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Anatomical Variations of the Trigeminal Nerve and Clinical Implications: A Scoping Review

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Abstract

The trigeminal nerve, often referred to as the fifth cranial nerve, is a nerve that consists of three branches and provides sensory and motor innervation to the facial area. Its anatomical variations present significant scientific and clinical interest. Detailed research was conducted in articles from 2011 onward in the PubMed database using the following keywords: trigeminal nerve, ophthalmic nerve, maxillary nerve, mandibular nerve, and anatomic variation. The anatomical variability detected was significant. Substantial anatomical variability was identified, while nerve variations were frequently linked to several clinical conditions, including neuralgia, chronic pain, and altered nerve block efficacy. The present review aims to highlight the variations in the distribution, course, and branching of the trigeminal nerve's divisions. Finally, the most frequently reported configurations across the synthesized literature involved accessory or duplicated nerve branches, followed by communicating anastomoses with adjacent neural structures and variations in bony canal pathways.

Categories: Anatomy
Keywords: anatomy variations, mandibular nerve, maxillary nerve, ophthalmic nerve, trigeminal nerve

Introduction And Background

The trigeminal nerve, also known as the fifth cranial nerve, is the largest cranial nerve. It is a mixed nerve divided into three branches: ophthalmic (V1), maxillary (V2), and mandibular (V3) [1]. It is the main sensory nerve of the face that also provides motor function to the masticatory muscles, the tensor tympani, the tensor veli palatini, the mylohyoid, and the anterior belly of the digastric muscle [2,3]. While the trigeminal ganglion houses the sensory neuronal cell bodies, the motor root courses inferiorly beneath the ganglion without synapsing, directly joining the mandibular division (V3) as it exits the skull. It provides sensory innervation to the eyeball, the paranasal sinuses, the face, the head, the anterior two-thirds of the tongue, the jaw, the teeth, and the gums (in contrast to taste, which is mediated by the chorda tympani branch of the facial nerve, CN VII) [1]. The trigeminal nerve carries no intrinsic parasympathetic fibers; its branches merely distribute autonomic fibers from CN III, VII, and IX. Postganglionic axons from the ciliary ganglion (CN III) travel via short ciliary nerves (V1) to the sphincter pupillae and ciliary muscle. Fibers from the pterygopalatine and submandibular ganglia (CN VII) hitchhike along V2 and V3 to supply the lacrimal/mucous glands and submandibular/sublingual glands, respectively, while fibers from the otic ganglion (CN IX) course with the auriculotemporal nerve (ATN) (V3) to the parotid gland [2].

The anatomical variations of the trigeminal nerve are numerous and involve both the position and the number of branches arising from the trigeminal ganglion or its divisions. In many cases, unexpected nerve branching patterns have been observed, including multiple or communicating branches, nerves following a different course, branches penetrating different anatomical regions than those described in the literature, and nerves intertwining abnormally around arteries in all three branches [3-7].

Consequently, the aim of this study is to provide a comprehensive scoping review of the anatomical variations of all three branches of the trigeminal nerve, their categorization, and the report of potential clinical implications of these variations, such as neuralgia, chronic pain, and nerve block efficiency.

Review

Materials and methods

Search Strategy

A scoping review was conducted in the international literature during the months of May and June of 2026. An investigation was conducted in PubMed using specific search criteria to ensure that the articles included in our analysis were relevant to the topic. The search employed the following keywords: "trigeminal nerve" OR "ophthalmic nerve" OR "maxillary nerve" OR "mandibular nerve" AND "anatomical variations". To ensure precision and completeness, data were extracted using a standardized form recording author/year,

study design, population, sample size (specimens/sides), methodology, evidence type (primary vs. secondary), and specific anatomical findings with prevalence. All authors contributed equally to the screening and extraction of data as well as the writing of the article. The research was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) guidelines, which provide a systematic framework for performing scoping reviews (Table *1*, Appendices). No review protocol was registered for this scoping review.

