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RESEARCH

The effects of temporomandibular disorders on superior semicircular canal morphology

Temporomandibular bozuklukların süperior semisirküler kanal morfolojisi üzerindeki etkisi

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Abstract

Purpose: Temporomandibular disorders (TMD) are the comprehensive conditions that affect the temporomandibular joint (TMJ), masticatory muscles, and/or associated structures. Superior semicircular canal (SSC) dehiscence has been associated with TMJ symptoms. This study aimed to assess the bone thickness and radio-morphological types of the superior semicircular canal which is anatomically adjacent to TMJ region in TMD patients compared to a matched-control group using cone-beam computed tomography images.

Materials and Methods: Fifty-six TMD patients and 56 gender and age-matched healthy controls who fulfilled diagnostic criteria for TMD Axis I were included to the study. Minimum bone thickness of SSC was measured. Morpho-radiological types of SSC were classified as dehiscence, papyraceous, normal, thick and pneumatised. The relationships between SSC types and age groups/gender were examined.

Results: The TMD group (0.9±0.8 mm) exhibited significantly lower bone thickness of SSC than the control group (1.5±1.1 mm). SSC types varied significantly between the groups, with a higher prevalence of dehiscence (23.2% and 8%, respectively) and papyraceous types (21.4% and 8.9%, respectively) and a lower prevalence of the normal type (40.2% and 64.3%, respectively) in the TMD group compared to the control group

Conclusion: This study suggests that TMD may lead to changes in the SSC morphology, particularly predisposing to dehiscence and papyraceous types. Understanding these associations could contribute to improve the diagnosis and management of TMD patients.

Keywords: Cone-beam computed tomography; morphology; superior semicircular canal; superior semicircular canal dehiscence; temporomandibular disorders

Öz

Amaç: Temporomandibular bozukluklar (TMB), temporomandibular eklem (TME), çiğneme kaslarını ve ilişkili yapıları etkileyen kapsamlı durumlardır. Süperior semisirküler kanal (SSK) dehissensi, TME semptomlarıyla ilişkilendirilmiştir. Bu çalışmada, TMB hastalarında TME bölgesine anatomik olarak komşu olan süperior semisirküler kanalın kemik kalınlığı ve radyomorfolojik tiplerinin, konik ışınlı bilgisayarlı tomografi görüntüleri kullanılarak eşleştirilmiş kontrol grubuyla karşılaştırılması amaçlandı.

Gereç ve Yöntem: Çalışmaya TMB Aksis I tanı kriterlerini karşılayan 56 TMB hastası ve 56 cinsiyet ve yaş eşleştirilmiş sağlıklı kontrol dahil edildi. SSK'nin minimum kemik kalınlığı ölçüldü. SSK'nin radyomorfolojik tipleri dehissens, papirüs, normal, kalın ve pnömatize olarak sınıflandırıldı. SSK tipleri ile yaş grupları/cinsiyet arasındaki ilişkiler incelendi.

Bulgular: TMB grubu (0.9±0.8 mm), kontrol grubuna (1.5±1.1 mm) göre önemli ölçüde daha az SSK kemik kalınlığı sergiledi. SSK tipleri gruplar arasında önemli ölçüde farklılık gösterdi, TMB grubunda kontrol grubuna göre, dehissens (sırasıyla %23.2 ve %8) ve papirüs (sırasıyla %21.4 ve %8.9) tiplerinin daha yüksek prevalansı ve normal tipin (sırasıyla 40.2% ve 64.3%) daha düşük prevalansı vardı.

Sonuç: Bu çalışma TMB'nin SSK morfolojisinde değişikliklere yol açabileceğini, özellikle dehissens ve papirüs tiplerine yatkınlık yaratabileceğini ortaya koymuştur. Bu ilişkilerin anlaşılması TMB hastalarının tanı ve tedavisinin iyileştirilmesine katkıda bulunabilir.

