

Three-dimensional computed tomography analysis to help define an endoscopic endonasal approach of the pterygopalatine fossa

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ABSTRACT

Background: The pterygopalatine fossa (PPF) can be entered endoscopically, but the endoscopic landmarks to localize the bony structures in the PPF are not well described. This study aimed to investigate the anatomy of the sphenopalatine foramen (SPF), vidian canal (VC), and foramen rotundum (FR) with regard to an endoscopic endonasal approach to the PPF using three-dimensional reconstruction of computed tomography (CT) scans.

Methods: The CT scans of 98 patients were retrospectively evaluated. The morphology of the SPF, VC, and FR as well as the spatial relationship between the SPF and VC were measured on a three-dimensional model.

Results: The mean diameters of the SPF, VC, and FR were 5.3 ± 1.3 mm, 2.4 ± 0.7 mm, and 2.8 ± 0.5 mm, respectively. The mean distance between the VC and posteroinferior margin of SPF was 3.8 ± 1.0 mm. The mean vertical and horizontal distances on the surface plane of sphenoid bone between the VC and FR were 5.8 ± 1.9 mm and 8.5 ± 1.9 mm, respectively. The whole or partial margin of the VC was above the inferior margin of the SPF in 92% (180/196) of the VC and lateral to the posterior margin of the SPF in 98% (195/196) of the VC. The distance between the VC and SPF had a positive correlation with the distances between the VC and FR.

Conclusion: The endoscopic endonasal approach to the PPF will be performed with greater accuracy and safety through comprehension of the spatial relationships between the SPF, VC, and FR.

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The pterygopalatine fossa (PPF) is a narrow space that is bounded by the maxillary bone, pterygoid process of sphenoid bone, and perpendicular lamina of palatine bone. It is filled with complex neurovascular contents and contains an important crossing point that communicates with the orbit, nasal cavity, middle cranial fossa, pharynx, foramen lacerum, and infratemporal fossa via foramina and fissures.¹

Surgical access to the PPF is difficult because of its protected position and its complex neurovascular anatomy. Obtaining access to the PPF has been traditionally accomplished through an extensive transcranial or transfacial approach,² but recent literature has described an endoscopic endonasal approach to the PPF.^{3,4} To perform the endoscopic endonasal approach successfully, endoscopic landmarks to localize the neurovascular structures in the PPF are important.

Various foramina and fissures providing communication with the PPF can be readily seen on computed tomography (CT) imaging, which is ideal for delineating bony anatomy.¹ The nasal cavity communicates with the PPF via the sphenopalatine foramen (SPF).⁴ The vidian canal (VC) and foramen rotundum (FR) exist in the bony surface of the posterior wall of the PPF. Clinically, the VC is an important landmark for the endonasal approach to the skull base, especially for the petrosal segment of the internal carotid artery and foramen lacerum.^{5,6} Furthermore, identification of the VC may be necessary for complete vidian neurectomy, which has been advocated for the management of intractable vasomotor rhinitis.⁷ The FR is known to be located laterally and superiorly to the VC and contains the maxillary branch of the trigeminal nerve. The FR may be used as

a landmark to trace the maxillary branch from the proximal portion to the distal portion as the nerve emerges from the FR.⁸ Although the structures of the PPF are well known, the specific location and spatial relationships of the VC and FR in relation to the SPF have not been well described. This study aimed to investigate the anatomy of the SPF, VC, and FR with reference to the endoscopic endonasal approach of the PPF using three-dimensional reconstruction of the CT scan.

MATERIALS AND METHODS

Records from patients who had undergone diagnostic paranasal high-resolution CT (HRCT) scans at our clinic between January and July 2010 were examined retrospectively for this study. Patients with traumatic, neoplastic, or inflammatory lesion that destroyed the wall of the PPF were excluded. Ninety-eight patients (196 sides; 37 male and 61 female patients) were involved in our study. The ages of the patients were between 19 and 84 years, with an average of 49 years. No significant age difference existed between genders ($p > .05$). This study was approved by the Institutional Review Board of the Catholic Medical Center Clinical Research Coordinating Center.