Database	Search Terms/Keywords Used	Date Range Filter	Search Date	Total Results
PubMed	"trigeminal nerve" OR "ophthalmic nerve" OR “maxillary nerve” OR “mandibular nerve” AND “anatomical variations”	2011-2026	May-June 2026	485

TABLE 1: Search strategy

Study Selection

The studies were carefully selected based on specific criteria that analyzed the anatomic variations of all three branches of the trigeminal nerve (Table *2*). The present review included studies published in journals and literature reviews. The search was limited to articles from the last 15 years, between 2011 and 2026, to ensure they address contemporary scientific issues. Regarding the exclusion criteria used, articles written in any language other than English were omitted. Moreover, studies that did not focus on the trigeminal nerve branches or their anatomical variations were also excluded. Thus, the exclusion criteria were the following: a) text not written in English, b) title or abstract not relevant to the subject, c) studies not focused on Trigeminal nerve branches and their anatomical variations, and d) abstract not available on PubMed. To handle overlapping evidence and avoid treating repeated descriptions as independent findings, all authors collaboratively cross-checked the extracted data and references to ensure that any duplicated cases or descriptions across different publications were meticulously identified and accounted for. In accordance with PRISMA guidelines, a total of 633 articles were initially identified through the search in PubMed. A total of 148 studies were deemed ineligible by publication-date filtering and were excluded before screening. The filter applied referred to publication years between 2011 and 2026. Subsequently, a total of 485 records were screened, all in PubMed. After thorough screening, 71 reports were assessed for eligibility, out of which 26 were finally included, resulting in the exclusion of 459 articles. The exclusions were due to two reasons: 45 full-text articles did not refer to anatomical variations of the trigeminal nerve and its branches, and 414 had titles and abstracts not relevant to the subject. Thus, this article is founded on data sourced from 26 credible references (Figure *1*). The identified anatomic variations were classified and presented in three categories according to the three divisions of the trigeminal nerve and the type of variation, with an additional category including a variation involving both the maxillary and mandibular divisions (V2 and V3). No formal critical appraisal of the quality of the included sources was undertaken, as the primary objective of this scoping review was to identify and categorize the reported anatomic variations of the trigeminal nerve and its branches rather than to assess the quality of the available evidence.

Category	Criterion	Description/Details
Inclusion criteria	Topic of interest	Studies investigating anatomical variations of the trigeminal nerve or any of its three main branches (V1, V2, V3)
	Study design	Peer-reviewed original studies, case reports, cadaveric dissections, radiographic/imaging studies, and literature reviews
	Publication period	Articles published between January 2011 and June 2026
	Database indexation	Studies indexed and accessible via PubMed
Exclusion criteria	Language	Articles written in any language other than English
	Relevance	Studies with titles or abstracts not relevant to trigeminal nerve anatomy
	Anatomical focus	Studies not focused specifically on branches or branching variations of the trigeminal nerve
	Abstract availability	Records where the abstract was not available on PubMed
	Publication date	Articles published prior to 2011

