DOI: 10.7860/IJARS/2023/61596.2891

Anatomical Variations of the Trigeminal Nerve, Trigeminal Ganglion and Foramen Ovale: A Systematic Review

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ABSTRACT

Introduction: The trigeminal nerve is principally responsible for controlling the sensory modalities of the face. The Foramen Ovale (FO) is one of the apertures present in the skull base, through which the mandibular nerve, a branch of the trigeminal nerve passes.

Aim: To deliver a thorough understanding of the anatomical variations of the trigeminal ganglion and FO that would be beneficial to neurologists and neurosurgeons when performing various treatments involving these structures.

Materials and Methods: The present systematic review was formulated according to Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines. Major electronic databases were screened and all types of studies including descriptive studies, surveys, full-text literature providing information about the variations in trigeminal ganglion and FO, were incorporated in the current review. Studies from 2001-2022 were included in this review. The risk of bias evaluation in the present study was conducted by using the review manager software (RevMan version 5.4) and risk assessment domains were classified as high, indeterminate, or low risk. The recommended approach to check biases such as selection, performance, attrition, reporting, and other biases was done.

Results: A total of 12 studies were examined. The studies measured the proper location and the size (diameter) of the trigeminal ganglion and FO using the MRI-based findings. It was observed that the length of the trigeminal nerve was found to be about 9.66 mm in the cistern (range 6.04-20.74 mm) in 50% of studies, whereas in 16.67% of the studies trigeminal nerve was longer in the older patients as compared to the normal anatomy. Additionally, the distinctive form of the FO was noted in the current investigation. In total, (n=4) 66.66% of the studies demonstrated the oval shape of the FO, and (n=3) 50% of studies noticed an almond shape, 50% identified a round shape; (n=2) (33%; n=2) displayed a slit form. Only one investigation demonstrated a bony bridged of FO whereas 33% showed tubercle and triangular shapes.

Conclusion: Majority of the studies showed that the length of the trigeminal nerve was found to be about 9.66 mm. Whereas, only one author reported that the trigeminal nerve is longer in the older patients as compared to the normal anatomy. The majority of studies demonstrated that the variations were observed in the shape of the FO, i.e., oval, round, almond, slit, spine.

Keywords: Almond shape, Oval, Skull base, Slit form

INTRODUCTION

In humans, the trigeminal nerve, the fifth cranial nerve is the large cranial nerve [1] primarily responsible for sensations of the mucous membranes. It is also the chief sensory innervation of other areas of the head [2]. The trigeminal/Gasserian ganglion is located in the trigeminal (Meckel's) cave, surrounded by cerebrospinal fluid, and contains the cell bodies of the sensory root of the trigeminal nerve [3].

Different neuropeptides and signalling molecules expressed by the trigeminal ganglion are crucial to gene expression, sensory modulation, peripheral and central sensitisation [4]. The motor root runs in front of and medial to the sensory root and passes beneath the ganglion; it leaves the skull through the FO and immediately below this foramen, joins the mandibular nerve.

Various areas of the face are innervated by the trigeminal nerve, which has three branches; the first one being ophthalmic (V1), second one maxillary (V2) and the third one mandibular (V3) nerves, which emerge from the trigeminal ganglion [2]. However, as a matter of fact trigeminal nerve is known to have many anatomical and developmental variations along all the morphological aspects which include location, varied diameter, shape and thickness of the nerve and its branches along their course and the pattern of branching from the main ganglion [2].

Trigeminal ganglia are of different sizes and thickness ranging from 14-22 mm in length and 4-5 mm in overall thickness [5-8]. The accurate thickness of the ganglion was found to be 1.5-2 mm after accounting for its concave shape [7,9]. According to the author's prior study [3], the trigeminal ganglion is generally 2 mm thick, less commonly 1 mm and rarely 3 mm thick [3]. The trigeminal cistern varies considerably in volume and shape. Sicardetal carried out the first radiological study on the trigeminal cistern in 1924 [5]. The volume of Trigeminal Cave (TC) was reported as approximately 1.5 mL by Putman TJ and Haptom AO, while Lunsford LD evaluated a range between 0.15-0.5 mL [10,11]. While, Hakanson S reported a mean volume of 0.6 mL (range: 0.2-1.4 mL) [12]. As reported by Ajayi NO et al., the TC has a volume of 0.14 mL (range 0.05-0.4) [13].

