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ORIGINAL ARTICLE

The evaluation of superior semicircular canal bone thickness and radiological patterns in relation to age and gender

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Abstract

Purpose The present study aims to evaluate the superior semicircular canal (SSC) bone thickness and radiological patterns in relation to age and gender in a Turkish population using cone beam computed tomography (CBCT).

Methods A total of 450 temporal bones were evaluated in the study by two examiners. The radiological patterns of SSC were categorized as follows: dehiscent, papyraceous, normal, thick and pneumatised patterns. The bone thickness of SSCs were measured.

Results The mean bone thickness of the SSC for females was 1.079 ± 0.8 mm. For males, the mean bone thickness was 0.952 ± 0.6 mm. There was no significant difference between males and females for the mean bone thickness of the SSC. ($p > 0.05$) The normal pattern was found in 258 temporal bones (57.3%). Seventy-two cases (16%) were defined as "papyraceous pattern"; 23 cases (5.1%) were defined as "thick pattern" and 42 cases (9.3%) were defined as "pneumatised pattern". SSC dehiscence was determined in 55 cases (12.2%). There was no significant difference between radiological patterns for age groups and gender ($p > 0.05$).

Conclusion There was no significant relationship between SSC bone thickness with age and gender. The radiological patterns of SSC were not associated with age and gender. Radiologists evaluating the head and neck region for various reasons should be aware of these structures and report not only the SSC dehiscence but also the papyraceous pattern.

Keywords Superior semicircular canal · Dehiscence · Cone beam computed tomography · Bone thickness

Introduction

Superior semicircular canal dehiscence (SSCD) and its clinical implications were first defined by Minor in 1998 [16]. SSCD can be defined as a structural alteration of the overlying bone of the superior semicircular canal (SSC). The bone defect in the superior part of the canal causes the lumen to be in contact with the middle cranial fossa. The clinical manifestations of SSCD were reported as vertigo or nystagmus triggered by loud sounds (Tullio phenomenon), tinnitus, autophony and changes in middle ear pressure [8, 12]. Also, it has been stated in one case that the SSCD is the passageway for an intracranial brain abscess [4]. The etiology of SSCD remains controversial. There is no consensus in the literature as to whether this condition is congenital or acquired. While some authors suggested a congenital condition, many others claimed that SSCD is caused by anomalies in the bone deposition in childhood and adolescence [4, 19].

Due to the complex anatomical structure of the temporal bone, accurate radiological examinations are crucial in the diagnosis of SSCD. Several studies reported that computed tomography (CT) overestimates the prevalence of SSCD. Sequeira et al. [20] stated that CT cannot be used as a gold standard for the diagnosis of SSCD, especially in small dehiscences. The use of cone beam computed tomography (CBCT), which has increased in recent years, has advantages such as relatively low radiation, increased spatial resolution and thin slices [18]. Only a few studies were conducted to evaluate SSC using CBCT in recent years [1, 12, 13]. Cisneros et al. [6] described five patterns for the roof of the superior semicircular canal: normal, thick, pneumatised, papyraceous and dehiscent. It was suggested that the papyraceous pattern may change to dehiscence as a result of rupture which can be triggered by a traumatic event [6, 15]. Since papyraceous and dehiscent patterns may result in

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pathological consequences, the evaluation of the frequency of radiological patterns of SSC can be useful for clinicians. The present study aims to evaluate the superior semicircular canal bone thickness and radiological patterns in relation to age and gender in a Turkish population.

Materials and methods

This retrospective study was independently reviewed and approved by Çukurova University Ethics Committee (year 2021; decision number 42). The CBCT images of the patients who referred to Çukurova University Faculty of Dentistry between January-2017 and January-2020 were evaluated in the study. The standard protocol at Oral and Maxillofacial Radiology Department contains acquiring signed informed consent from all patients for evaluation of their CBCT records for any reasons. Inclusion criteria were listed as CBCT images with high diagnostic quality, having no previous surgical procedure and no trauma to the craniofacial region and visibility of bilateral temporal bones in the scanning area. Patients with bone diseases, congenital syndromes that may affect the craniofacial region, patients consuming drugs that may affect bone metabolism, and low-quality CBCT images were excluded from the study. A total of 450 temporal bones were included in the study.

