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ORIGINAL RESEARCH ORİJİNAL ARAŞTIRMA

Paranasal Sinus Mucoceles Invading the Orbit: A Retrospective Analysis of Radiological and Surgical Features

Orbita İnvazyonu Gösteren Paranazal Sinüs Mukoselleri: Radyolojik ve Cerrahi Özelliklerin Retrospektif Analizi

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ABSTRACT Objective: This study aimed to evaluate the clinical and radiological characteristics of paranasal sinus (PNS) mucoceles with orbital extension, with a particular focus on anatomical variations that may predispose to disease progression. **Material and Methods:** This retrospective study included 17 patients who underwent surgery for PNS mucoceles invading the orbit between February 2019 and January 2025, and 17 control subjects with no sinonasal pathology on computed tomography (CT) imaging. Preoperative paranasal CT scans were evaluated for maxillary and frontal sinus development as well as lamina papyracea (LP) positioning using the Bolger and Herzallah classification systems, respectively. **Results:** The most common mucocele locations were the frontoethmoidal (41.18%) and frontal (23.53%) sinuses. Maxillary sinus hypoplasia (MSH) was significantly more frequent in the mucocele group (41.18%) than in the controls (5.88%) (p=0.039). No statistically significant differences were observed in the frontal sinus aeration or LP position between the groups. Most mucoceles were managed endoscopically (82.35%), with only 1 recurrence (5.88%) observed. In 29.41% of cases, the etiology was secondary to prior surgery or trauma. **Conclusion:** MSH may represent an anatomical predisposition for PNS mucoceles with orbital extension. Although no significant differences were noted in frontal sinus aeration or LP positioning, endoscopic marsupialization proved to be an effective and safe surgical approach with a low recurrence rate. These findings underscore the importance of thorough preoperative imaging and early diagnosis to prevent advanced orbital complications.

Keywords: Paranasal sinus diseases; mucocele; orbital disease; tomography

ÖZET Amaç: Bu çalışmada, orbita invazyonu gösteren paranazal sinüs (PNS) mukosellerinin klinik ve radyolojik özelliklerini, hastalık progresyonuna yatkınlık oluşturabilecek anatomik varyasyonlara odaklanarak değerlendirmek amaçlanmıştır. **Gereç ve Yöntemler:** Bu retrospektif çalışmaya, Şubat 2019 ile Ocak 2025 tarihleri arasında orbita invazyonu nedeniyle PNS mukoseli cerrahisi uygulanan 17 hasta ile bilgisayarlı tomografi (BT) görüntülemelerinde sinonazal patolojisi olmayan 17 kontrol birey dâhil edildi. Preoperatif paranasal BT görüntüleri; maksiller ve frontal sinüs gelişimi ile lamina papyracea (LP) pozisyonu açısından Bolger ve Herzallah sınıflamalarına göre değerlendirildi. **Bulgular:** Mukosellerin en sık görüldüğü lokalizasyonlar frontoetmoidal (%41,18) ve frontal sinüsler (%23,53) idi. Maksiller sinüs hipoplazisi (MSH), mukosel grubunda (%41,18) kontrol grubuna (%5,88) kıyasla anlamlı olarak daha sık görüldü (p=0,039). Frontal sinüs havalanması ve LP pozisyonu açısından gruplar arasında istatistiksel olarak anlamlı bir fark bulunmadı. Olguların büyük çoğunluğu endoskopik yöntemle tedavi edildi (%82,35) ve yalnızca 1 nüks (%5,88) gözlendi. Vakaların %29,41'inde etiyoloji daha önceki cerrahi girişim veya travmaya bağlıydı. **Sonuç:** MSH, orbita invazyonu gösteren PNS mukoselleri için anatomik bir yatkınlık oluşturabilir. Frontal sinüs havalanması ve LP pozisyonunda anlamlı fark bulunmasa da, endoskopik marsupiyalizasyon düşük nüks oranıyla etkili ve güvenli bir cerrahi yaklaşım olarak öne çıkmaktadır. Bu bulgular, ileri düzey orbital komplikasyonları önlemek için preoperatif görüntülemenin titizlikle değerlendirilmesi ve erken tanının önemini vurgulamaktadır.