Anahtar kelimeler: Konik ışınlı bilgisayarlı tomografi; morfoloji; süperior semisirküler kanal; süperior semisirküler kanal dehissensi; temporomandibular bozukluklar

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INTRODUCTION

Temporomandibular disorders (TMD) is a comprehensive expression that can be diagnosed by evaluating a range of disorders affecting the temporomandibular joint (TMJ) located between the temporal and mandibular bones, masticatory muscles and/or related structures[1]. TMD can negatively impact the quality of daily life by leading to depression, somatization, or disruptions in sleep quality[2,3]. The semicircular canals which consist of three canals (lateral, posterior, and superior) are part of the bony labyrinth within the inner ear. The superior semicircular canal (SSC) is oriented perpendicular to the axis of the petrous bone, and a portion of the SSC is closely associated with the arcuate eminence[4]. Minor et al. introduced the existence of a syndrome known as superior semicircular canal dehiscence (SSCD), which has a surgical solution and present with vestibular, auditory, and clinical signs[5]. Although SSCD is a relatively recently discovered disorder, significant progress has been made over the past quarter-century. It has become a popular research topic in terms of imaging, diagnosis, and symptomatology[6]. SSCD is an uncommon condition with an uncertain etiology. The management of SSCD is typically tailored to the intensity of the symptoms. In cases where patients present with minimal or no symptoms, a conservative strategy focusing on non-invasive trigger avoidance is often recommended. On the other hand, individuals with more severe and disabling symptoms may benefit from surgical intervention for symptom relief[7]. Kurt et al. demonstrated the association between SSCD and TMJ symptoms using cone-beam computed tomography (CBCT) images[8]. The evidence regarding the potential association between the SSC and TMD symptoms is limited.

The primary hypotheses (H1) of the current study are: 1) There is a significant difference in SSC thickness between the TMD and control groups. 2) There is a significant difference in SSC types between the TMD and control groups.

The secondary hypotheses (H1) of the current study are: 1) There is a significant difference between age groups and SSC types in the examined groups. 2) There is a significant difference between gender and SSC types in TMD, control, and all patient groups. 3) There is a significant difference in osteoarthritis findings between the TMD and control groups.

This study aims to contribute to the existing literature by investigating potential associations between SSC morphology and TMD, an area that has been less extensively explored compared to vestibular and auditory symptoms in SSC-related pathologies. CBCT, which provides high-resolution images for the evaluation of particularly hard tissues in the maxillofacial region, is considered a highly suitable imaging modality for examining the SSC[9,10]. By employing high-resolution CBCT imaging and examining specific anatomical variations in SSC thickness and morphology, this study seeks to provide novel insights that may improve the understanding of anatomical risk factors in TMD patients. Furthermore, it proposes that SSC variations may contribute to vestibular symptoms in TMD patients, offering new perspectives for clinical assessment and management.

MATERIALS AND METHODS

Study population

This investigation was carried out in accordance with the guidelines specified in the 1964 Helsinki Declaration and its later amendments and was approved by the Ethical Review Board for Non-Interventional Clinical Research at Çukurova University (2023/137-20). Patients visiting the Department of Oral Diagnosis and Maxillofacial Radiology at Çukurova University Faculty of Dentistry complete an informed consent form, medical history form, and TMD evaluation form as part of the routine clinical protocol, followed by a TMD examination. Items appraised concerned TMJ noises (crepitus and clicking), jaw movements/deviations, palpation/movement pain and pain locations.

From the pool of 138 TMD patients who underwent CBCT in our department between September 2022 and September 2023, 28 males and 28 females were randomly chosen. All CBCT scans were performed by a radiology technician with 10 years of experience. Among the 989 healthy individuals (without any systemic disease) who underwent CBCT, individuals matched with TMD patients by gender and age were initially selected. Subsequently, 28 males and 28 females were randomly selected from the pool of matched healthy individuals within the same time frame. As per the diagnostic criteria for TMD Axis I[1], headache attributed to TMD, arthralgia, myofascial pain, myalgia, local myalgia are included in the pain-

related TMD group. Subluxation, degenerative joint disease, disc displacement disorders which are included in the intra-articular TMD group were defined as "TMD". Degenerative bone changes indicating osteoarthritis were classified as osteophyte, erosion, flattening, sclerosis and pseudocyst[11].