HRCT scans were performed in 0.69-mm slices with a CT scanner (Sensation 16; Siemens Medical Systems, Munich, Germany). After the imaging data were stored in a Digital Imaging and Communication in Medicine file, they were imported to a personal computer. The axial views were examined by one observer, layer by layer, and the axial reconstructions were modified using 3D-DOCTOR software (Able Software Corp., Lexington, MA) so that the nasal floor in the coronal and sagittal planes was horizontal. The software provided line segmentation. We marked several points according to anatomic boundaries, and the software drew straight lines between each set of two adjacent points. A three-dimensional reconstruction was generated after segmentation (Fig. 1). All measurements were taken on the three-dimensional reconstruction.

The diameters of the SPF, VC, and FR were measured horizontally at the greatest distance (Fig. 2), and the distance between the VC and posteroinferior margin of the SPF was measured as the shortest distance between the margin of the VC and posteroinferior margin of the SPF. The vertical and horizontal distances between the VC and FR were defined as the vertical and horizontal distances from the center

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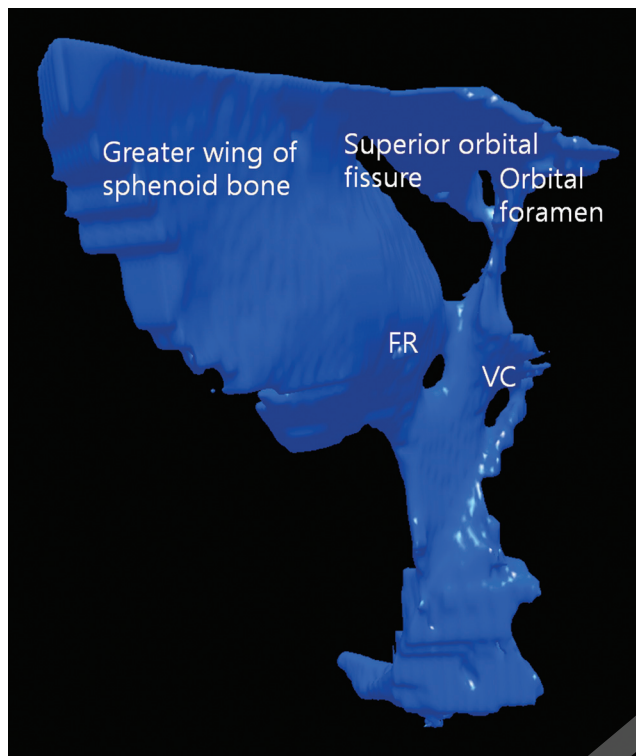


Figure 1. The anterior view of the right-sided sphenoid bone including its pterygoid process and greater wing on three-dimensional reconstruction model. The base of the pterygoid process and greater wing form the posterior boundary of the pterygopalatine fossa (PPF). The vidian canal (VC) and the foramen rotundum (FR) open into the posterior wall of the PPF. The VC is medially in the base of the pterygoid process and the FR is superolateral to VC.

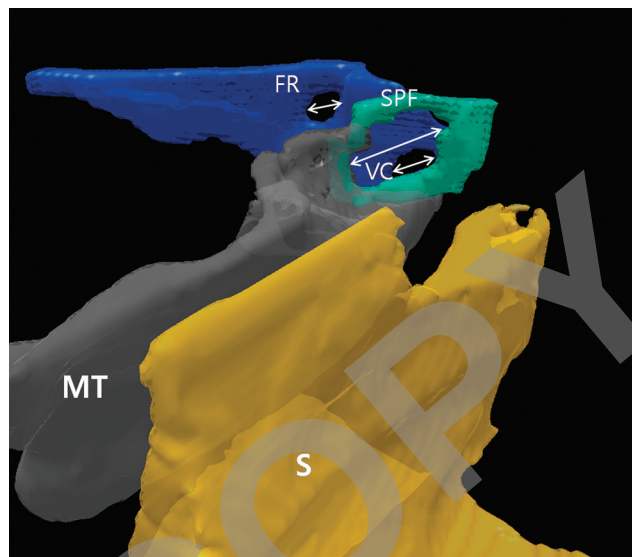


Figure 2. The measurements of the diameters of the sphenopalatine foramen (SPF), foramen rotundum (FR), and vidian canal (VC) on the three-dimensional model. The nasal septum, middle turbinate, SPF, VC, FR, and posterior wall of the pterygopalatine fossa (PPF) in the right nasal cavity were observed on the three-dimensional model. These structures were marked with different colors separately in accordance with anatomic boundaries on the axial views. The SPF was posterior to the middle turbinate and the VC was shown on the posterior wall of the PPF through the SPF. The diameters (arrows) of the SPF, VC, and FR were the largest horizontal diameter. (S, nasal septum, yellow and partially resected for being more visible to other structures; MT, middle turbinate, gray; SPF is green; VC is blue; FR is blue).

