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Original Research Article

Morphological Variations of Pharyngeal Constrictor Muscles: A Cadaveric Observational Study

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Abstract

Background: The pharyngeal constrictor muscles form the posterior and lateral walls of the pharynx and play an indispensable role in deglutition, speech, and airway protection. A precise understanding of their morphological variations is crucial for surgeons undertaking transoral robotic surgery, pharyngeal dissections, head and neck oncological procedures, and cricopharyngeal myotomy for Zenker's diverticulum.

Objectives: To document the morphological variations in the origin, insertion, innervation, and inter-muscular relationships of the three pharyngeal constrictor muscles (superior, middle, and inferior) in adult Indian cadavers; to characterise pharyngeal raphe types; and to assess clinically relevant parameters including raphe length, constrictor thickness, and the prevalence of Killian's dehiscence.

Methods: Thirty formalin-fixed adult cadavers of both sexes were dissected using the conventional posterior approach in the Anatomy Department, Government Thanjavur Medical College, and Thanjavur, India. Origins, insertions, innervation patterns, muscle morphology, pharyngeal raphe configuration, raphe length, constrictor thickness, and Killian's dehiscence were systematically evaluated.

Results: The superior constrictor showed the greatest morphological diversity: additional buccal mucosal origin (3.33%), dorsal muscular bundles (16.65% combined), petropharyngeus attachment (5%), external stylopharyngeus course (10%), and buccopharyngeal membranous morphology (13.33%). The middle constrictor was largely unremarkable except for one specimen (1.67%) with the lingual artery traversing its fibres. Anomalous innervation of the inferior constrictor from the recurrent laryngeal nerve (3.33%) and the external laryngeal nerve (1.67%) was noted. Pharyngeal raphe type 3 (full-length) predominated (53.84%), with 3.33% showing complete absence of raphe. Killian's dehiscence was present in 96.66% of specimens.

Conclusion: The superior pharyngeal constrictor exhibits the highest frequency of morphological variations among the three constrictors. These findings have direct implications for pharyngeal motility, dysphagia, surgical planning, and management of pharyngo-oesophageal disorders. Awareness of these variations is essential for clinicians and surgeons working in the head and neck region.

Keywords: Pharyngeal Constrictor Muscles, Morphological Variations, Cadaveric Study, Pharyngeal Raphe, Killian's Dehiscence, Deglutition, Stylopharyngeus, Petropharyngeus, Dysphagia, Cricopharyngeus.

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Introduction

The pharynx is a funnel-shaped fibromuscular membranous tube extending from the base of the skull to the lower border of the cricoid cartilage, measuring approximately 12–14 cm in length. It is conventionally divided into three anatomically distinct regions: the nasopharynx, oropharynx, and laryngopharynx [1]. As the common passage for both air and ingested material, the pharynx plays a paramount role in deglutition, phonation, and airway protection. Normal swallowing, or deglutition, involves the highly coordinated contraction of over 25 pairs of muscles, with the pharyngeal constrictors forming the central effector apparatus of the pharyngeal phase [2]. The pharyngeal constrictor complex consists of three overlapping paired muscles: the superior (SC), middle (MC), and inferior (IC) pharyngeal constrictors. Their arrangement has been classically likened to three flower pots stacked one atop another, with each successive muscle arising more laterally and anteriorly, and each inserting posteriorly into the median fibrous pharyngeal raphe [3, 4]. The superior constrictor arises from four distinct sites — the pterygoid hamulus, the pterygomandibular raphe, the mylohyoid line of the mandible, and the lateral surface of the tongue base — and is therefore morphologically the most complex of the three [5]. The middle constrictor originates from the stylohyoid ligament and the greater and lesser horns of the hyoid bone.

The inferior constrictor is divided into a thyropharyngeal part (from the oblique line of the thyroid cartilage) and a cricopharyngeal part (from the lateral surface of the cricoid cartilage), the latter forming the functional upper oesophageal sphincter [6]. The structures passing through the gaps between adjacent constrictors are of considerable surgical relevance. The gap between the skull base and the superior constrictor (sinus of Morgagni) transmits the auditory tube, levator veli palatini, ascending palatine artery, and palatine branches of the ascending pharyngeal artery. The glossopharyngeal nerve and stylopharyngeus pass between the superior and middle constrictors, while the superior laryngeal vessels and internal laryngeal nerve pass between the middle and inferior constrictors. The recurrent laryngeal nerve and inferior laryngeal vessels pass below the inferior constrictor [7].

