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Anatomical aspects of optic nerve decompression in transcranial and transsphenoidal approach

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ABSTRACT

Purpose: The proximal portion of the optic nerve is quite prone to injury at the entrance of the optic foramen by tumoral or traumatic pathologies. As a result, it is important to show which way and which part we can effectively and safely decompress the pathologies affecting the optic nerves. In this study, we compared the decompression of the proximal segment of the optic canal Likewise, we investigated the anatomy and histopathology of the opticocarotid region from below and above.

Materials and methods: A total of 30 adult sellar and parasellar samples were extracted from human cadavers. Anatomical dissection and histological examination were performed from transcranial and transsphenoidal ways. The walls of the proximal optic canal were evaluated with an operating microscope and endoscope. The relationship between the optic canal, the internal carotid artery, and the optic nerve were qualitatively and quantitatively examined.

Results: Similar rates of circular optic canal decompression were achieved by each approach; however, by means of decompression, the transsphenoidal approach was superior for the inferior and medial portions of the optic nerve and transcranial approach was superior for the superior and lateral portions and also more appropriate for optic nerve mobilization.

Conclusion: This is one of the first studies to reveal the ways of the decompression of the proximal optic canal by transcranial and transsphenoidal approaches. According to this study, the medial and inferior proximal portions of the optic nerves are histologically more prone to injury caused by traction or compression. Transcranial or transsphenoidal approach should be preferred according to the location of the pathology and anatomical and histological characteristics of this region.

1. Introduction

Sellar and parasellar tumors, sphenoid sinus and posterior ethmoidal sinus lesions, maxillofacial traumas, vascular pathologies and inflammatory processes can affect the optic canal and the optic nerve (Chen et al., 2007; Maurer et al., 1999; Taha et al., 2011). Optic nerve decompression is used for these pathologies, leading to optic nerve damage (Cascone et al., 2012; Feldon, 2007; Maurer et al., 1999; Pletcher and Metson, 2007; Taha et al., 2011, Tan et al., 2007).

Transethmoidal optic nerve decompression was first described by Sewell in 1926, and an intracranial approach was reported as early as 1922 by Dandy as Maurer mentioned (Maurer et al., 1999). The optic canal consists of four walls, including the following: 1) superior wall, anterior or superior root of lesser wing; 2) inferior wall, optic strut, namely, posterior root of lesser wing; 3) medial wall, the body of sphenoid bone; and 4) lateral wall, the anterior clinoid process (Onofrey et al., 2007).

Optic nerve decompression can be performed for the superior, lateral, inferior and medial walls of the optic canal (Al-Mefty et al., 1998; Evans et al., 2000; Locatelli et al., 2011; Yılmazlar et al., 2012). The dural sheath of the proximal part of the optic nerve is tightly bound with the periosteum of the lesser wing; therefore, its strict adherence to the optic nerve is most vulnerable to injury in the optic foramen entrance (Yılmazlar et al., 2012).

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Optic nerve decompression can be performed by unroofing the optic canal by a transcranial approach. This approach is particularly suitable for intracranial pathologies extending to the optic canal (Yılmazlar et al., 2012). Following unroofing the optic canal, anterior clinoidectomy is performed in to decompress the optic canal laterally. Decompressed optic nerve length can be increased two-fold by anterior clinoidectomy (Evans et al., 2000).

Transcranial approaches may pose some problems for the pathologies which affect the optic nerve inferiorly, whereas the transsphenoidal approach is more suitable for pathologies affecting the optic canal inferiorly and medially (Yılmazlar et al., 2012). With the introduction of functional endoscopic sinus surgery since 1980s, endoscopic techniques have been developed (Steinsapir et al., 2011; Zada et al., 2010).

In this study, the limits of optic nerve decompression were compared using a microsurgical transcranial approach and an endoscopic transsphenoidal approach. The anatomic and histological details of the region and the anatomic landmarks were investigated during the transcranial and transsphenoidal approach. Also, the anatomical relations of the proximal part of the optic canal, the surgical importance of anatomic landmarks and the availability of mobilization of the optic nerve were examined.

2. Materials and Methods

In this study, a total of 30 adult sellar and parasellar samples which were collected after consents for clinical autopsy cases at Neurosurgery Department of Uludag University, Faculty of Medicine, were used. Approval of the Ethics Committee of Uludag University was obtained for the study (No: 2013-4/3: date: 26.02.2013). A bicoronal skin incision followed by bifrontooccipital craniotomy with the aid of an electrical vibration saw was performed for each cadaver in the autopsy room. The dura was opened in the same plan and the cerebral and cerebellar hemispheres were revealed. The skull base was exposed removing the cerebral and the cerebellar hemispheres. As described by Yılmazlar et al. (2005), four incisions were made from the lateral to the foramen rotundum and the foramen ovale bilaterally in the middle cranial fossa, from the posterior ethmoidal sinuses anterior to the planum sphenoidale in the anterior cranial fossa, and from one-third of the clivus in the posterior cranial fossa. Samples containing planum sphenoidale and tuberculum sella anteriorly, cavernous sinuses laterally and superior part of the clivus posteriorly were extracted (Fig. 1). Both internal carotid arteries were washed with saline solution and residual blood clots removed. A total of 30 cadaveric samples ready to operate on were stored in 10% formalin.

The measurements and assessments for the anatomical and histological research were made on the 30 obtained cadaveric samples. Macroscopic and microscopic examinations simulating the transcranial route were made on 10 cadaveric samples. Then, anatomical dissections and measurements were made to the analyzed samples by a microsurgical technique. Macroscopic and transsphenoidal endoscopic/microscopic examinations were made to 10 cadaveric samples. Anatomic dissections were made with an endoscopic technique, and measurements were made with a microscopic technique to the samples. The other 10 cadaveric samples were used for histological examination.

2.1. Anatomic dissections

The proximal optic canal consists of four walls. Superior and lateral walls to the proximal optic canal were examined (Fig. 1a), the falciform ligament was explored, and the optic canal was dissected by transcranial approach as shown in Fig. 1b. The inferior and medial walls were examined and dissected by transsphenoidal approach as shown in Fig. 2.

