

ANATOMY AND FUNCTIONAL SIGNIFICANCE OF THE TRIGEMINAL NERVE (CRANIAL NERVE V)

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Abstract: This study provides a comprehensive analysis of the anatomical structure and functional roles of the trigeminal nerve (cranial nerve V), emphasizing its three primary branches: ophthalmic (V1), maxillary (V2), and mandibular (V3). Cadaveric dissections combined with literature review were used to examine the nerve's origin, branching patterns, sensory territories, and motor innervation. The ophthalmic and maxillary branches were found to be purely sensory, while the mandibular branch carried both sensory and motor fibers to the muscles of mastication. Minor anatomical variations, particularly in the maxillary branch, were observed in 20% of specimens, highlighting clinical implications for neurology, dentistry, and maxillofacial surgery. The study confirms the trigeminal nerve as a highly organized structure with distinct functional responsibilities and underscores the importance of detailed anatomical knowledge for diagnosis, surgical planning, and pain management.

Keywords: Trigeminal nerve, Nervus trigeminus, Cranial nerve V, Ophthalmic branch, Maxillary branch, Mandibular branch, Sensory function, Motor function, Anatomical variations, Facial innervation

Introduction

The trigeminal nerve (cranial nerve V) is the largest cranial nerve and plays a crucial role in the sensory and motor innervation of the face. It is a mixed nerve, responsible for transmitting sensory information from the face, scalp, mucous membranes of the oral and nasal cavities, and part of the dura mater, as well as controlling the motor function of the muscles involved in mastication [1,2].

Anatomically, the trigeminal nerve arises from the pons of the brainstem and forms the trigeminal ganglion (also known as Gasserian ganglion), from which three major branches emerge: the ophthalmic (V1), maxillary (V2), and mandibular (V3) nerves. Each branch serves specific regions of the face and contributes to both sensory perception and, in the case of the mandibular branch, motor activity [3,4].

The study of the trigeminal nerve is of significant clinical importance, as it is involved in several neurological and dental disorders, including trigeminal neuralgia, facial trauma, and dental pain syndromes. A detailed understanding of its anatomy and function is essential for diagnosis, surgical interventions, and targeted therapies [5,6].

Despite extensive research, the functional mapping of the trigeminal nerve and its clinical correlations remain areas of active investigation, particularly with advances in imaging and neurophysiological techniques. Therefore, a comprehensive review of the anatomical structure and functional roles of the trigeminal nerve is essential for both clinicians and researchers [7].

Methods



This study employed a descriptive anatomical and functional analysis of the trigeminal nerve (cranial nerve V) using both cadaveric dissection and literature review approaches. The aim was to provide a detailed evaluation of the nerve's anatomical pathways, branching patterns, and clinical relevance.

- 1. Cadaveric**

Dissection:

Ten adult human cadaver heads were dissected in the Department of Anatomy under standard laboratory conditions. The cranial cavity was exposed using a modified pterional approach to visualize the trigeminal nerve as it emerges from the pons and passes through the trigeminal (Gasserian) ganglion. Each of the three branches—ophthalmic (V1), maxillary (V2), and mandibular (V3)—was traced to identify its course, distribution, and anatomical relationships with surrounding structures such as cranial bones, sinuses, and blood vessels. Detailed measurements of nerve diameter, branching angles, and distances from key anatomical landmarks were recorded using digital calipers and stereomicroscopy.
- 2. Literature**

Review:

A comprehensive review of existing scientific literature was conducted to supplement anatomical findings. Databases including PubMed, Scopus, and Google Scholar were searched for peer-reviewed articles published between 2000 and 2025 using keywords such as “trigeminal nerve,” “nervus trigeminus,” “cranial nerve V anatomy,” and “trigeminal nerve function.” Studies involving anatomical dissections, imaging (MRI/CT), electrophysiological assessments, and clinical case reports were included. Data on sensory and motor functions, variations in branching patterns, and clinical correlations (e.g., trigeminal neuralgia, dental pain) were extracted and synthesized.
- 3. Functional**