Anahtar Kelimeler: Paranazal sinüs hastalıkları; mukosel; orbita hastalıkları; tomografi

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Paranasal sinus (PNS) mucoceles are epithelium-lined, mucus-filled cystic lesions that progressively expand within the PNSes.[1] Obstruction of the sinus ostium or chronic inflammatory processes are considered the primary etiologic factors. These may arise due to mass lesions, fibrosis, chronic infections such as sinusitis, benign tumors (e.g., osteoma), prior surgery or trauma, radiotherapy, or, less commonly, malignancy.[2-4] Approximately 70-90% of mucoceles originate in the frontal, frontoethmoidal, or ethmoidal sinuses, which are anatomically adjacent to the orbit.[5,6]

Owing to their expansile nature, mucoceles can cause bony erosion and extend into adjacent compartments such as the orbit or intracranial space, leading to complications including proptosis, diplopia, or vision loss.[7,8] Bone resorption may be mediated by local production of inflammatory cytokines (e.g., prostaglandins, interleukin-1, and tumor necrosis factor), although some studies suggest that internal pressure from mucus accumulation may also contribute to expansion.[9-11]

Early drainage of the mucoceles is critical to prevent severe complications. Historically, open surgical approaches were used to completely excise the mucocele lining.[12] However, endoscopic marsupialization has become the preferred method because of its safety and because complete removal of the cyst wall is not necessary.[13] The primary surgical objective is to achieve wide, lasting drainage while minimizing trauma-especially in cases with orbital or skull base dehiscence-to reduce the risk of recurrence.

Beyond the surgical technique, a detailed evaluation of the sinonasal anatomy is essential both for understanding the disease pathophysiology and for operative planning.[14,15] Computed tomography (CT) remains the gold standard for imaging the PNSes. Anatomical variations such as maxillary or frontal sinus underdevelopment and the position of the lamina papyracea (LP) may influence the direction of expansion and the likelihood of orbital invasion.

This study aimed to evaluate the radiological and clinical features of PNS mucoceles with orbital invasion, investigate potential anatomical risk factors, and assess surgical management outcomes in this subset of patients.

MATERIAL AND METHODS

STUDY DESIGN

This retrospective study was conducted at a single tertiary center following approval by the local institutional review board (Ankara Bilkent City Hospital, date: February 12, 2025, no: TABED 1-25-1005). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and its later amendments.

STUDY POPULATION

Between February 2019 and January 2025, patients who underwent surgery for PNS mucoceles with radiological evidence of erosion of the LP or the superior/inferior orbital walls were included. The control group comprised an equal number of individuals who underwent paranasal sinus computed tomography (PNCT) for unrelated reasons, showed no significant sinonasal pathology, and were matched for demographic characteristics. Only patients whose preoperative PNCT was performed at the study center, whose clinical records-including preoperative history, examination findings, and intraoperative notes-were available, and who completed postoperative follow-up were included. Patients were excluded if their imaging was performed externally, preoperative documentation was incomplete, or they were lost to follow-up.

DATA COLLECTION

The hospital's electronic medical records system (HICAMP Innova, Ankara, Türkiye) was reviewed to extract demographic data, surgical technique, recurrence status, and suspected etiology. Cases associated with prior surgery or trauma were considered secondary; all others were classified as primary. The mucocele locations were categorized as maxillary, ethmoidal, frontal, sphenoidal, maxilloethmoidal, frontoethmoidal, or sphenoethmoidal.

Radiological Assessment

Preoperative PNCT scans were evaluated using the hospital's Picture Archiving and Communication System. All scans were obtained using a Revolution EVO scanner (GE Healthcare, USA) with the fol-

