). Histologic examination revealed a normal ciliated respiratory epithelium with a few mucus-producing goblet cells. In all tissue specimens the epithelium was made up of 2 cell layers and no inflammatory cells were present. The underlying connective tissue had a loose aspect and differed in thickness from subject to subject. In all patients a mild chronic inflammatory infiltrate (mostly lymphocytes and plasma cells) was observed. No eosinophilic granulocytes were detected.

The average thickness of the Schneiderian membrane was 0.97 ± 0.36 mm. A wide variability was observed among individuals. The mean sinus mucosal thickness ranged between 0.45 ± 0.07 mm and 1.40 ± 0.14 mm. By contrast, slight differences were assessed intra-individually. The differences between the highest and lowest per-subject values varied between 0 and 0.3 mm. Only 2 individuals had differences of 0.4 or 0.5 mm.

The sinus mucosal thickness was positively associated with gingival phenotype. The correlation was highly significant and provided 99.5% power with $\alpha = .05$ ($r = 0.801$, $P < .0001$, Fig 1). The thickness of the Scheinederian membrane was 1.26 ± 0.14 mm (range 0.95 to 1.40 mm) in individuals with thick gingival architecture and 0.61 ± 0.15 mm (range 0.45 to 0.85 mm) in subjects with thin gingival tissues (Figs 2a and 2b).

DISCUSSION

The results of this study suggest that there is a positive correlation between sinus mucosal thickness and gingival phenotypes. Great care was taken in selecting the study population to avoid confounding factors. All individuals enrolled in the study did not have any sinus pathologies or periapical infections on the maxillary posterior teeth, as this could influence the Schneiderian membrane thickness. The presence of a clearly depicted and continuous lamina dura at the apical third of maxillary premolar and molar roots was considered essential for enrollment.[20] In addition, to ensure reliability in measuring labial gingival thickness, patients were required to have healthy gingiva with no previous periodontal surgery at the maxillary anterior teeth. Patients who had previous orthodontic treatments that could affect gingival thickness in the maxillary anterior region were also excluded. Characteristics of gingival phenotypes were defined by the conditions observed in the maxillary anterior region as described by Müller and Eger.[12] They reported a thin phenotype characterized by scalloped and thin (0.6 to 0.8 mm) facial gingiva at the maxillary incisors and canines, and a thick phenotype with flat gingival tissues more than 1 mm thick associated with a square form of teeth.[18] It has been demonstrated that periodontal phenotypes influence the thickness of the masticatory mucosa in other parts of the dentition.[19] Thus, they affect gingival thickness at the maxillary posterior teeth as well.[18]

In the present study, gingival thickness was evaluated using the method previously described by Paolantonio.[17] Müller et al reported a correlation coefficient of 0.92 between measurements performed with an ultrasonic device and those recorded using endodontic reamers.[21]

The literature provides sporadic information concerning the thickness of the normal antral mucosa. Histologic data report an average thickness of 1 mm.[9,22] A mean thickness of 0.97 ± 0.36 mm with wide inter-individual variability (range 0.45 to 1.40 mm) was observed in the present study. The thickness of the healthy Schneiderian membrane was found to be higher in individuals with thick gingival architecture (1.26 ± 0.14 mm) compared to subjects with thin gingival tissues (0.61 ± 0.15 mm). The correlation between the 2 parameters was statistically significant.

Variations in the sinus mucosal thickness were due to the connective tissue layer. In all 20 patients the epithelial lining comprised 2 cell layers and was uniformly thick. This finding is in agreement with the morphologic pattern of masticatory mucosa. It has been shown that the epithelium of the vestibular gingiva is about 0.3 mm thick.[23] Therefore, periodontal phenotypes rely especially on the thickness of the lamina propria.

It is important to emphasize that individuals with healthy maxillary sinuses were selected for this study. However, the definition of a healthy maxillary sinus varies in many studies. The definition is typically based on the anamnestic absence of pathology and the absence of radiographic or endoscopic signs of pathology. In the present investigation, histologic examination of the sinus mucosa was added to the clinical, radiographic, and endoscopic criteria. All tissue specimens displayed the presence of few inflammatory cells in the connective tissue, while no inflammatory infiltrate was observed in the epithelial layer. Inflammatory cells were mainly plasma cells and lymphocytes. No eosinophilic granulocytes were observed; thus, allergic sinusitis could be ruled out.[24] This slight inflammatory reaction should be interpreted as a normal physiologic activity of the mucosal airway defense system.[25] Recent studies have reported that the healthy maxillary sinus is not sterile.[26]

In the present study the sinus mucosal thickness was assessed on formalin-fixed sections. It is known that tissue fixation leads to cell shrinkage, which may decrease the reliability of the measurements of tissue thickness. Previous histologic investigations demonstrated that tissue shrinkage following formalin fixation is minimal (about 4%).[27,28] Therefore, it appears these alterations have a minimal impact on the calculation of the antral membrane thickness.

In spite of the small number of patients, our findings may be clinically relevant. Maxillary sinus membrane perforation is the most common complication that occurs with sinus augmentation.[6,29,30] Lacerations are most likely to occur when the sinus membrane is thin.[8,9] The wide variability in the sinus mucosal thickness observed in the present investigation would seem to suggest an inter-individual change in the risk of perforations. Although every sinus mucosa should be treated delicately to avoid membrane tears, the prediction of maxillary sinus mucosal thickness may have practical implications for this type of surgery. During preoperative planning it may provide information on both technical difficulties of sinus surgery and resilience properties of the Schneiderian membrane.[8] This may be relevant during maxillary sinus elevation procedures through a lateral window as well as via a crestal access. If the sinus mucosa is thin, the skill of the operator is more important to the clinical outcome. During membrane elevation, as well as condensing of the grafting material, every attempt should be made to adjust the pressure applied to the sinus mucosa to safeguard against membrane perforation. Further investigations are needed to confirm these preliminary data.