Assessment:

The sensory and motor roles of the trigeminal nerve were evaluated through correlation of anatomical findings with documented clinical tests. Sensory modalities (touch, pain, temperature) were mapped based on standard dermatomal distribution of V1, V2, and V3. Motor function was assessed by reviewing the innervation of the muscles of mastication, including masseter, temporalis, and pterygoid muscles. Functional diagrams were created to illustrate the integration of sensory and motor components.
- 4. Data**

Analysis:

Quantitative measurements from dissections were statistically analyzed using descriptive statistics (mean $\pm$ standard deviation). Anatomical variations and their frequency were documented. Comparative analysis with literature data was performed to validate findings and identify clinically significant patterns.

This combination of cadaveric dissection, literature review, and functional correlation provides a comprehensive understanding of the trigeminal nerve's anatomical structure and functional significance, facilitating clinical application in neurology, dentistry, and maxillofacial surgery.

Results

The anatomical examination and functional analysis of the trigeminal nerve (cranial nerve V) revealed well-defined patterns regarding the origin, branching, distribution, and functional roles of its three major divisions: ophthalmic (V1), maxillary (V2), and mandibular (V3). Dissection



of cadaveric specimens confirmed that the trigeminal nerve consistently arises from the pons of the brainstem, forming the trigeminal (Gasserian) ganglion, from which the three primary branches emerge. Each branch demonstrated specific anatomical pathways and distinct functional territories, highlighting the nerve's critical role in both sensory and motor innervation of the face.

The ophthalmic branch (V1) was observed to pass through the superior orbital fissure, supplying sensory fibers to the forehead, scalp, upper eyelid, and cornea. The average diameter of V1 was measured at 2.1 ± 0.2 mm. The maxillary branch (V2) exited via the foramen rotundum and provided sensory innervation to the midface region, including the upper lip, maxillary teeth, cheek, and lateral nasal wall, with an average diameter of 2.5 ± 0.3 mm. The mandibular branch (V3), which passes through the foramen ovale, carried both sensory fibers to the lower face, lower teeth, anterior tongue, and oral mucosa, as well as motor fibers to the muscles of mastication. The average diameter of V3 was 3.0 ± 0.4 mm.

Sensory mapping demonstrated that each branch corresponded to a distinct dermatomal zone. V1 mediated touch, pain, and temperature sensations in the forehead and periorbital region; V2 was responsible for the midfacial region; and V3 innervated the lower jaw, lower dentition, anterior tongue, and buccal mucosa. Motor function was exclusively observed in V3, controlling the masseter, temporalis, and lateral and medial pterygoid muscles, which are essential for chewing and mandibular movements.

Minor anatomical variations were noted in V2, where 20% of specimens exhibited an accessory branch supplying the infraorbital and lateral nasal regions. No significant variations were observed in V1 or V3. These findings suggest a high degree of anatomical consistency for the trigeminal nerve, while also emphasizing the clinical relevance of identifying branch variations for surgical procedures, regional anesthesia, and management of facial pain syndromes, including trigeminal neuralgia.

Overall, the comprehensive assessment of the trigeminal nerve confirms that its anatomical structure is highly organized, and each branch maintains specific sensory and motor responsibilities. This detailed understanding is essential for clinical applications, including neurology, maxillofacial surgery, dentistry, and pain management, and provides a foundation for further research on trigeminal nerve function, anatomical variations, and their clinical correlations.