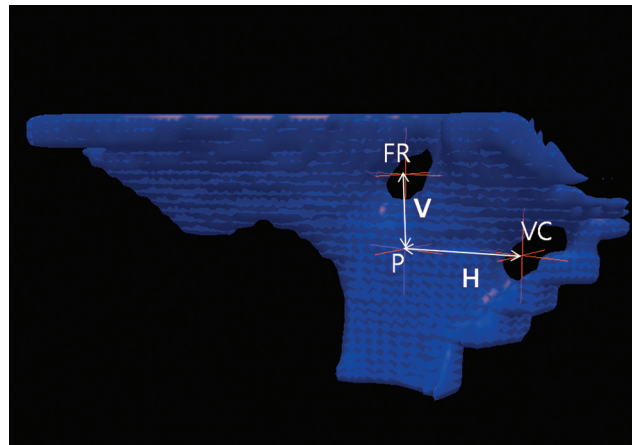


Figure 3. The measurements of the distances between the vidian canal (VC) and foramen rotundum (FR) on the three-dimensional model. The point (P) was defined as the intersecting point of the vertical line that passes through the center of the FR and the horizontal line that passes through the center of the VC on the surface of the sphenoid bone. The vertical distance (V) between the VC and FR was the distance from the center of the FR to P and the horizontal distance (H) between the VC and FR was the distance from the center of the VC to P.

of the VC to the center of the FR on the surface plane of sphenoid bone (Fig. 3).

The horizontal and vertical imaginary planes were drawn in the axial view to determine the vertical and horizontal relationship between the VC and margin of the SPF. The horizontal imaginary plane was defined as the plane that was parallel to the nasal floor and passed through the inferior margin of the SPF, and the vertical imaginary plane was defined as the plane that was parallel to the sagittal plane and passed through the posterior margin of the SPF. The vertical relationship between the VC and inferior margin of the SPF was classified as being on a superior, same, and inferior plane relative to the inferior margin of the SPF. "Superior plane" meant that the inferior margin of the VC was above the horizontal imaginary plane (Fig. 4). "Inferior plane" meant that the superior margin of the VC was below the horizontal imaginary plane. "Same plane" meant that the superior margin of the VC was higher than the horizontal imaginary plane, but the inferior margin of the VC was lower than the horizontal imaginary plane. The horizontal relationship between the VC and posterior margin of the SPF was classified as being on a lateral, same, and medial plane relative to the posterior margin of the SPF. "Lateral plane" meant that the medial margin of the VC was lateral to the vertical imaginary plane (Fig. 5). "Medial plane" meant that the lateral margin of the VC was medial to the vertical imaginary plane. "Same plane" meant that the medial margin of the VC was medial to the vertical imaginary plane, but the lateral margin of the VC was lateral to the vertical imaginary plane.

The anatomic factors that may affect the distances between the VC and FR were evaluated for locating the FR easily. Statistical analysis was done using statistical software SPSS (SPSS, Inc., Chicago, IL).

Statistical comparisons between genders were performed using *t*-test. Pearson's correlations were applied to define the relationship of the distances between the VC and FR with anatomic measurements. A value of $p < 0.05$ was considered significant.

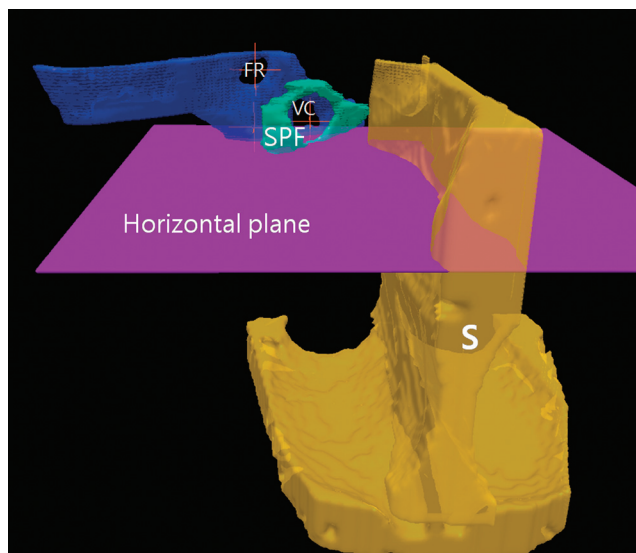


Figure 4. The vertical relationships between the vidian canal (VC) and inferior margin of the sphenopalatine foramen (SPF). An imaginary plane that passed through the inferior margin of the SPF horizontally was made. The level of the VC was superior to the imaginary plane, which meant that the whole margin of VC was above the inferior margin of the SPF.