CBCT images of individuals over 18 years age with clearly visualized bilateral temporal bones in the scanning area and excellent diagnostic quality were included to the study. The exclusion criteria included systemic diseases that could affect the masticatory system, metabolic bone diseases (e.g., osteoporosis, osteomalasia), a history of craniofacial trauma or surgery, skeletal asymmetries, congenital syndromes (e.g., Treacher Collins, Crouzon), and pathological maxillary/mandibular conditions. Furthermore, individuals under the age of 18, using medications that affect bone metabolism (e.g., bisphosphonates, corticosteroids, antiepileptics), and pregnancy were also excluded.

Image analysis

CBCT (Planmeca ProMax® 3D Mid, Helsinki, Finland; voxel size: 400 µm, 27 sec, 10 mA, 90 kV) images were evaluated with Planmeca Romexis software 3.8.1.R. Following the initial examination of the 3D scans in the axial plane, reformatted planes (the Pöschl and Stenvers planes) were generated. The Pöschl plane was adjusted perpendicular to the long axis of the petrous bone, at an angle of ~45° with the coronal and sagittal planes (Figure 1a). It was aligned parallel to the SSC. SSC was examined as a ring in this plane (Figure 1b).

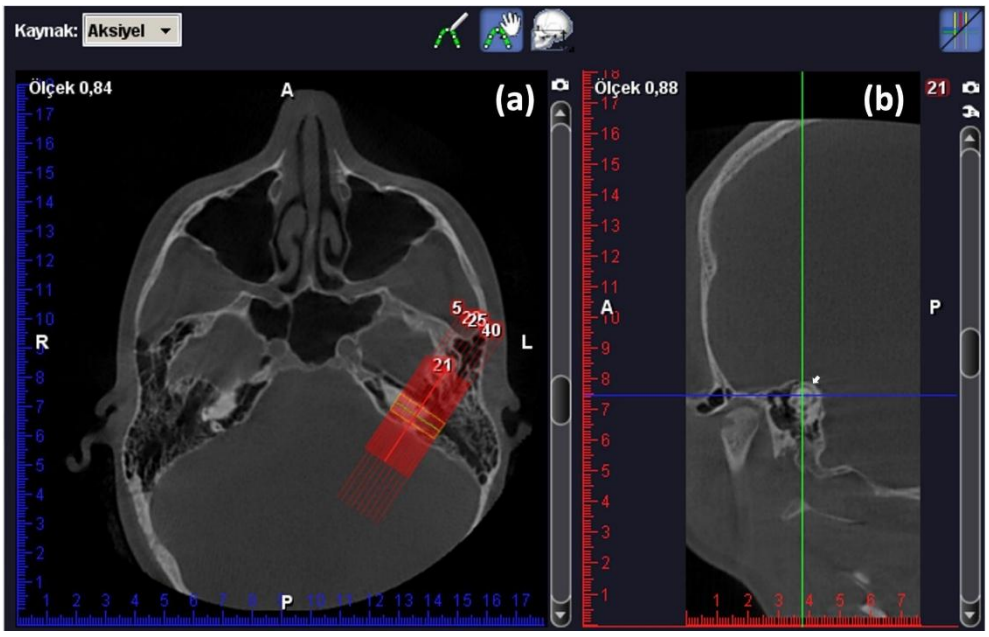

Figure 1. The Pöschl plane with reformatted cone beam computed tomography images
(a) Angle of reformation showed on axial plane (b) Ring view of SSC indicated by arrow in Pöschl plane