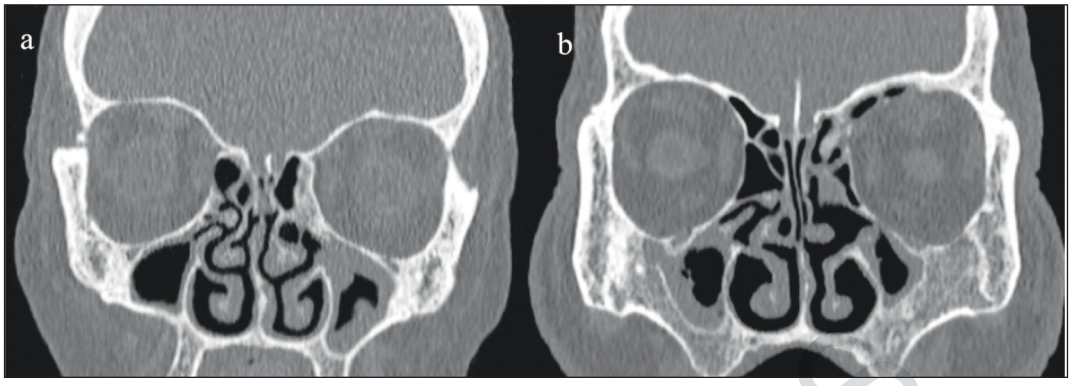

FIGURE 1: Coronal CT images demonstrating MSH. **(a)** Type 1 hypoplasia: mild reduction in sinus pneumatization with a normal uncinate process and open infundibulum; **(b)** Type 2 hypoplasia: moderate reduction in pneumatization with a hypoplastic or aplastic uncinate process and obstructed infundibulum
CT: Computed tomography; MSH: Maxillary sinus hypoplasia

lowing parameters: 0.625 mm slice thickness, 0.5-second rotation time, 512×512 matrix, 64×0.625 collimation, 140 kV tube voltage, and 30 mA tube current.

In both groups, the radiological assessment focused on the presence of maxillary sinus hypoplasia (MSH), frontal sinus hypoplasia (FSH), and the anatomical position of the LP. MSH was classified on coronal CT images according to the Bolger classification: type 1 (mild reduction in pneumatization with a normal uncinate process and an open infundibulum), type 2 (moderate reduction in pneumatization with a hypoplastic or aplastic uncinate process, an obstructed infundibulum), and type 3 (severe hypoplasia with absence of the uncinate process and a groove-like sinus) (Figure 1a, Figure 1b).[16]

FSH was assessed using the method described by Guerram et al.[17] Supraorbital and midorbital reference lines were drawn on coronal CT: the supraorbital line was tangent to the upper orbital margins, and the midorbital line was vertical, parallel to the midsagittal plane, passing through the midpoint between the medial and lateral orbital walls. Based on these lines, the frontal sinuses were classified as aplastic (no pneumatization), hypoplastic (pneumatization below the supraorbital line), medium (above supraorbital but medial to midorbital line), or hyperplastic (pneumatization extending lateral to the midorbital line) (Figure 2).

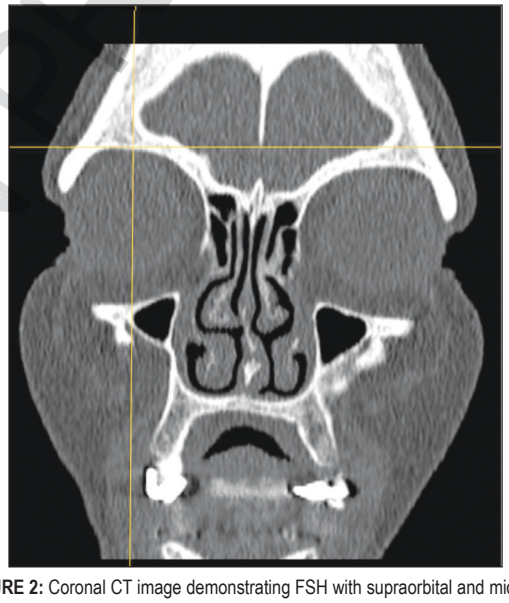

FIGURE 2: Coronal CT image demonstrating FSH with supraorbital and midorbital reference lines
CT: Computed tomography; FSH: Frontal sinus hypoplasia

The LP position was classified according to the method described by Herzallah et al., which measures the LP's medial or lateral deviation from the middle meatal antrostomy (MMA) point.[18] An LP located within 2 mm of the MMA point was classified as type 1; located 2-4 mm medially as type 2A; >4 mm medially as type 2B; 2-4 mm laterally as type 3A; and >4 mm laterally as type 3B. Measurements were made on coronal sections at the junction of the uncinate process and inferior turbinate (Figure 3).