The trigeminal ganglion plays a vital role in regulating neuropeptides, thus acting as a potent vasodilator. Cluster headaches are accompanied by an abundance of calcium-related peptides like calcitonin gene-related peptide in the ganglion, which plays an essential role in their pathophysiology. The semilunar ganglion also has involvement in the often underappreciated perineural spread of tumours, which is a common metastatic phenomenon involving a delayed diagnosis [14]. For this reason, an appropriate knowledge about the accurate location of ganglion is essential for the treatment involving the trigeminal nerve [14].

Similarly, FO also shows, morphological and anatomical variations according to the study done by Prakash KG et al., which revealed that, the variations in the shapes of the FO were found to be due to developmental reasons [15]. In addition, a study done by John D and Thenmozhi, showed different osseous structures including the bony spine, plate, tubercles and variations in shape like round, slit, almond, oval are present due to variations in the ossification of the greater wing of the sphenoid bone during the developmental process [16]. Therefore, it is of clinical importance to medical practitioners to be thorough with the developmental variation, especially in case of trigeminal neuralgia or any other lesions seen in the cranial cavity [16].

According to Mishra MG et al., neurosurgeons can develop new and innovative procedures to approach the middle cranial fossa by specific knowledge of variations of the FO [17]. As a result of their study, they found 80% spines and 100% tubercles arising from the anterior margin of the FO. Hence, a proper and accurate knowledge of the FO and positioning of trigeminal ganglion is necessary for neurosurgeons for the administration of nerve blocks as well as for the diagnostic procedures such as percutaneous biopsy of cavernous sinus tumours, electroencephalographic analysis, microvascular decompression, percutaneous trigeminal rhizotomy and administration of anaesthesia to the mandibular nerve V_3. Due to the possibility of being interrupted by spines and tubercles, surgeons should avoid going towards the anterior margin of the FO [17]. Accurate assessment and identification of diseases affecting the trigeminal nerve depends on having a thorough understanding of the anatomical relationships and differences between the trigeminal ganglion-nerve complex and its perineural vascular plexus. Hence, this present review assesses the variations of FO, trigeminal ganglion with origin and course of the trigeminal nerve.

MATERIALS AND METHODS

The protocol for this systematic review was made based on the PRISMA-P statement and all changes were appropriately noted. Studies from 2001-2022 were included in this review.

Inclusion criteria:

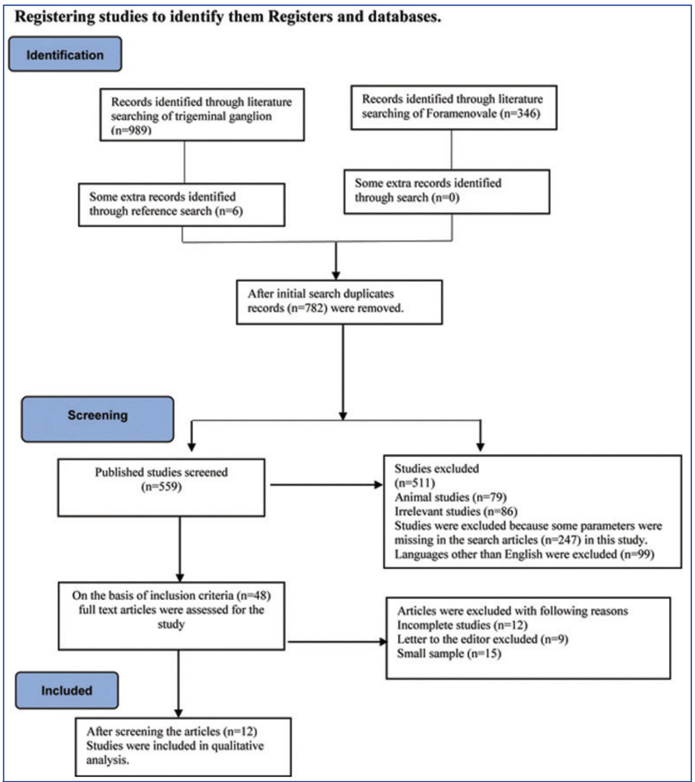
- Studies which describe the anatomical variations of trigeminal ganglion, nerve and their branching pattern were included.
- Studies that provide information about the anatomical examination of the FO.
- Articles available in English language only.

