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Morphometric Assessment of the Optic Canal Using Computed Tomography: A Single-Centre Cross-Sectional Study

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ABSTRACT:

Background: Population- and protocol-related variation may influence optic canal measurements. This study evaluated computed tomography–based optic canal morphometry in adults examined at a single centre in Moradabad, India.

Methods: This prospective cross-sectional study included 100 adults aged 18–60 years undergoing clinically indicated non-contrast head computed tomography. Orbital-opening width, central canal width, cranial-opening width, canal length and distance from the midsagittal plane were measured bilaterally on axial bone-window images. Bilateral differences, sex-related variation and associations with age were examined, including adjusted linear mixed-effects models.

Results: Participants had a mean age of 40.55±12.37 years; 70 were male and 30 female. Right/left mean measurements were 3.52/3.55 mm for orbital opening, 3.61/3.70 mm for central canal, 4.00/4.17 mm for cranial opening, 6.90/7.05 mm for canal length and 11.72/11.83 mm for midsagittal-plane distance. After adjustment, males had larger orbital, central and cranial widths and midsagittal-plane distances than females (all FDR-adjusted $P<0.001$), but canal length did not differ. Only central canal width remained significantly greater on the left (adjusted difference, 0.093 mm; FDR-adjusted $P=0.026$). No age-related association remained significant after FDR correction.

Conclusion: Optic canal morphometry demonstrated clear sex-related differences but limited bilateral and age-related variation, providing context-specific anatomical data for CT interpretation in this adult population.

1. INTRODUCTION

The optic canal is a short osseous passage located at the superomedial aspect of the orbital apex. It connects the orbit with the middle cranial fossa and transmits the optic nerve, ophthalmic artery, meningeal coverings and sympathetic nerve fibres[1]. Its boundaries are formed by the body and lesser wing of the sphenoid bone, the optic strut and the anterior clinoid process. Because these structures occupy a confined anatomical space, detailed knowledge of the normal dimensions and variations of the optic canal is important for both radiological assessment and surgical planning[2].

The clinical importance of optic canal morphometry extends beyond anatomical description[3]. Traumatic injury, inflammatory disease and tumours arising from the orbit, sphenoid bone or skull base may involve the canal and compromise the intracanalicular segment of the optic nerve[4]. Surgical procedures such as optic nerve decompression, anterior clinoidectomy and transcranial or endoscopic endonasal approaches also require bone removal close to the optic nerve and ophthalmic artery[5]. Measurements of canal length, calibre and orientation can therefore help define the available surgical corridor and reduce the risk of neurovascular injury[6]. Optic canal calibre has also been associated with the severity of papilloedema and visual impairment in idiopathic intracranial hypertension, while bilateral asymmetry may be present even in individuals without local optic canal disease[7].

Computed tomography (CT) is well suited to optic canal evaluation because it provides high-resolution visualization of the surrounding bone and allows measurements to be obtained in multiple planes[8]. Previous CT-based studies have assessed canal length, orbital and cranial opening dimensions, minimum diameter, cross-sectional area and bilateral symmetry[9]. However, the reported measurements have not been uniforming across studies. Differences have been observed according to the portion of the canal examined, sex, side and the measurement technique employed. A CT-based study from North India reported larger measurements in males for several optic canal parameters but did not identify significant right–left differences[3]. Existing evidence suggests that optic canal measurements should be interpreted in the context of the population examined and the imaging and measurement protocols used, rather than regarded as universal anatomical values. Although CT-based optic canal morphometry has been reported in a broader North Indian population [8], data specifically from adults examined in Moradabad remain limited. Locally generated measurements may provide context-specific anatomical information for CT interpretation and the assessment of the orbital apex and adjacent skull-base structures. Therefore, this single-centre cross-sectional study aimed to characterize CT-based optic canal morphometry in adults examined in Moradabad and to evaluate side- and sex-related differences and associations with age.

2. MATERIALS AND METHODS

Study design and setting: This prospective, single-centre, cross-sectional observational study was conducted in the Department of Radiodiagnosis, Teerthanker Mahaveer Hospital and Research Centre, Moradabad, Uttar Pradesh, India, between April 2025 and May 2026.