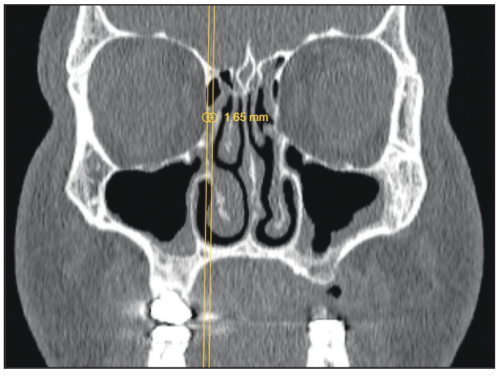

FIGURE 3: Coronal CT image showing the localization of the lamina papyracea relative to the middle meatal antrostomy point, based on the Herzallah classification
CT: Computed tomography

STATISTICAL ANALYSIS

Statistical analyses were performed using the Statistical Package for the Social Sciences software, version 26.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics (mean, standard deviation, median, minimum, maximum, and percentage) were calculated. The normality of the distribution was evaluated using both visual inspection and analytical tests (Kolmogorov-Smirnov and Shapiro-Wilk tests). As most variables were non-normally distributed, non-parametric tests were used. Categorical variables (e.g., MSH, FSH, Herzallah types) were analyzed with the chi-square test or Fisher's exact test as appropriate. LP-MMA distances were compared using the Mann-Whitney U test. A p value <0.05 was considered statistically significant.

RESULTS

Seventeen patients with PNS mucoceles invading the orbit were included in the study. Of these, 9 patients (52.94%) were female and 8 patients (47.06%) were male. The mean age of the patient group was 53.82±20.75 years (range, 18-83). Mucoceles were on the left side in 12 patients (70.59%) and on the right side in 5 patients (29.41%). The control group consisted of 17 individuals with similar demographic characteristics and a mean age of 49.00±17.19 years (range, 23-82). There was no statistically significant difference in age distribution between the 2 groups (Mann-Whitney U test, p=0.448) (Table 1).

In the mucocele group, the distribution of mucocele locations was as follows: frontoethmoidal in 7 patients (41.18%), frontal in 4 patients (23.53%), ethmoidal in 4 patients (23.53%), maxillary in 1 patient (5.88%), and sphenoethmoidal in 1 patient (5.88%). Three patients (17.65%) underwent combined external and endoscopic approaches, while 14 patients (82.35%) were treated exclusively via an endoscopic technique. Recurrence was observed in only one case (5.88%) during the follow-up period. Regarding etiology, 4 mucoceles (23.53%) were considered secondary to previous surgery, 1 case (5.88%) was attributed to prior trauma, and the remaining 12 cases (70.59%) were classified as primary.

TABLE 1: Demographic characteristics of the mucocele and control groups

Characteristic	Mucocele group (n=17)	Control group (n=17)	p value
Age, $\bar{X}$±SD (years)	53.82±20.75	49.00±17.19	0.448*
Female, n (%)	9 (52.94%)	8 (47.06%)	0.732**
Male, n (%)	8 (47.06%)	9 (52.94%)	
Left side, n (%)	12 (70.59%)	11 (64.71%)	0.714**
Right side, n (%)	5 (29.41%)	6 (35.29%)	

*Mann-Whitney U test; **Pearson chi-square test; SD: Standard deviation

MSH was observed in 5 patients (29.41%) as type 1 and in 2 patients (11.76%) as type 2 in the mucocele group. In contrast, only 1 case of type 1 MSH (5.88%) was identified in the control group, with no additional MSH cases. The frequency of MSH was significantly higher in the mucocele group than in the controls (Fisher's exact test, p=0.039). The frontal sinus aeration patterns were assessed in both groups. In the mucocele group, 1 patient (5.88%) exhibited aplasia, 1 (5.88%) exhibited hypoplasia, 1 (5.88%) exhibited hyperplasia, and 14 (82.35%) had medium aeration. In the control group, 2 patients (11.76%) had hypoplasia, 1 (5.88%) had hyperplasia, and 14 (82.35%) had medium aeration (Table 2). No statistically significant difference in frontal sinus aeration was found between the groups (Table 2).