Clinically, the inferior constrictor occupies a special position. The potential gap between the thyropharyngeus and cricopharyngeus parts, termed Killian's dehiscence, is the site of predilection for the formation of Zenker's pharyngeal diverticulum when neuromuscular incoordination leads to failure of cricopharyngeal relaxation [8, 9]. Similarly, variations in pharyngeal constrictor innervation have implications for dysphagia, aspiration, and disorders of the upper oesophageal sphincter. With the growing application of transoral robotic surgery for oropharyngeal neoplasms and obstructive sleep apnoea, a thorough understanding of pharyngeal anatomy and its variants is increasingly critical [10].

Despite several anatomical descriptions in standard textbooks, systematic studies documenting the morphological variations of all three pharyngeal constrictors in the same cohort of Indian cadavers are limited. Previous works by Shimada and Gasser [11], Sakamoto [12], Choi et al. [13], and Tsumori et al. [14] have reported variations in individual constrictors, primarily in Japanese and Korean populations, but comparative data for Indian subjects are sparse. The present study was therefore undertaken to provide a comprehensive cadaveric description of the morphological variations of all three pharyngeal constrictor muscles in a South Indian population.

The specific objectives of this study were: (i) to determine the detailed pattern of origin, insertion, and muscle alignment of each of the three pharyngeal constrictors; (ii) to document accessory muscular bundles and anomalous attachments of the superior constrictor; (iii) to examine structures passing between the constrictors and between the superior constrictor and the skull base; (iv) to characterise the pharyngeal raphe by type, length, and morphology; (v) to record variations in the innervation of the inferior constrictor; (vi) to measure the thickness of the pharyngeal constrictors; and (vii) to determine the prevalence and morphology of Killian's dehiscence in adult Indian cadavers.

Materials and Methods

This observational cadaveric study was conducted in the Department of Anatomy, Government Thanjavur Medical College, Thanjavur, Tamil Nadu, and India. Thirty formalin-fixed adult cadavers of both sexes, aged 55–75 years, donated to the department, formed the study material. Each cadaver constituted one specimen, yielding a total of 60 dissected sides for bilateral structures. The study was carried out following the ethical guidelines of the institution for the use of cadaveric material in anatomical research.

Standard dissection instruments (scalpels, scissors, forceps, probes, and bone saws) were used. Pharyngeal raphe length was measured with a flexible measuring tape and a Vernier calliper (electronic, precision ±0.01 mm), and constrictor thickness was measured with the same electronic Vernier calliper.

Dissection was performed according to the method described in Cunningham's Manual of Practical Anatomy, 15th Edition (pages 137–149) [15], supplemented by the posterior pharyngeal exposure technique of Tobin and Jacobs [16]. Cadavers were placed in the prone position to expose the posterior pharyngeal wall. The head was first separated from the trunk by transecting the spinal column between C1 and C4 and severing the prevertebral musculature through the retropharyngeal space. The head was then positioned face-down on the dissection table with the cut end of the skull resting flat, providing an unobstructed posteroinferior view of the pharynx.

The posterior cervical musculature, prevertebral fascia, and buccopharyngeal fascia were meticulously removed from the pharyngeal constrictor muscles, exposing the dorsal surface.

For superior constrictor dissection, the specimen was further sectioned in the median sagittal plane, the oral mucosa was excised, and the medial pterygoid muscle was reflected to expose the superior constrictor from both the facial and oral sides. The middle constrictor was exposed by identifying its origin on the greater horn of the hyoid bone and tracing the fibres to the midline raphe. The inferior constrictor was dissected to clearly delineate the thyropharyngeus and cricopharyngeus parts. The junctional region and raphe were closely examined under adequate illumination, and the morphology of each raphe was recorded.

The following parameters were systematically evaluated: (a) origin variations of the superior constrictor — including accessory fibres from buccal mucosa, dorsal muscular bundles, petropharyngeus, and external course of stylopharyngeus; (b) morphological subtype of the buccopharyngeal part of the superior constrictor (types A, B, and C); (c) middle constrictor origin variations, specifically involvement of the lingual artery; (d) innervation of the inferior constrictor, including contributions from the recurrent laryngeal nerve (RLN) and external laryngeal nerve (ELN); (e) pharyngeal raphe type (1, 2, 3, or absent); (f) pharyngeal raphe length; (g) constrictor thickness; and (h) presence and morphology of Killian's dehiscence.