2.2. Transcranial anatomic dissections

Anatomical landmarks related to the optic canal were examined under an operation microscope (Carl Zeiss OPMI Pentero, Jena, Germany) in 10 cadaveric samples (Fig. 1a). Decompression of the superior wall of the proximal optic canal was provided, removing the falciform ligament. Decompression of the lateral wall of the proximal optic canal was provided, removing the medial one-third of the anterior clinoid process with a high-speed drill (Fig. 1b).

2.3. Transsphenoidal anatomic dissections

Proximal optic nerve decompression by a transsphenoidal approach was performed to 10 cadaveric samples. Anatomic landmarks located on the sphenoid sinus roof used during the transsphenoidal approach were evaluated. After removing the mucous membrane, the bony structure was seen. The carotid prominence, the optic prominence, and the lateral and medial opticocarotid recesses were also examined (Fig. 2). The inferior and medial walls of the proximal optic canal were decompressed by an endoscopic approach (Optic Storz, Schramberg, Germany), and recorded images were used for the measurements (Fig. 3).

After removal of the inferior and medial walls of the proximal optic canal in 10 cadaveric samples, the limits of the mobilization of the optic nerve were tested.

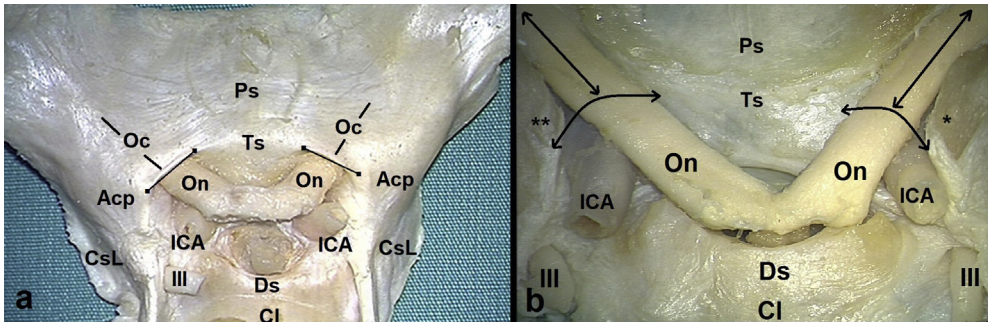

Fig. 1. Cadaveric sellar-parasellar samples (**a**) Cranial view. (**b**) Cranial view after optic canal decompression. **Oc** Optic canal, **Ps** Planum sphenoidale, **Ts** Tuberculum sella, **On** Optic nerve, **ICA** Internal carotid artery, **CsL** Cavernous sinus Lateral wall, **Cl** Clivus, **III** Third nerve, **Acp** Anterior clinoid process, **Ds** Dorsum sella. *Anterior clinoid process partially removed; **anterior clinoid process completely resected to remove the lateral wall and to decompress the optic nerve. **Curved arrows** represent the decompression of the superior wall of the proximal optic canal with the falciform ligament removal. **Straight arrows** represent the decompression of the superior wall of the distal optic canal with the dural sheath removal.

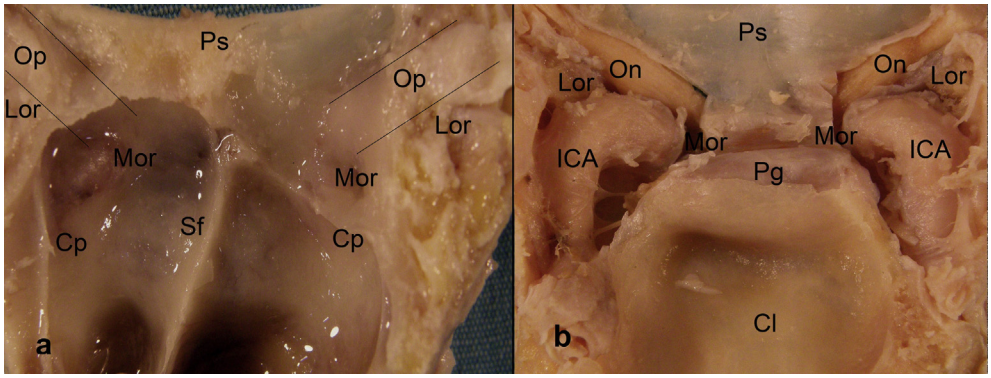

Fig. 2. Sellar and opticocarotid region inside the sphenoid sinus. (**a**) After removal of the mucosa of the sphenoid sinus. Anatomic landmarks appear on the sphenoid sinus roof. Long linear lines show projection of optic nerves. (**b**) Pituitary gland, cavernous carotid artery and decompressed optic nerves bilaterally. **Op** Optic prominence, **Cp** Carotid prominence, **Mor** Medial opticocarotid recess, **Ps** Planum sphenoidale, **Sf** Sellar Floor, **ICA** Internal carotid artery, **On** Optic nerve, **Pg** Pituitary gland.

2.4. Anatomic measurements

Measurements were done with Autodesk AutoCAD 2013, California, USA. The degree of circular decompression and the degree of optic nerve mobilization were measured with Autodesk AutoCAD 2013, California, USA by using the images taken in coronal plane according to optic nerve.

2.5. Transcranial measurements

2.5.1. Transcranial measurements of the superior wall of the proximal optic canal

Measurements of superior wall of proximal optic canal:

a) The axis of the ellipsoid falciform ligament that forms the superior wall of the proximal optic canal was measured (Fig. 1a).

2.5.2. Transcranial measurements of the lateral wall of the proximal optic canal

Measurements of lateral wall of proximal optic canal:

a) The distance between the tip of anterior clinoid process and ophthalmic artery was measured in 9 cadaveric samples (Fig. 4c). In one sample, the left-sided ophthalmic artery was lacerated, and the measurements were taken from the right side.