TABLE 2: Eligibility criteria for study inclusion and exclusion

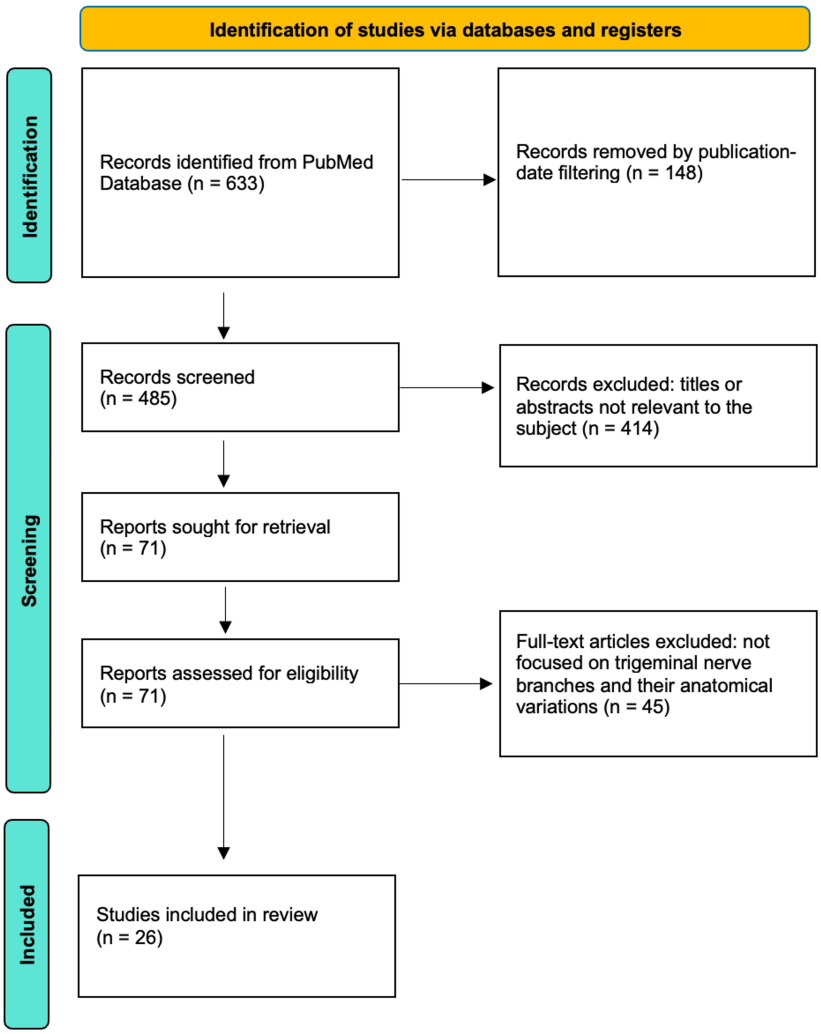


FIGURE 1: PRISMA diagram

Results

We conducted a thorough search of 26 articles published between 2011 and 2026 in the PubMed database. Following a comprehensive review of all referenced articles, we found that there are multiple variations in all three of the trigeminal nerve's branches. Notably, many different types of nerve variations were reported in the articles. Prevalence data highlighted commonly known and frequent variations, such as the communicating branches between the mylohyoid nerve (MHN) and the lingual nerve (LN) or the inferior alveolar nerve (IAN) and the LN. Other articles emphasized rare bifurcations, trifurcations, and duplications of nerves that had been detected in unique cases. Specifically, 13 articles reported some form of communication between nerve branches that deviate from their usual distribution. Moreover, 21 articles pointed out different nerve courses, and 19 articles reported multiple branches where singular nerves should exist. Arterial correlations have also been detected in six articles. According to a thorough study of the literature, these variations may complicate surgical and anesthetic procedures such as nerve blocks (Table *3*).

Study	Study Design	Country/Population	Sample Size and Denominator	Assessment Method	Study Type	Principal Anatomical Variation/Findings	Prevalence (%)/Status
McDonough et al., 2023 [1]	Cadaveric case series	USA	n = 10 cadavers/20 sides	Gross dissection	Primary research	Intercommunication between V2 and V3 at the internal cranial base	NR
Alwardian et al.,	Narrative review	International	Literature	Literature review	Secondary	General overview of trigeminal neuralgia and	NR

