Diagnosing Pathological Changes in the Non-thickening Sinus Mucosa: A Retrospective CBCT Study with Psudocolor Imaging

Kalınlaşma Göstermeyen Sinüs Mukozasındaki Patolojik Değişimlerin Teşhis Edilmesi: Sahte Renklendirme ile Bir Retrospektif KİBT Çalışması

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ABSTRACT

Objective: The aim of this study is to test the utility of pseudocolor imaging in the diagnosis and evaluation of the maxillary sinus mucosa, which has a suspicion of pathological change even though no thickening pattern is formed.

Methods: Patients with healthy teeth without apical lesions from premolars and molars adjacent to the right and left maxillary sinus on one side (control) and tooth/teeth with apical lesions on the other side (study) were selected (n=17) and included in the study. Cochran's Q test was used to compare distribution of color anterior (A), medial (M) and posterior (P). Post-hoc analysis was performed using Bonferroni correction.

Results: The rate of multicolor in the anterior and medial side of the pathological side (52.9% and 47.1%) was higher than the healthy side (35.3% and 29.4%), and it was not statistically significant (p=0.300 and p=0.290). Independently of the groups (n=34), the ratio of multicolor in color A (44.1%) was significantly higher than in color P (20.6%) (p=0.047). On the pathological side (n=17), the ratios of multicolor in color A and M (52.9% and 47.1%, respectively) were higher than in color P (23.5%), but this difference was not statistically significant (p=0.148).

Conclusion: In implant surgery planning, pseudocolor imaging can be an alternative as a non-invasive adjunctive diagnostic method, especially in the evaluation of the sinus mucosa of maxillary posterior edentulous region in patients with unknown dental history.

Keywords: CBCT, pseudocolor imaging, sinus mucosa

ÖZ

Amaç: Bu çalışmanın amacı, kalınlaşma paterni oluşmamasına rağmen patolojik değişiklik şüphesi olan maksiller sinüs mukozasının tanı ve değerlendirilmesinde sahte renklendirmenin kullanılabilirliğini test etmektir.

Yöntemler: Bir tarafta (sağ veya sol) maksiller sinüse komşu premolar ve molar dişlerinde apikal lezyonu olmayan sağlıklı dişleri (kontrol) ve diğer tarafında apikal lezyonu olan diş/dişleri (çalışma) olan hastalar (n=17) seçildi. Anterior (A), medial (M) ve posterior (P) renk dağılımını karşılaştırmak için Cochran'ın Q testi kullanıldı. Post-hoc analiz Bonferroni düzeltmesi kullanılarak yapıldı.

Bulgular: Patolojik tarafta anterior ve medialde çok renklilik oranı (%52,9 ve %47,1) sağlıklı tarafa göre (%35,3 ve %29,4) daha yüksekti ancak fark istatistiksel olarak anlamlı değildi (p=0,300 ve p=0,290). Gruplardan bağımsız olarak (n=34), anteriorda çok renklilik oranı (%44,1), posteriordan (%20,6) anlamlı derecede yüksekti (p=0,047). Patolojik tarafta (n=17), anterior ve medialde çok renklilik oranı (sırasıyla; %52,9 ve %47,1) posteriora göre (%23,5) daha yüksekti, ancak bu fark istatistiksel olarak anlamlı değildi (p=0,148).

Sonuç: İmplant cerrahisi planlamasında özellikle dental öyküsü bilinmeyen maksiller posterior dişsiz hastaların sinüs mukozasının değerlendirilmesinde non-invaziv yardımcı tanı yöntemi olarak sahte renklendirme alternatif olabilir.

Anahtar Sözcükler: KİBT, sahte renklendirme, sinüs mukozası

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Introduction

The proximity of the apical maxillary posterior teeth and the maxillary sinus creates an anatomical relationship that should be considered especially in dental treatments such as implant surgery (1). Pathology of the sinus mucosa is among the pre-operative evaluation criteria, as is the presence of septa, which is an anatomical variation in the maxillary sinus (2,3).

When the maxillary sinus mucosa thickness exceeds 3 mm, it is considered pathological (4). However, there is no evidence that the mucosal thickness will definitely increase in the presence of infection/pathology in the maxillary sinus (5). Degeneration in the sinus mucosa can be observed not only with thickening of the mucosa, but also with fibrotic changes without thickening of the mucosa causing structural differences (6). Today, cone-beam computed tomography (CBCT) is frequently preferred in the preoperative evaluation of the maxillary sinus and is more useful in determining volumetric changes such as mucosal thickening (7).