Descriptive statistics were used to summarise all findings. Results are presented as frequencies (counts) and percentages. Comparisons with published studies are made qualitatively. No inferential statistical testing was performed due to the descriptive observational nature of the study.

Results

Thirty adult cadavers (60 dissected sides for bilateral structures) were examined. The findings are presented under the individual constrictor muscles, the pharyngeal raphe, and the morphometric parameters.

Table 1 summarises the full spectrum of variations observed in the superior constrictor. The classical four-part origin was confirmed in 29 of 30 specimens (96.67%). In one specimen (3.33%), additional lower fibres of the SC arose from the buccal mucosa and connected transversely with the tongue muscles, consistent with the observations of Leonhardt (1987) [17] and DuBrul (1988) [18].

A longitudinal muscular bundle descending over the dorsal surface of the SC and spreading onto the MC was identified in 5 of 30 specimens (16.65% combined): unilateral right in 1 (3.33%), unilateral left in 2 (6.66%), and bilateral in 2 (6.66%). In a comparative study on 22 cadavers (44 sides), Sakamoto (2009) [19] reported a similar dorsal bundle in 13.6% of sides (6 specimens), including 9.1% bilateral cases, consistent with our findings.

Petropharyngeus — a supernumerary elevator muscle arising from the base of the petrous temporal bone and running medially to the styloid process — was found in 3 specimens (5%), all on the right side, with an unusual external course to the SC. Shimada et al. (1991) [20] reported petropharyngeus in only 1.4% of 614 cadavers, and Sakamoto (2009) [19] found it in 18.2% of sides in 22 cadavers (44 sides). The lower incidence in our series may reflect ethnic and sampling differences.

The stylopharyngeus showed an anomalous external attachment to the SC, without piercing it, in 6 sides (10%): 4 on the right and 2 on the left. This was associated with petropharyngeus variations on the right side in 3 specimens. Choi et al. (2020) [13] reported accessory stylopharyngeus bundles in 18.2% and petropharyngeus in 25% of specimens using surgical microscopy, yielding higher detection rates than our gross dissection.

Table 1: Summary of Superior Pharyngeal Constrictor (SC) Morphological Variations (n = 30 specimens / 60 sides)

S.No	Variation Type	No. of Specimens (sides)	Percentage (%)
1	Normal origin (4 classical parts)	29 (58 sides)	96.67
2	Additional fibres from buccal mucosa	1 (2 sides)	3.33
3	Dorsal muscular bundle – Right side only	1	3.33
4	Dorsal muscular bundle – Left side only	2	6.66
5	Dorsal muscular bundle – Bilateral	2	6.66
6	Petropharyngeus – Right side (external course to SC)	3	5.00
7	Stylopharyngeus external course to SC	6 (10 sides)	10.00

The morphology of the buccopharyngeal part of the SC was sub classified according to Tsumori et al. (2007) [14] into three types: type A (fully membranous), type B (partially membranous), and type C (no membrane). In the present study, type A was found in 6 sides (10%), type B in 2 sides (3.33%), and type C in 52 sides (86.67%). Tsumori et al. [14], studying 54 sides, found type A in 13%, type B in 18.5%, and type C in 68.5%, suggesting a higher proportion of the membranous subtype in their Japanese cohort (Table 2).

Table 2: Morphological Subtypes of the Buccopharyngeal Part of the Superior Constrictor (n = 60 sides)

S. No.	Buccopharyngeal Part Morphology	No. of Sides	Percentage (%)
1	Type A – Fully membranous (superior to inferior)	6	10.00
2	Type B – Partially membranous (superior area only)	2	3.33
3	Type C – Absence of membrane (Normal)	52	86.67

The middle constrictor showed normal origin and insertion in 59 of 60 sides (98.33%). In one specimen (1.67%), a right-sided lingual artery was entrapped within the fibres of the MC near its origin, a variant with potential haemodynamic implications. The inferior constrictor was composed of its two classical parts (thyropharyngeus and cricopharyngeus) in all 30 specimens, and the normal origin pattern was maintained throughout. However, important innervation variations were noted. Cricopharyngeus received additional motor supply from the recurrent laryngeal nerve on the left side in 2 specimens (3.33%). In one specimen (1.67%), the external laryngeal nerve coursed deep to the thyropharyngeus on the right side and supplied it before terminating as the motor nerve to the cricothyroid muscle. These findings are in agreement with Sakamoto (2013) [21] and Hammond et al. (1997) [22], who documented variable laryngeal nerve contributions to the inferior constrictor (Table 3).