Ethical considerations: The study protocol was approved by the Institutional Ethics Committee of Teerthanker Mahaveer University, Moradabad (TMU/IEC/2024-25/044; approval date: 18/11/2025). Written informed consent was obtained from all participants before enrolment. Participant information and CT images were anonymized before analysis.

Study participants: The study included adult patients referred from the outpatient and inpatient departments for clinically indicated non-contrast computed tomography (NCCT) of the head. No additional CT examination or radiation exposure was undertaken solely for research purposes. Eligible participants were enrolled prospectively until the required sample size was achieved.

Sampling procedure: Eligible participants were recruited consecutively from patients undergoing NCCT head examinations during the study period. Each participant contributed measurements from the right and left optic canals. The two optic canals from the same participant were treated as paired observations and not as independent samples.

Eligibility criteria

Inclusion criteria: Participants were included when they:

- underwent clinically indicated NCCT of the head during the study period;
- were aged 18–60 yr;
- had technically adequate CT images permitting clear visualization of both optic canals; and
- had no clinical or radiological abnormality expected to alter optic canal morphology.

Exclusion criteria: Participants were excluded in the presence of:

- craniofacial trauma or skull-base fracture involving the orbital or optic canal region;
- congenital craniofacial or skull-base anomaly;
- previous cranial, orbital or skull-base surgery;
- tumour or another space-occupying lesion involving the orbit, optic canal or adjacent skull base;
- metabolic bone disease;
- infection, erosion or destructive lesion involving the skull or orbit; or
- motion artefacts, incomplete coverage or other technical limitations that prevented reliable measurement.

CT acquisition and image evaluation

All NCCT head examinations were performed using a United Imaging uCT 780 160-slice CT system (United Imaging Healthcare, Shanghai, China) according to the standard institutional head CT protocol. Images were reconstructed using a bone algorithm and reviewed on the picture archiving and communication system in the axial plane.

Morphometric measurements: Both optic canals were measured separately on optimal axial bone-window images using electronic callipers and previously described anatomical landmarks. Measurements included the internal width at the orbital opening, centre and cranial opening; canal length between the centres of the orbital and cranial openings; and perpendicular distance from the medial canal wall to the midsagittal plane. All measurements were recorded bilaterally in millimetres using consistent image orientation, magnification and window settings.

Outcome measures: The primary outcomes were the CT-based morphometric measurements of the optic canal. Secondary outcomes were right–left differences and sex-related differences in the measured parameters.

Statistical analysis: Data were entered and coded using Microsoft Excel and analysed using IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, USA). Adjusted analyses were performed using Python version 3.12.13. Categorical variables were summarized as frequencies and percentages, whereas continuous variables were presented as mean ± standard deviation with 95% confidence intervals where applicable. Right–left measurements were compared using the paired-samples t-test, and male–female differences were assessed using the independent-samples t-test. Associations between age and individual optic canal measurements were examined using Pearson's correlation coefficient. Separate linear mixed-effects models were fitted for each morphometric parameter to account for bilateral measurements within participants. Side, sex and mean-centre age were included as fixed effects, with participant identification as a random intercept. Models were estimated using restricted maximum likelihood. Side-by-sex and side-by-age interactions were examined in sensitivity analyses. The Benjamini–Hochberg false-discovery-rate procedure was applied across the five morphometric outcomes. All tests were two-sided, and $P<0.05$ was considered statistically significant.

3. RESULT

3.1 Participant characteristics

A total of 100 participants, comprising 70 (70%) males and 30 (30%) females, were included. The overall mean age was 40.55 ± 12.37 yr. The mean age was 39.84 ± 11.84 yr among males and 42.20 ± 13.60 yr among females (Table 1).

Table 1. Demographic characteristics of the study participants

Sex	Frequency, n (%)	Age (yr), mean ± SD
Male	70 (70.0)	39.84 ± 11.84
Female	30 (30.0)	42.20 ± 13.60
Overall	100 (100.0)	40.55 ± 12.37

3.2 Overall CT morphometry of the optic canal

The overall CT-based morphometric measurements of the optic canal are presented in Table 2. Mean values and corresponding 95 per cent confidence intervals were estimated separately for the right and left sides.

