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Parasellar region meningiomas with optic canal (OC) invasion: Correlation between the degree of decompression of the OC and the improvement of visual acuity

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ABSTARCT

Purpose: To evaluate the correlation between the degrees of circumferential decompression of the optic canal (OC) and the improvement of visual acuity in patients with parasellar meningiomas (PMs) with optic canal invasion.
Methods: This is a monocentric retrospective study conducted at author's institution. The visual acuity was evaluated preoperative and at 3-months after surgery with Snellen acuity test. The degree of decompression of the OC was calculated through postoperative multiplanar CT-scan reconstructions in coronal plane at intraorbital opening (IOO), intracranial opening (ICO) and middle point between them (MP). OC was then divided in two segments (anterior and posterior).
Results: 29 consecutive patients were identified. Improvement of visual acuity was observed in 18 patients (62 %). Mean decompression achieved at ICO, MP and IOO was 226.2°± 43.6° (range: 68.7°-297.1°), 217.5° ± 37.2° (range: 75.3°-268.7°) and 204.6°± 41.2° (range: 67.3°-252.6°) respectively. A decompression > 90° of the anterior segment of the OC, a decompression > 180° of the posterior segment and a full-length decompression > 90° were associated visual acuity improvement at univariate analysis ($p = 0.010$, $p = 0.002$ and $p < 0.001$, respectively). A decompression > 180° of the posterior segment and a full-length decompression > 90° of the OC maintained statistical significance at multivariate analysis ($p = 0.030$ and $p = 0.035$, respectively).
Conclusion: Anterior segment decompression > 90° and posterior segment decompression > 180° were associated with improvement of visual acuity at 3 months after surgery. A full-length decompression of the optic canal > 90° showed better visual outcome, while a full-length decompression > 180° did not seem to be related to significative improvements in visual acuity.

1. Introduction

The parasellar region is an anatomically complex area characterized by the presence of several neurovascular structures in a relatively narrow space [1]. In this context, parasellar meningiomas (PMs) can be quite a surgical challenge, as their removal requires a careful manipulation of these delicate structures [2]. Moreover, neurological deficits could be already present at time of surgery due to the compression of the meningioma on the cranial nerves [3]. Visual deficits frequently occur in case of PMs because of their tendency to invade of the optic canal (OC) and it is not uncommon to observe in clinical practice the absence of improvement of visual function after surgery [4].

Although several studies have demonstrated that extradural clinoidectomy with the unroofing of the optic canal is a safe and effective

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technique associated with favorable visual outcomes in PMs surgery, the degree of bony decompression of the OC necessary to obtain visual improvement remains controversial [4–6].

The aim of this study is to evaluate whether there is a minimum degree of circumferential decompression of OC that could be associated with an improvement in visual acuity and whether the visual outcome can be influenced not only by the extent of decompression but also by the portion of the optic nerve (ON) which have been decompressed.

2. Methods

In this single center retrospective study, adult patients with PMs who underwent surgical resection were identified. All surgical procedures were performed by the same Senior Surgeon (FZ) at the authors' Institute (Department of Neurosurgery - AOU City of Health and Science of Turin) between 2013 and 2023.

Inclusion criteria were: (a) histopathological diagnosis of meningioma; (b) patients that underwent extradural anterior clinoidectomy (EAC) and unroofing of the optic canal (UOC) through pterional approach; (c) ON sheet opening during surgical procedure; (d) presence of visual acuity impairment before surgery; (e) Radiological invasion of the OC confirmed intraoperatively; (f) visual acuity evaluation performed before surgery and 3 months after surgical procedure; (g) availability of 0.5 mm postoperative CT-scan (Fig. 1).

Patients with history of traumatic optic neuropathy, with other pathologies affecting the eyes or patients who received any kind of eye surgery before the time of the diagnosis were excluded. A minimum follow-up of 3-months was considered for this study.