ImageJ (Wayne Rasband, National Institutes of Health-NIH, Maryland, USA) is an image processing program that has functions such as trabecular structure assessment and automatic cell counting and is used in dentistry (8,9). In dental radiographs, the thickness and densities of the tissues are represented by gray values, and the differences in tissue thickness can be made more visible by creating the spectrum with the ImageJ pseudocolor method (10).

The aim of this study is to test the utility of pseudocolor imaging in the diagnosis and evaluation of the maxillary sinus mucosa, which has a suspicion of pathological change even though no thickening pattern is formed.

Methods

This study was approved by the Clinical Research Ethics Committee of the Faculty of Medicine, Alanya Alaaddin Keykubat University (approval number: 03-04/02.03.22). The study was carried out in accordance with the ethical rules of the Declaration of Helsinki. Consent was obtained from the patients whose data were included in the study.

Samples Collection

All CBCT (90 kVp, 5 mA, 8.1 s, 0,35 mm voxel size, Kavo OP 3D Pro) images taken at Alanya Alaaddin Keykubat University Faculty of Dentistry between January 2020 and December 2021 in the largest FOV (17*15 cm) were analyzed retrospectively (n=204). Patients with healthy teeth without apical lesions from premolars and molars adjacent to the right and left maxillary sinus on one side (control) and tooth/teeth with apical lesions on the other side (study) were selected. Among these patients, those whose mucosal thickness did not exceed 3 mm at the floor of both maxillary sinuses (n=17) were included in the study. Individuals with a sinus mucosa thickness exceeding 3 mm even on one side, those with a history of surgical treatment and malignancy including the maxillary sinus, and those diagnosed as having a disease that had an effect on the mucosal thickness such as allergic rhinitis and sinusitis were excluded from the study.

Image Acquisition in CBCT

When the base of the maxillary sinus is examined in the sagittal section, it has an appearance that tends to the superior as it goes from the middle part to the anterior and posterior directions. For this reason, the maxillary sinuses (both control and study) were divided into three equal parts as anterior (A), medial (M) and posterior (P) at the lower border of the zygomatic arch in sagittal section, and the mucosal thicknesses at the projection of the midpoints of these parts were measured on coronal section. The coronal cross-sectional image (CCSI) of these midpoints (A, M and P images) was selected for pseudocolor imaging (Figure 1).

Image acquisition in ImageJ

Image J version 1.8 software was used to analyze the images. CCSIs were saved as TIFF files and then added to Image J. The contrasts of CCSIs added to ImageJ with the File/Open command were adjusted with the Image/type/ 32-bit command
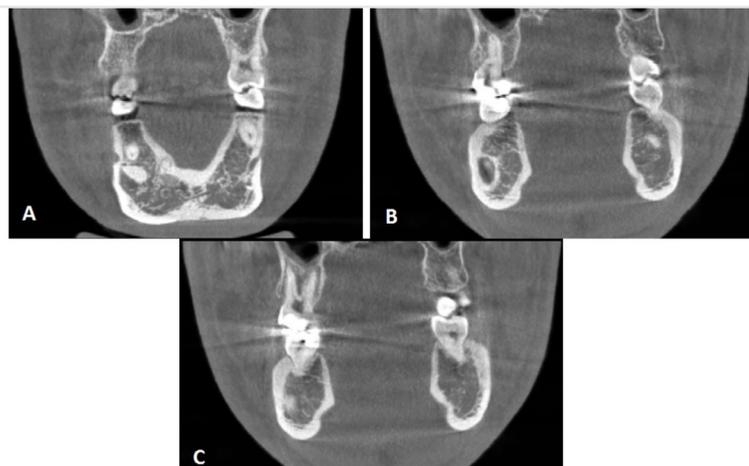
Figure 1. Images of anterior **(A)**, medial **(B)**, and posterior **(C)** sinus mucosa obtained from CBCT coronal sections

CBCT: Cone-beam computed tomography

to provide a more detailed separation of the color spectrum. Then, the Image/Zoom/Maximize command was used to facilitate the selection process of the thin sinus mucosa. The Process/Noise/Despeckle command was used to create a spectrum suitable for evaluation by increasing the blurred image and decreasing the noise. The final pseudocolor form of CCSIs was obtained with the Image/Lookup Tables/Spectrum command. Using the "freehand selection tool", the mucosa lining the floor of the maxillary sinus in CCSI was selected as the analysis region (Figure 2). Finally, this pseudocolor region was transformed into numerical data with the analysis/histogram command. The numerical data obtained for each section were used for statistical analysis. In addition, pseudocolor images were evaluated by two oral and maxillofacial radiologists with 5 years of experience. The sinus mucosa in the section was scored according to whether it consisted of one color (score 1) or of two or more colors (score 2). In case of discrepancy between the scores, the observers re-evaluated the sections they scored differently and reached a consensus by choosing the greater score (Figure 3).