Table 3: Variations in Middle Constrictor (MC) and Inferior Constrictor (IC) Morphology and Innervation (n = 30 specimens)

S. No.	Muscle / Variation	No. of Specimens	Percentage (%)
1	MC – Normal origin	59	98.33
2	MC – Lingual artery embraced within fibres (right side)	1	1.67
3	IC (CP) – Normal innervation (pharyngeal plexus only)	58	96.67
4	IC (CP) – Additional RLN supply (left side)	2	3.33
5	IC (TP) – Normal innervation (pharyngeal plexus only)	59	98.33
6	IC (TP) – Additional ELN coursing deep to IC (right side)	1	1.67

The pharyngeal raphe was classified according to Shimada and Gasser (1988) [11] into three main types. In the present study, type 3 (full-length raphe traversing all three constrictor pairs from the pharyngeal tubercle of the occipital bone to the inferior constrictor) was the most frequent, observed in 16 specimens (53.84%). Type 2 (raphe between SC and MC only, absent between IC) was seen in 8 specimens (26.66%), and type 1 (raphe present only between the IC muscles) was found in 5 specimens (16.66%). One specimen (3.33%) showed complete absence of the raphe, which was not reported as a separate type in the original Shimada–Gasser classification. Notably, Shimada and Gasser [11], working on 236 cadavers from three racial groups (Mongoloids, Caucasoids, Negroids), found type 1 most common (47%), followed by type 2 (40%) and type 3 (13%), a pattern strikingly inverse to the present study's findings (Table 4).

Table 4: Pharyngeal Raphe Types Observed in 30 Cadavers (Classification per Shimada & Gasser, 1988)

S. No.	Pharyngeal Raphe Type	Description	No. of Specimens	%
1	Type 1	Raphe present only between IC muscles; absent between SC and MC	5	16.66
2	Type 2	Raphe between SC and MC; absent between IC muscles	8	26.66
3	Type 3	Continuous raphe from pharyngeal tubercle through all three constrictors	16	53.84
4	Type 4 (Absent)	No raphe observed	1	3.33

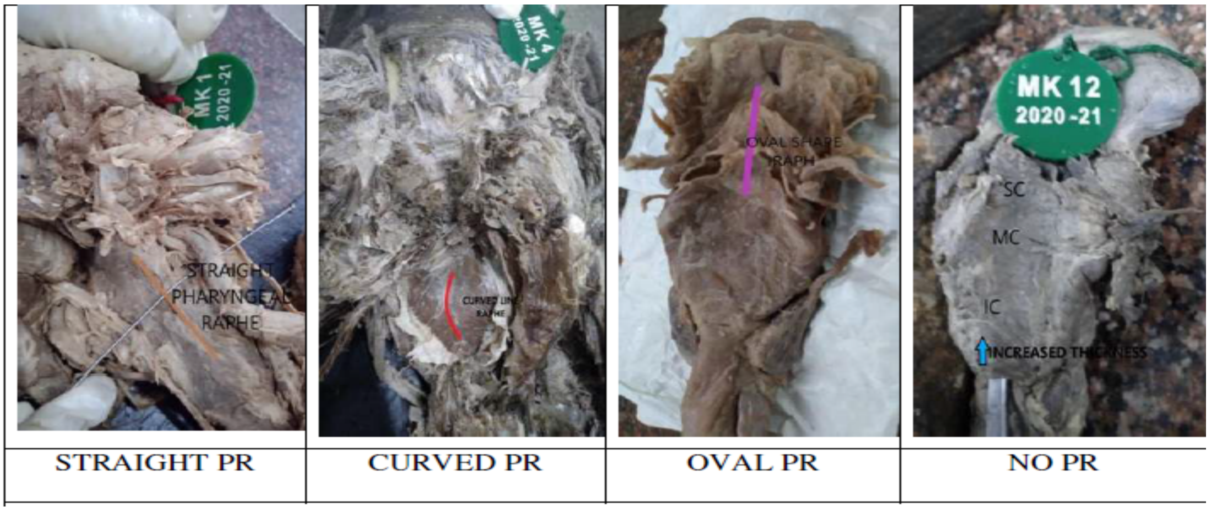

Figure 1: Types of Pharyngeal raphe

Pharyngeal raphe length was measured from the pharyngeal tubercle to the lower end of the inferior constrictor. The normal range was 12–14 cm. In 28 specimens (93.33%), the raphe fell within the normal range. Two specimens (6.67%) showed a shortened raphe (<12 cm, measuring 10.5 cm and 8.9 cm respectively), possibly attributable to specimen decomposition, post-radiation changes, or pathological fibrosis [23].