2.1. Surgical technique

After induction of general anesthesia, the patient is positioned supine, with the head fixed in a Mayfield three-point clamp. The head is then rotated 60° contralaterally to the tumor, and the head of the bed is tilted 20° upward. A standard curvilinear frontotemporal incision is made, and the skin flap and the underlying temporalis muscle with its fascia are reflected in separate layers anteriorly. A small hole is completed using a high-speed drill at the level of the temporal squama, above the posterior root of the zygomatic bone, to allow the insertion of the craniotome. Then, a standard pterional craniotomy is completed. The bony operculum is lifted and detached from the underlying dura using a Penfield dissector. (Fig. 2a) The lateral portion of the sphenoid ridge is drilled until the meningo-orbital band (MOB) is visualized, coagulated, and cut, to allow exposure of the underlying bony structures. (Figs. 2b, 2c) Egg-shelling of the lateral wall and roof of the optic canal is performed using a diamond drill, and the residual bone is removed using a microdissector or microcurette, After the exposure of the optic nerve within the optic canal is completed, the dura is dissected from the anterior clinoid process (ACP), which can then be removed by drilling. The root of the ACP, represented by the optic strut (OS), is fractured using a small Lempert forceps with a straight tip. (Figs. 2d, 2e) Then, the dura mater is opened, the falciform ligament is cut, and the entire length of the sheath of the optic nerve is opened (Fig. 2f), allowing safe handling of the optic nerve and the removal of any portion of the tumor that extends into the canal. Finally, debulking and detaching of the meningioma from the surrounding neurovascular structures are performed. The entire surgical procedure is completed without using brain retractors to avoid damaging the frontal lobe.

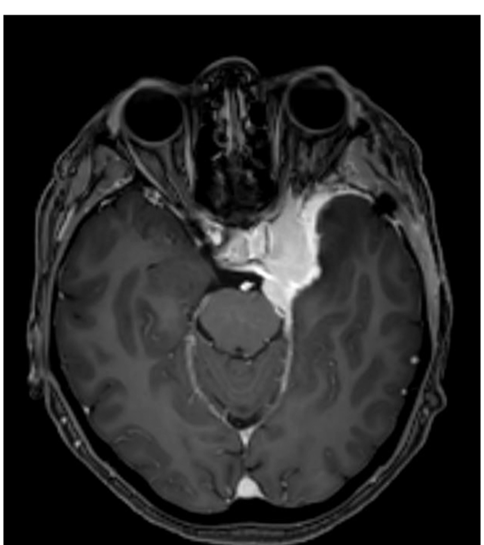

Fig. 1. Parasellar meningioma on T1-weighted MRI with gadolinium enhancement with optic canal involvement.

2.2. Visual outcome

Visual acuity was studied preoperatively and 3-months after surgery by a senior ophthalmologist. Visual changes were considered in case of variation of one line or more in the recorded level of Snellen acuity and classified in 3 subgroups (improved, stable, worsened). Finally, patients were divided in 2 groups:

1. Group 1: patients with improvement of visual acuity after surgery
2. Group 2: patients without improvement of visual acuity after surgery (stable of worsened visual acuity).

2.3. Radiological outcome

Decompression of the OC was studied using postoperative 0.5 mm CT-scan multiplanar reconstructions.

Degrees of decompression were calculated through coronal plane reconstruction in 3 specific points of the OC (Fig. 3):

1. Intracranial Opening (ICO)
2. Middle Part (MP)
3. Intraorbital Opening (IOO)

Subsequently, with these points serving as references, the optic canal (OC) was divided into two segments: a posterior segment (extending from ICO to MP) and an anterior segment (extending from MP to IOO).

As various authors reported that an exposure of at least 90°-180° of the optic nerve is generally necessary for successful optic nerve decompression [7,8], 90° and 180° were selected as the cutoffs for the degree of decompression for statistical analysis. A decompression of the posterior segment greater than 90° or 180° was considered if both ICO and MP exhibited decompression angles greater than 90° or 180°, respectively. Similarly, a decompression of the anterior segment greater than 90° or 180° was considered if both MP and IOO exhibited decompression angles greater than 90° or 180°, respectively. A full-length decompression of the OC greater than 90° or 180° was considered if all three points (ICO, MP, and IOO) exhibited decompression angles greater than 90° or 180°, respectively.