In 5 mucocele patients, the LP could not be classified because of extensive bony erosion. Among the remaining 12 patients, 9 (75%) were classified as type 1 and 3 (25%) as type 2A according to the Herzallah classification. In the control group, 13 patients (76.47%) were type 1, 3 (17.65%) were type

TABLE 2: Maxillary and frontal sinus findings in the mucocele and control groups

Finding	Mucocele group (n=17)	Control group (n=17)	p value
Type 1 MSH, n (%)	5 (29.41%)	1 (5.88%)	0.175*
Type 2 MSH, n (%)	2 (11.76%)	0 (0.00%)	0.485*
Frontal sinus aplasia, n (%)	1 (5.88%)	0 (0.00%)	1.000*
FSH, n (%)	1 (5.88%)	2 (11.76%)	1.000*
Frontal sinus hyperplasia, n (%)	1 (5.88%)	1 (5.88%)	1.000*
Frontal sinus medium aeration, n (%)	14 (82.35%)	14 (82.35%)	1.000*

*Fisher's exact test; MSH: Maxillary sinus hypoplasia; FSH: Frontal sinus hypoplasia

TABLE 3: LP findings in the mucocele and control groups

Finding	Mucocele group	Control group	p value
Herzallah Type 1, n (%)	9 (75%)	13 (76.47%)	1.000*
Herzallah Type 2A, n (%)	3 (25%)	3 (17.65%)	0.669*
Herzallah Type 3A, n (%)	-	1 (5.88%)	1.000*
Medial LP, n (%)	10 (83.33%)	13 (76.47%)	1.000*
Mean distance to MMA (mm)	1.42±1.54	0.59±1.45	0.132**
Range (mm)	1.87 lateral to 3.86 medial	2.75 lateral to 2.78 medial	-

*Fisher's exact test **Mann-Whitney U test; LP: Lamina papyracea; MMA: Middle meatal antrostomy

Note: In 5 patients from the mucocele group, LP classification could not be determined due to bony defects.

2A, and 1 (5.88%) was type 3A. No statistically significant difference was found between the groups in LP classification (Fisher's exact test, p=1.000; Pearson chi-square test, p=0.640). In terms of LP position relative to the MMA point, LP was medially located in 10 patients (83.33%) in the mucocele group and in 13 patients (76.47%) in the control group. The mean LP distance from the MMA was 0.94±1.52 mm medial, ranging from 2.75 mm lateral to 3.86 mm medial. There was no statistically significant difference in LP positioning between the groups (Mann-Whitney U test, p=0.132) (Table 3).

DISCUSSION

This study evaluated the clinical and radiological characteristics of PNS mucoceles with orbital extension, with a particular focus on paranasal anatomical variations. The most frequent mucocele locations were the frontoethmoidal and frontal sinuses, consistent with prior literature indicating a predilection for the anterior ethmoid complex. Notably, MSH was significantly more prevalent in the mucocele group than in the controls, suggesting a potential anatomical predisposition. In contrast, no significant differences were observed in the frontal sinus aeration patterns or LP classifications between the groups.

In this cohort, 11 of 17 mucoceles (64.7%) originated from the frontal or ethmoidal sinuses-regions known for their anatomical proximity to the orbit and thin bony walls. This distribution aligns with previous findings. Har-El et al. reported orbital extension in 83.3% of 108 mucocele cases, with 61.1% arising from the frontal or frontoethmoidal region.[19] Similarly, Malik et al. observed orbital invasion in 97% of their cases, most of which originated from the frontal or ethmoid sinuses.[20] These results reinforce the hypothesis that the ethmoid and frontal sinuses are particularly susceptible to orbital invasion because of their anatomical configuration. In our series, 4 mucoceles (23.53%) were considered secondary to previous surgery, 1 (5.88%) to trauma, and the remaining 12 cases (70.59%) were classified as primary. Although most studies report prior surgery or trauma as the predominant causes, our findings suggest a higher incidence of spontaneous or idiopathic mucoceles.[8,21,22]

MSH is a relatively uncommon anatomical variation with inconsistently defined diagnostic criteria. The most widely used classification is that of Bolger et al., which delineates 3 types; however, the distinction between types 1 and 2 remains subjective and may contribute to variability in prevalence reporting.[16] Bolger et al. found unilateral MSH in 10.4% of cases, whereas Erdem et al. reported a prevalence of 6.4% in a larger CT-based study.[16,23] In contrast, our study found MSH in 41.18% of patients with mucoceles, a markedly higher rate. This discrepancy may stem from anatomical vulnerability in cases with orbital invasion, differences in evaluation criteria, or limited sample size.