REFERENCES

1. Del Fabbro M, Testori T, Francetti L, Weinstein R. Systematic review of survival rates for implants placed in grafted maxillary sinus. Int J Periodontics Restorative Dent 2004;24: 565–577.
2. Wiltfang J, Schultze-Mosgau S, Merten HA, Kessler P, Ludwig A, Engelke W. Endoscopic and ultrasonographic evaluation of the maxillary sinus after combined sinus floor augmentation and implant insertion. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;89:288–291.
3. Proussaefs P, Lozada J, Kim J, Rohrer MD. Repair of the perforated sinus membrane with a resorbable collagen membrane: A human study. Int J Oral Maxillofac Implants 2004;19:413–420.
4. Reiser GM, Rabinovitz Z, Bruno J, Damoulis PD, Griffin TJ. Evaluation of maxillary sinus membrane response following the elevation with the crestal osteotome technique in human cadavers. Int J Oral Maxillofac Implants 2001;16:833–840.
5. Schwartz-Arad D, Herzberg R, Dolev E. The prevalence of surgical complications of the sinus graft procedure and their impact on implant survival. J Periodontol 2004;75:511–516.
6. Ardekian L, Oved-Peleg E, Mactei EE, Peled M. The clinical significance of sinus membrane perforation during augmentation of the maxillary sinus. J Oral Maxillofac Surg 2006;64: 277–282.
7. Summers RB. The osteotome technique: Part 3—Less invasive methods of elevating the sinus floor. Compendium 1994; 15:689–708.
8. Berengo M, Sivolella S, Majzoub Z, Cardioli G. Endoscopic evaluation of the bone-added osteotome sinus floor elevation procedure. Int J Oral Maxillofac Surg 2004;33:189–194.
9. van der Bergh JP, ten Bruggenkate CM, Disch FJ, Tuinzing DB. Anatomical aspects of sinus floor elevations. Clin Oral Implants Res 2000;11:256–265.
10. Drettner B. Pathophysiology of paranasal sinuses with clinical implications. Clin Otolaryngol Allied Sci 1980;5:277–284.
11. Schroeder HE. The periodontium. In: Oksche A, Vollrath L (eds). Handbook of Microscopic Anatomy. Berlin: Springer, 1986,5:233–247.
12. Müller HP, Eger T. Gingival phenotypes in young male adults. J Clin Periodontol 1997;24:65–71.
13. Müller HP, Könömen E. Variance components of gingival thickness. J Periodontal Res 2005;40:239–244.
14. Awaida JP, Woods SE, Doerzbacher M, Gonzales Y, Miller TJ. Four-cut sinus computed tomographic scanning in screening for sinus disease. South Med J 2004;97:18–20.
15. Petruson B. A form to show extension of tumors in the nose and sinus. Arch Otolaryngol 1982;108:460–461.
16. Westergen V, Lundblad L, Timpka T. Interobserver variations in assessment of antral disease from direct sinuscopic observations compared to video recordings. Am J Rhinol 1998;12: 159–165.
17. Paolantonio M. Treatment of gingival recessions by combined periodontal regenerative technique, guided tissue regeneration and subpedicle connective tissue graft. A comparative clinical study. J Periodontol 2002;73:53–62.
18. Müller HP, Heinecke A, Schaller N, Eger T. Masticatory mucosa in subjects with different periodontal phenotypes. J Clin Periodontol 2000;27:621–626.
19. Müller HP, Eger T. Masticatory mucosa and periodontal phenotype: A review. Int J Periodontics Restorative Dent 2002;22: 172–183.
20. Halse A, Molven O, Fristad I. Diagnosing periapical lesions-Disagreement and borderline cases. Int Endod J 2002;35: 703–709.
21. Müller HP, Schaller N, Eger T. Ultrasonic determination of thickness of masticatory mucosa: A methodologic study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1999;88:248–253.
22. Cormack DH, Ham AW (eds). Histology. Philadelphia: Lippincott, 1987:187–202.
23. Schroeder HE. Differentiation of Human Oral Stratified Epithelia. Basel: Karger, 1981.
24. Eliashar R, Levi-Schaffer F. The role of the eosinophil in nasal diseases. Curr Opin Otolaryngol Head Neck Surg 2005;13: 171–175.
25. Kauffman H, Tomee J. Inflammatory cells and airway defense against Aspergillus fumigatus. Immunol All Clin North Am 1998;18:619–639.
26. Jiang RS, Liang KL, Jang JW, Hsu CY. Bacteriology of endoscopically normal maxillary sinuses. J Laryngol Otol 1999,113: 825–828.
27. Boonstra H, Oosterhuis JW, Oosterhius AM, Fleuren GJ. Cervical tissue shrinkage by formaldehyde fixation, paraffin wax embedding section cutting and mounting. Virchows Arch A Pathol Anat Histopathol 1983;402:195–201.
28. Jonmarker S, Valdman A, Lindberg A, Hellström M, Egevad L. Tissue shrinkage after fixation with formalin injection of prostatectomy specimens. Virchows Arch 2006;449:297–301.
29. Barone A, Santini S, Sbordone L, Crespi R, Covani U. A clinical study of the outcomes and complications associated with maxillary sinus augmentation. Int J Oral Maxillofac Implants 2006;21:81–85.
30. Aimetti M, Romagnoli R, Ricci G, Massei G. Maxillary sinus elevation: The effect of macrolacerations and microlacerations of the sinus membrane as determined by endoscopy. Int J Periodontics Restorative Dent 2001;21:581–589.