Image analysis

The maxillofacial imaging of the patients was performed with CBCT device (Planmeca ProMax® 3D Mid, Helsinki, Finland; exposure parameters: 90 kV, 10 mA, 27 s scan time, voxel size: 0.4 mm^3). Image analysis were performed using the Planmeca, Romexis viewer software in a dark and quiet room.

After the examination of three-dimensional images in the axial plane, the Pöschl and Stenvers planes were reformatted. The Pöschl plane is positioned at an angle of approximately 45° to the sagittal and coronal planes. It provides an intact ring view of the normal SSC. The Stenvers plane is positioned perpendicular to the Pöschl plane.

The evaluation of SSCs was performed in three planes (the axial, Pöschl and Stenvers planes). The slice thickness was 0.4 mm. The radiological patterns of SSCs were categorized according to Cisneros et al. [6].

- Dehiscent pattern: The absence of bone covering the SSC (Fig. 1).
- Papyraceous pattern: The bone thickness of the SSC is ≤ 0.5 mm (Fig. 2a).
- Normal pattern: The bone thickness of the SSC is between 0.6 and 1.7 and defined as a normal pattern (Fig. 2b).

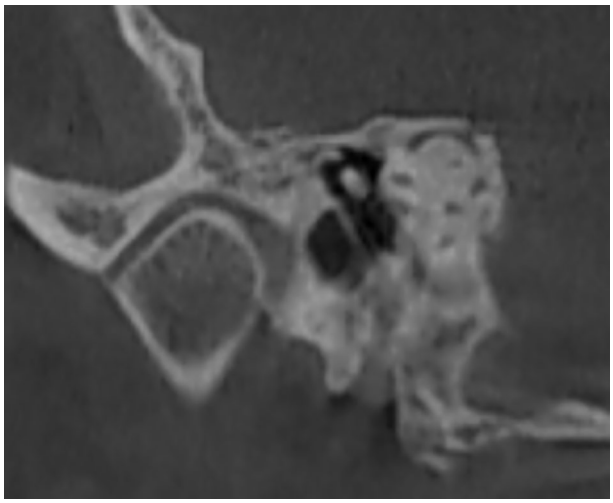


Fig. 1 The superior semicircular canal dehiscence was shown in cone beam computed tomography image

- Thick pattern: The bone thickness of the SSC is ≥ 1.8 mm (Fig. 2c).
- Pneumatised pattern: The SSC is characterized by multiple supralabyrinthine cells presenting as a woven structure (Fig. 2d).

The minimum bone thickness of SSC was measured from the inner surface of the roof of SSC to the inner surface of the middle cranial fossa (Fig. 2a–d).

The images were analyzed by two experienced oral and maxillofacial radiologists. The examiners were calibrated beforehand to identify temporal bone structures. Two weeks later, 20% of all measurements were repeated to evaluate intraobserver reliability. The examiners were blinded to the clinical information of patients.

Statistical analysis

Statistical analyses were performed using SPSS software package 25.0 (Chicago, IL, USA). The significance level was determined as $p < 0.05$. The age and gender of the patients were determined. Descriptive statistics were used to summarize the data. According to gender, the evaluation of the mean bone thickness of the SSC was made using the independent samples *t* test. The Chi-square test was used to determine the effect of age and gender on the radiological patterns of the SSC. The mean age was compared for the radiological patterns of the SSC using the Kruskal–Wallis test. The intraclass correlation coefficient (ICC) was used to test inter-rater reliability. Intra-rater (test–retest) reliability, which measures the reliability of repeated measurements for each reviewer, was analyzed with the Pearson correlation