Constrictor thickness, measured by electronic Vernier calliper, was 0.15–1.5 mm in 29 specimens (96.66%). One specimen (3.34%) exhibited increased thickness exceeding 1.5 mm (recorded at 1.84 mm), consistent with inflammatory or radiation-induced changes, as described in the systematic review by Grepl et al. (2020) [23].

Killian's dehiscence — the potential gap between the thyropharyngeus and cricopharyngeus portions of the inferior constrictor — was identified in 29 of 30 specimens (96.66%). In the remaining specimen (3.34%), the two parts formed a complete muscular ring with no appreciable gap; this specimen also demonstrated the increased constrictor thickness noted above. The high prevalence of Killian's dehiscence in this elderly cohort (aged 55–75 years) is consistent with prior reports indicating greater dehiscence in older individuals compared to adolescents (Table 5).

Table 5: Pharyngeal Raphe Length, Constrictor Thickness, and Killian's Dehiscence in 30 Specimens

S.No	Parameter	Finding	No. of Specimens	Percentage (%)
1	Pharyngeal Raphe Length	Normal (12–14 cm)	28	93.33
2	Pharyngeal Raphe Length	Short (<12 cm)	2	6.67
3	PC Thickness	Normal (0.15–1.5 mm)	29	96.66
4	PC Thickness	Increased (>1.5 mm)	1	3.34
5	Killian's Dehiscence	Present	29	96.66
6	Killian's Dehiscence	Absent	1	3.34

Structures between the Constrictors: All structures passing through the gaps between the constrictors — including the eustachian tube and levator veli palatini in the sinus of Morgagni; the stylopharyngeus muscle and glossopharyngeal nerve between SC and MC; the superior laryngeal vessels and internal laryngeal nerve between MC and IC; and the recurrent laryngeal nerve and inferior laryngeal vessels below the IC — were found within normal anatomical limits in all 30 specimens, with no gross variation detected.

Discussion

This gross anatomical study on 30 adult formalin-fixed cadavers at Government Thanjavur Medical College systematically examined the morphological characteristics of all three pharyngeal constrictor muscles. The cadavers were in the elderly age group (55–75 years), which is relevant because many pharyngeal variations and pathologies, such as Zenker's diverticulum and dysphagia, are more prevalent in older individuals.

The superior pharyngeal constrictor demonstrated the greatest morphological diversity of the three muscles, which corresponds to its complex, four-part embryological origin from the mesoderm of the third branchial arch [24]. The finding of an additional origin from the buccal mucosa with transverse attachment to the tongue muscles in one specimen (3.33%) is compatible with the description of Leonhardt (1987) [17] and DuBrul (1988) [18], and may reflect the glossopharyngeal part of the SC being more extensively developed. Such a variant could contribute to altered pharyngeal wall compliance and modify the efficiency of the oral preparatory phase of swallowing. The dorsal muscular bundles over the SC, found in 16.65% of specimens (combined unilateral and bilateral), are consistent with the supernumerary elevator muscle variants described by Thane (1894) [25] and Bergman et al. (1988) [26]. These accessory longitudinal fibres have been postulated to provide supplementary elevation of the pharyngeal wall, potentially compensating for age-related constrictor weakness. The petropharyngeus (5%), also arising from the petrous temporal bone, is a known supernumerary elevator muscle with widely varying reported incidences: 1.4% in Shimada et al. (1991) [20], 4.5–18.2% in Sakamoto (2009) [19], and 25% in Choi et al. (2020) [13] using surgical microscopy. The differences likely reflect methodological (gross dissection versus microscopy) and ethnic factors.

The anomalous external course of the stylopharyngeus attaching to the SC without piercing it (10%) is surgically noteworthy. In standard anatomy, the stylopharyngeus passes between the SC and MC to reach the interior of the pharynx, innervated exclusively by the glossopharyngeal nerve [27].