Statistical Analysis

The sample size was calculated using the G*Power 3.1.9 program. In this study, the average of the anterior analysis
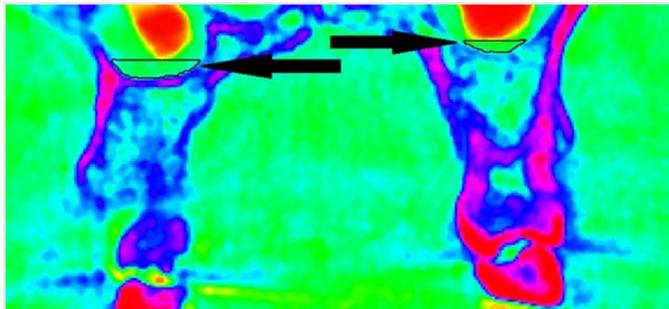
Figure 2. Region of interest (ROI) determination in analysis of the mucosa at the floor of the maxillary sinus

data of all patients was 93.91±11.65, while the average of the posterior analysis data was 85.55±11.38, and a statistically significant difference was found. According to these findings, the effect size was calculated as d=2.428. For 95% statistical power and 0.05 margin of error, the minimum sample size planned to be included in the study was 12 patients, 6 patients for the pathological group and 6 patients for the healthy group.

Descriptive analyses were given using mean ± standard deviation for continuous data and with n (%) for categorical data. The normality assumptions were controlled by using the Shapiro-Wilk test. Categorical variables were analyzed with Pearson chi-square test and Fisher's Exact test. Independent t-test was used for comparison of the outcome variables between study groups. The means of outcome measures were compared by using repeated measures ANOVA. Cochran's Q test was used to compare distribution of color A, M and P. Post-hoc analysis was performed using Bonferroni correction. Data were analyzed using Statistical Package for the Social Sciences Statistics v23.0 (IBM Corp., Armonk, NY). Two-sided p values <0.05 were considered statistically significant.

Results

A total of 17 patients, 12 males and 5 females, with a mean age of 37.18±8.58 were included in the study (Table 1). There was no statistically significant difference in the mean of A (p=0.601), M (p=0.510) and P (p=0.769) measurements taken from the healthy and pathological sides. When all measurements were compared independently of the groups, the mean of A and M measurements (93.91±11.65 and 90.15±14.51, respectively) were found to be significantly higher than the mean of P measurements (85.55±11.38) (p=0.001). Similarly, the mean of A and M measurements on the pathological side (94.97±9.63 and 91.82±13.1, respectively) were found to be significantly higher than the mean of P measurements (86.13±11) (p=0.001). Measurements from the healthy side were statistically similar (p=0.125) (Table 2).
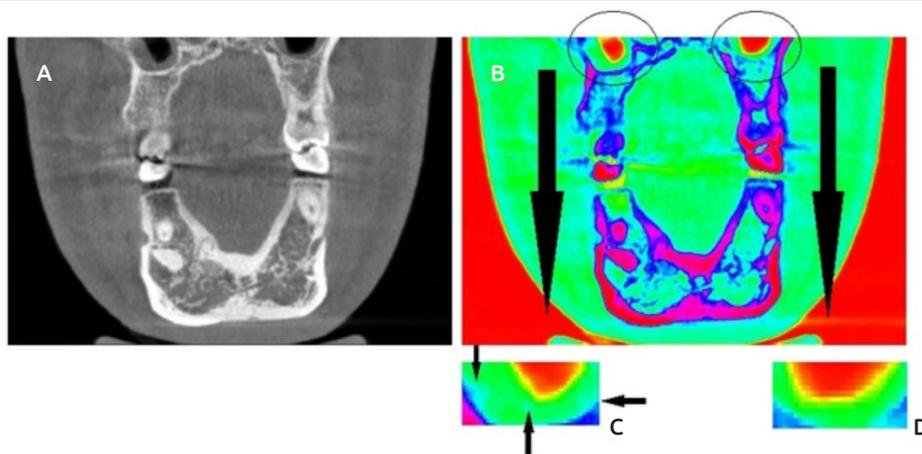
Figure 3. Color scoring in pseudocolor CCSI. Original CCSI (A), pseudocolor CCSI (B), multicolor CCSI (blue foci in green area indicated by arrow) (C) and single color CCSI (D)

