Anatomic Study on Sphenoidal Emissary Foramen by Using Cone-Beam Computed Tomography

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Objectives: The goal of this retrospective study is to evaluate the radiologic anatomy of sphenoidal emissary foramen (SEF) by using cone-beam computed tomography (CBCT) scans.

Methods: Three hundred seventeen (189 female and 128 male) full-head CBCT images were evaluated in this study. Incidence, diameter, shape, confluence to foramen ovale, and distance to anatomic structures of SEF were noted.

Results: In the 317 analyzed images, the SEF was identified in 89 (28.1%) images. Of these, 67 (21.1%) were unilateral, 22 were (6.9%) bilateral. The maximum mean diameter of SEF was measured 2.66 mm on the right side and 2.82 mm on the left side ($P = 0.16$). The most observed SEF shape was oval with the incidence of 68.5% ($P \leq 0.05$). Confluence was observed in 23.4% of SEF whereas 84.6% were located in the left side ($P \leq 0.05$).

Conclusion: Observations in this study tender new anatomic parameters regarding SEF incidence, characteristics, and distances to proximate anatomic structures. Knowledge related to SEF variations will be helpful for neurosurgeons and radiologist.

Key Words: Cone-beam computed tomography, foramen vesalius, sphenoid bone, sphenoidal emissary foramen

Recognition of skull base with all its foramina is important not only for understanding the complex regional neurovascular anatomy but also for distinguishing normal from potentially abnormal structures.1

Sphenoidal emissary foramen (SEF) also known as foramen vesalius is a small, inconstant but symmetrical opening allows transmission between the middle cranial fossa and the scaphoid fossa. It transmits an emissary vein that connects the cavernous sinus to the pterygoid venous plexus.1

The small SEF, if present, is generally situated postero medially from the foramen rotundum and antero medially from the foramen ovale (FO), foramen spinosum (FS), and carotid canal (Fig. 1A-B).

Hence SEF is positioned near these structures especially to FO, neurosurgery may misplace the needle during percutaneous intervention targeting the FO for treatment of the trigeminal neuralgia, resulting in severe complications such as intracranial bleeding.2,3

Three normal types of SEF were classified: a well-formed foramen, 1 to 2 mm in size, lack of visualization of the foramen, and partial assimilation of the foramen with the FO.2

Confluence of the SEF with the FO is easily understood, considering that they transmit similar venous structures. In fact, when the SEF is not present, the sphenoidal emissary vein is thought to pass through the FO. Indeed, SEF may form by the development of a bony spicule in the anterior aspect of the FO, thus dividing it into 2 separate foramina.3

Advances in the use of 3-dimensional imaging have greatly improved the visualization of craniofacial structures. The introduction of cone-beam computed tomography (CBCT) during the past decade offers advantages over plain CT, such as smaller machines, reduced costs, higher resolution, and increased accessibility so with the development of CBCT, 3-dimensional assessment of the craniofacial region has become an alternative for patient imaging.4

The aim of this study is to assess the incidence, proximity to anatomic structures, morphometry, and confluence of SEF by analyzing floor of the middle cranial fossa with CBCT.

MATERIALS AND METHODS

The study protocol was carried out according to the principles described in the Declaration of Helsinki, including all amendments and revisions. The ethical approval was granted by the X University Ethical Committee (institutional review board number 2017/94).

Cone-beam computed tomography data of patients who recruited to outpatient clinic for several reasons in university hospital were retrospectively evaluated. Patients with evidence of bone disease (especially osteoporosis), relevant drug consumption, skeletal asymmetries or trauma, congenital disorders, a history of surgery, as well as any tumor or malignancy were excluded from the study. Full-head CBCT scans in a subgroup of Turkish population were included and technically inadequate scans were excluded from the study.

The final study group included 317 patients (189 female, 128 male) with an age range from 13 to 58 years (mean age 18.34 ± 6.6 years). The CBCT images were obtained using the I-CAT 3D Imaging System (Imaging Sciences International, Hatfield, PA) with following parameters: 5 mA, 120 kVp, 16 × 13 cm field of vision. Images were evaluated in the axial and 3-dimensional reformatted images (Fig. 1C-D).

Shapes of SEF as round, oval, and irregular were recorded. The foramen was defined as a round or ovoid structure with a sclerotic rim and a lucent center seen on at least 2 adjacent sections. Images were evaluated for the presence or absence and unilateral or bilateral pattern of SEF. Also, diameter of SEF, distance to FO, FS, and midline and confluence were evaluated (Fig. 1E). Confluence of 2 foramina (SEF and ovale) was defined as a complete lack of bony separation on all sections.