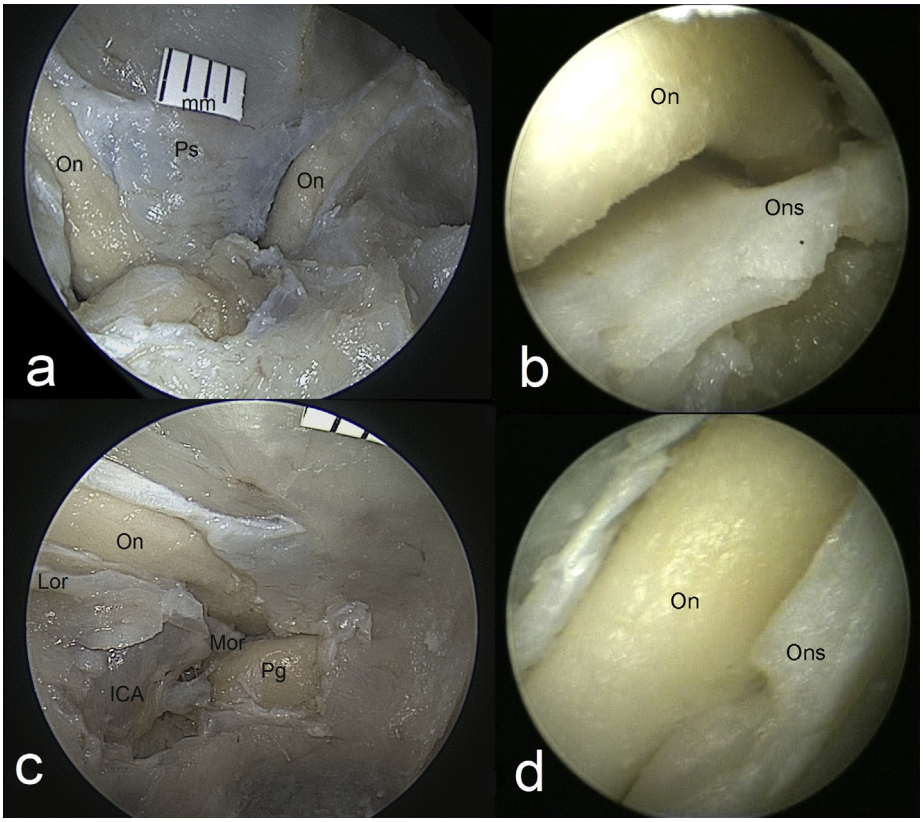

Fig. 3. Inferior and medial walls of the optic canal removed by endoscopic technique on the sphenoid sinus roof. **(a)** Inferomedial decompression of the both optic nerves. **(b)** Inferomedial decompression of the proximal part of the right optic nerve in the samples. (**c**) Inferior and medial decompression of the right optic nerve from medial opticocarotid recess (**Mor**) to the lateral opticocarotid recess **(Lor). (d)** Inferior and medial decompression of the left optic nerve **On** Optic nerve, **Ons** Optic nerve sheath, **Pg** Pituitary gland, **ICA** Internal carotid artery, **Ps** Planum sphenoidale.

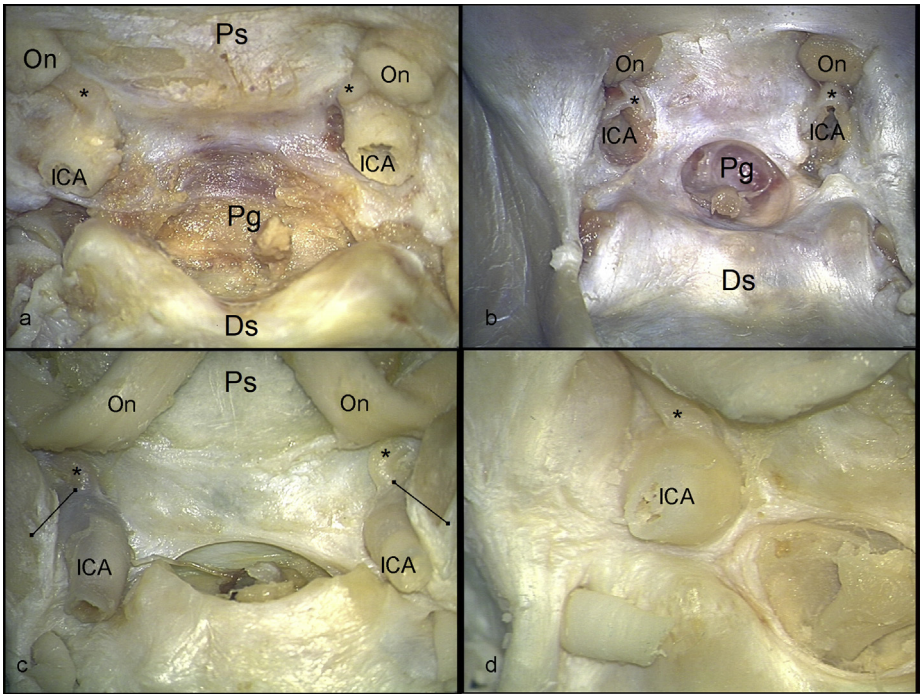

Fig. 4. Ophthalmic artery (*) seen in four different samples. (**a)** Origin of the ophthalmic artery was inferomedial to the optic nerve. (**b)** Origin of the ophthalmic artery was inferior to the optic nerve. (**c** and **d)** Both optic nerves were elevated and the origins of the ophthalmic arteries were seen. **On** Optic nerve, **ICA** Internal carotid artery, **Ps** Planum sphenoidale, **Pg** Pituitary gland, **Ds** Dorsum sella, **Line** distance between clinoid ophthalmic artery origin.

b) The lateral decompression of the proximal optic nerve was provided by removal of the medial 1/3 of the anterior clinoid process. The circular decompression degree after removal of the lateral wall was measured.

After decompression of the superior wall of the optic canal and anterior clinoidectomy, the mean circular opening degrees were measured and these measurements were compared using the Wilcoxon rank sum test. A p value of <0.05 was considered statistically significant.

2.6. Transsphenoidal measurements

2.6.1. Transsphenoidal measurements of the inferior wall of the proximal optic canal

Measurements of the inferior wall of the proximal optic canal:

a) The length of decompression made to the inferior wall of the proximal optic canal was measured (Fig. 2b).
b) The degree of circular decompression after removal of the inferior wall of the proximal optic canal was measured.

2.6.2. Transsphenoidal measurements of the medial wall of the proximal optic canal

Measurements of the medial wall of the proximal optic canal:

a) The length of decompression made to the medial wall of the proximal optic canal was measured (Fig. 2b).
b) The degree of circular decompression after removal of the medial wall of the proximal optic canal was measured.