Exclusion criteria:

- Abstracts of conferences
- Copyrights and duplicate articles
- Studies/articles of trigeminal ganglion without MRI based findings were excluded. We excluded studies that did not have an MRI-based trigeminal ganglion finding. The basis of keeping this exclusion criterion was without MRI it is impossible to know the anatomy as well as exact positioning of the ganglion.
- Animal studies.

Search Strategy

A thorough literature search was performed using Google scholar, Embase, MEDLINE, PubMed, Scopus, web of science and Wiley databases. All articles as well as case reports and literature reviews published were reviewed in the study. Authors searched for Medical Subject Headings (MeSH) terms and free text terms associated with all fields as well as Boolean operators as appropriate for anatomical variation of trigeminal nerve, distribution of trigeminal nerve, radiological aspects of the trigeminal nerve, structure and function of the trigeminal ganglion, anatomy of trigeminal nerve, Trigeminal ganglion and its clinical implications, as well as the location and anatomical variation of trigeminal ganglion were searched on databases. Full text articles, case studies, case series dealing with anatomy, pathology, embryology of trigeminal nerve, available in the English language, in humans were included in this review. Literatures with no full text accessibility and those which were not found in the particular original data were not used in the present review. This document provides a comprehensive search strategy in preferred reporting items for systematic review charts which is shown in the [Table/Fig-1].



[Table/Fig-1]: (PRISMA) flowchart for a systematic review that only included database and register searches.

STATISTICAL ANALYSIS

After the initial search, selected articles available from the database were arranged in an Excel sheet, from where the duplicate articles were removed. Then, abstracts and full text articles were reviewed by two authors independently. To conduct this study they read all the selected articles and a final decision was taken.

RESULTS

In this systematic review, initial search yielded 989 articles. After analysing complete available data a total (n=12) studies were selected on the basis of inclusion criteria [Table/Fig-2] [3,15,16,18-26].

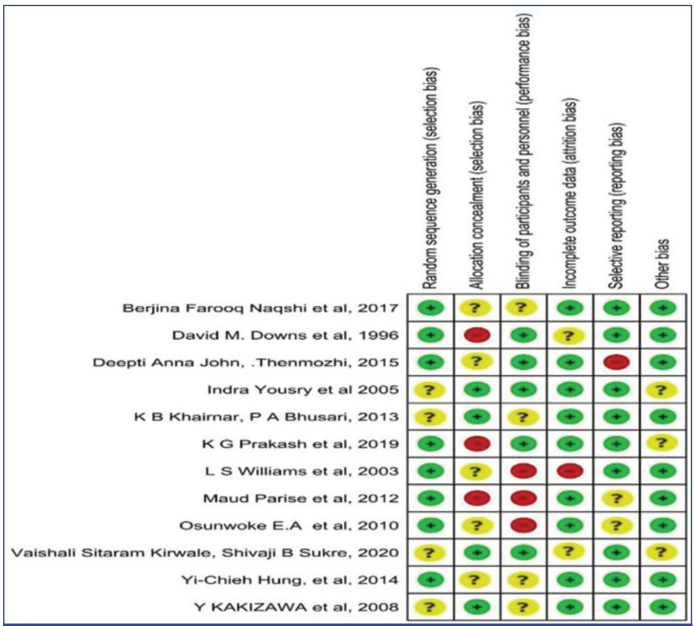
Overall, 50% of included studies revealed that the length of the trigeminal nerve was found to be about 9.66 mm in the cistern (range 6.04-20.74 mm). Whereas, in the 16.67% of the studies demonstrated that the trigeminal nerve is longer in the older patients as compared to the normal anatomy. Additionally, the distinctive form of FO was noted in the current investigation. In total, (n=4) 66.66% of the studies demonstrated the oval shape of the foramen oval, and (n=3) 50% of studies noticed an almond shape, 50% identified a round shape; (n=2) (33%; n=2) displayed a slit form. Only one investigation demonstrated a bony bridge of FO, whereas 33% showed tubercle and triangular shapes.