2.4. Statistical analysis

Descriptive statistics were reported with mean and standard deviation for cardinal variables and with frequency and percentage for categorical variables. We performed the Shapiro-Wilk test to test the assumption of data normality. We performed Levene's test to assess the equality of variances. According to the assumption met, T-student's test was adopted to evaluate associations between cardinal variables and visual outcome. Chi-square test (χ^2) was adopted to evaluate associations between categorical variables and visual outcome at univariate

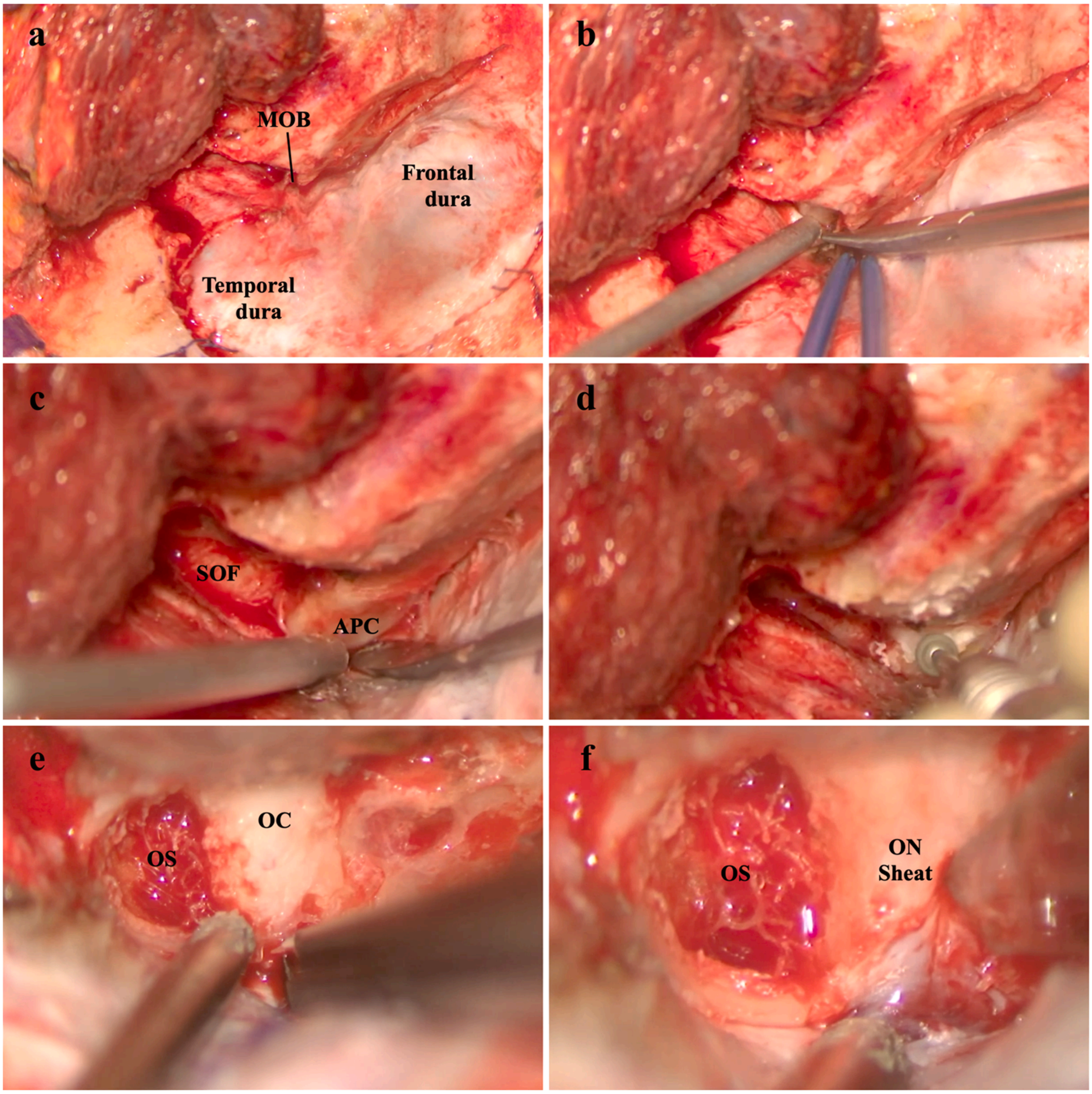

Fig. 2. Step-by-Step Extradural Clinoidectomy (EAC) and Unroofing of the Optic Canal (UOC): (a) After the pterional craniotomy and drilling of the lesser wing of the sphenoid, the frontal and temporal dura mater and the meningo-orbital band (MOB) are exposed; (b) coagulation and cutting of the MOB; (c) exposure of the superior orbital fissure (SOF) and the anterior clinoid process (ACP); (d) drilling of the ACP; (e) after egg-shelling of the roof of the optic canal, the residual bone is removed using a microdissector or microcurette; (f) incision of the optic nerve sheath. MOB: meningo-orbital band; SOF: superior orbital fissure; ACP: anterior clinoid process; OS: optic strut; OC: optic canal; ON: optic nerve.

analysis. Variables with statistically significant association on univariate analysis were included in a multivariable binary logistic regression model. The level of statistical significance was set at $p < 0.05$. Statistical analysis was performed using IBM SPSS Version 26.0 (IBM Corp., Armonk, New York, USA).