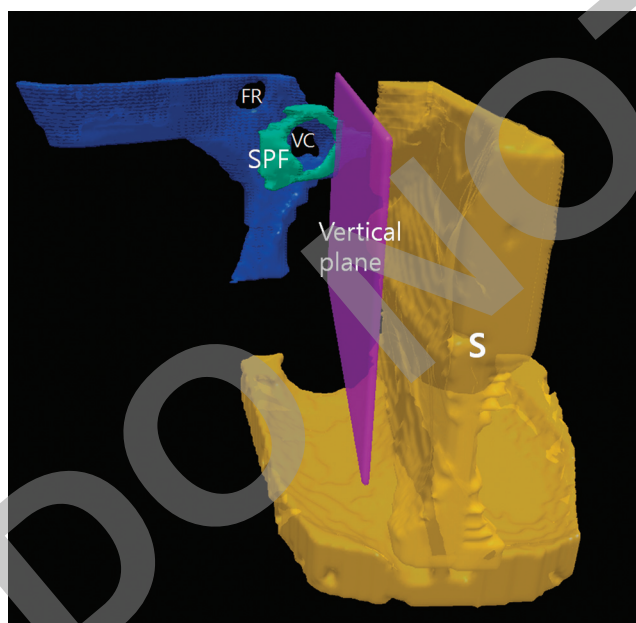


Figure 5. The horizontal relationships between the vidian canal (VC) and posterior margin of the sphenopalatine foramen (SPF). An imaginary plane that passed through the posterior margin of the SPF vertically was made. The position of the VC was lateral to the imaginary plane and meant that the whole margin of VC was lateral to the posterior margin of the SPF.

RESULTS

One hundred ninety-six reconstruction models of the SPF, VC, and FR were generated, and each structure was individually evaluated. The mean diameters of the SPF, VC, and FR were 5.3 ± 1.3 mm, 2.4 ± 0.7 mm, and 2.8 ± 0.5 mm, respectively. The mean distance between the VC and posteroinferior margin of the SPF was 3.8 ± 1.0 mm. The mean vertical and horizontal distances on the surface of the

sphenoid bone between the VC and FR were 5.8 ± 1.9 mm and 8.5 ± 1.9 mm, respectively (Table 1).

The VC was on a plane superior to the inferior margin of the SPF in 110 of 196 (56%) VCs, and on a plane inferior to that of the SPF in 16 of 196 (8%) VCs. It was on the same plane as that of the SPF in 70 of 196 (36%) VCs. The VC was on a plane lateral to the posterior margin of the SPF in 138 of 196 (70%) VCs and on a plane medial to that of the SPF in three of 196 (2%) VCs. It was on the same plane as that of the SPF in 55 of 196 (28%) VCs (Table 2).

The vertical distance between the VC and FR had a positive correlation with the horizontal distance between the VC and FR and the distance between the VC and posteroinferior margin of the SPF. The horizontal distance between the VC and FR had a positive correlation with the distance between the VC and posteroinferior margin of the SPF and diameter of the VC. However, the vertical and horizontal distance between the VC and FR had a negative correlation with the diameter of the SPF ($p < 0.05$; Table 3).

DISCUSSION

Endoscopic approaches to the PPF provide superior visualization and facilitate identification of important neurovascular structures. These approaches provide access to the adjacent regions, which are frequently affected because of their intimate relationship with the PPF structures without significantly increasing morbidity.⁹ Nevertheless, in clinical situations, it may be difficult to identify neurovascular structures with clarity because of surrounding fat, bleeding, or pathological changes. Extensive dissections may place these structures at risk for injury.