Quality evaluation of the included studies: RevMan software version 5.4., evaluated the risk of bias. On the domains and criteria, individual studies were classified as low, unclear or high risk. According to the selection bias (generation of random sequence), performance bias (blinding of patients and personnel), attrition bias (incomplete outcome data), selective reporting (reporting bias) and other biases, risk assessment domains were categorised as high, unclear or low risk. Therefore, the overall risks for the distinct studies were assessed as the low risk (+), high risk (-) as well as unclear risk (?) in [Table/Fig-3] [3,15,16,18-26]. Atleast one bias domain was found to contain serious methodological inadequacies in all studies. In the most problematic domains, randomisation was insufficient/non existent, blinding of outcome assessors was low [Table/Fig-4].

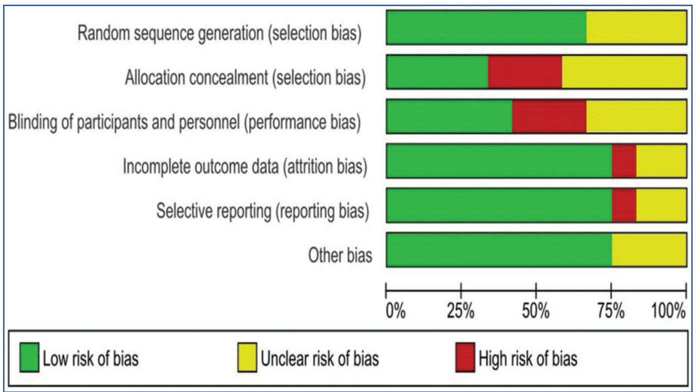
S. No.	Author (year)	Study place	Sample size	Study design	MRI based finding of trigeminal ganglion	Conclusion
1.	Yousry I et al., (2005) [3]	Germany	42 patients (21 men and 21 Female)	Observational study	The study showed that the Trigeminal Ganglion was commonly 2 mm thick, less commonly, 1 mm and infrequently, 3 mm thick.	They concluded that the improved 3 Dimensional Constructive Interference in the Steady State (3D CISS) sequence was quite beneficial. It is advisable to use improved 3D CISS as well as the 3 Dimensional enhanced Time Of Flight (3D TOF) MRA sequences for a thorough MR imaging examination of the trigeminal ganglion and roots.
2.	Williams LS et al., (2003) [18]	Florida	32 patients (16 male and 16 Female)	Retrospective study	The study showed 2-3 mm size of the trigeminal ganglion-nerve and its perineural plexus complex. The enhanced ganglion or nerve with distinct vascular plexus is found to be 4% (0-10), 18% (9-18) and 3% (0-7).	This study illustrated normal MR appearance of the trigeminal ganglion and its branches. They found that the ganglion, V2 and V3 both are nearby and consistently seen on thin-section MR studies of the skull base.
3.	DM Downs et al., (1996) [19]	Aurora	57 patients	Retrospective study	In 100 of the 114 caves examined, Meckel's cave was identified on the inferolateral side. Several of the other caves had a thickened enhancement area inferolateral to the dura.	They concluded that the gasserian ganglion enhances on MR images and should not be confused with a pathologic process.
4.	Parise M et al., (2012) [20]	Brazil	26 patients (20 female, 6 male)	Prospective study	The cisternal segment of trigeminal ganglion in which the lengths on the unaffected side was found to be 9.6 mm and on the affected side 7.9 mm were observed for the diagnosis of trigeminal neuralgia.	The area of the Cerebellopontine Angle can be easily and directly estimated using the trigeminal nerve cisternal measurement in the treatment of the trigeminal neuralgia.
5.	Kakizawa Y et al., (2008) [21]	Japan.	110 patients (60 female and 50 male)	Anatomical study	In this study, findings in asymptomatic individuals were helpful in determining which MR images might be indicative of symptomatic individuals. Trigeminal nerve length was 9.66+1.71 mm, trigeminal nerve distance was 31.97+1.82 mm and trigeminal nerve angle was 9.71+5.83° (18 standard deviations). The trigeminal nerve was considerably longer in elder patients.	Described the variations in older people's typical anatomy. The diagnostic procedures for microvascular decompression can be improved with knowledge of the normal anatomy which might improve the viability of such surgeries' results.