2.7. Histological analysis

Ten cadaveric samples without anatomic dissection were decalcified. A total of 40 sagittal sections were obtained to examine the ligamentous structure of the inferior and superior sides, and 60 axial sections were obtained to examine the optic nerve, internal carotid artery, and surrounding anatomical structures and ligaments in the medial and lateral sides. Sections were dyed with hematoxylin-eosin and Masson trichrome.

3. Results

3.1. Results of anatomic dissections

3.1.1. Results of transcranial anatomic dissection

The superior decompression of the optic nerve was achieved by removal of the ellipsoid shaped falciform ligament in 10 obtained cadaveric samples (Fig. 1b). The decompression was wide on the proximal part and narrow on the distal part.

Clinoidal penumatization was determined bilaterally after removal of the medial part of the anterior clinoid process in one sample.

Considering the relationship between the ophthalmic artery and the internal carotid artery, ophthalmic artery was not seen bilaterally in one sample. In another sample, left ophthalmic artery was lacerated during clinoidectomy and vascular integrity was damaged. The origin of the ophthalmic artery was inferior to the optic nerve in four samples (44.4%) and inferomedial to the optic nerve in five samples (55.5%) on the right side; inferior to the optic nerve in six samples (66.6%) and inferomedial to the optic nerve in three samples (33.3%) on the left side. The course of the ophthalmic artery was found to be laterally after the origin of the artery in all samples (Fig. 4).

3.1.2. Results of transsphenoidal anatomic dissection

The lateral opticocarotid recess was found to be prominent bilaterally in all of the 10 samples. The medial opticocarotid recess was found to be prominent in five of 10 samples (50%) on the right side and eight of 10 (80%) samples on the left side. The distance between the most medial part of the medial opticocarotid recess and the most medial part of the lateral opticocarotid recess was found to be prominent in all of the samples (Fig. 2).

The tubercular recess was found to be prominent in all of the 10 samples. The optic nerve was found to be immobile even after decompression of the proximal part of the optic nerve by transsphenoidal approach.

3.2. Results of anatomic measurements

3.2.1. Results of the transcranial measurements of the superior wall of the proximal optic canal

The small axis of the falciform ligament that forms the superior wall of the proximal optic canal was measured as in the range of minimum 3.92 mm and maximum 9.81 mm (mean6.38 ± 1.71 mm) on the right side and in the range of minimum 5.31 mm and maximum 9.44 mm (mean 7,64 ± 1,59 mm) on the left side (Table 1) (Fig. 1a).

3.2.2. Results of the transcranial measurements of the lateral wall of the proximal optic canal

The decompression after removal of the superior wall of the proximal optic canal and the decompression after removal of the lateral wall were compared with each other using the Wilcoxon rank sum test. We found that removal of the medial third of the anterior clinoid process significantly increased the circular decompression of the proximal optic nerve ($p < 0,05$).

The distance between the tip of the anterior clinoid process and the ophthalmic artery was measured as in the range of minimum 0.51 mm and maximum 3.89 mm (mean 1.76 ± 1.40 mm) on the right side and in the range of minimum 0.58 mm and maximum 4.74 mm (mean 1.82 ± 1.67 mm) (Table 2).

3.3. Results of transsphenoidal measurements

3.3.1. Results of the transsphenoidal measurements of the inferior wall of the proximal optic canal

The length of decompression of the inferior part of the proximal optic canal was measured as in the range of minimum 2.91 mm and maximum 6.60 mm (mean 4.85 ± 0.97 mm) on the right side and in the range of minimum 2.72 mm and maximum 6.39 mm (mean 4.11 ± 1.44 mm) on the left side (Table 3).

The degree of circular decompression after removal of the medial of the proximal optic canal was measured as in the range of minimum 45° and maximum 90° (mean 71.50 ± 14.91°) on the right side and in the range of minimum 60° and maximum 90° (mean 74.50 ± 8.31°) on the left side (Table 4).

Table 1
Measurement of the small axis of the falciform ligament.

Sample No.	Left (mm)	Right (mm)
1	6,93	9,44
2	4,62	8,24
3	5,28	6,39
4	6,39	6,23
5	5,97	8,50
6	9,81	9,80
7	6,63	7,17
8	3,92	6,12
9	5,98	5,31
10	8,31	9,22
Mean ± SD	6,38 ± 1,71	7,64 ± 1,59

SD, standard deviation.

Table 2
Distance between the anterior clinoid process and the ophthalmic artery.

Sample No.	Distance Between Opth A-Clinoidal Tip (Left) (mm)	Distance Between Opth A-Clinoidal Tip (Right) (mm)
1	4,74	3,89
2	–[a]	–[a]
3	0,70	0,93
4	0,75	0,51
5	1,07	0,52
6	–[a]	3,76
7	1,02	2,99
8	1,47	1,43
9	0,58	0,49
10	4,26	1,33
Mean ± SD	1,82 ± 1,67	1,76 ± 1,40

Opth A, ophthalmic artery; SD, standard deviation.
[a] Ophthalmic artery could not be found bilaterally in sample 2 and on the left side in sample 6.

3.4. Results of histopathological analysis

The dura is bright pink, the internal carotid artery is dark pink and the nucleus is purple in color in sections dyed with hematoxylin-eosin. The collagen is blue, the cytoplasm, the keratine, and the intracellular fibers are red and the nucleus is black in color in sections dyed with Masson trichrome.

The sections decomposed during fixation were not included in the analysis.

The collagen fibers were more loose and irregular on the lateral side of the optic nerve, but more regular and tightly bound on the medial and distal part of the optic nerve, and these areas are more prone to traction. The pia-arachnoid sheath was tightly attached to the optic nerve in each level.

The ophthalmic artery traveled with the optic nerve through the optic canal and was located inferior to the optic nerve within the optic nerve sheath. In some sections lateral and medial to the optic nerve, an interstitial space was seen between the pia arachnoid sheath and the dural sheath (Fig. 6).