3. Results

29 patients were identified matching inclusion and exclusion criteria. Mean age at surgery was 58.8 ± 9.6 years (range: 39–75 years). Cavernous sinus was involved in 7 patients (24 %). Gross total resection (GTR) was achieved in 17 patients (59 %), while a near total resection was performed in 12 cases (41 %). At histopathological examination, 27 meningiomas were Grade 1 (93 %) and 2 were Grade 2 (7 %) according to WHO classification 2021. Only 2 patients showed surgical site bleeding at postoperative CT-scan (7 %), but neither required surgery. No other postoperative complication was identified. New onset neurological deficits were observed in 8 patients (28 %): 4 patients showed CN III deficit (14 %), 2 patients CN V deficit (7 %) and 2 patients CN VI deficit (7 %). Among them, only 1 patient presented persistence of CN III deficit at discharge (3 %).

3.1. Visual outcome

At 3 months after surgery, an improvement in visual acuity was documented in 18 patients (62 %), while 8 patients showed stability in visual acuity (27 %) and 3 patients developed a worsening (11 %). The duration of visual acuity impairment before surgery was 11.45 ± 8.9 months (range: 1–24 months). Gender, age at surgery, duration of visual acuity impairment before surgery, histological grade and extent of resection did not show any statistical association with visual outcome ($p > 0.05$).

3.2. Optic canal decompression

Mean decompression achieved at ICO, MP and IOO was 226.2° ± 43.6° (range: 68.7°-297.1°), 217.5° ± 37.2° (range: 75.3°-268.7°) and 204.6° ± 41.2° (range: 67.3°-252.6°) respectively.