All measurements were done twice by 2 observers. To assess intraobserver reliability, the Wilcoxon matched-pairs signed rank test was used for repeat measurements. The interobserver reliability was determined by the intraclass correlation coefficient (ICC) and the coefficient of variation (CV) ($CV = \frac{\text{standard deviation}}{\text{mean}} \times 100\%$). Values for the ICC range from 0 to 1. Intraclass correlation coefficient values >0.75 show good reliability, and the low CV demonstrates the precision error as an indicator for reproducibility.

The SPSS 10.0 software (SPSS Inc, IBM Company Headquarters, Chicago, IL) was used for storing and analyzing data. The significance level value was set at 0.05. The chi-squared test was used to test for differences of the SEF groups and the percentage
values. The comparison of values between gender and sides were made using the independent samples t test.

**RESULTS**

Repeated CBCT evaluation and measurements indicated no significant intraobserver difference for both observers \( (P > 0.05) \). Overall intraobserver consistency for observer 1 was rated at 86.9% and 89.3%, while the consistency for observer 2 was found to be 87.8% and 90.7% between the 2 evaluations and measurements, respectively. All measurements were found to be highly reproducible for both observers and no significant difference was obtained from 2 measurements of the observers \( (P > 0.05) \). There was a high interobserver agreement and a high ICC and low CV demonstrated that the procedure was standardized between the evaluations and measurements of the observers. No statistical differences were found among observers’ evaluations and measurements \( (P < 0.05) \).

The mean measurements of both observers were indicated as final data for further analysis.

We observed that the SEF was present in 89 (28.1%) images. Of these 33.7% (30) were male, 66.3% (59) were female \( (P > 0.05) \) and 67 (21.1%) were unilateral, 22 were (6.9%) bilateral. In unilateral images, 36 (53.7%) were in the right side and 31 (46.3%) were in the left side \( (P > 0.05) \).

For the comparison between right and left sides in terms of distance and diameter measurements, independent samples t test was used (Table 1). When the mean of maximum diameter was compared according to gender, no statistically significant difference was observed \( (P = 0.225) \). Mean diameters also did not differ between the left and right sides \( (P = 424) \).

Of total foramina studied 28 (25.2%) were round, 76 (68.5%) were oval and 7 (6.3%) were irregular. The oval shape of SEF was found to be statistically higher than the other groups \( (P < 0.05) \).

The presence of a confluence was noted in 26 (23.4%) of analyzed skulls. Of these, 22 (84.6%) were in the left side and 4 (23.4%) were in the right side \( (P < 0.05) \).

**DISCUSSION**

Presence of SEF may cause an infection to spread from the extracranial origin or infratemporal region into the middle cranial fossa. Reason for the occurrence of this is the emissary vein passing through this foramen connects the venous system of the face through the pterygoid venous plexus, to the cavernous sinus.13 Additionally, using basic neurosurgical techniques such as radiofrequency rhizotomy in the therapy of trigeminal neuralgia by approaching through the FO, in the event of the presence of the SEF, the neurosurgeon should realize the proximity of this structure. Powerful justifications from several various researches indicated that the misplacing of the needle from the FO could penetrate the SEF, make a puncture in the cavernous sinus, the cave of Meckel, and cause bleeding in the temporal lobe.6

According to Wood, FO may be subdivided into 2 portions due to in growing spicules of bone. The anterior part is known as SEF. Hence, it is an expression of cranial venous outlets and it occurs only in humans.1 Lanzieri et al1 suggested that asymmetry of size was a likely indicator of underlying disease. In 4 of their 6 patients, asymmetry was associated with an abnormality, including a carotid cavernous fistula with inferior venous drainage through the SEF, destruction by tumor, and neurofibromatosis.

The incidence of the SEF and the side of location presents a wide variability among different studies. Previous studies’ results according to distribution and presence of SEF are given in Table 2. The variability of the SEF presence may depend on ethnic differences or evolutionary processes.14 In the current study, the incidence of unilaterally observed SEF (21.1%) fall within the published range; however, bilateral SEF incidence (6.9%) is lower than the publication data.

In a study done by Raval et al10, SEF was round in 72%, oval in 24%, and irregular in 4% of total foramina present. They measured the mean maximum dimension of SEF as 0.98 ± 0.67 mm on right side and 1.12 ± 0.73 mm on left side. Shinohara et al11 found these values as 0.67 ± 0.28 mm on right side and 0.76 ± 0.39 mm on left side. In line with Raval et al,10 our results showed that the least detected shape was irregular but in contrary oval shape was the most observed type of foramen. In the current study, also mean of the maximum SEF diameter was measured higher than the above-mentioned literatures.