4. Discussion

There are many pathological entities that may cause injury by damaging the optic canal and optic nerve (Al-Mefty et al., 1998; Cascone et al., 2012; Chen et al., 2007; Feldon, 2007; Maurer et al., 1999; Onofrey et al., 2007; Pletcher and Metson, 2007; Taha et al., 2011; Tan et al., 2007; Yang et al., 2006). A transcranial approach and decompression of the optic nerve may be used for intervention in these pathologies. Similarly, pathological entities involving the sphenoid sinus and ethmoid sinuses as well as nasal pathologies may affect the optic nerve due to their close anatomic proximity (Li et al., 2008; Locatelli et al., 2011; Pillai et al., 2008). A transsphenoidal approach is more appropriate for such pathologies (Li et al., 2008; Locatelli et al., 2011; Pillai et al., 2008). The site with the highest possibility for the involvement of optic nerve is its proximal portion, due to histological and anatomical features of the surrounding tissues (Onofrey et al., 2007). Thus, it is of utmost importance to have robust data on anatomy and surgery of the proximal part of the optic nerve and optic canal. In the present study, we investigated qualitatively and quantitatively the possibility of decompressing and mobilizing the proximal part of the optic nerve. Herein, we attempted to learn the limits of the mobility

Table 3
Longitudinal length measurements of right and left optic nerves after inferomedial decompression.

Sample No.	Right ON Proximal Inferior Decomp. (mm)	Left ON Proximal Inferior Decomp. (mm)	Right ON Proximal Medial Decomp. (mm)	Left ON Proximal Medial Decomp. (mm)
1	4,34	6,39	5,66	8,38
2	4,28	5,02	7,98	7,51
3	6,60	2,72	9,43	2,96
4	5,52	6,23	9,27	9,63
5	3,98	3,24	6,08	4,78
6	2,91	3,12	5,73	5,78
7	4,11	3,45	6,28	5,29
8	4,50	4,61	6,69	8,56
9	4,65	2,16	8,58	4,29
10	4,93	4,19	9,46	6,55
Mean ± SD	4,85 ± 0,97	4,11 ± 1,44	7,51 ± 1,59	6,37 ± 2,12

Decomp, decompression; ON, optic nerve.

and the exposure of the optic nerve during interventions for tumoral, vascular, and inflammatory processes.

Al-Mefty et al. (1998) performed decompression of bilateral optic nerves along with removal of bony structures on the superior wall and on both sides of the optic canal in pediatric patients with loss of vision being followed up with a diagnosis of osteopetrosis. Limits of circular decompression on optic nerves were not previously reported anatomically in the literature. It was reported only that visual abilities were improved clinically in patients. There were several noncomparative anatomical studies to guide these clinical ones. For instance, in a cadaveric study by Maniscalco and Habal (1978), in which 83 optic canals were examined, the mean length of the optic canal was 9.22 mm (range, 5.5–11.5 mm) (Maniscalco and Habal, 1978). Recently, partial decompression of the optic canal with the clinical approach has gained popularity (Taha et al., 2011; Yılmazlar et al., 2012). Thus, decompressing the proximal portion of the optic canal may suffice in many cases. In the present study, focusing on the size of proximal optic canal can result in measurement of length for decompression performed with removal of falciform ligament, making the superior wall of the proximal optic canal 6.38 ± 1.71 mm on the right and 7.64 ± 1.59 mm on the left. The length of superior decompression of the proximal optic nerve removing the falciform ligament was observed to correspond to two-thirds of the total length of the optic nerve in the optic canal. Thus, in addition to total decompression, proximal decompression can also be encountered as a solution in many pathological processes. However, it should be kept in mind that decompression performed is wider proximally and markedly narrower distally, due to the ellipsoid shape of the falciform ligament (Fig. 1a). For some pathology, it does not suffice to remove only the proximal portion of the superior wall (Attia et al., 2012; Dolenc, 1985). In such cases, an anterior clinoid process making the lateral wall of the optic canal is of the utmost importance. Thus, we examined the anatomical structures removing the anterior clinoid process to determine whether it was possible to further increase the decompression (Fig. 1b). Yang et al. (2006) reported that extradural anterior clinoidectomy performed by removing a part of the ala major or the complete ala minor was an effective and reliable approach to decompression of the optic nerve in patients with traumatic optic neuropathy (Yang et al., 2006). Lehmberg et al. (2013) also reported that the anterior clinoidectomy procedure significantly improved vision in the post-operative period in patients with meningioma in close proximity to the optic canal (Lehmberg et al., 2013). In a cadaveric morphometric study, Evans et al. (2000) reported two-fold increase in the length of the optic nerve decompressed by anterior clinoidectomy (Evans et al., 2000). All these data indicate that anterior clinoidectomy is clinically important in decompression of the optic nerve. Due to risk of opening the sphenoid sinus pneumatization during the medial wall removal of the optic canal through a transcranial approach, we focused on the superior and lateral walls to achieve decompression via the transcranial approach. Although our study was an anatomic study, laceration occurred on the wall of ophthalmic artery during clinoidectomy in one sample. Also, a bilaterally pneumatized clinoid process was found in one sample. In the present study, we found that optic nerve mobilization was quite limited even after following anterior clinoidectomy. On the other hand, even limited mobilization facilitated seeing the origin of the ophthalmic artery. When the origin of the ophthalmic artery was assessed, we observed that the origin of the ophthalmic artery was inferior and inferomedial to the optic nerve. As reported by Natori and Rhoton (1984), the ophthalmic artery ran lateral to the optic nerve and passed through the optic foramen to reach the orbit (Natori and Rhoton, 1984). In the present study, the ophthalmic artery was

Table 4
Degree of circular decompression after removal of the inferior and medial walls of the proximal optic canal.

Sample No	Right ON Proximal Inferior Decomp. (°)	Left ON Proximal Inferior Decomp. (°)	Right ON Proximal Medial Decomp. (°)	Left ON Proximal Medial Decomp. (°)
1	50	30	60	70
2	70	70	90	80
3	40	50	60	60
4	50	55	60	75
5	60	60	80	70
6	30	60	45	80
7	80	90	90	90
8	70	60	80	70
9	60	80	80	70
10	60	90	70	80
Mean ± SD	57,00 ± 14,94	64,50 ± 18,62	71,50 ± 14,91	74,50 ± 8,31

Decomp, decompression; ON, optic nerve; SD, standard deviation.