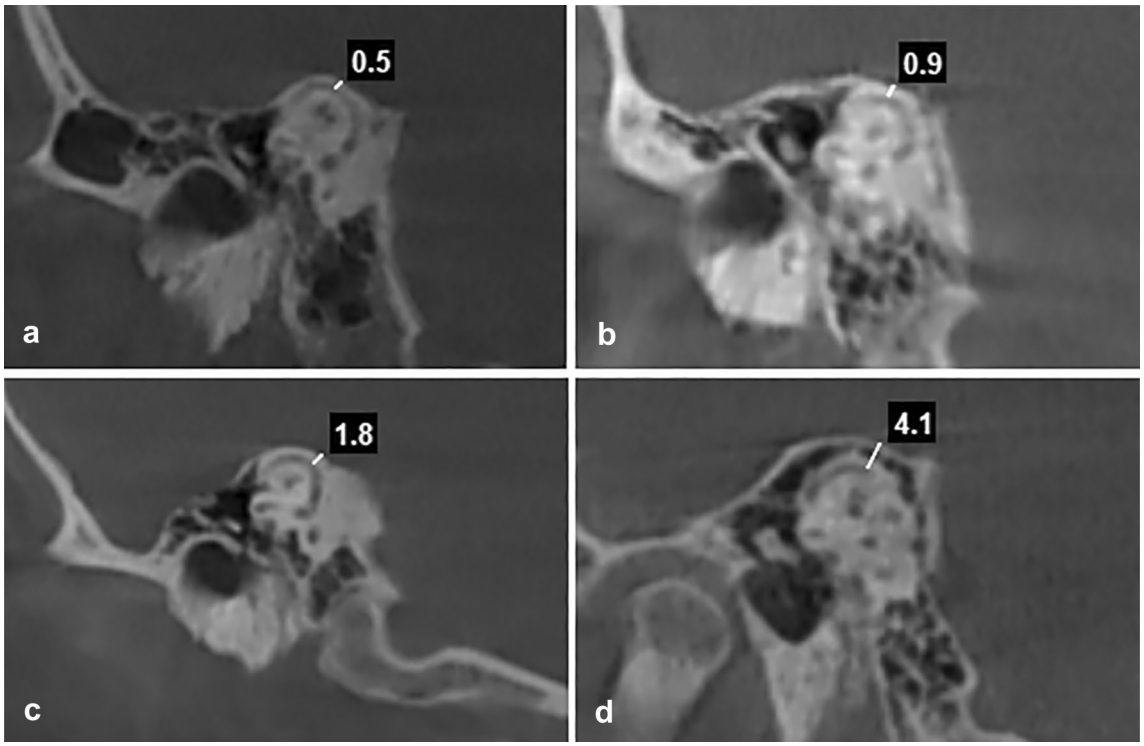


Fig. 2 Reformatted cone beam computed tomography images and measurements. **a** Papyraceous pattern. **b** Normal pattern. The minimum bone thickness of SSC was measured. **c** Thick pattern. **d** Pneumatised pattern

Table 1 Age and gender distributions of the study

Gender	*N* (%)	Minimum	Maximum	Mean	Standard deviation
Female	126 (56%)	16	69	37.17	15.97
Male	99 (44%)	14	69	38.22	17.16
Total	225 (100%)	14	69	37.64	16.49

Table 2 The bone thickness of the SSC according to gender

Genders	Mean	Standard deviation	Minimum	Maximum	*p* value
Females	1.079	0.802	0	4.470	0.071
Males	0.952	0.656	0	3.300	
Total	1.024	0.743	0	4.470	

SCC superior semicircular canal. Independent samples *t* test (*$p < 0.05$)

coefficient. The intraclass correlation coefficient (ICC) was 0.92 ($p < 0.0001$), which implies excellent inter-rater reliability. The Pearson correlation coefficient was 0.98 ($p < 0.0001$) (B.E.) and 0.95 ($p < 0.0001$) (D.S.Ç.) for each comparison, significant at the 0.01 level (two-tailed). Therefore, the intra-rater reliability was also excellent.

Results

A total of 450 temporal bone belonging to 225 patients were evaluated. There were 126 females (56%) and 99 males (44%) included in the study. The mean age of the participants was 37.64 (Table 1).

The mean bone thickness of the SSC for females was 1.079 ± 0.802 mm. For males, the mean bone thickness was 0.952 ± 0.656 mm. There was no significant difference between males and females for the mean bone thickness of the SSC ($p > 0.05$) (Table 2).