Table 2. Overall CT-based morphometric measurements of the optic canal according to side

Parameter	Right side, mean ± SD (95% CI), mm	Left side, mean ± SD (95% CI), mm
OO	3.52 ± 0.33 (3.46–3.59)	3.55 ± 0.33 (3.49–3.62)
COC	3.61 ± 0.35 (3.54–3.68)	3.70 ± 0.41 (3.62–3.78)
CO	4.00 ± 0.61 (3.88–4.12)	4.17 ± 0.62 (4.05–4.29)
CL	6.90 ± 0.73 (6.75–7.04)	7.05 ± 0.60 (6.93–7.17)
MSP	11.72 ± 1.27 (11.47–11.98)	11.83 ± 1.56 (11.52–12.14)

Values are expressed as mean ± standard deviation (95% confidence interval); n=100n=100 participants for each side. OO, orbital opening width; COC, centre optic canal width; CO, cranial opening width; CL, canal length; MSP, distance from the midsagittal plane.

3.3 Bilateral comparison of optic canal measurements

Paired analysis showed that the centre optic canal width, cranial opening width and canal length were significantly greater on the left side. No significant side-to-side differences were observed in orbital opening width or distance from the midsagittal plane. The magnitude of the observed differences was small, with absolute Cohen's dzd_z values ranging from 0.06 to 0.29 (Table 3).

Table 3. Paired comparison of right- and left-sided optic canal measurements

Parameter	Mean paired difference, R−L (95% CI), mm	*t*	*P* value	Cohen's dzd_z
OO	−0.03 (−0.09 to 0.03)	−0.94	0.352	0.09
COC	−0.09 (−0.15 to −0.03)	−2.86	0.005*	0.29
CO	−0.17 (−0.32 to −0.02)	−2.32	0.023*	0.23

CL	−0.15 (−0.29 to −0.01)	−2.18	0.032*	0.22
MSP	−0.11 (−0.49 to 0.27)	−0.57	0.568	0.06

Paired-samples tt-test; *P<0.05*P<0.05. Mean difference was calculated as right minus left; therefore, a negative value indicates a greater measurement on the left side. Cohen's dzd_z represents the standardized paired difference. OO, orbital opening width; COC, centre optic canal width; CO, cranial opening width; CL, canal length; MSP, distance from the midsagittal plane.

3.4 Bilateral asymmetry of optic canal parameters

The individual bilateral asymmetry index was calculated for each morphometric parameter. The distance from the midsagittal plane showed the highest median asymmetry index of 10.67% (IQR: 4.75–16.89%), followed by the cranial opening, with a median asymmetry of 7.61% (IQR: 3.06–17.57%). An asymmetry index of ≥10% was observed most frequently for the midsagittal-plane distance (53.0%) and cranial opening (38.0%). The corresponding proportions with an asymmetry index of ≥20% were 20.0% and 18.0%, respectively. At the participant level, 85 participants had an asymmetry index of ≥10% in at least one parameter, while 43 had an asymmetry index of ≥20% in at least one parameter (Table 4).

Table 4. Distribution of bilateral asymmetry indices and proportions meeting the descriptive thresholds

Parameter	Median AI (%)	IQR (%)	AI ≥10%, n (%)	AI ≥20%, n (%)
OO	5.02	2.81–11.12	28 (28.0)	5 (5.0)
COC	5.62	2.48–10.33	26 (26.0)	3 (3.0)
CO	7.61	3.06–17.57	38 (38.0)	18 (18.0)
CL	5.17	2.52–11.27	28 (28.0)	9 (9.0)
MSP	10.67	4.75–16.89	53 (53.0)	20 (20.0)

AI was calculated as |Right − Left|/[(Right + Left)/2] × 100. The thresholds of 10% and 20% were used for descriptive analysis and should not be interpreted as clinical diagnostic cut-offs. AI, asymmetry index; IQR, interquartile range; OO, orbital opening; COC, centre of the optic canal; CO, cranial opening; CL, canal length; MSP, distance from the midsagittal plane.