6.	Hung YC et al., (2014) [22]	Taiwan	106 patients, (36 male and 70 female)	Retrospective study	106 patients were found to have an average nerve length of 9.6 mm in the cistern (range 6.04-20.74 mm). There was a median (targeting length) of 3.8 mm observed amongst the radiation shot and brainstem (range 1.81-10.84 mm). Their study showed a positive relationship among the nerve length and targeting length.	As shown in their study, anatomical nerve variations, the rate of pain relief was not different for patients receiving Dorsal Root Entry Zone- targeted (DREZ) Gamma Knife Surgery (GKS). In contrast, facial hyperaesthesia was more common in patients with longer nerves (>11 mm) or lower targeting ratios (<36%). If the targeting ratio is adjusted, particularly for patients with longer nerves, facial hyperesthesia can be reduced and effective pain control can be maintained.
S. No.	Author and year	Study place	Sample size	Study design	MRI based finding of Foramen Ovale (FO)/Non MRI based findings of Foramen Ovale (FO)	Conclusion
7.	Khairnar KB and Bhusari PA (2013) [23]	Nashik	100 human skull	Anatomical study	It's anon MRI based finding. The outcomes of this study reported various shapes of FO ranging from oval, round, almond and triangular shaped FO. In terms of shape, oval-shaped FOs were the most common, followed by almond-shaped, round-shaped, and spine-shaped FOs.	FO plays an important role in surgical and diagnostic procedures such as percutaneous trigeminal rhizotomy in trigeminal neuralgia, as well as transfacial fine needle aspiration. Neurosurgeons should consider this study as worthwhile because FO and Foramenspinosum have such clinical significance.
8.	Osunwoke EA et al., (2010) [24]	Nigeria	87 dried skull	Morphometric study (Cadaver based)	Length of right foramen spinosum was 2.34±0.05 mm on average, while the left foramen spinosum length was 2.36±0.05 mm on average. Both the right and left foramen spinosum measured between 1.0 mm and 2.0 mm in width. The left foramen spinosum measured 1.61±0.03 mm in width on average, compared to 1.66±0.03 mm for the right foramen spinosum. The average of the right and left foramen spinosum's length and width did not significantly differ from one another.	In this study, they demonstrated that medical professionals should consider the study's clinical and anatomical implications when treating patients with trigeminal neuralgia and when doing diagnostic procedures to find tumours and aberrant bone outgrowths.
9.	Prakash KG et al., (2019) [15]	Kerala, India	62 (124 sides) dry adult Indian human skull	Anatomical study (Cadaver based)	The FO were found with bony variations like, spine shaped, tubercles shaped, bony bridge/bar shaped and confluence shaped. The adult skull measurements were taken in this study. The mean length, width and diameter of FO were obtained with values of 7.64±1.194 mm for the right side 5.128±0.827 mm and 30.808±7.545 mm^2 and for the left- side the values were 7.561±1.123 mm, 5.244±0.950 mm and 31.310±8.262 mm^2, respectively.	This study concluded that, the variations in the shapes of the FO were due to developmental reasons.
10.	Kirwale VS et al., (2020) [25]	Aurangabad	112 adult dry human skulls	Anatomical study	Various shapes of the FO were found in this study, such as oval, almond, round, D shaped and triangular shape were present in 66.07%, 14.28%, 10.72% and 7.15%, 1.78% of skull. The mean width of foramen was about 4.18+0.78 mm and 4.28+0.81 mm on right and left-side respectively.	In this study, various morphologies of foramen ovale including oval, almond, rounded, D-shaped and triangular were discovered. Abnormal outgrowths including the existence of a bony pterygo-alar bar and spur were also detected.