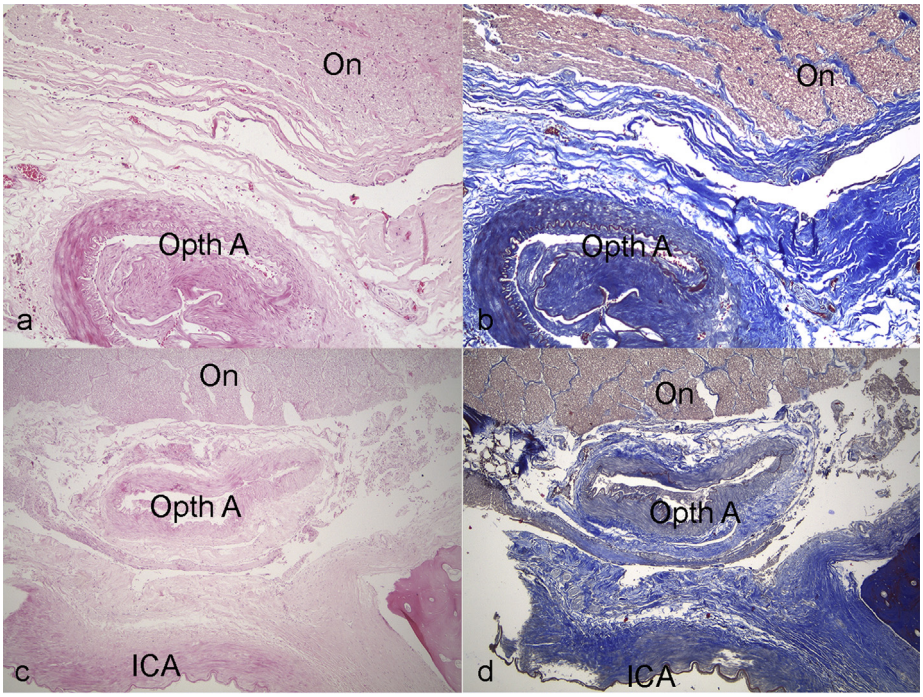

Fig. 5. Ophthalmic artery and optic nerve relation in axial sections (**a**) Hematoxylin-eosin (H&E) ×100. (**b**) Masson's trichrome (MT) ×100. (**c**) Optic nerve, ophthalmic artery and internal carotid artery relations. H&E ×40. (**d**) MT ×40. **On** Optic nerve, **Opth A** Ophthalmic artery, **ICA** Internal carotid artery.

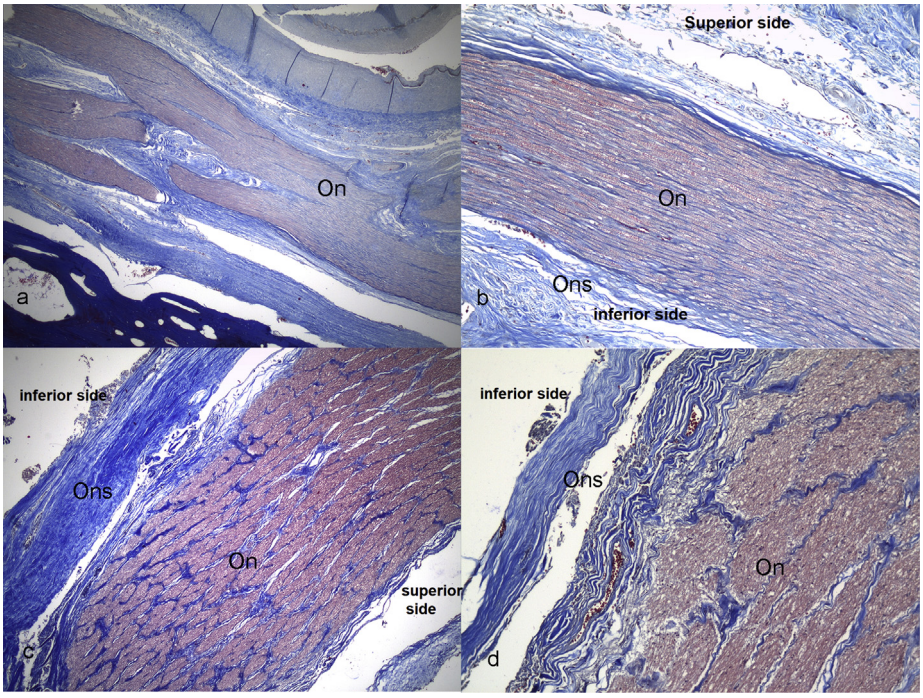

Fig. 6. **S**agittal histological sections of the optic nerve and optic canal. (**a** and **b**) Both sides of the optic nerve and surrounding optic nerve sheath (Masson's trichrome (MT) ×25 and ×40, respectively). (**c** and **d**) Inferior side of the optic nerve and surrounding optic nerve sheath in the sagittal section (MT ×40 and ×100, respectively). **On** Optic nerve, **Ons** optic nerve sheath.

observed to run laterally after exiting the internal carotid artery in all 10 cadaveric samples. The distance between the origin of the ophthalmic artery and the clinoid tip was measured in 9 samples. It ranged between 0.51 and 3.89 mm (mean: 1.76 ± 1.40 mm) on the right and between 0.58 and 4.74 mm (mean: 1.82 ± 1.67 mm) on the left side. The ophthalmic artery, however, was unable to be observed in one sample. For this sample, it was considered that the ophthalmic artery might be intracavernous. Rhoton (2002) reported that the ophthalmic artery originated from inside the cavernous sinus in 8% of cases (Rhoton, 2002). The distance

between the ophthalmic artery and the clinoid process was observed to be very short (Fig. 4). Understanding the course of the ophthalmic artery and its close relationship with the clinoid tip, and considering this close relationship particularly during clinoidectomy, is of great importance to avoid injuries of the optic nerve and ophthalmic artery.