In vidian neurectomy, the vidian nerve could be transected within the PPF through the SPF by endoscopic transnasal approach,¹⁰ whereas this approach did not gain great popularity because of the difficulty in accurate nerve identification and transection within the PPF. Accordingly, recent methods were introduced that the vidian nerve could be transected in the floor of the sphenoid sinus (transsphenoidal approach) or before its entrance into the PPF (transnasal approach) during endoscopic vidian neurectomy.¹¹ It was assumed that the difficulty in the identification of neurovascular structures may be caused by the inaccuracy of the localization of the bony structures that contain neurovascular structures. Therefore, it would be helpful to verify the anatomic measurements and spatial relationships of bony landmarks for the endoscopic endonasal approach to avoid injury to important structures.¹¹

As the endoscopic approach has become a popular approach, several studies including endoscopically and radiologically anatomic studies in relation to the landmarks for the endoscopic approach have been published.^{1,3,8,9,11–14} However, the measurements in these studies are not sufficient in evaluating the spatial relationships and distances among the structures of the PPF.^{1,12,13} In the relationship between the VC and SPF, it was reported that the orifice of the VC lay in the same axial plane as the SPF and was located 5–6 mm posterolateral to the posterior margin of the SPF.¹⁰ However, it may be somewhat difficult to locate the VC within the PPF based on the same axis plane as the SPF and the posterolateral distance from the posterior margin of the SPF because the vertical diameter of the SPF was ~ 6.5 mm compared with 21.6 mm in the height of the PPF.^{15,16} We categorized the same axial plane of the SPF into more detailed classifications using the imaginary lines that pass through the posterior and inferior margins of the SPF. In this study, the whole or partial margin of the VC was above the inferior margin of the SPF in 92% of the VCs and lateral to the posterior margin of the SPF in 98% of the VCs. The detailed classification of the position of the VC by the margins of the SPF showed that the VC would be around the posterior and inferior margin of the SPF. Kassam *et al.* reported that intersection of the floor of the sphenoid sinus with the medial pterygoid plate was a useful landmark for localizing the VC, and the identification of the VC was

Table 1 Linear and spatial measurements in relation to the diameter of the sphenopalatine foramen (SPF), vidian canal (VC), and foramen rotundum (FR)

Measurement (mm)	Total (n = 196)		Male (n = 74)		Female (n = 122)	
	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range
SPF	5.3 $\pm$ 1.3	2.2–11	5.3 $\pm$ 1.5	2.6–11.0	5.3 $\pm$ 1.1	2.2–8.0
VC	2.4 $\pm$ 0.7	0.8–4.5	2.4 $\pm$ 0.7	0.8–4.5	2.4 $\pm$ 0.6	1.2–4.5
FR*	2.8 $\pm$ 0.5	1.4–4.4	3.0 $\pm$ 0.6	1.4–4.2	2.8 $\pm$ 0.4	1.5–4.4
SPF-VC	3.8 $\pm$ 1.0	0.5–8.8	3.8 $\pm$ 1.2	0.5–8.8	3.9 $\pm$ 0.9	1.6–6.5
VC-FR (V)	5.8 $\pm$ 1.9	1.0–13.6	5.8 $\pm$ 1.8	2.0–11.4	5.8 $\pm$ 1.9	1.0–13.6
VC-FR (H)	8.5 $\pm$ 1.9	5.1–13.5	8.5 $\pm$ 1.6	5.1–13.5	8.5 $\pm$ 1.7	5.2–12.6

*p < 0.05.

FR = diameter of the foramen rotundum; SPF-VC = the distance between the vidian canal and posteroinferior margin of the sphenopalatine foramen; VC-FR (V) = the vertical distance on the surface plane of sphenoid bone between the vidian canal and foramen rotundum; VC-FR (H) = the horizontal distance on the surface plane of sphenoid bone between the vidian canal and foramen rotundum.

Table 2 The vertical relationship of the vidian canal (VC) and inferior margin of the sphenopalatine foramen (SPF) and horizontal relationship of the VC and posterior margin of the SPF

	Vertical Relationship		Horizontal Relationship	
Superior	110/196 (56%)	Lateral	138/196 (70%)	
Same plane	70/196 (36%)	Same plane	55/196 (28%)	
Inferior	16/196 (8%)	Medial	3/196 (2%)	

Vertical Relationship, the vertical relationship of the vidian canal and inferior margin of the sphenopalatine foramen; **Horizontal Relationship**, the horizontal relationship of the vidian canal and posterior margin of the sphenopalatine foramen.