Natsis et al12 indicated a positive correlation between SEF size and the distance between FO and SEF. This finding is contrary to the results reported by Ozer and Govsa who found a negative correlation between the SEF perimeter and the distance

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**TABLE 1.** Comparison Between Both Sides for the Values of Distances and for the Values of Diameter

<table>
<thead>
<tr>
<th>Measurement, mm</th>
<th>Right Side</th>
<th>Left Side</th>
<th>P</th>
</tr>
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<tbody>
<tr>
<td>Diameter</td>
<td>2.66 ± 0.76</td>
<td>2.82 ± 0.96</td>
<td>0.161</td>
</tr>
<tr>
<td>Distance FO-FO</td>
<td>2.31 ± 1.31</td>
<td>2.21 ± 1.14</td>
<td>0.569</td>
</tr>
<tr>
<td>Distance FO-FS</td>
<td>11.32 ± 1.98</td>
<td>11.26 ± 2.13</td>
<td>0.833</td>
</tr>
<tr>
<td>Distance FO-midline</td>
<td>19.57 ± 2.53</td>
<td>15.8 ± 1.97</td>
<td>0.0007</td>
</tr>
</tbody>
</table>

**TABLE 2.** Reported Incidence and Distribution of Sphenoidal Emissary Foramen by Various Authors

<table>
<thead>
<tr>
<th>Author’s Name</th>
<th>Year of Publication</th>
<th>Percentage of Bilateral Distribution, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ginsberg et al</td>
<td>1994</td>
<td>80 / 49.7</td>
</tr>
</tbody>
</table>
| Kodama et al | 1997 | 21.75 /
| Gupta et al | 2005 | 32.85 / 22.85 |
| Kale et al | 2009 | 45 / 25.1 |
| Chaiamsaksunt et al | 2012 | 10.9 / 12.7 |
| Ozer and Govsa | 2013 | 34.8 / 9.3 |
| Nimala et al | 2014 | 50 / 23.3 |
| Jadhera et al | 2016 | 28.8 / 11.2 |
| Natsis et al | 2017 | 40 / 21.5 |
SEF–FO. They measured the mean distances of SEF to the FO as 2.30 ± 1.14 mm (right) and 2.46 ± 0.89 mm (left) and SEF to the FS as 10.76 ± 1.26 mm (right) and 10.42 ± 1.29 mm (left). The authors suggested that the diameter of SEF as <0.5 mm was safer to work with, while bigger than 0.5 mm opening types were highly risky for percutaneous techniques on the FO.

Chaisuksunt et al10 evaluated 377 Thai adult dry skulls and stated that most of the SEF were found in male and on the left side. Kodama et al13 found no significant differences in the ratio of SEF between the male and the female, and between the left side and the right side in line with the current study. Based on the results of Shinohara et al11, the occurrence of the unilateral SEF was found more commonly on the left side than on the right side. Kodama et al13 observed no remarkable differences in the ratio between the male and the female, and between the left side and the right side in terms of SEF.

Raval et al10 observed the duplication of SEF in 1% of total skulls, which was similar to findings in the study done by Kale et al14 (1%), but these findings were lower than Singh et al15 (2%). Among SEF detected in this study, confluence with FO was observed with the incidence of 23.4% and most of them were in the left side.

The particularly complex bony and neurovascular anatomy of the skull base makes it an attractive target for high-spatial-resolution imaging. The CBCT analysis is highly recommended for better surgical outcomes and to reduce the postoperative complications. By using appropriate imaging system to pinpoint vital structures, the risk of damage to them during surgery can be reduced.

Although there are many studies addressing the morphology and morphology of SEF in human skulls, CBCT usefulness has not yet been proven. There have been numerous studies in the literature regarding morphology and morphological characteristics of SEF esp. in dry skulls; however, only a limited number of in vivo researches were conducted for this anatomic landmark using CT and none from CBCT imaging. Among those studies that used CT imaging, included less subjects than the current study. To our knowledge, the current study was the first to evaluate the anatomic characteristics of SEF by using CBCT.

In conclusion, these results of this study can provide detailed knowledge of the anatomic characteristics in this particular area. CBCT imaging with lower radiation dose and thin slices can be a powerful tool before any surgical approach to the skull base esp. in transsphenoidal approaches.

REFERENCES