Transsphenoidal approaches may be more appropriate for decompression of the optic nerve and removal of the lesion in the pathologies involving the optic canal inferiorly and medially. The fact that no cerebral retraction is required, providing a wide and bilateral panoramic view enabling better visualization of the sellar and parasellar neurovascular structures and decreased surgical time, has made the transsphenoidal approach popular (Li et al., 2008; Maurer et al., 1999; Pillai et al., 2008; Steinsapir et al., 2011; Taha et al., 2011). After the 1990s, optic nerve decompression with endoscopic methods has begun to be used more frequently (Zada et al., 2010). The internal carotid artery is tightly surrounded by ligamentous structures in this region, increasing risk of injury to the internal carotid artery during decompression and mobilization of the optic nerve (Chen et al., 2007; Locatelli et al., 2011; Ozcan et al., 2010; Yılmazlar et al., 2012). Therefore, exploring the anatomical landmarks on the roof of sphenoid sinus is mandatory for safe surgery. As a result, many anatomic studies have been conducted in this region to guide the transsphenoidal approach, and many anatomical landmarks have been evaluated (Chen et al., 2007; Locatelli et al., 2011; Ozcan et al., 2010; Yılmazlar et al., 2012). Kassam et al. (2005) defined the medial opticocarotid recess as key anatomic landmark for all transsphenoidal skull base approaches (Kassam et al., 2005). In their anatomic study, Cavallo et al. (2007) reported that the medial opticocarotid recess intracranially corresponding to the medial clinoid process could rarely be seen through the sphenoid sinus (Cavallo et al., 2007). In the aforementioned study, it was reported that the lateral opticocarotid recess, the carotid prominence, and the optic prominence might also be used to determine the medial opticocarotid recess. In their anatomic study in which eight patients undergoing optic nerve decompression were reviewed, Li et al. (2008) reported that the lateral opticocarotid recess was bilateral in all samples. These authors concluded that the lateral opticocarotid recess is a reliable anatomical landmark for endoscopic transsphenoidal surgery (Li et al., 2008). Locatelli et al. (2011), in their cadaveric study in six subjects, defined the lateral opticocarotid recess representing pneumatization of the optic strut of the anterior clinoid process as the most reliable anatomic landmark in determining the optic nerve and its direction (Locatelli et al., 2011). In another study by Yılmazlar et al. (2012), in which 30 cadaveric samples were reviewed, the floor of the sella and the lateral opticocarotid recess were defined as the most important anatomic landmarks (Yılmazlar et al., 2012). The tubercular recess was seen clearly in 28 of 30 samples, and thus it was defined as an important landmark determining the beginning of the proximal segment through which the optic nerve enters the optic canal (Yılmazlar et al., 2012). In a study of 41 subjects conducted by Maurer et al. (1999), it was reported that 180-degree decompression could be achieved by a microscopic transnasal-transethmoidal-transsphenoidal approach (Maurer et al., 1999). On the other hand, several complications were reported, such as cerebrospinal fluid (CSF) leakage, meningitis, and damage to the internal carotid artery. Maurer et al. (1999) reported that decompression of 8–10 mm could be achieved from the orbit to the chiasm by a microscopic transnasal transethmoidal-transsphenoidal approach (Maurer et al., 1999). Maniscalco and Habal (1978) performed decompression of the optic nerve using a transorbital-transethmoidal approach and reported the average length of decompression of the optic nerve as 7.3 mm (Maniscalco and Habal, 1978). In the present study, decompression of only the proximal part of the optic nerve was performed using a transsphenoidal approach in 10 cadaveric samples. After decompression had been performed, measurement was made from the microscopic views. After removal of mucosa of the sphenoid sinus, the medial optic-carotid recess was remarkable on the right in five (50%) of the samples and on the left in eight (80%) of the samples (Fig. 2a). Consistent with the literature data, the lateral opticocarotid recess and the tubercular recess were observed bilaterally remarkably in all 10 samples. During the process of identifying and determining the inferior and medial walls of the proximal optic canal, lateral opticocarotid and tubercular recesses were used, and a safe surgical simulation was attempted. Circular decompression degrees were measured following decompression by the transsphenoidal approach (Fig. 2b). The total degree of circular decompression after removal of the both inferior and medial walls was measured as 128.5° ± 29.44° on the right and 139 ± 24.69° on the left. In the present study, it was seen that, although the degrees of circular decompression were less compared to those in the previously published data, anatomically safer decompression of the proximal optic nerve was unable to be performed. The length of the decompression by removing the inferior and medial walls of the proximal optic nerve was also measured in addition to that of circular decompression, which resulted in data consistent with that in the literature in terms of the ability to decompress the optic nerve. Medial longitudinal length of decompression of the proximal optic nerve was measured as 4.85 ± 0.97 mm on the right and 4.11 ± 1.44 mm on the left. The longitudinal length measured following decompression of medial wall of the proximal optic nerve was 7.51 ± 1.59 mm on the right and 6.37 ± 2.12 mm on the left. When mobilization of the optic nerve was assessed following decompression of the proximal optic nerve via the transsphenoidal approach, we found that the optic nerve was unable to be mobilized. It was considered that several factors precluded transsphenoidal mobilization of the proximal optic nerve, including the presence of tendinous structures such as the Zinn's ring, thick dural sheath lateral and superior to the optic nerve, as well as connective tissues around the dural sheath.

Considering the histopathological examinations, pia-arachnoid layers of the optic nerve were found to be tightly attached to the optic nerve. For some sections, more remarkable interstitial space (i.e., the space between the dura and the arachnoid) could create a line for dissection during surgery, enabling cleavage during opening of the dural sheath of the optic nerve due to more remarkable dissociation during fixation. Connective tissue was more irregularly and loosely arranged lateral to the optic nerve (Fig. 5a, b), whereas it was observed be arranged more tightly and regularly on the medial side (Fig. 5b, c). During longitudinal decompression of the optic nerve, encountering a thicker and organized connective tissue on the medial side would be a warning to avoid the complications which may occur due to opening the bony optic canal on the sphenoid and ethmoid sinuses. In the sagittal sections (Fig. 6), the dural sheath was thicker inferiorly (Fig. 6c, d) than superiorly, while collagen tissue arrangement was looser and irregular. This may increase the vulnerability of the optic nerve to surgical damage, particularly in its inferior parts during retraction and mobilization.