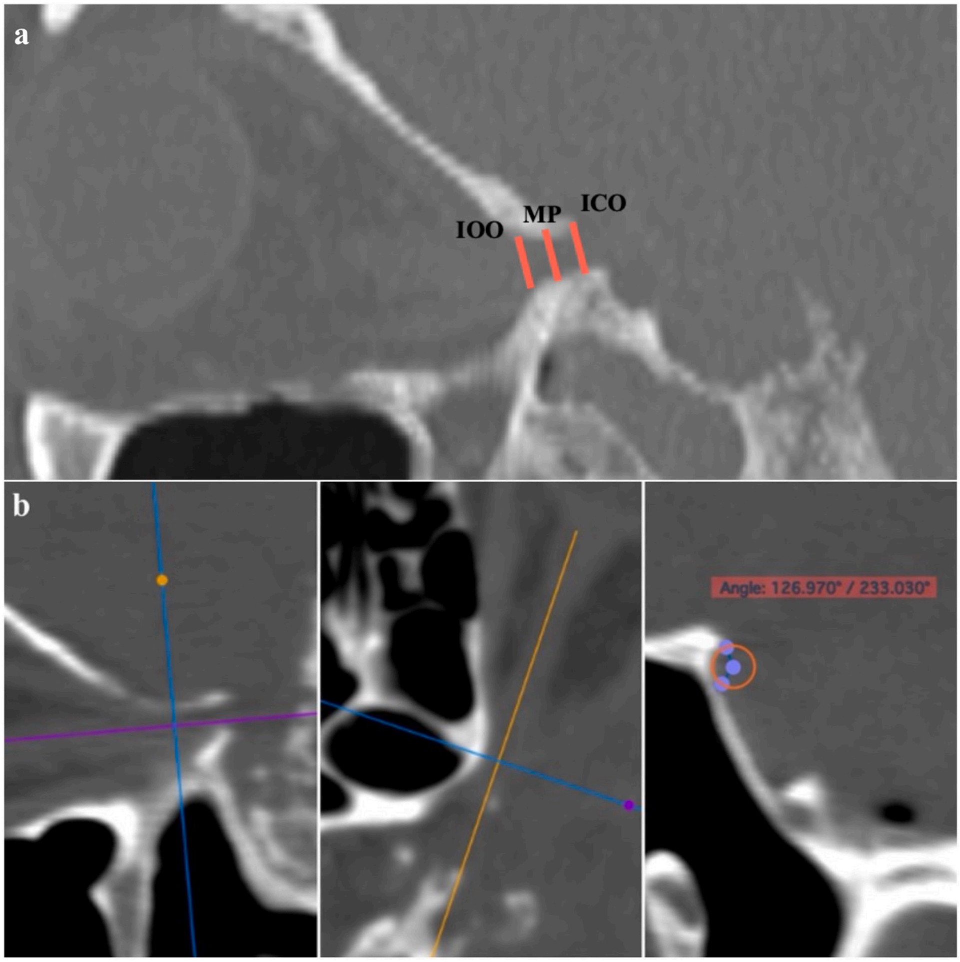

Fig. 3. Evaluation of the degree of decompression of the optic nerve canal. (a) Three specific points of the optic canal were considered: intracranial opening (ICO), intraorbital opening (IOO), and the midpoint between the two (middle point, MP). Subsequently, the optic canal was divided into two segments: anterior segment (between IOO and MP) and posterior segment (between MP and ICO); (b) The degree of bone decompression was calculated using multiplanar reconstruction of postoperative CT scans, with the axes aligned along the optic canal on both the axial and sagittal planes. The degree of decompression was calculated on the coronal plane at each of the three points: ICO, MP, and IOO. If both ends of the considered segment exhibited decompression angles greater than 90° or 180°, the degree of decompression of the segment itself was approximated as greater than 90° or 180°, respectively.

A decompression $> 90^\circ$ was obtained in 26 patients at ICO (89 %), in 24 patients in MP (82 %) and in 22 patients (76 %) at IOO, while a decompression $> 180^\circ$ was accomplished in 18 patients at ICO (62 %), in 20 patients in MP (69 %) and in 17 patients (58 %) at IOO.

Posterior segment of OC resulted decompressed $> 90^\circ$ in 25 cases (86 %) and $> 180^\circ$ in 19 cases (66 %); anterior segment of OC was decompressed $> 90^\circ$ 23 cases (79 %) and $> 180^\circ$ in 17 cases (59 %).

Full-length decompression of the OC $> 90^\circ$ was achieved in 21 patients (72 %), while a full-length decompression$> 180^\circ$ was observed in 16 patients (55 %).

All clinical data were summarized in Table 1.

3.3. A decompression > 90° of the anterior segment of correlation between visual outcome and degrees of decompression

the OC resulted to be associated with improvement of visual acuity at 3 months after surgery in 70 % of patients ($p = 0.010$), while a decompression $> 180^\circ$ did not show a statistically significative correlation with visual acuity improvement ($p > 0.05$).

On the other hand, 84 % of patients who received a decompression $> 180^\circ$ of the posterior segment of the OC had better clinical outcomes at 3 months after surgery ($p = 0.002$).

Finally, a full-length decompression $> 90^\circ$ was associated with a statistically significative improvement of visual acuity (81 % of patients, $p < 0.001$), while a full-length decompression $> 180^\circ$ was not correlated with a better visual outcome ($p > 0.05$).

A decompression $> 180^\circ$ of the posterior segment and a full-length decompression $> 90^\circ$ of the OC maintained statistical significance at multivariate analysis ($p = 0.030$ and $p = 0.035$, respectively). (Table 2)

4. Discussion

Parasellar meningiomas are often associated with OC involvement, ON compression and visual impairment. According to the literature, the rate of visual deficits in these patients varies from 57 % to 96 %[9–11]. For this study, only patients with PMs with OC invasion presenting visual impairment at diagnosis were included to evaluate the impact of OC decompression on visual improvement.

Our results showed an improvement in visual acuity in 62 % of patients at 3 months after surgery. Similar rates of surgical improvement have been reported by other authors, with visual improvement rates ranging from 25 % to 80 % [4,12]. This wide variability in visual outcomes is likely associated with multiple factors such as symptoms duration, patient age, optic sheath opening, type of surgical intervention, and the extent of OC decompression[6,13]. These factors make the topic highly debated in the literature.

Table 1
Population characteristics.