2021 [2]			synthesis		literature	anatomical variations	
Somayaji et al., 2012 [3]	Review/overview	India	Literature synthesis	Literature review	Secondary literature	Mandibular nerve variations (bifid canals, communicating branches)	NR
Thotakura et al., 2013 [4]	Cadaveric case series	India	n = 15 cadavers/30 sides	Gross dissection	Primary research	Posterior division variations, ATN-IAN loops, MHN variations	NR
Somayaji et al., 2012 [5]	Review	India	Literature synthesis	Literature review	Secondary literature	Maxillary nerve branching and clinical applications	NR
Tomaszewska et al., 2015 [6]	Review	Poland	Literature synthesis	Literature review	Secondary literature	Maxillary nerve anatomy, cavernous course, and variations	NR
Kalashnik-Vakulenko et al., 2026 [7]	Retrospective radiological study	Ukraine	n = 100 patients	MSCT scans	Primary research	Anatomical features of V1, V3, and carotid arteries	NR
Haladaj et al., 2019 [8]	Cadaveric study	Poland	n = 40 cadavers/80 sides	Gross dissection	Primary research	Supraorbital and supratrochlear nerve branching and exit points	Variable (e.g., accessory branches in ~5%)
Kim et al., 2023 [9]	Surgical observational study	South Korea	n = 52 sides	Endoscopic surgery	Primary research	Lateral branch of supraorbital nerve morphological variations	Reported
Tomaszewska et al., 2014 [10]	Systematic review, meta-analysis, and CT/skull study	Poland/International	1200 CTs and 150 dry skulls	CT scans and craniometric measurements of dry skulls	Mixed (primary + secondary)	Greater palatine foramen position relative to molars	Position opposite 3rd molar (~15%), 2nd molar (~65%), between (~20%)
Hafeez et al., 2015 [11]	Cadaveric dissection study	Canada/International	n = 10 cadavers/20 semi-heads	Gross dissection	Primary research	Greater palatine nerve branching patterns in the canal	1 to 4 trunks exiting (multiple patterns)
Nderitu et al., 2016 [12]	Cadaveric study	Kenya	n = 21 cadavers/42 sides	Gross dissection	Primary research	Nasal and labial branches of infraorbital nerve (ION)	Internal nasal bifid in 59.5%; External nasal present in 65.47%
Takakura et al., 2026 [13]	Anatomical/clinical study	Japan	n = 30 sides	Microdissection	Secondary/clinical	Superior labial branch of ION distribution	Reported
Kuvat et al., 2013 [14]	Case report	Turkey	n = 1 patient/1 side	Surgical observation	Primary research	Rare duplication of the infraorbital nerve on the right side	Single case report (absent bilaterally in other patients, i.e., 0% in normal series)
Ference et al., 2015 [15]	Cadaveric study	USA	n = 25 cadavers/50 sides	Gross dissection and CT	Primary research	ION course relative to maxillary sinus roof (Types I, II, III)	Type I: ~65%, Type II: ~27%, Type III (in sinus): ~7.8% (increases to 27.7% with ethmoid cells)
Stoyanov 2024 [16]	Cadaveric case report	Bulgaria	n = 1 specimen/1 side	Gross dissection	Primary research	ION trifurcation trapping the infraorbital artery in a loop	Single case report
Ohshima et al., 2023 [17]	Cadaveric anatomical study	Japan	n = 20 cadavers/40 sides	Gross dissection	Primary research	ION branch distribution patterns and anastomoses	Anastomosis types categorized (1, 2, 3)
Choi et al., 2019 [18]	Cadaveric study	USA/International	n = 30 cadavers/60 sides	Gross dissection	Primary research	Origin, course, and branching of the MHN	Branching variations from IAN/V3 documented
Kitagawa et al., 2025 [19]	Comprehensive review	Japan/International	Literature synthesis	Literature review	Secondary literature	Lingual nerve anatomy and comprehensive variations	NR
Ghabriel et al., 2019 [20]	Cadaveric fine-dissection study	Australia	n = 18 cadavers/36 sides	Fine microdissection	Primary research	Lingual nerve course, variations, and communicating branches	Communications with hypoglossal/MHN up to 90%

Öçbe et al., 2024 [21]	Radiological MRI study	Turkey	n = 150 patients/300 canals	Pulse-sequence MRIs	Primary research	Inferior alveolar nerve (IAN) and mandibular canal (MC) variations	4 distinct types identified (forward, retromolar, buccolingual, multiple)
Wolf et al., 2016 [22]	Cadaveric case series	USA	n = 12 cadavers/24 sides	Gross dissection	Primary research	Variant IANs, lingual nerve communications, and arterial loops	Documented in specific specimens
Maekawa et al., 2020 [23]	Cadaveric case report	Japan	n = 1 specimen/1 side	Gross dissection	Primary research	Unusual trifurcation of mandibular nerve near pterygoid muscle	Single case report
Komarnitki et al., 2015 [24]	Cadaveric study	Poland	n = 30 cadavers/60 sides	Gross dissection	Primary research	Proposed classification of auriculotemporal nerve, based on the root system	Root configurations categorized
Patel et al., 2019 [25]	Cadaveric case report	USA	n = 1 specimen/1 side	Gross dissection	Primary research	Buccal nerve with two distinct roots of origin on the left side	Single case report
Kempa et al., 2025 [26]	Narrative review	Greece/International	Literature synthesis	Literature review	Secondary literature	Foramen ovale variations and relation to trigeminal neuralgia	NR

TABLE 3: Characteristics of the included articles

ATN, auriculotemporal nerve; CT, computed tomography; MHN, mylohyoid nerve; MRI, magnetic resonance imaging; MSCT, multislice computed tomography; NR, not reported

Discussion

Ophthalmic Nerve (V1)