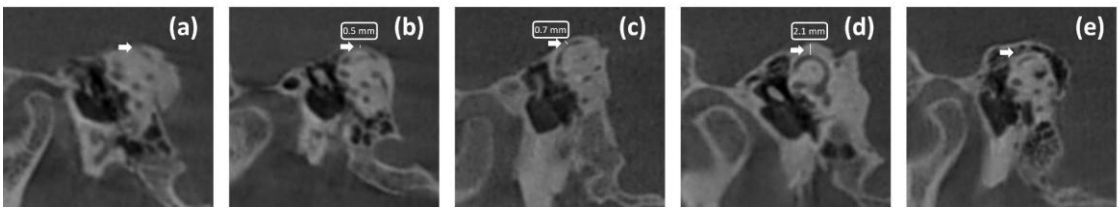

Figure 2. Cone-beam computed tomography images view of Superior Semicircular Canal's Types. (a) Dehiscence; (b) Papyraceous; (c) Normal; (d) Thick; (e) Pneumatised.

Minimum bone thickness of SSC was measured. Radiological types of SSC were classified as dehiscence (discontinuity in the bone covering the SSC), papyraceous (≤0.5 mm), normal (0.6-1.7 mm), thick (≥1.8 mm) and pneumatised (multiple supralabyrinthine cells) (Figure 2)[12].

The analysis of the scans and and all categorical evaluations were conducted by two oral and maxillofacial radiologists, with 6 (HDY) and 16 (BE) years of experience, respectively. Ten days later, the all measurements (minimum bone thickness of SSC) were re-administered to assess intra/inter-observer reliability and averaged for each patient. Throughout this process, the examiners were kept unaware of the clinical information of the patients, thus maintaining the integrity of the study. In addition, there was no difference between the two clinicians in terms of categorical evaluations.

Statistical analysis

The sample size was calculated based on a medium effect size, as no similar studies were found in the literature (G*Power 3.1). The analysis details are as follows: Test family: χ^2 tests, statistical test: Goodness-of-fit test: Contingency tables, effect size w: 0.3 (medium), power (1-β): 0.95. To assess normal distribution, the Kolmogorov-Smirnov test was employed. For the comparison of age and bone thickness of SSC between groups (TMD-control comparison and gender comparison), the Mann-Whitney U test was used. Chi-square test was applied to evaluate the relationship between TMD-control groups and radiological types of SSC-osteoarthritis findings. The column ratios were analyzed in relation to one another to identify the parameter contributing to the observed significance, with p-values adjusted using the Bonferroni correction method. Fisher's exact test (with the Monte Carlo Simulation and 99% confidence interval) was applied to examine the influence of age groups (18-24; 25-34; 35-44; 45-54; 55-64; ≥65) on the radiological types of the SSC. Chi-square test or Fisher's exact test were applied to examine the relationship between gender and radiological types of SSC. The intraclass correlation coefficients (ICCs) were calculated to evaluate intra/inter-observer reliability for bone thickness of SSC. The significance level was established as $p<0.05$ [SPSS 20.0 (Chicago, IL, USA)].

RESULTS

The total sample size was determined to be 224 sides (α: 0.05, medium effect size: 0.3, power: 95%). A total of 112 sides from 56 individuals diagnosed with TMD (28 males and 28 females) and 112 sides from 56 healthy (control) individuals (28 males and 28 females) were examined. All ICCs were found to be greater than 0.89 ($p<0.001$). The mean age for both the control and TMD groups was 38.47±16.25 (ranging from 18 to 69). The ages for females (37.96±15.29) and males (38.97±17.21) were similar ($p=0.881$).

The bone thickness of SSC in the control group was significantly higher than that in the TMD group ($p<0.001$). No significant difference was observed in the bone thickness of SSC between females and males in TMD and control groups (Table 1).

Table 1. The bone thickness of superior semicircular canal according to groups

	TMD (n=112)			**Control (n=112)**		**p**
mean±sd	0.9±0.8			1.5±1.1		<0.001*
mdn(min-max)	0.8(0-3.2)			1.2(0-4.5)		
	Female (n=56)	Male (n=56)	p	Female (n=56)	Male (n=56)	p
mean±sd	0.9±0.8	1±0.8	0.365	1.4±1.1	1.5±1	0.829
mdn(min-max)	0.7(0-3.1)	0.9(0-3.2)		1.2(0-4.5)	1.2(0-4)	

TMD: Temporomandibular disorders; Mann-Whitney U test (*p<0.05). mdn: median, sd: standard deviation

In this study, a significant difference was observed among the groups in terms of SSC types ($p<0.001$). When the SSC types that cause this difference were examined, it was found that the prevalence of dehiscence and papyraceous types in the TMD group was significantly higher than in the control group, while the prevalence of the normal type was significantly lower (Table 2).