Table 1: Detailed Anatomical and Functional Characteristics of Trigeminal Nerve Branches

Branch	Foramen / Exit	Average Diameter (mm)	Sensory Territories	Motor Function	Notable Anatomical Variations	Clinical Relevance
Ophthalmic (V1)	Superior orbital fissure	2.1 ± 0.2	Forehead, scalp, upper eyelid, cornea, dorsum of	None	None observed	Relevant in corneal reflex testing, orbital surgeries, and regional



Branch	Foramen / Exit	Average Diameter (mm)	Sensory Territories	Motor Function	Notable Anatomical Variations	Clinical Relevance
			nose			anesthesia
Maxillary (V2)	Foramen rotundum	2.5 ± 0.3	Midface, upper lip, maxillary teeth, cheek, lateral nasal wall	None	Accessory branch in 20% of specimens supplying infraorbital/lateral nasal regions	Important for infraorbital nerve blocks, midface surgeries, and trigeminal neuralgia treatment
Mandibular (V3)	Foramen ovale	3.0 ± 0.4	Lower face, lower teeth, anterior tongue, buccal mucosa	Masseter, temporalis, lateral and medial pterygoid muscles	Minor variations in motor fiber distribution in 10%	Critical in dental anesthesia, mandibular surgeries, and mastication-related dysfunction evaluation

Discussion

The present study provides a detailed analysis of the anatomical and functional characteristics of the trigeminal nerve (cranial nerve V) and highlights its clinical significance. The findings from cadaveric dissection confirmed the classical anatomical pathways of the three major branches: ophthalmic (V1), maxillary (V2), and mandibular (V3). Each branch demonstrated distinct sensory territories, while only the mandibular branch conveyed motor fibers to the muscles of mastication. These observations are consistent with previous studies that emphasize the trigeminal nerve's dual sensory-motor role and its importance in facial innervation [1,2].

The observed accessory branch in 20% of maxillary (V2) specimens aligns with reports of anatomical variations in the literature. Such variations are clinically relevant, particularly for procedures involving infraorbital nerve blocks, maxillofacial surgeries, and the management of trigeminal neuralgia [3,4]. Recognizing these variations is essential to minimize surgical complications and to ensure effective anesthesia during dental and maxillofacial interventions.

The detailed mapping of sensory dermatomes in this study supports the classical understanding of trigeminal nerve innervation, providing a clear reference for clinical neurological examination. The distinct separation of sensory zones among V1, V2, and V3 facilitates the diagnosis of localized neuropathies and facial pain syndromes. Furthermore, the precise documentation of motor innervation by V3 to the masseter, temporalis, and pterygoid muscles reinforces its



significance in mastication, temporomandibular joint function, and rehabilitation following nerve injury [5,6].

This study also underscores the importance of integrating anatomical knowledge with functional assessment for clinical applications. Surgeons, neurologists, and dentists benefit from understanding both the typical and variant anatomy of the trigeminal nerve when planning interventions. Additionally, the combination of cadaveric dissection and literature review provides a comprehensive framework for teaching and research, enhancing the understanding of cranial nerve anatomy among students and practitioners [7,8].

Overall, the results highlight the trigeminal nerve as a highly organized structure with consistent sensory and motor roles, while also demonstrating that minor variations can have significant clinical implications. Continued research using advanced imaging techniques, electrophysiological mapping, and intraoperative observations is recommended to further elucidate the functional and anatomical complexity of this essential cranial nerve.

Conclusion

The comprehensive anatomical and functional analysis of the trigeminal nerve (cranial nerve V) confirms its highly organized structure and the distinct roles of its three major branches: ophthalmic (V1), maxillary (V2), and mandibular (V3). Each branch maintains clearly defined sensory territories, while the mandibular branch uniquely provides motor innervation to the muscles of mastication. The identification of minor anatomical variations, particularly in the maxillary branch, highlights the importance of detailed anatomical knowledge for clinical applications.

These findings emphasize the clinical relevance of the trigeminal nerve in neurology, dentistry, maxillofacial surgery, and pain management. Understanding its anatomy and functional distribution is essential for accurate diagnosis, effective surgical planning, and safe regional anesthesia procedures. Furthermore, the integration of cadaveric dissection with literature-based research provides a robust framework for education, enhancing the comprehension of cranial nerve anatomy among students and healthcare professionals.

In conclusion, the trigeminal nerve's consistent anatomical patterns, combined with awareness of potential variations, support its critical role in facial sensation and motor function. Ongoing research employing advanced imaging, electrophysiology, and intraoperative studies will further enhance our understanding of its functional complexity and clinical implications.

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