The ophthalmic nerve arises from the anteromedial part of the Gasserian ganglion, which sits in the Meckel cavity, and it is a solely sensory nerve. It enters the orbit via the superior orbital fissure; however, in a multislice computed tomography (MSCT) scan study, it was clearly identifiable in only 88% of cases, reflecting imaging detection limits rather than anatomical absence or true variation [2,7]. The largest branch of the Ophthalmic nerve is the frontal nerve, which divides into the supraorbital and supratrochlear nerves [8]. According to the literature, differences in the branching point of the two nerves mentioned above occur with their branching in the distal half of the orbit's length (Type I) in 18 out of 50 observed cases (36% of cases) or in the proximal half of the orbit close to the superior orbital fissure (Type II) in 32 out of 50 cases (64% of cases) [8]. In both cases, the supraorbital nerve was usually thicker than the supratrochlear, and in the second case, an accessory supratrochlear nerve emerged in two specimens. Moreover, in the first case, a small number of the supraorbital nerves gave medial and lateral branches, compared to the higher occurrence rate in the second case [8]. When it comes to the lateral branch of the supraorbital nerve, variations in the thickness of the nerve between small, medium, and large ones are reported, as well as positional and morphological variations [9]. Additionally, regarding variations in exit points, in cases with double exit points, the lateral supraorbital nerve exited through the lateral aperture, while the medial supraorbital nerve exited through the more medial point. Both exit points showed variability, appearing either as a foramen or a notch. The lateral branch gave rise to both deep and superficial branches, while the medial branch gave rise only to superficial ones, and the supratrochlear nerve exited beneath the supraorbital margin and rarely through the notch [8].

Anatomical Variation Between V2 and V3

Direct intercommunications between the maxillary V2 and mandibular V3 divisions represent rare but clinically important variants. For instance, reports have documented neural anastomoses connecting the V2 trunk with the motor root or motor branches of V3 [1]. Such communications result in an aberrant mixing of sensory and motor fibers, which provides a plausible anatomical explanation for persistent pain or residual facial sensation following surgical rhizotomy or selective root transection [6].

Maxillary Nerve (V2)

The maxillary nerve exits the convexity of the trigeminal ganglion, runs in the inferior part of the lateral wall of the cavernous sinus, and gives off its first branch, the middle meningeal nerve, before exiting the middle cranial fossa through the foramen rotundum into the pterygopalatine fossa [6]. The nerve gives off two ganglionic branches, the zygomatic branch, which further divides into zygomaticofacial and

zygomaticotemporal, the superior alveolar nerves, posterior, middle and anterior, and the infraorbital nerve (ION) with its three branches: the palpebral, nasal and labial nerves [5].

Palatine Nerves

Two nerves, the lesser and the greater palatine nerves, are divisions of the palatine nerve, pass through the pterygopalatine ganglion, and constitute sensory branches of the V2. The former descends through the lesser palatine foramen, while the latter is a continuation of the descending palatine nerve and passes through the greater palatine canal and the greater palatine foramen [6]. An original study on dry skulls, head CT scans, and a meta-analysis of previous studies highlighted that the location of the greater palatine foramen (GPF) may vary among (a) being opposite to the third maxillary molar, (b) being opposite to the second maxillary molar, (c) being between the two, (d) being distal to the third maxillary molar, or (e) being mesial to the second maxillary molar. Ultimately, the most common location was that of category (a), with a pooled prevalence of 63.9% [10]. Variations in the position of the greater palatine foramen indicate a variant course of the greater palatine nerve itself. Furthermore, Hafeez et al. reported four variations in the branching pattern of the greater palatine nerve within the greater palatine canal, after the dissection of 20 semi-heads. Either one thick lateral trunk exited the foramen along with a slender medial one, three trunks exited the foramen, four branches exited the foramen, or two trunks divided into two more trunks each; all of which variations were mostly anterior to the course of the greater palatine artery [11].