Table 2. SSC types according to TMD and control groups

	TMD	Control	Total	p
SSC Type				
Dehiscence	26(23.2)†	9(8)	35(15.6)	<0.001*
Papyraceous	24(21.4)†	10(8.9)	34(15.2)	
Normal	45(40.2)†	72(64.3)	117(52.2)	
Thick	8(7.1)	9(8)	17(7.6)	
Pneumatised	9(8)	12(10.7)	21(9.4)	
Total	112(100)	112(100)	224(100)	

SSC: Superior semicircular canal, TMD: Temporomandibular disorders
n(%). Chi-square test (*p<0.05). † indicates a statistically significant difference between the columns († p values corrections with Bonferroni method).

Table 3. SSC types according to age groups

			Age groups					p
	18-24	25-34	35-44	45-54	55-64	≥65	Total	
SSC Type								
TMD								
Dehiscence	4(30.8)	7(29.2)	5(20.8)	3(16.7)	4(17.4)	3(30)	26(23.2)	0.076
Papyraceous	1(7.7)	5(20.8)	10(41.7)	3(16.7)	2(8.7)	3(30)	24(21.4)	(0.069-0.083)
Normal	5(38.5)	10(41.7)	5(20.8)	7(38.9)	15(65.2)	3(30)	45(40.2)	
Thick	-	2(8.3)	2(8.3)	4(22.2)	-	-	8(7.1)	
Pneumatised	3(23.1)	-	2(8.3)	1(5.6)	2(8.7)	1(10)	9(8)	
Total	13(100)	24(100)	24(100)	18(100)	23(100)	10(100)	112(100)	
Control								
Dehiscence	1(6.7)	3(8.6)	2(6.7)	1(10)	1(11.1)	1(7.7)	9(8)	0.204
Papyraceous	2(13.3)	6(17.1)	-	1(10)	1(11.1)	-	10(8.9)	(0.194-0.215)
Normal	10(66.7)	22(62.9)	20(66.7)	6(60)	5(55.6)	9(69.2)	72(64.3)	
Thick	2(13.3)	1(2.9)	6(20)	-	-	-	9(8)	
Pneumatised	-	3(8.6)	2(6.7)	2(20)	2(22.2)	3(23.1)	12(10.7)	
Total	15(100)	35(100)	30(100)	10(100)	9(100)	13(100)	112(100)	
All								
Dehiscence	5(17.9)	10(16.9)	7(13)	4(14.3)	5(15.6)	4(17.4)	35(15.6)	0.657
Papyraceous	3(10.7)	11(18.6)	10(18.5)	4(14.3)	3(9.4)	3(13)	34(15.2)	(0.645-0.669)
Normal	15(53.6)	32(54.2)	25(46.3)	13(46.4)	20(62.5)	12(52.2)	117(52.2)	
Thick	2(7.1)	3(5.1)	8(14.8)	4(14.3)	-	-	17(7.6)	
Pneumatised	3(10.7)	3(5.1)	4(7.4)	3(10.7)	4(12.5)	4(17.4)	21(9.4)	
Total	28(100)	59(100)	54(100)	28(100)	32(100)	23(100)	224(100)	

SSC: Superior semicircular canal, TMD: Temporomandibular disorders; n(%). Fisher's exact test (with the Monte Carlo Simulation technique and 99% confidence interval).

In the TMD group, the control group and all patients, no statistically significant relationship was found between age groups and SSC types (Table 3). In the TMD group, the control group and all patients, no statistically significant relationship was found between gender and SSC types (Table 4). In this study, a significant difference was observed among the groups in terms of osteoarthritis findings ($p<0.001$). When the osteoarthritis findings that cause this difference were examined, it was found that the prevalence of osteophyte, erosion and flattening types in the TMD group was significantly higher than in the control group, while the prevalence of the normal type was significantly lower (Table 5).