Variable	Value
Gender	
Male	13/29 (45 %)
Female	16/29 (55 %)
Age at surgery	58.8 ± 9.6 years (range: 39–75 years)
Duration of visual deficit before surgery	11.45 ± 8.9 months (range: 1–24 months)
Grade	
I	27/29 (93 %)
II	2/29 (7 %)
Cavernous Sinus Invasion	
Yes	7/29 (24 %)
No	22/29 (76 %)
Extent of resection	
GTR	17/29 (59 %)
NTR	12/29 (41 %)
Postoperative complications	
Yes	2/29 (7 %)
No	27/29 (93 %)
New onset neurological deficits	
CN III	4/29 (14 %)
CN V	2/29 (7 %)
CN VI	2/29 (7 %)
No deficits	8/29 (28 %)
Persistence of neurological deficit at discharge	
Yes	1/29 (3 %)
No	28/29 (97 %)
OC decompression	
ICO	226.2°± 43.6° (range: 68.7° - 247.1°)
MP	217.5°± 37.2° (range: 75.3° - 238.7°)
IOO	204.6°± 41.2° (range: 67.3°- 232.6°)
Visual Outcome at 3 months	
Improved	18/29 (62 %)
Stable	8/29 (27 %)
Worsened	3/29 (11 %)

To our knowledge, this is the first study attempting to associate postoperative visual outcomes with a quantitative evaluation of OC decompression. To reduce the risk of confounding factors, all enrolled patients were operated on by the same senior surgeon (FZ), using the same surgical procedure (EAC with UOC through a pterional approach), and the optic sheath was opened in all cases.

Our results showed a statistical correlation between decompression > 90° of the anterior segment of OC and improvement in visual acuity at 3 months after surgery ($p = 0.023$). Furthermore, when a decompression > 180° of the posterior segment of OC was achieved, higher rates of visual improvement were also observed ($p = 0.023$).

Slavin et al. documented that, although the diameter of the OC is quite stable throughout its length (5.15 mm at ICO vs. 5.2 mm at IOO), the diameter of the ON is larger at ICO (4.25 mm) than at IOO (2.86 mm), resulting in an ON/OC ratio that is remarkably higher in the posterior part of the OC (82.6 %) compared to the anterior part (55 %) [14]. Thus, it seems reasonable that a lower degree of decompression in the anterior segment of the OC could be sufficient to obtain visual improvement, while in the posterior segment of the OC, a wider decompression may be necessary due to the higher ON/OC ratio.

Furthermore, patients who underwent a full-length OC decompression > 90° presented higher rates of visual acuity improvement ($p = 0.035$), while a full-length decompression > 180° did not show a statistical correlation ($p > 0.05$), emphasizing the importance of anterior segment compression on visual outcomes.

Hénaux et al. reported that, while the rate of preoperative visual impairment is lower in cases of IOO involvement than ICO involvement (83 % vs. 90 %), the visual outcome in those patients is significantly poorer (11 % vs. 49 %) [15]. The relatively narrow environment of the OC near the IOO seems to allow greater tolerance of tumor growth before the onset of visual symptoms [6]; however, ON is more susceptible to damage in this area due to its smaller size. Therefore, in cases of anterior ON involvement, it seems reasonable to recommend early decompression to achieve the best visual recovery.

Although the duration of visual impairment before surgery was not statistically associated with visual outcome in this study, it is widely acknowledged that long-term preoperative visual deficits, especially in older patients, are associated with lower rates of postoperative visual improvement [13,16]. This discrepancy could be related to the small sample size, the short duration of follow-up considered, and the wide variability in the duration of visual symptoms among our patients.

The type of surgery is still a topic of debate. Although most authors affirm that UOC improves visual outcomes in cases of lesions involving the OC [17–19], some surgeons believe that the same visual improvement can be achieved without UOC [20]. A recent meta-analysis showed that UOC is a safe and effective technique to improve preoperative impaired vision and make GTR easier to achieve in selective patients with tuberculum sellae meningiomas [21].

Even more controversial is the impact of clinoidectomy on visual outcomes. Recent literature shows that EAC is the most used procedure in all series, allowing for better rates of visual improvement [22].

Table 2
Analysis of association between the degree of optic canal decompression and visual improvement. Statistically significant differences are reported in bold.