Infraorbital Nerve

The ION is a direct continuation of the maxillary nerve, passing through the inferior orbital fissure, groove, and canal, where it gives off the superior alveolar branches, before finally exiting through the infraorbital foramen [12,13]. After its facial exit, it terminates into the inferior palpebral, nasal, and superior labial (SL) nerves [12,13]. Typically, the ION runs along the roof of the maxillary sinus and is a single nerve on each side of the face. A rare case of ION duplication on the right side during a double-jaw surgery was reported. The two nerves had distinct foramina and different thicknesses [14]. Additionally, according to a study, three different types of variations in the course of the ION were detected: (i) nerve contained totally within the roof of the maxillary sinus, (ii) the canal of the nerve below the roof of the sinus but still juxtaposed to it, (iii) the nerve descending in the sinus lumen suspended from the roof via a septation or the lamella of an ethmoid cell [15]. It is noted that the presence of an infraorbital ethmoid cell significantly increases the percentage of nerves in the sinus from 7.8% to 27.7% (according to measurements made from a total of 100 consecutive computed tomography sinus studies obtained), and Type III nerves end their course in a foramen inferior to the other two types [15]. Studies have also focused on the infraorbital neurovascular bundle and its location in relation to the orbital floor and the maxillary sinus. Another study described the relationship between the ION and the infraorbital artery (IOA), mentioning mostly parallel courses but also sometimes “C-shaped” or spiral patterns [16]. Moreover, in a case report, Stoyanov et al. reported a rare variation in which the ION formed a trifurcation and the artery passed between two of the branches, getting trapped between them as the two nerves merged into one [16]. Anatomical variations have been mentioned regarding the divisions of the ION. More specifically, the SL nerve gives rise to multiple subbranches (medial or lateral) and normally emerges as two branches from the ION [13]. However, another study noted that the SL was unbranched and later further divided or gave rise to an accessory branch that passed through an accessory infraorbital foramen [12]. When it comes to the nasal branches of the ION, the same study that was performed on 42 formalin-fixed cadavers identified unique variations. The internal nasal (IN) nerve was bifid in 59.5% of the cases and single in the rest, while the external nasal (EN) nerve was located only in 65.47% of the cases (calculated from the aforementioned cohort of 42 cadavers). In a few samples, there were communicating branches between the EN and the IN nerves, or the EN emerged from the infraorbital foramen as one trunk with the palpebral nerve before they separated further down their course [12]. Finally, according to the literature, anastomoses between the divisions of the ION are categorized into three types: anastomosis between IN and medial SLs, anastomosis between medial and lateral SLs, and anastomosis between ION-medial SLs and medial-lateral SLs [17].

Mandibular Nerve (V3)

The mandibular nerve is the largest division of the trigeminal nerve, and it is mixed, therefore containing sensory and motor fibers. It exits via the foramen ovale, where the main trunk gives off the nervus spinosus (meningeal branch) and the nerve to the medial pterygoid. It then divides into an anterior trunk - giving off the masseteric, deep temporal, lateral pterygoid, and buccal nerves (BLs) - and a posterior trunk that gives rise to the auriculotemporal, lingual, and IANs [1-4]. Interindividual variability has been reported regarding the diameter and location of the mandibular foramen in relation to the mental foramen [7], in addition to asymmetry in the course of the mandibular canal (MC) with high, intermediate, and low MCs [3]. A study also highlighted the phenomenon of a bifid MC bilaterally or ipsilaterally and a rare case of a trifid MC in a panoramic radiographic study [3].

Mylohyoid Nerve

The MHN, also referred to as “nervus mylohyoideus,” originates from the IAN of the posterior branch of the

mandibular nerve. It usually innervates the mylohyoid muscle, the anterior belly of the digastric muscle, and the mandibular teeth but may also contribute sensory supply to the lower incisors, premolars, and chin [3,18]. Normally, the MHN arises from the IAN 13.4 to 14.7 mm proximal to the mandibular foramen, but there have been reports of it branching directly from the trunk of the mandibular nerve [18]. There have been documented cases of the MHN originating from the lingual or the glossopharyngeal nerve, traveling in the MC and not below the mylohyoid groove or duplicating and exiting through an accessory foramen [18]. Moreover, there have been reports of communicating branches between the MHN and the LN either in the submental triangle, adjacent to the mandibular third molar, or in the submandibular triangle [18,19]. A study observed this exact communication bilaterally, with a thicker branch arising from the MHN and coursing deep to meet the LN deep to the mylohyoid muscle [4].