11.	John D et al., (2015) [16]	Chennai	30 adult dry skulls of unknown sex	Anatomical study (Cadaver based)	Variations were detected in the shape of FO i.e., tubercles, spine and bony plates of the skulls.	They suggested that accurate knowledge of the anatomical variations of FO is essential for neurosurgeons.
12.	Naqshi BF et al., (2017) [26]	Jammu	17 human skull and 3 sphenoid bone.	Anatomical study (Cadaver based)	In their study, on 40 sides in 20 bones FO was observed with various shapes like the ovale, round, almond, slit, spine and one had bony plate.	They concluded that the Percutaneous trigeminal rhizotomy for trigeminal neuralgia relies on the foramen ovale. It is essential to have a thorough understanding of the variations in these foramina when performing surgery within the middle cranial fossa.

[Table/Fig-2]: Tabulation of all the studies depicting the variations in the trigeminal ganglion [3,15,16,18-26].
3D CISS: 3D constructive interference in the steady state; 3D TOF: 3D time of flight



[Table/Fig-3]: An illustration of the risk of bias graph showing the review authors' assumptions for each risk of bias item for each included study [3,15,16,18-26].



[Table/Fig-4]: Risk of bias graph: percentages demonstrating review authors' evaluation of each risk of bias item across all collected literatures.

DISCUSSION

Identification of the correct trigeminal ganglion position is clinically significant. Involvement of trigeminal nerve, the sensory nerve of the face causes neuropathic pain called trigeminal neuralgia which is a feeling of burning, shooting or stabbing sensation [27]. Trigeminal neuralgia has a wide range of causes, most commonly it is a consequence of nerve compression. Management procedures and interventions of trigeminal nerve and related structures require accurate knowledge of anatomy for better results.

As previously reported, there is a larger Transitional Zone (TZ) on the sensory trigeminal nerve compared to the facial nerve. The TZ of the trigeminal nerve is located in the vicinity of the brainstem at a distance of 2-10 mm [28-34]. The authors of previous clinical reports suggested that Microvascular Decompression (MVD) performed only at the trigeminal nerve TZ was adequate whereas, Jannetta PJ et al., reported that TZ of the trigeminal nerve extends further distally [29,35]. Therefore, every cistern should be checked for nerves and each vessel should be addressed and treated accordingly.

Similar study conducted by, Sindou M et al., stated that the compression site was located at the middle part of the cisternal portion of the trigeminal nerve in the 45% of 579 patients and near the Meckel's cave in 10% [36]. On the other hand, no vessels compressing the trigeminal nerve were found in the operative field in 7.5% of all 3256 patients.

Younger patients may be more vulnerable to mechanical alterations in the posterior fossa, according to the findings of Parise M et al., [20]. They discovered an age-specific, positive, but not statistically significant, association between the Cerebellopontine Angle (CPA) cisternal area and age. Similar study conducted by Rasche D et al., raising the question of why elderly people, who are more frequently affected by trigeminal neuralgia, have a paradoxically higher CPA cisternal size as a result of brain atrophy [37]. Although the cause is still unclear, it appears that neurovascular contact made possible by brain dropping in this patient population has a stronger effect on trigeminal neuralgia development.