Table 4. SSC types according to gender

	TMD		p	Control		p	All		p
	Female	Male		Female	Male		Female	Male	
SSC Type									
Dehiscence	14(25)	12(21.4)	0.963 †	5(8.9)	4(7.1)	0.955 †	19(17)	16(14.3)	0.902 ‡
Papyraceous	13(23.2)	11(19.6)		6(10.7)	4(7.1)		19(17)	15(13.4)	
Normal	21(37.5)	24(42.9)		35(62.5)	37(66.1)		56(50)	61(54.5)	
Thick	4(7.1)	4(7.1)		4(7.1)	5(8.9)		8(7.1)	9(8)	
Pneumatised	4(7.1)	5(8.9)		6(10.7)	6(10.7)		10(8.9)	11(9.8)	
Total	56(100)	56(100)		56(100)	56(100)		112(100)	112(100)	

SSC: Superior semicircular canal, TMD: Temporomandibular disorders; n(%). †Fisher's exact test, ‡Chi-square test.

Table 5. Osteoarthritis findings according to TMD and control groups

	TMD	Control	Total	p
Osteoarthritis				
Normal	24(21.4)†	65(58)	89(39.7)	<0.001*
Osteophyte	27(24.1)†	15(13.4)	42(18.8)	
Erosion	21(18.8)†	7(6.2)	28(12.5)	
Flattening	29(25.9)†	16(14.3)	45(20.1)	
Sclerosis	9(8)	8(7.1)	17(7.6)	
Pseudocyst	2(1.8)	1(0.9)	3(1.3)	
Total	112(100)	112(100)	224(100)	

TMD: Temporomandibular disorders; n(%). Chi-square test (*$p<0.05$). † indicates a statistically significant difference between the columns († p values corrections with Bonferroni method).

DISCUSSION

The current study intends to assess the bone thickness and types of the SSC in TMD patients compared to a matched control group using CBCT images. In the literature, SSC structure has been examined by evaluating three-dimensional images[8,12-16]. It is crucial to evaluate CT images carefully, as it can potentially influence the decision for surgical intervention in cases of SSCD. Some studies have indicated several false-positive assessments in the detection of SSCD with CT[17-19]. CT imaging has the potential to overestimate the size of dehiscences. Therefore, it is crucial to clearly define clinical symptoms and consider other diagnostic indicators before proceeding with surgery[19]. Cloutier et al. reported that the potential for overdiagnosis still exists, even with reformation and a 0.55 mm-collimated helical CT[20]. Bremke et al.'s study determined that digital volume tomography (DVT) images appear to be more effective than high-resolution CT images for detecting the thin bone

lining of the SSC[9]. Dalchow et al. reported that DVT, an imaging technique based on the principles of CBCT, is an excellent tool to examine SSC structures[10]. Due to its high spatial resolution and smaller voxel size, CBCT has been shown as a convenient method for the evaluation of small anatomical structures like SSC[8]. Additionally, it offers a significant advantage of much lower radiation dosage compared to CT[21]. Considering all these reasons, this study utilized CBCT images for the evaluation of SSC.

The debate on whether SSCD is a congenital or acquired condition remains unresolved. While some studies suggest a higher prevalence of SSCD and a decrease in SSC bone thickness with aging, particularly due to degenerative changes[22-24], others, such as Hagiwara et al., highlight its presence in early childhood, suggesting a possible congenital etiology[25]. In the current study, there was no significant relationship found between age groups and SSC types in both groups. These results are consistent with studies reporting no association between age and bone thickness or types of SSC[8,14,26]. In the current study, similar to the studies by Akay et al.[13] and Evlice et al.[14] no significant relationship was found between SSC types and gender. Crovetto et al. unlike this, reported that a slight osteopenia was observed in the bone covering the SSC with aging in women associated with menopause[24].