Optic canal decompression	N° patients (total)	Visual Outcome			
		Improved	Not improved	p-value (univariate)	p-value (multivariate)
Anterior Segment				**0.010**	>0.05
≤90°	6 (21 %)	2 (33 %)	4 (67 %)		
> 90°	23 (79 %)	16 (70 %)	7 (30 %)		
Posterior Segment				>0.05	>0.05
≤90°	4 (24 %)	2 (50 %)	2 (50 %)		
> 90°	25 (86 %)	16 (64 %)	9 (36 %)		
Full-length OC				**<0.001**	**0.030**
≤90°	7 (28 %)	1 (14 %)	6 (86 %)		
> 90°	21 (72 %)	17 (81 %)	4 (29 %)		
Anterior Segment				>0.05	>0.05
≤180°	12 (41 %)	6 (50 %)	6 (50 %)		
> 180°	17 (59 %)	12 (71 %)	5 (39 %)		
Posterior Segment				**0.002**	**0.035**
≤180°	10 (34 %)	2 (20 %)	8 (80 %)		
> 180°	19 (66 %)	16 (84 %)	3 (16 %)		
Full-length OC				>0.05	>0.05
≤180°	13 (45 %)	7 (54 %)	6 (46 %)		
> 180°	16 (55 %)	11 (69 %)	7 (31 %)		

Lehmberg et al. showed that in patients who underwent EAC, the visual improvement rate was 61 %, while in patients who did not undergo it, the rate was only 25 % [9].

Therefore, in the presence of paraclival meningiomas with OC involvement, our recommendation is to routinely perform EAC and UOC to achieve early tumor devascularization, easier removal of intra- and extra-OC components, better rates of GTR, and more effective OC decompression.

Finally, in recent years, the endoscopic transorbital approach seems to represent a minimally invasive, safe, and effective way to treat lesions in this region, with good results in both the extent of resection and visual outcomes [23,24]. Although this type of approach was not considered in our study, our findings, providing quantitative parameters on OC decompression correlated with visual improvement, could help to improve postoperative visual outcomes in increasingly minimally invasive approaches, while reducing complications and surgical times.

According to our findings, it seems reasonable to aim for complete decompression of the optic canal whenever possible, while avoiding excessive anterior decompression unless it is necessary for the removal of the intracanalicular component of the tumor. This could optimize the surgical procedure, maximizing clinical benefits while minimizing surgical risks. Further studies will be necessary to assess the extent of optic canal decompression based on the length of OC invasion, to evaluate the possibility of a decompression tailored to preoperative MRI findings.

4.1. Limitations

The retrospective nature of this study, the limited number of patients and the short follow-up are the main limitations of this study. Furthermore, only visual acuity was considered as endpoint of this study, not considering other aspects of visual function, such as visual field. Also, the length of OC invasion was not evaluated in this study.

Finally, although the optic canal was decompressed along its entire length in all cases, the degree of decompression was evaluated only at three specific points, approximating the decompression of the segment to that of its ends. The potential presence of areas with greater shrinkage within the segment itself should be considered a possible bias in our results. However, to our knowledge, this is the first attempt to correlate the improvement of postoperative visual acuity with the degree of bone decompression of the optic canal in PMs patients with OC invasion.

5. Conclusion

Anterior segment decompression $> 90^\circ$ and posterior segment decompression $> 180^\circ$ were associated with improvement of visual acuity at 3 months after surgery. A full-length decompression of the optic canal $> 90^\circ$ showed better visual outcome, while a full-length decompression $> 180^\circ$ did not seem to be related to significative improvements in visual acuity. These findings seem to suggest more attention in case of the involvement of the anterior part of OC. Moreover, these data could provide useful information regarding how far surgeons should pursue bony removal of the optic canal to achieve a decompression that can lead to clinical benefits for patients, optimizing surgical times and reducing surgical complications.

Statements and declarations

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CRediT authorship contribution statement

Francesco Zenga: Supervision, Project administration. **Alessandro Pesaresi:** Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation. **Giuseppe Di Perna:** Writing – review & editing, Supervision. **Enrico Lo Bue:** Writing – original draft. **Raffaele De Marco:** Writing – original draft. **Irene Portonero:** Investigation, Data curation. **Alice Antico:** Investigation, Data curation. **Federica Penner:** Supervision. **Fabio Cofano:** Writing – review & editing, Supervision. **Diego Garbossa:** Supervision. **Michele Maria Rosario Lanotte:** Supervision. **Bianca Maria Baldassarre:** Conceptualization.

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