5. Conclusion

Although there is no significant difference between transcranial and transsphenoidal approaches by means of decompression limits, the transsphenoidal approach has several advantages, such as being less invasive, not requiring cerebral retraction, and decreasing time of surgery significantly. In case of pathologies which affect the optic canal superolaterally, the transcranial approach would provide much more and safer proximal optic canal

decompression and optic nerve release process than the transsphenoidalapproach. The study results also suggest that the medial and inferior proximal parts of the optic nerve which can be provided by transphenoidal approach are histologically more prone to an injury caused by traction or compression. In other words, the transcranial approach is slightly more advantageous to longitudinal decompression of the entire optic canal and optic nerve mobilization compared to the transsphenoidal approach, in safe hands.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

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Conflicts of interest

None.

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Appendix A. Supplementary data

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References

Al-Mefty O, Fox JL, Al-Rodhan N, Dew JH: Optic nerve decompression in osteopetrosis. J Neurosurg 68: 80–84, 1998
Attia M, Umansky F, Paldor I, Dotan S, Shoshan Y, Spektor S: Giant anterior clinoidal meningiomas: surgical technique and outcomes. J Neurosurg 117: 654–665, 2012
Cascone P, Rinna C, Reale G, Calvani F, Iannetti G: Compression and stretching in Graves orbitopathy: emergency orbital decompression techniques. J Craniofac Surg 23: 1430–1433, 2012
Cavallo LM, de Divitiis O, Aydin S, Messina A, Esposito F, Iaconetta G, et al: Extended endoscopic endonasal transsphenoidal approach to the suprasellar area: anatomic considerations-part 1. Oper Neurosurg 61: 4–33, 2007
Chen CT, Huang F, Tsay PK, Tsai YJ, Lin CH, Chen YC, et al: Endoscopically assisted transconjunctival decompression of traumatic optic neuropathy. J Craniofac Surg 18: 19–26, 2007
Dolenc VV: A combined epi- and subdural direct approach to carotid-ophthalmic artery aneurysms. J Neurosurg 62: 667–672, 1985
Evans JJ, Hwang YS, Lee JH: Pre- versus post-anterior clinoidectomy measurements of the optic nerve, internal carotid artery, and opticocarotid triangle: a cadaveric morphometric study. Neurosurgery 46: 1018–1023, 2000
Feldon SE: Visual outcomes comparing surgical techniques for management of severe idiopathic intracranial hypertension. Neurosurg Focus 23: 1–7, 2007
Kassam A, Synderman CH, Mintz A, Gardner P, Carrau RL: Expanded endonasal approach: the rostrocaudal axis. Part I. Crista galli to the sella turcica. Neurosurg Focus 19: 1–12, 2005
Lehmberg J, Krieg SM, Mueller B, Meyer B: Impact of anterior clinoidectomy on visual function after resection of meningiomas in and around the optic canal. Acta Neurochir 155: 1293–1299, 2013
Li J, Wang J, Jing X: Transsphenoidal optic nerve decompression: an endoscopic anatomic study. J Craniofac Surg 19: 1670–1674, 2008
Locatelli M, Caroli M, Pluderi M: Endoscopic transsphenoidal optic nerve decompression: an anatomical study. Surg Radiol Anat 33: 257–262, 2011
Maniscalco JE, Habal MB: Microanatomy of the optic canal. J Neurosurg 48: 402–406, 1978
Maurer J, Hinni M, Mann W, Pfeiffer N: Optic nerve decompression in trauma and tumor patients. Eur Arch Otorhinolaryngol 256: 341–345, 1999
Natori Y, Rhoton AL: Transcranial approach to the orbit: microsurgical anatomy. J Neurosurg: 78–86, 1984
Onofrey CB, Tse DT, Johnson TE, Neff AG, Dubovy S, Buck BE, et al: Optic canal decompression: a cadaveric study of the effects of surgery. Ophthalmol Plast Reconstr Surg 23: 261–266, 2007
Ozcan T, Yilmazlar S, Aker S, Korfali E: Surgical limits in transnasal approach to opticocarotid region and planum sphenoidale: an anatomic cadaveric study. World Neurosurg 73: 326–333, 2010
Pillai P, Lubow M, Ortega A, Ammirati M: Endoscopic transconjunctival surgical approach to the optic nerve and medial intraconal space: a cadaver study. Oper Neurosurg 63: 204–209, 2008
Pletcher SD, Metson R: Endoscopic optic nerve decompression for nontraumatic optic neuropathy. Arch Otolaryngol Head Neck Surg 133: 780–783, 2007
Rhoton AL: The supratentorial arteries. Neurosurgery 51: 53–120, 2002
Steinsapir KD, Goldberg RA: Perpective traumatic optic neuropathy: an evolving understanding traumatic optic neuropathy. Am J Ophthalmol 151: 928–933, 2011
Taha ANM, Erkmen K, Dunn IF, Pravdenkova S, Al-Mefty O: Meningiomas involving the optic canal: pattern of involvement and implications for surgical technique. Neurosurg Focus 30: 1–8, 2011
Tan YC, Yu CC, Chang CN, Ma L, Chen YR: Optic nerve compression in craniofacial fibrous dysplasia: the role and indications for decompression. Plast Reconstr Surg 120: 1957–1962, 2007
Yang Y, Wang H, Shao Y, Wei Z, Zhu S, Wang J: Extradural anterior clinoidectomy as an alternative approach for optic nerve decompression: anatomic study and clinical experience. Oper Neurosurg 59: 253–262, 2006
Yılmazlar S, Kocaeli H, Aydıner F, Korfalı E: Medial portion of the cavernous sinus: quantitative analysis of the medial wall. Clin Anat 18: 416–422, 2005
Yılmazlar S, Saraydaroglu Ö, Korfalı E: Anatomical aspects in the transsphenoidal-transethmoidal approach to the optic canal: an anatomic-cadaveric study. J Craniomaxillofac Surg 40: 198–205, 2012
Zada G, Governale LC, Law ER: Intraoperative conversion from endoscopic to microscopic approach for the management of sellar pathology: incidence and rationale in a contemporary series. World Neurosurg 73: 334–337, 2010