3.5 Sex-related differences in optic canal morphometry

Male participants had higher mean measurements than female participants for the orbital opening, centre of the optic canal, cranial opening and distance from the midsagittal plane on both sides. The differences were statistically significant for these parameters (all P≤0.043). The largest standardized differences were observed for the left cranial opening (Cohen's d=0.90), right midsagittal-plane distance (d=0.86) and right orbital opening (d=0.79). Canal length did not differ significantly between males and females on either the right (P=0.421) or left (P=0.096) side (Table 5).

Table 5. Sex-related comparison of bilateral optic canal morphometric measurements

Parameter	Side	Male (mm)	Female (mm)	Mean difference (95% CI), mm	t	P value	Cohen's d
OO	Right	3.60 ± 0.31	3.35 ± 0.30	0.245 (0.111–0.378)	3.64	<0.001	0.79
OO	Left	3.60 ± 0.34	3.45 ± 0.28	0.144 (0.004–0.284)	2.05	0.043	0.45
COC	Right	3.68 ± 0.37	3.44 ± 0.25	0.242 (0.096–0.389)	3.29	0.001	0.72
COC	Left	3.79 ± 0.43	3.50 ± 0.26	0.288 (0.121–0.455)	3.43	<0.001	0.75
CO	Right	4.12 ± 0.65	3.72 ± 0.37	0.394 (0.142–0.646)	3.10	0.003	0.68
CO	Left	4.32 ± 0.62	3.81 ± 0.43	0.515 (0.268–0.762)	4.14	<0.001	0.90
CL	Right	6.94 ± 0.74	6.81 ± 0.70	0.128 (−0.186–0.443)	0.81	0.421	0.18

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CL	Left	7.12 ± 0.60	6.90 ± 0.58	0.219 (−0.039–0.477)	1.68	0.096	0.37
MSP	Right	12.03 ± 1.19	11.01 ± 1.16	1.020 (0.507–1.533)	3.94	<0.001	0.86
MSP	Left	12.10 ± 1.51	11.22 ± 1.54	0.878 (0.221–1.536)	2.65	0.009	0.58

Values are expressed as mean ± standard deviation. Comparisons were performed using the independent-samples t-test. Mean differences were calculated as male minus female; therefore, positive values indicate higher measurements in males. Cohen's d was calculated using the pooled standard deviation. OO, orbital opening; COC, centre of the optic canal; CO, cranial opening; CL, canal length; MSP, distance from the midsagittal plane; CI, confidence interval.

3.6 Association of age with optic canal measurements

Age showed a weak negative correlation with right-sided canal length (Spearman's ϱ=−0.21\rho=-0.21, P=0.033P=0.033). No statistically significant correlations were observed between age and the remaining right- or left-sided optic canal measurements (Table 6).

Table 6. Correlation of age with bilateral optic canal measurements

Parameter	Right side, Spearman's ϱ	*P* value	Left side, Spearman's ϱ	*P* value
OO	0.19	0.054	0.13	0.187
COC	−0.01	0.941	0.11	0.284
CO	0.11	0.270	0.06	0.563
CL	−0.21	0.033*	−0.02	0.843
MSP	0.10	0.328	0.09	0.399

∗P<0.05*P<0.05. OO, orbital opening width; COC, centre optic canal width; CO, cranial opening width; CL, canal length; MSP, distance from the midsagittal plane. All measurements were analysed in millimetres.

3.7 Adjusted linear mixed-effects analysis

As shown in Table 7, males had significantly larger orbital opening, central optic canal width, cranial opening and midsagittal-plane distance than females after adjustment for age and side (all FDR-adjusted P<0.001); canal length showed no sex-related difference (P=0.197). The central optic canal was significantly wider on the left (adjusted difference, 0.093 mm; 95% CI, 0.028–0.157; FDR-adjusted P=0.026), while differences in cranial opening and canal length were borderline (both FDR-adjusted P=0.053). No age-related association or interaction remained significant after FDR correction.