CCSI: Coronal cross-sectional image

The rate of multicolor in the anterior and medial side of the pathological side (52.9% and 47.1%) was higher than the healthy side (35.3% and 29.4%), and it was not statistically significant (p=0.300 and p=0.290). The single and multicolor ratios of the groups in the posterior were not statistically different (p=0.999) (Table 3). Independently of the groups (n=34), the ratio of multicolor in color A (44.1%) was significantly higher than in color P (20.6%) (p=0.047). On the pathological side (n=17), the ratios of multicolor in color A and M (52.9% and 47.1%, respectively) were higher than in color P (23.5%), but this difference was not statistically significant (p=0.148). Color A, M, and P distributions in the healthy side were statistically similar (p=0.311) (Table 4). Distribution of single color and multicolor sinus mucosa by gender is shown in Table 5.

Discussion

Strict inclusion criteria in studies dealing with the maxillary sinus may result in a small sample size and an unbalanced gender distribution (6,7,11). It was aimed to provide maximum standardization for case-control comparison by including individuals without systemic disease in whom the maxillary sinus mucosa is bilaterally not thickened, but the teeth with periapical lesions are only on one side. Although there is no evidence that maxillary sinus mucosal thickening is more common in males, the results of related studies suggest that the sinus mucosa is more prone to thickening in males (7,12,13). Whereas sinus mucosal thickening did not occur, 70% of our participants, consisting of individuals with pathological changes in mucosa, were male patients, which supported this finding.

Although there was no statistically significant difference between the healthy and pathological side, ImageJ analysis values of the sinus mucosa were higher in the pathological side than the healthy side in all three regions (A, M and P). As the tissue density increases, it is a normal result that the ImageJ numerical values increase, and it can be thought that the pathological sinus mucosa becomes more compact than the healthy mucosa due to fibrotic change or fluid accumulation. The fact that the sinus mucosa on the side of the teeth with apical lesions is more prone to thickening than on the healthy side is consistent with this interpretation (14). While the A and M values were found to be statistically significantly higher on the pathological side compared to the P value, no statistically significant difference was found between the regions on the healthy side. The difficulty in treating the maxillary molars, especially the mesiobuccal apex, due to their anatomical structures, and their close relationship with the sinus floor are considered as an important etiological factor in odontogenic maxillary sinus pathologies (1,12,15). Considering the anatomical proximity of the apex of the maxillary teeth with the maxillary sinus, it can be thought that

Table 1. Patients' descriptive features

Variables	n=17
Age (year), mean ± SD	37.18±8.58
Gender, n (%)	
Male	24 (70.6)
Female	10 (29.4)

SD: Standart Deviation

Table 2. Measurement comparison of healthy and pathological sides

Group	A mean ± SD	M mean ± SD	P mean ± SD	p value[1]
All sides (n=34)	93.91±11.65[a]	90.15±14.51[a]	85.55±11.38[b]	0.001
Pathological side (n=17)	94.97±9.63[a]	91.82±13.1[a]	86.13±11[b]	0.001
Healty side (n=17)	92.84±13.6	88.48±16.03	84.96±12.05	0.125
p value[2]	0.601	0.510	0.769	

[1]Repeated measures ANOVA with post-hoc Bonferroni correction, [2]Independent t-test. Same letters in a row denote the lack of statistically significant difference. A: Anterior sinus mucosa, M: Medial sinus mucosa, P: Posterior sinus mucosa

Table 3. Comparison of the color characteristics of the healthy and pathological sides

Colors	Pathological side n (%)	Healthy side n (%)	p value
Color A			
Single color	8 (47.1)	11 (64.7)	0.300
Multicolor	9 (52.9)	6 (35.3)	
Color M			
Single color	9 (52.9)	12 (70.6)	0.290
Multicolor	8 (47.1)	5 (29.4)	
Color P			
Single color	13 (76.5)	14 (82.4)	0.999
Multicolor	4 (23.5)	3 (17.6)	

Pearson chi-square test, Fisher's Exact test

Table 4. Comparison of color A, M and P

Colors	A n (%)	M n (%)	P n (%)	p value
All sides (n=34)				
Single color	19 (55.9)[a]	21 (61.8)[a,b]	27 (79.4)[b]	0.047
Multicolor	15 (44.1)[a]	13 (38.2)[a,b]	7 (20.6)[b]	
Pathological side (n=17)				
Single color	8 (47.1)	9 (52.9)	13 (76.5)	0.148
Multicolor	9 (52.9)	8 (47.1)	4 (23.5)	
Healthy side (n=17)				
Single color	11 (64.7)	12 (70.6)	14 (82.4)	0.311
Multicolor	6 (35.3)	5(29.4)	3 (17.6)	