When examined according to radiological patterns, the normal pattern was found in 258 temporal bones (57.3%). Seventy-two cases (16%) were defined as "papyraceous pattern"; 23 cases (5.1%) were defined as "thick pattern" and 42 cases (9.3%) were defined as "pneumatised pattern". SSCD was determined in 55 cases (12.2%). There was no significant difference between radiological patterns for age groups and gender ($p > 0.05$). The distribution of age groups and gender according to the radiological patterns are shown in Table 3.

Table 3 Relationships between age/gender and radiological patterns of SSC

Age groups	Radiological patterns of SSC					Total	*p*
	Normal pattern 258 (57.3%)	Papyraceous pattern 72 (16%)	Thick pattern 23 (5.1%)	Pneumatized pattern 42 (9.3%)	Dehiscent pattern 55 (12.2%)	450 (100%)	
Up to 19 years	34 (13.2%)	6 (8.3%)	2 (8.7%)	7 (16.7%)	8 (14.5%)	57 (12.7%)	0.076[a]
20–29 years	82 (31.8%)	20 (27.8%)	5 (21.7%)	12 (28.6%)	15 (27.3%)	134 (29.8%)	
30–39 years	47 (18.2%)	25 (34.7%)	10 (43.5%)	6 (14.3%)	10 (18.2%)	98 (21.8%)	
40–49 years	28 (10.9%)	7 (9.7%)	6 (26.1%)	7 (16.7%)	7 (12.7%)	55 (12.2%)	
50–59 years	38 (14.7%)	6 (8.3%)	–	5 (11.9%)	9 (16.4%)	58 (12.9%)	
60 + years	29 (11.2%)	8 (11.1%)	–	5 (11.9%)	6 (10.9%)	48 (10.7%)	
Age						Total	
Mean	37.36	37.53	34.26	37.64	40.45	37.64	0.820[b]
Standard deviation	16.97	15.45	7.80	17.58	17.48	16.49	
Genders						Total	
Female	145 (56.2%)	38 (52.8%)	15 (65.2%)	25 (59.5%)	29 (52.7%)	252 (56%)	0.817[a]
Male	113 (43.8%)	34 (47.2%)	8 (34.8%)	17 (40.5%)	26 (47.3%)	198 (44%)	

SCC superior semicircular canal

[a]Chi-square test (*$p < 0.05$)

[b]Kruskal–Wallis test (*$p < 0.05$)

Discussion

After the discovery of SSCD syndrome, the number of studies on the anatomical structures of the temporal bone has increased [23, 24]. Some authors stated that CT overestimates the presence of SSCD [7, 14, 21]. Tavassolie et al. [21] concluded that the radiographic measurements overestimated the length and width of the dehiscence compared with the actual surgical measurements. Mondina et al. [17] also highlighted the limitations of CT imaging. The overestimation of SSCD can be due to partial volume averages and limitations in scanner resolution [1, 10]. CBCT is considered an appropriate imaging modality because of its smaller voxel size and high spatial resolution [12]. Bremke et al. [3] suggested that CBCT is better to identify thin bone layers compared to high-resolution CT. Therefore, CBCT was used to evaluate temporal bones in the present study.

Although the number of studies on SSCD has increased in the literature, it is not clear whether this condition is congenital or acquired. Nadgir et al. [19] reported a statistically significant increase in the prevalence of radiographic dehiscence with advancing age. Their study findings supported an acquired etiology for SSCD rather than congenital. Davey et al. [9] demonstrated that the thickness of the SSC decreases with older age. Crovetto et al. [8] stated that they have found a slight thinning of the bone covering of SSC due to aging. However, Hagiwara et al. [11] reported that bone thickness overlying SSC was much thinner in children compared to adults. Kurt et al. [12] and Mahulu et al. [13] reported no significant relationship between age and SSC bone thickness. In the present study, no significant relationship was found between age and SSC bone thickness. Our results are similar to those of Kurt et al. and Mahulu et al. [12, 13].