Table 7. Adjusted associations of side, sex and age with optic canal morphometric parameters using linear mixed-effects models

Parameter	Left–right difference, B (95% CI), mm	P/FDR-P	Male–female difference, B (95% CI), mm	P/FDR-P	Age effect, B/year (95% CI), mm	P/FDR-P
OO	0.031 (−0.035 to 0.097)	.352/.440	0.206 (0.092 to 0.320)	<.001/<.001	0.005 (0.001 to 0.009)	.022/.111
COC	0.093 (0.028 to 0.157)	.005/.026	0.271 (0.130 to 0.412)	<.001/<.001	0.003 (−0.003 to 0.008)	.337/.337
CO	0.170 (0.024 to 0.315)	.023/.053	0.468 (0.276 to 0.660)	<.001/<.001	0.006 (−0.001 to 0.013)	.115/.192

CL	0.155 (0.014 to 0.296)	.032/.053	0.159 (−0.084 to 0.402)	.197/.197	−0.006 (−0.015 to 0.003)	.175/.219
MSP	0.110 (−0.268 to 0.487)	.566/.566	0.981 (0.564 to 1.399)	<.001/<.001	0.014 (−0.002 to 0.029)	.084/.192

B represents the adjusted mean difference or change. A positive side coefficient indicates a larger measurement on the left; a positive sex coefficient indicates a larger measurement in males. FDR-P values were calculated using the Benjamini–Hochberg procedure.