The position of the LP may serve as an anatomical predictor of orbital invasion by the sinonasal mucoceles. Although the classification developed by Herzallah et al. was originally intended to identify the

risk of accidental LP injury during endoscopic entry into the maxillary sinus, it also offers valuable insight into LP positioning relative to key anatomical landmarks.[18] In our study, no statistically significant difference was found between the mucocele and control groups regarding LP position relative to the MMA point. Interestingly, Ozcan et al. reported that patients with MSH had significantly more medially positioned LPs.[24] Despite the relatively high frequency of MSH in our mucocele group, a similar medial shift of the LP was not observed. This discrepancy may be attributed to the limited sample size of our study, particularly considering that LP classification could not be performed in 5 cases due to extensive bony erosion. The reduced number of evaluable patients may have diminished the statistical power to detect subtle anatomical associations.

Although no statistically significant difference was observed in the frontal sinus aeration patterns between the groups, the potential role of frontal sinus underdevelopment in obstructing sinus drainage and predisposing to mucocele formation cannot be entirely excluded. Future studies with volumetric or 3D assessment of the frontal sinus development may provide more definitive insights.

Endoscopic marsupialization was the primary treatment modality in our series, consistent with the current literature emphasizing its efficacy and safety. Only one patient (5.88%) experienced recurrence, supporting the effectiveness of endoscopic techniques even in cases with orbital involvement. Several studies have shown that wide marsupialization with preservation of mucosal integrity and avoidance of scarring are critical for long-term success.[12,13]

LIMITATIONS

The main limitation of this study is the relatively small sample size, which may have reduced the statistical power to detect subtle differences in anatomical variables such as LP positioning. Furthermore, LP classification could not be performed in 5 patients due to extensive bony erosion, further limiting the number of analyzable cases in that subgroup. Additionally, the retrospective design and single-center setting may restrict the generalizability of the findings.

Despite these limitations, a major strength of this study is its focused evaluation of radiological anatomical features in patients with mucoceles specifically invading the orbit-a subgroup that represents a more advanced disease state and poses greater surgical complexity.

CONCLUSION

The findings of this study suggest that MSH is a contributing anatomical factor in the development of PNS mucoceles with orbital extension. Although no significant differences were observed in frontal sinus aeration patterns or LP positioning, the high prevalence of MSH in affected patients underscores the need for careful radiological evaluation of the sinonasal anatomy in patients at risk. Further multicenter studies with larger cohorts are warranted to validate these findings and to better understand the anatomical predispositions that may influence the course and complications of PNS mucoceles.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Burak Hazır, Erdem Ağgünlü, Mustafa Çolak, Aykut İkincioğulları, Serdar Ensari, Hacı Hüseyin Dere;* ***Design:*** *Burak Hazır, Erdem Ağgünlü;* ***Control/Supervision:*** *Mustafa Çolak, Aykut İkincioğulları, Serdar Ensari, Hacı Hüseyin Dere;* ***Data Collection and/or Processing:*** *Burak Hazır, Erdem Ağgünlü;* ***Analysis and/or Interpretation:*** *urak Hazır, Erdem Ağgünlü, Mustafa Çolak, Aykut İkincioğulları, Serdar Ensari, Hacı Hüseyin Dere;* ***Literature Review:*** *Burak Hazır, Erdem Ağgünlü;* ***Writing the Article:*** *Burak Hazır;* ***Critical Review:*** *Mustafa Çolak, Aykut İkincioğulları, Serdar Ensari, Hacı Hüseyin Dere;* ***References and Fundings:*** *Burak Hazır, Erdem Ağgünlü;* ***Materials:*** *Burak Hazır.*

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