Osunwoke EA et al., showed that there was no significant difference between the mean of the length and width of the right and left FO [24]. The length of right and left foramen spinosum was 1.5-3.5 mm and 1.0-4.0 mm, respectively and findings of this study may be helpful to medical practitioners in cases of trigeminal neuralgia and in detecting tumours and abnormal bony outgrowths.

Findings based on MRI from included studies: A study conducted by Yousry I et al., depicted the results of the 22 patients (44 sides) who experienced non-enhanced 3D CISS MR imaging [3]. They reported that enhanced 3D Constructive interference in the steady state magnetic resonance imaging sequence was most effective for showing the trigeminal ganglia, sinus ganglia as well as the sinus lips. While, the enhanced three-dimensional time of flight sequence normally showed the developing V_1, V_2 and V_3 branches. The analysed trigeminal ganglion was generally 2 mm thick; less commonly 1 mm and very uncommonly 3 mm.

Williams LS et al., discovered the trigeminal ganglion-nerve and its perineural plexus complex and estimated its size to be around 2-3 mm [18].

Additionally, their study reported about the inter observer reliability for the imaging of the structures for evaluating the morphology as well as regulating the development of the trigeminal ganglion, V_2 and V_3 in which they discussed about K score which ranged around 0.41 mm for imaging of V_3 to 0.79 mm for estimating morphology of the trigeminal ganglion.

Kakizawa Y et al., mainly described the anatomical variations of trigeminal nerve in older people [21]. They demonstrated that the trigeminal nerve was considerably longer in older patients. In their study, the evaluated mean (6 standard deviation (SD) length of the trigeminal nerve was found to be 9.66±1.71 mm. Whereas, the mean distance among the bilateral trigeminal nerves was found to be 31.97±1.82 mm. In addition, the mean angle amongst the trigeminal nerve as well as the midline was shows about 9.71±5.83°. A similar study was done by Hung YC et al., [22].

They evaluated the length of trigeminal nerve in the cistern (nerve length) in 106 patients which was found to be about 9.6 mm in which a range between 6.04-20.74 mm was found. The length of target amongst the radiation shot and brainstem, median of (targeting length) were observed to be about 3.8 mm (range 1.81-10.84 mm) a study done by Parise M et al., in which 26 patients were analysed [20]. They stated that the size of the CPA cistern and the length of the nerve can play a role in the pathogenesis of essential TN.

They also observed that the CPA cistern area of affected side was about (124.1±48 mm^2; range: 32.8-234.4 mm^2).

Downs DM et al., observed the appearance of gasserian ganglions in 57 patients, including the evaluation of Meckel's cave [19]. In their study, 100 of the 114 caves were observed other 14 caves also had thickened enhancements blended into the durainfero laterally. In addition, Computed Tomography (CT) scans of the cadaveric specimens also revealed a small semilunar structure within Meckel's cave according to the author.

A similar study was done by John D et al., on 30 adult dry skulls of unknown sex [16]. The main objective of the study was to comprehend the various FO anatomical differences. The many osseous structures, including bony plates, tubercles and the larger wing of the sphenoid bone develops differently at different times, which causes variations including round, slit, almond, and oval. When performing neurological operations on the middle cranial fossa, the information offered should be considered. So, they recommended that the accurate knowledge of positioning of FO essential for neurosurgeons.

A similar study was done by John D et al., on 30 adult dry skulls of unknown sex [16]. Almost every research found that the FO varied in width, measuring 4.18+0.78 mm on the right and 4.28+0.81 mm on the left [25]. Whereas, according to Prakash KG et al., they studied 62 (124 sides) dry adult Indian human skulls of unknown sex and origin obtained from the Bone Bank of the Department of Anatomy [15].

They stated that variations in FO shapes are caused by developmental factors, which may seriously complicate clinical and diagnostic procedures. In diagnosis and treatment of various conditions, where microneurosurgical and microvascular approaches are essential, clinicians need detailed knowledge of anatomy and morphology, including variations of FO, as observed in the their study.