4. Discussion

This study provides CT-based bilateral morphometric data for the optic canal in adults examined at a single centre in Moradabad. The cranial opening was wider than the orbital opening and central canal, while the mean canal length was approximately 7 mm. The principal adjusted findings were larger orbital-opening width, central canal width, cranial-opening width and midsagittal-plane distance in males. Canal length did not differ significantly according to sex. Although several left-sided measurements were greater in the unadjusted analysis, only the central canal width retained a significant side difference after adjustment and false-discovery-rate correction. No age-related association remained significant after correction. The mean orbital-opening widths were 3.52 mm on the right and 3.55 mm on the left, whereas the corresponding cranial-opening widths were 4.00 and 4.17 mm. This progressive increase towards the cranial opening is consistent with previous CT-based and anatomical studies. In a North Indian CT study, **Sthapak et al. (2023)** reported orbital-opening diameters of 3.17 mm in males and 2.97 mm in females, compared with cranial-opening diameters of 4.34 and 3.99 mm, respectively[10]. **Kalthur et al. (2015)**[11] similarly reported mean CT-derived orbital- and cranial-opening widths of 2.98 and 4.59 mm . Although the general configuration is comparable, the absolute values differ between studies, possibly because of differences in participant characteristics, image reconstruction, section orientation and the landmarks used for measurement. The mean canal lengths in the present study were 6.90 mm on the right and 7.05 mm on the left. These values are lower than the sex-specific means of 9.38–9.81 mm reported by **Sthapak et al. (2023)**[10], but higher than the mean of 5.61 mm reported by **Zhang et al. (2019)**[12]. Zhang et al. defined canal length according to the extent of osseous enclosure on multiplanar CT images, whereas the present study measured the centre-to-centre distance between the orbital and cranial openings on axial images. Consequently, differences in canal length between studies should not be attributed solely to population variation; the imaging plane and operational definition of the endpoints are also likely to influence the measurement. In the paired analysis, central canal width, cranial-opening width and canal length were greater on the left. However, after accounting for the paired observations and correcting for multiple comparisons, only the central canal remained significantly wider on the left, with a small adjusted difference of 0.093 mm (95% CI, 0.028–0.157; FDR-adjusted P=0.026) (Table 7). The adjusted side effects for the cranial opening and canal length were borderline, while no side difference was observed for the orbital opening or midsagittal-plane distance. **Sthapak et al. (2023)**[10], found no overall right–left difference in optic canal measurements, and an anatomical study by **Radunovic et al. (2019)** also reported no significant bilateral differences in the canal apertures or central segment[13]. In contrast, **Zhang et al. (2019)**[12] demonstrated that appreciable individual asymmetry may occur even when a consistent directional difference is absent at the group level. Therefore, the small mean left–right difference observed in the present study should not automatically be considered clinically important, and individual measurements should be interpreted bilaterally. Sex was more consistently associated with optic canal dimensions. After adjustment for age and side, males had larger orbital openings by 0.206 mm, central canal widths by 0.271 mm, cranial openings by 0.468 mm and midsagittal-plane distances by 0.981 mm; all remained significant after FDR correction. Canal length showed no significant sex-related difference. The findings agree with the North Indian study by **Sthapak et al. (2023)**[10], which reported larger orbital and cranial openings and greater midsagittal-plane distances in males. **Pirinc et al. (2023)** also observed a wider intracranial aperture in males on multidetector CT[14]. These consistent findings suggest sex-related variation in canal calibre and position. Nevertheless, head size, body size and other craniofacial measurements were not available in the present study; therefore, the observed differences cannot be attributed to sex independently of overall cranial dimensions. No age effect remained significant after adjustment for multiple comparisons. Although isolated nominal associations appeared in the unadjusted and adjusted analyses, their absence after FDR correction suggests that they may represent chance findings. **Pirinc et al. (2023)** reported differences among age groups, but their participants ranged from infancy to 90 years[14]. The narrower age range of 18–60 years in the present study may have limited the ability to identify developmental or late-life changes. Furthermore, the cross-sectional design does not permit conclusions regarding within-person changes over time. The measurements obtained in this study may provide local anatomical context when reviewing CT examinations of the orbital apex and adjacent skull base. However, they should not be interpreted as universal normal ranges or as surgical safety thresholds. Measurements in an individual patient should be evaluated with reference to both sides, the imaging protocol and the relevant clinical findings. The strengths of the study include its prospective design, bilateral assessment using consistent landmarks and analysis of paired measurements using participant-level random effects. Adjustment for multiple comparisons also reduced the likelihood of emphasizing chance associations. The study nevertheless has several limitations. It was conducted at a single hospital using a clinically referred sample, which may not represent the general population of Moradabad or other regions. The unequal numbers of males and females may have reduced precision in the female subgroup. Measurements were obtained by a single observer, and intraobserver and interobserver reliability were not assessed. Analysis was restricted to axial bone-window images from one CT system, without comparison with multiplanar or three-dimensional measurements. Cranial size, height, body size and other potential explanatory variables were not recorded. Finally, the study included only adults aged 18–60 years and did not evaluate whether the observed anatomical differences were associated with clinical or surgical outcomes.

5. CONCLUSION

In this single-centre sample of adults from Moradabad, orbital-opening width, central canal width, cranial-opening width and midsagittal-plane distance were greater in males, whereas canal length did not differ significantly according to sex. Bilateral differences were small and, after correction for multiple comparisons, were limited to central canal width; no age association remained significant. These findings provide context-specific descriptive data but require confirmation using multicentre samples, standardized imaging methods and observer-reliability assessment.

6. DECLARATIONS

Ethics approval and consent to participate: The study was approved by the Institutional Ethics Committee of Teerthanker Mahaveer University, Moradabad (TMU/IEC/2024-25/044; approval date: 18/11/2025). Written informed consent was obtained from all participants.

Consent for publication: Not applicable.

Availability of data and materials: De-identified data are available from the corresponding author on reasonable request.

Competing interests: The authors declare no competing interests.

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Authors' contributions: A.S. was primarily responsible for data collection and contributed to the study design, CT-based morphometric measurements, data curation, and preparation of the original draft. R.K. conceptualized and supervised the study, guided the methodology and data collection, contributed to interpretation of the findings, and critically reviewed and revised the manuscript. A.K., J.Y., and C.S. contributed to the literature review, interpretation of the morphometric findings, and critical revision of the manuscript. K.K. contributed to data organization, data curation, and manuscript preparation. R.K. contributed to interpretation of the findings and critical review of the manuscript. All authors read and approved the final manuscript.

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