Lingual Nerve

The LN arises from the posterior division of the mandibular nerve and arises in the infratemporal fossa, innervating the lingual gingiva, the mucous membranes of the floor of the mouth, and the anterior two-thirds of the tongue [20]. The nerve divides into lingual branches, medial and lateral, as well as several other branches to the gingiva, the sublingual ganglion, and the submandibular ganglion. The course of the nerve may change in relation to the position or motion of the tongue, switching between higher and more inferior courses [19]. When it comes to variations in the LN, there are mostly communicating branches. There have been many reports of communication loops between the lingual and hypoglossal nerves with significantly high appearance rates reaching up to 90% (36 of 40 sides) [19,20]. Also, there have been observed communications with the MHN (as mentioned above), with the two nerves merging in many different locations, and this communication could provide a different course for collateral sensory transmission [4,18-20]. Finally, there could be one, two, or three communicating branches between the LN and the IAN nerves adjacent to the mylohyoid muscle [19,20].

Inferior Alveolar Nerves

The IAN arises from the posterior division of the mandibular nerve (V3) and descends deep to the lateral pterygoid muscle, subsequently coursing superficial to the medial pterygoid muscle in the infratemporal fossa. Although primarily sensory, its proximal trunk conveys motor fibers that branch off as the MHN just prior to the IAN's entry into the mandibular foramen; within the MC, it carries sensory fibers that terminate as the incisive and mental nerves [21-23]. The bifurcation of this nerve is not rare but is more common in males than females [3,21]. In one report, a classification of the variations of the MC and the IAN was presented, with pulse sequence MRIs, using a 3.0-T MRI and the routine MRI protocol for pulse sequence turbo spin echo (TSE) sequences, thus assessing the course of the nerve. More specifically, they identified four types of variations, with the first being the most common: (a) forward canal with the branch separating from the main canal forward and horizontally, and then either rejoining the main canal or not; (b) retromolar canal with the branch separating from the main canal in the retromolar region; (c) buccolingual canal with the branch moving forward to the buccal or lingual side of the main canal; and (d) multiple branches [21]. There has been a report of three minor branches arising from the mandibular nerve (posterior, middle, and anterior branches) and travelling close to the pterygoid muscle. The middle and posterior branches arose as one trunk, then bifurcated, and finally, the three branches merged into one back in the IAN close to the inferior alveolar artery [23]. Also, when it comes to other variations, the occurrence of communicating branches is common. In the case report that was mentioned above, two branches connecting the middle and posterior divisions were discovered [23]. It was also identified that communicating branches between the LN and IAN occurred after routine dissection of the infratemporal fossa of a female donor (bilateral variation) and a male donor (left-sided variation) [22]. A similar communication between the ATN and IAN in the left infratemporal region of a specimen was observed by Thotakura et al. This branch bifurcated and created a loop for the MHN to pass through. On the right side of the same specimen, two communication branches were found between the IAN and the ATN [4]. According to a classification proposed by Komarnitki et al., the IAN can also serve as an origination point for the ATN. It was highlighted that the ATN can originate from the MN or from the IAN, and in the case of a bifurcated type of IAN, the ATN roots can start from the anterior or posterior ramus of the IAN trunk. Additionally, the ATN was further classified into five different categories according to the number of its roots: one-root, two-root, three-root, four-root, and five-root variants, with the three-root variant being the most common (32% of all 30 cadavers) [24]. Lastly, there have been reports of arterial nerve correlations. Somayaji et al. reported two cases in which the maxillary artery passed through a connecting nerve loop that originated in the ATN and the IAN bilaterally [3]. A bifurcation of the IAN around the maxillary artery on the right side of the face was detected in another case [22].

Buccal Nerve

The BL is a terminal branch of the mandibular nerve, passing between the heads of the lateral pterygoid, then deep to the temporalis tendon and anterior to the ramus of the mandible to the cheek. It is also known to often join the buccal branches of the facial nerve [3]. According to another report, an unusual variation of the BL was noted, in which the nerve started as one trunk rising from the main trunk of the mandibular nerve and then divided into two branches, superficial to the maxillary artery and posterior to the buccal artery: an anterior branch and a posterior one. The branches rejoined after the heads of the lateral pterygoid

muscle and continued a normal course [25].