Table 3 Correlation of the vertical and horizontal distance on the surface plane of sphenoid bone between the vidian canal and the foramen rotundum with anatomic measurements

VC-FR (V)			VC-FR (H)		
		<i>p</i> Value			<i>p</i> Value
VC-FR (H)	0.241	0.001*	VC-FR (V)	0.241	0.001*
SPF-VC	0.189	0.008*	SPF-VC	0.207	0.004*
SPF	−0.195	0.006*	SPF	−0.170	0.017*
VC	−0.010	0.893	VC	0.223	0.002*

*p < 0.05.

SPF = the diameter of the sphenopalatine foramen; VC = the diameter of the vidian canal; SPF-VC = the distance between the vidian canal and posteroinferior margin of the sphenopalatine foramen; VC-FR (V) = the vertical distance on the surface plane of sphenoid bone between the vidian canal and foramen rotundum; VC-FR (H) = the horizontal distance on the surface plane of sphenoid bone between the vidian canal and foramen rotundum.

best facilitated by drilling the floor of the sphenoid sinus to lie in the same plane as the clival recess and locating the insertion of the medial pterygoid plate.⁶ This technique is intuitive and easy to teach when identifying the VC endoscopically. The spatial relationship and distances in our results may help to minimize bony dissections of the posterior wall of the PPF when this technique is performed. To our knowledge, this study is the first time the relationship of the VC and margin of the SPF has been described in this manner. Dissecting PPF fat from the inferior margin of the SPF posterosuperiorly and from the posterior margin of the SPF posterolaterally will facilitate to avoid excessive dissection in the PPF.

In the relationship between the neural structures of the PPF and inferior margin of the SPF, Isaacs and Goyal suggested that entering the PPF at any level below the SPF would avoid injury to the neural structures because all of the neural structures of the PPF except the greater and lesser palatine nerve were located superior to the horizontal plane of the inferior margin of the SPF.¹¹ In this study, 8% of the VCs was inferior to the inferior margin of the SPF. This result suggests that the surgeon must be careful to avoid injury to neural structures in case of dissecting the PPF below the inferior margin of the SPF.

The VC is an important landmark leading to the FR during endoscopic access to the PPF and infratemporal fossa.^{12,13,17,18} In this study, the FR was located 5.8 mm vertically and 8.5 mm horizontally from the VC on the surface plane of the sphenoid bone. This study was different from previous studies, which reported the shortest distance between two foramina in endoscopic dissection or on coronal CT scan.^{11–13} The posterior wall of the PPF is formed by the base of the pterygoid process and the greater wing of the sphenoid bone and directed forward and laterally.¹⁹ The short distances between the two foramina on coronal CT scan plane could not reflect the actual distance between the VC and FR on the posterior wall of the PPF.^{12,13} In our study as well as previous studies, the distances between the bony structures in the PPF were relatively variable. The large range and standard deviations for our measurements may limit clinical value of these findings, especially during an endoscopic approach where small distances are relatively significant when dissection is performed. Considering large variability of these measurements, we evaluated the anatomic factors that affected the distances between the VC and FR, and these correlations would supplement the limits to the clinical value to a certain degree.

The diameter of the SPF was negatively correlated with the distances between the VC and FR. However, the distance between the VC and posteroinferior margin of the SPF had a positive correlation with the distances between the VC and FR. Therefore, the diameter of the SPF and the distance between the VC and SPF may be used as predictive factors for determining distances between the VC and FR. By locating the VC and FR, the vidian nerve and maxillary nerve are easily identified at the orifice where they enter the PPF. In particular, because the course of the distal portion of the maxillary nerve is variable, locating the FR can help to prevent surgeons from injuring the nerve.⁷

This study is limited by the use of CT measurements to estimate the anatomy of the PPF. The axial reconstructions, software errors, and human errors decrease the accuracy of the measurements. However, the advent of HRCT and advanced image guidance software allow these methods to evaluate reliable landmarks.²⁰ Our results may be used as a reference to approach the diseases related to the vidian nerve and PPF.

CONCLUSION

We have described the spatial relationships between the SPF, VC, and FR and correlation between anatomic measurements using a three-dimensional reconstruction of CT scans. The vertical and horizontal relationships between the VC and margins of the SPF can reliably serve as a guide to safely identify the VC *via* the SPF. The distance between the VC and FR has been described as the vertical and horizontal distance on the surface plane of the sphenoid bone. The spatial relationship between bony structures found in this study will allow surgeons to perform safe and suitable procedures for endoscopic endonasal approaches to the PPF.

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