As part of a study done by Khairnar KB et al., they studied about 100 human skulls in the Department of Anatomy at MVPS Medical College, Nashik discussed the clinical and anatomical value of the trigeminal ganglion to the medical community in trigeminal neuralgia patients as well as in examining any aneurysms or vascular abnormalities of the cranial cavity [23].

When planning approaches to the middle cranial fossa, neurosurgeons can use this information to identify and preserve the neurovascular structures. They think that the information they have on the FO will be instructive for physicians as well as anatomists. According to a similar study by, Naqshi BF et al., they studied 17 human skulls and 8 spenoid bones from the postgraduate department of anatomy at the Government Medical College, Jammu [26]. They discovered that the FO plays an important surgical role in percutaneous trigeminal rhizotomy for trigeminal neuralgias. The understanding of the variations of these foramina should be taken into consideration for surgeries in the middle cranial fossa. Both anatomists and doctors can enhance their knowledge by taking into consideration the findings from this study.

The FO is important for several invasive and diagnostic procedures. For electroencephalographic data obtained in cases undergoing amygdalohippocampectomy electrodes are positioned at the foramen ovale to conduct the analysis, providing useful neurophysiological knowledge [38]. Before attempting an open biopsy of a cavernous sinus tumour, percutaneous biopsy through the FO can be effectively completed through surgical techniques [39]. Nasopharyngeal tumour typically spreads through the FO and does so intracranially [40]. Anatomical differentiation of foramen oval is of importance when treating trigeminal neuralgia through surgery performed through it. Furthermore, the presence of any stenosis or bony plate leads to reduced patency making it difficult to perform surgical procedures via this route [41,42]. Bony plates, tubercles, and spines, though very rare, are caused by the osseous overgrowth of the bone between its first appearance and the perfect ring's formation. On the other hand, if these osseous structures are noticed at the critical sites, they might cause difficulties, such as obstruction or the trigeminal ganglion blockage. The shape of the FO is also important because structures pass through it. V_3 and other tissues may be compressed if the FO is slit-shaped [14]. Similar, research done by Khan AA et al., demonstrated that the FO's slit-like shape signifies an over-growth during the period of development between the FO's initial appearance and the perfect ring formation [43]. These bony obstructions could hinder transcutaneous insertion of a needle into the FO or result in mandibular neuralgia. Trigeminal nerve morphology including its size (diameter) and anatomy are affected by the different shapes of FO.

Limitation(s)

There are several limitations regarding the anatomical variations in the trigeminal ganglion, trigeminal nerve and FO. The main one is that most authors described the triangular plexus, trigeminal ganglion and TC, trigeminal nerve without clear-cut respective distinctions, including in the surgical and electrophysiological literature. Further studying the plexual anastomoses revealed itself difficult. In addition to further anatomical and histological studies, high-field MRI studies, trigeminal nerve tractography might help to better understand the plexual distribution, variation of trigeminal ganglion, trigeminal nerve and functional significance of the trigeminal plexus.

CONCLUSION(S)

The trigeminal nerve was found to be around 9.66 mm long, according to the bulk of the research' findings, which led us to this conclusion. However, just one paper claimed that elderly patients' trigeminal nerves were longer than they would be according to normal anatomy. The majority of research showed that the FO may take on several shapes, including oval, round, almond, slit, and spine.

Acknowledgement

The contributions made by each of the authors towards the publication of this systematic review and technical help are duly acknowledged with gratitude.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Nov 19, 2022
- Manual Googling: Jan 27, 2023
- iThenticate Software: Feb 15, 2023 (15%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? NA
- Was informed consent obtained from the subjects involved in the study? NA
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Nov 18, 2022**
Date of Peer Review: **Jan 02, 2023**
Date of Acceptance: **Feb 16, 2023**
Date of Publishing: **May 01, 2023**