Clinical Implications

This scoping review is of clinical interest because a thorough understanding of it can suggest solutions to many problems faced by clinicians and surgeons. Acquiring more knowledge about the anatomical variations of the trigeminal nerve may help minimize the risk of iatrogenic injury, iatrogenic nerve damage, or complications, thereby supporting more predictable outcomes and increasing the success of surgical procedures and maxillary reconstruction surgery, especially plate placement [12]. Through the study of variations in the nerve's course, many questions regarding treatment failure in trigeminal and auriculotemporal neuralgia are answered [1]. Several variations and intertwining of different nerves and neighboring arteries may cause compression, thus being directly associated with various pathological conditions such as trigeminal neuralgia, chronic pain, numbness, headaches, and migraines, while simultaneously complicating regional anesthesia procedures and nerve blocks (e.g., ION blocks) [2,5,6,14,22,26]. Furthermore, it remains to be investigated whether the branches that, in some cases, overlap in their distribution can be considered for transplantation, such as harvesting a graft or variations used as implants (MN variations being used as implants over an edentulous mandible) [18]. A table of trigeminal nerve variations is necessary to prevent iatrogenic nerve injury and avoid anesthesia failures, as summarized in Table *4*.

Anatomical Variation	Procedure at Risk	Consequence	Practical Tip
Bifid/trifid canal; accessory MHN	IAN block, mandibular osteotomy, implants	Failed anesthesia, nerve injury, hemorrhage	Preoperative CBCT; use Gow-Gates or Akinosi block
ION duplication; accessory foramen	ION block, Le Fort I osteotomy, midface trauma	Incomplete midfacial block, nerve transection	Subperiosteal dissection on bone; local infiltration
GPF position variability	Greater palatine block, palatal graft harvest	Palatal numbness, arterial hemorrhage	Incisions ≥ 5 mm from gingiva; palpate molar region
SON lateral branch/notch vs. foramen	Endoscopic brow lift, coronal flap	Forehead dysesthesia, cutaneous denervation	Stay strictly subperiosteal; identify notch/foramen first
Foramen ovale variants (spines, septa)	Percutaneous rhizotomy/balloon compression	Cannulation failure, vascular puncture	Cranial base CT; use fluoroscopy or neuronavigation
V2-V3 communicating branches	Trigeminal rhizotomy, microvascular decompression	Incomplete pain relief in trigeminal neuralgia	Consider alternative pain pathways if symptoms persist

TABLE 4: Clinical and surgical implications of anatomic variations

CBCT, cone-beam computed tomography; CT, computed tomography; GPF, greater palatine foramen; IAN, inferior alveolar nerve; ION, infraorbital nerve; MHN, mylohyoid nerve; SON, supraorbital nerve

Limitations

Several limitations of the present review should be noted. First, the search strategy was confined exclusively to a single database (PubMed) and English-language publications, resulting in a relatively small final cohort of 26 studies analyzed. Second, the vast heterogeneity and sheer number of anatomical variations documented across the literature precluded a standardized, quantitative synthesis. No protocol registration was implemented, no grey literature was included, but secondary reviews were included along with primary studies and studies co-authored by the review team. Additionally, it should be highlighted that the units were inconsistent (specimens vs. sides). Furthermore, potential selection bias exists within the primary literature, as several studies evaluated symptomatic patients undergoing surgical interventions rather than random population samples. Consequently, the precise clinical implications and true prevalence of these variations cannot be definitively established from the current dataset, highlighting the need for future standardized, multicenter anatomical and radiographic investigations.

Conclusions

Many anatomical variations in the trigeminal nerve have been reported, with various complications and thus significant clinical relevance. Therefore, to minimize these complications and ameliorate the prognosis of invasive procedures, surgeons must be aware of the possible variations of the nerves. The variations mentioned above highlight potential structural mechanisms associated with persistent pain conditions, helping to guide targeted diagnostic and therapeutic considerations. However, further research is needed in

this specific field to determine the exact nature of the correlation between nerve variability and these medical conditions.

Appendices

Section	Item	PRISMA-ScR Checklist Item	Reported on Page #
Title			
Title	1	Identify the report as a scoping review.	1
Abstract			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	1
Introduction			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	1, 2
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	2
Methods			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a web address); and if available, provide registration information, including the registration number.	2
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	2
Information sources	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	2
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	2, Table 1
Selection of sources of evidence	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	2-3, Table 2
Data charting process	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	2, 3
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	2
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	-
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	2, 3
Results			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	3, Figure 1
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	3, Table 3

Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	-
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	Table 3
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	3
Discussion			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	3-8, Table 4
Limitations	20	Discuss the limitations of the scoping review process.	8
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	9
Funding			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	-

TABLE 5: Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) checklist

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Thekla Kandyli, Dimitrios Filippou, Nikoleta Sinou, Alexandros Samolis, Amir Shihada

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Disclosures

Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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