In the present study, no significant relationship was found between gender and SSC patterns. Also, there was no significant relationship between SSC thickness and gender. Akay et al. [1] reported that SSCD was determined more frequently in female patients. However, there was no significant difference between males and females for SSCD. Mahulu et al. [13] also found no significant difference between males and females for SSC thickness in a Chinese population. Contrary to these studies, Crovetto et al. [8] have found slight osteopenia of the roof of the SSC in menopausal women. They stated that decreasing estrogen levels in menopause might promote bone resorption.

In the literature, a few studies highlighted that papyraceous pattern can be predisposed to SSCD [4, 6, 22]. Watters et al. [22] reported two women with acute vertigo and oscillopsia after childbirth. CT examination confirmed the diagnosis of SSCD. They suggested that vaginal delivery caused an increase in intracranial pressure, triggering rupture of the thin roof of SSC. Minor et al. [15] also mentioned the existence of a "second traumatic event" in the medical story of some patients with SSCD. While Akay et al. [1] reported that 9.5% of evaluated SSCs had the papyraceous pattern, Cisneros et al. [6] determined the frequency of the papyraceous pattern as 14.1%. In the present study, the frequency of the papyraceous pattern was determined as 16%. A papyraceous lamina can be responsible for the rupture of SSCD. The authors suggest that SSCs with papyraceous

pattern should also be reported in radiological examinations, since they may be a predisposing factor for dehiscence.

Studies have reported different rates for the incidence of SSCD. In the study of Cisneros et al. [6], the incidence of SSCD was reported as 1.84%. Kurt et al. [12] found this incidence as 6.28% in their CBCT study. A recent study by Akay et al. [1] also used CBCT and determined SSCD in 16.5% of the study population. In a study sample consisted of patients with spontaneous cerebrospinal fluid otorrhea, Allen et al. [2] determined the SSCD as 15.2%. The differences between the results can be attributed to the study populations. Age and gender distributions of study populations may be the cause of these discrepancies. Ceylan et al. [5] evaluated 186 temporal bones in a Turkish study population. They found the prevalence of SSCD as 12% in their CT study. In the present study, SSCD was determined in 12.2% of 450 temporal bones. The present study findings are similar to Ceylan et al. [5]. In a previous study, it was mentioned that slice thicknesses used in CBCT images may also affect these results [1]. In the present study, 0.4 mm slice thicknesses were used.

The pneumatised pattern of SSC can often be observed in temporal bones with pneumatised structure. Cisneros et al. [6] suggested that during embryological development, the bone apposition of the three primitive layers could not be fully achieved, resulting in a pneumatised pattern. Since the internal layer of pneumatised SSC has an adequate thickness, it is not considered clinically important [6]. In the present study, 42 temporal bones (9.3%) had the pneumatised pattern.

There was no significant difference between radiological patterns for age groups ($p > 0.05$). However, none of the cases over 50 years old had SSC with thick pattern. Patients with a thick SSC pattern at a younger age may have thinner SSC patterns with advancing age due to osteoporosis. The relationship between SSC thickness and osteoporosis should be investigated in these elderly cases. Also, p value ($p = 0.076$) was very close to the significance level [five cells (16.7%) had expected count less than 5]. Since this is a concern about the reliability of the test and the Chi-square test is considered to be a sampling sensitive analysis method, this aforementioned result may be different in studies with larger samples. Therefore, it can be considered as a limitation of the study. Further studies with larger numbers should be conducted to overcome this situation.

Conclusion

There was no significant relationship between SSC bone thickness with age and gender. The radiological patterns of SSC were not associated with age and gender. While SSCD was found in 12% of the temporal bones, a considerable portion of the cases (16%) had the papyraceous pattern. Radiologists evaluating the head and neck region for various reasons should be aware of these structures and report not only the SSCD but also the papyraceous pattern.

Author contributions BE: project development, manuscript writing, data collection, and image analysis; DSÇ: manuscript writing, data collection, and image analysis; HD: data collection and data analysis.

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Availability of data and materials Not applicable.

Code availability Not applicable.

Declarations

Conflict of interest All authors declare that they have no conflict of interest.

Ethical approval This retrospective study was independently reviewed and approved by Çukurova University Ethics Committee (year 2021; decision number 42). All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Consent to participate Informed consent was obtained from all patients for being included in the study.

Consent for publication All authors gave consent for the publication of the article.

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