The etiology of SSCD is still uncertain[7], and it remains a topic of controversy in the field of craniofacial disorders. In individuals with SSCD, important clinical symptoms such as autophony, aural fullness, vertigo, nystagmus, and vestibular symptoms can be observed[24,27,28]. The treatment may vary as conservative or surgical depending on the severity of the symptoms[7].

Previous studies investigating SSC types using cadaver, CT, and CBCT images have reported prevalence ranges as follows: dehiscence type (1.84%–16.5%), papyraceous type (6.1%–17.71%), normal type (42%–74.2%), thick type (2.8%–22%), and pneumatised type (3.06%–12%)[8,12-16]. The prevalences of all SSC types in the control group (dehiscence type, 8%; papyraceous type, 8.9%; normal type, 64.3%; thick type, 8%; and pneumatized type, 10.7%) were within the range reported in the literature. In the current study, the TMD group exhibited similar prevalence of thick and pneumatized types (7.1% and 8%, respectively), lower prevalence of the normal type (40.2%), and higher prevalence of papyraceous and dehiscence type (21.4% and 23.2%, respectively) when compared to the literature. Additionally, the prevalence of papyraceous and dehiscence types in the TMD group was significantly higher than control group.

SSC dehiscence and papyraceous type were observed more frequently in TMD group compared to control group. The reason for this may be that osteoarthritis findings are observed in a large number of patients in the TMD group. According to the study findings, the prevalence of erosion, flattening and osteophytes, which are signs of osteoarthritis, were also significantly increased in the TMD group. In previous studies, it has been suggested that there is thinning and dehiscence in the temporal bone structures in patients with degenerative joint disease and patients in menopausal age[24,29]. Similar to our findings, Kurt et al. showed that 80% of patients with SSCD have had osteoarthritis findings such as flattening, surface irregularities, and osteophyte formation[8].

Sencimen et al. examined the relationships between the TMJ and ligaments and suggested that unexplained otological problems may result from excessive stretching of the condyle[30]. To the best of our knowledge, the study by Kurt et al. is the only study that has examined the relationship between SSCD and TMJ symptoms. In this study, among 175 patients, SSCD was found in 20 cases, and all patients with SSCD had TMJ symptoms[8]. The higher prevalence of SSCD in TMD patients compared to the control group in the current study supports this finding. As far as we are aware, there have been no studies that specifically examined the SSC in patients diagnosed with "TMD" or compared them with a control group. In the literature, in addition to the clinical significance of SSCD, attention has also been drawn to the possibility of the papyraceous type serving as a risk factor for SSCD[12,31-33]. Therefore, it is stated that clinically, the patterns of primary importance are dehiscence and papyraceous types[12,14]. In the current study, the higher prevalence of papyraceous and dehiscence types in the TMD group, exceeding both the reported prevalence ranges in the literature and those in the control group, suggests that TMD can be a predisposing factor for these types. A point to consider is that TMD, similar to SSCD, may also be associated with vertigo[34]. This condition may be attributed to the anatomical proximity between the TMJ and inner ear structures, as well as possible neurophysiological connections between vestibular systems. TMD is a comprehensive

disorder affecting the temporal and mandibular bones, masticatory muscles, and the TMJ. The main limitation of this study is that the relationships between SSC and TMD subgroups were not examined, which may restrict the applicability of the results to specific patient subgroups. Additionally, in patients with unilateral disc displacement, measurements taken on the contralateral side may have influenced the results in the study group. Other limitations of this study include its retrospective design, which prevents a full explanation of the cause-and-effect mechanism of these changes in SSC, and the fact that it is a single-center study. For these reasons, it is recommended to plan prospective and multicenter studies with larger sample sizes, distinguishing between unilateral and bilateral cases, and including TMD subgroups. This study suggests that TMD may lead to changes in the SSC, particularly predisposing to dehiscence and papyraceous types. Understanding these associations could contribute to improve diagnosis and management of TMD patients.

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Peer-review: Externally peer-reviewed.
Conflict of Interest: The authors declare that they have no conflict of interest.
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