Cochran's Q test with post-hoc Bonferroni correction. Same letters in a row denote the lack of statistically significant difference. A: Anterior sinus mucosa, M: Medial sinus mucosa, P: Posterior sinus mucosa

Table 5. Distribution of single color and multicolor sinus mucosas by gender

Colors	Pathological side n (male/female)	Healthy side n (male/female)
Color A		
Single color	8 (4/4)	11 (7/4)
Multicolor	9 (5/4)	6 (3/3)
Color M		
Single color	9 (5/4)	12 (7/5)
Multicolor	8 (5/3)	5 (2/3)
Color P		
Single color	13 (6/7)	14 (8/6)
Multicolor	4 (2/2)	3 (2/1)

A: Anterior sinus mucosa, M: Medial sinus mucosa, P: Posterior sinus mucosa

the detection sensitivity of sinus pathologies with pseudocolor imaging can be found to be reliable by conducting studies with larger samples. The higher A and M values on the pathological side compared to P may be explained by the close relationship between the apex of infected maxillary molars/molars and the anterior and medial floor of the maxillary sinus. In other words, the fact that the maxillart dental arch and maxillary tooth apex is in anatomically far relationship with the posterior sinus mucosa may cause these results.

On the pathological side, the multicolor ratio in A and M was higher than P, which was consistent with the numerical data findings of ImageJ analysis. However, a statistically significant difference could not be obtained in the color comparison, as in the numerical data. It can be demonstrated that pseudocolor imaging can be used effectively in the diagnosis of maxillary sinus mucosal pathologies with similar studies to be planned with larger samples. The lack of experience of oral and maxillofacial radiologists in color image interpretation is considered to be one of the most important factors in the limited prevalence of this method (16-18). It may be possible to diagnose sinus mucosa with no thickening but fibrotic changes may be possible with pseudocolor images instead of grayscale radiographic images that the human eye has difficulty in distinguishing.

Although in a study using 2D radiographs, no thickening was observed in the sinus mucosa in maxillary edentulous patients (19), it was determined that mucosal thickening increased in edentulous patients in a CBCT study (12). In other words, it can be concluded that there is no consensus about the maxillary sinus mucosal status of edentulous patients. In maxillary implant supported prosthesis planning with sinus lifting operation, the accuracy of diagnosis of the preoperative condition of the maxillary sinus and sinus mucosa affects the implant surgery success and thus the success of the dental prosthesis (1). Pseudocolor imaging may provide a non-invasive guide for the determination of implant localization during the preoperative implant planning process, especially in maxillary posterior edentulous patients whose dental history is unknown and there is no thickening of the sinus mucosa.

Using different voxel sizes can affect image quality (20). The CBCT data included in this study were images of patients with the largest FOV and had a voxel size of 0.35 mm. Since this study was a retrospective study, the effect of different voxel sizes on image quality and pseudocolor images could not be evaluated. Evaluating the effect of different voxel sizes on pseudocolor images may be the subject of new studies planned for this purpose.

Study Limitations

The sample size is low because a strict inclusion procedure is used to ensure a high standardization between the study and control groups. Although the effect size of the statistical results is high, more participatory studies are needed.

Conclusion

ImageJ pseudocolor imaging may be an alternative method for the diagnosis of maxillary sinus mucosal pathologies in cases where dental etiology is suspected and mucosal thickening is not observed. New studies with a larger sample size are needed in order to develop it as a non-invasive adjunctive diagnostic method in the planning of implant surgery, especially in the evaluation of the sinus mucosa of maxillary posterior edentulous region in patients with unknown dental history.

Ethics

Ethics Committee Approval: This study was approved by the Clinical Research Ethics Committee of the Faculty of Medicine, Alanya Alaaddin Keykubat University (approval number: 03-04/02.03.22). The study was carried out in accordance with the ethical rules of the Declaration of Helsinki.

Informed Consent: Obtained.

Peer-review: Externally peer reviewed.

Authorship Contributions

Concept: S.Ş., Design: S.Ş., Data Collection or Processing: S.Ş., T.Ç., Analysis or Interpretation: S.Ş., T.Ç., İ.T.G., Y.Y.S., Literature Search: S.Ş., T.Ç., İ.T.G., Y.Y.S., Writing: S.Ş., İ.T.G.

Conflict of Interest: No conflict of interest was declared by the authors.

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