An external attachment, as found in this study, may impair the normal elevation and shortening of the pharynx during the pharyngeal phase of deglutition. Choi et al. (2020) [13] have emphasised the functional interdependence of the stylopharyngeus and SC in producing effective pharyngeal clearance, and anomalies of this relationship have been correlated with aspiration risk in elderly patients [28]. The three-type classification of the buccopharyngeal part of the SC (types A, B, C) by Tsumori et al. (2007) [14] was confirmed in our series, although the type C (membrane less) pattern was more prevalent (86.67%) than in their study (68.5%). The buccopharyngeal part is the only region where the SC shares an origin with the buccinator muscle via the pterygomandibular raphe; a membranous type may facilitate a more gradual transmission of contractile force between these muscles.

The middle constrictor was largely unremarkable in this series, consistent with its simpler origin from the stylohyoid ligament and hyoid bone. The single case (1.67%) of the lingual artery coursing within the MC fibres is a surgically hazardous variant: compression of the artery by muscular contraction could theoretically produce transient ischaemia of the tongue, and inadvertent injury during dissection could cause significant haemorrhage. Sakamoto (2014) [29] described the fan-shaped insertion of the MC and noted occasional fibre attachments to adjacent structures; however, vascular entrapment by the MC has not been widely reported in the literature.

The innervation of the inferior constrictor by the pharyngeal plexus (consisting of branches from the vagus, glossopharyngeal, and superior cervical sympathetic ganglia) is well established. However, contributions from the recurrent laryngeal nerve (RLN) to the cricopharyngeus and from the external laryngeal nerve (ELN) to the thyropharyngeus have been reported variably in the literature [22, 30, 31]. In the present study, RLN supply to the cricopharyngeus was found in 3.33% and ELN supply to the thyropharyngeus in 1.67% of specimens. These anatomical variants are clinically significant: iatrogenic damage to the RLN during thyroid surgery or neck dissection could compromise cricopharyngeal function, contributing to post-operative dysphagia or aspiration, particularly in specimens with this variant innervation [21]. Similarly, the ELN coursing deep to the thyropharyngeus before supplying the cricothyroid could be severed during inferior constrictor myotomy, impairing high-pitched phonation [32].

The predominance of the type 3 pharyngeal raphe (53.84%) in our study contrasts markedly with the findings of Shimada and Gasser (1988) [11], who found type 1 most common (47%) and type 3 least common (13%) in their multiracial series of 236 cadavers.

This difference may reflect genuine ethnic variation in pharyngeal musculature development, as the present study included exclusively South Indian cadavers. The complete absence of the raphe in 3.33% of specimens is a novel finding not classified in the Shimada–Gasser system and may represent a developmental variant in which the two halves of each constrictor interdigitate directly without an intervening fibrous seam. Such a configuration might reduce pharyngeal motility by limiting independent lateral expansion of the posterior pharyngeal wall.

The high prevalence of Killian's dehiscence (96.66%) in this elderly cohort supports the established view that this anatomical gap becomes more pronounced with age. Killian's dehiscence is the anatomical prerequisite for the formation of Zenker's pharyngeal diverticulum, which arises when neuromuscular incoordination between the thyropharyngeus and cricopharyngeus — the former propulsive (oblique fibres) and the latter sphincteric (transverse fibres), and innervated by different neural pathways — creates raised intrapharyngeal pressure that forces the mucosa and submucosa posteriorly through the dehiscence [9]. The one specimen lacking a dehiscence but showing a complete muscular ring with increased thickness (possibly secondary to inflammatory change) underscores the relationship between constrictor thickness and pharyngeal pathology documented by Grepl et al. (2020) [23].

The implications of these findings extend beyond descriptive anatomy. Variations in the SC have been associated with altered velopharyngeal function and Passavant's ridge formation in cleft palate patients [33]. Variations in inferior constrictor innervation have implications for the management of high vagal and recurrent laryngeal nerve lesions, and for the outcomes of cricopharyngeal myotomy in Zenker's diverticulum — a procedure in which the cricopharyngeus is divided to relieve the functional obstruction [34]. The present findings, derived from a South Indian population, add to the growing body of literature on ethnic and population-specific anatomical variants, which are increasingly recognised as relevant to procedure planning in contemporary surgical practice.

Conclusion

This cadaveric study of 30 adult specimens has provided a detailed morphological account of the pharyngeal constrictor muscles in a South Indian population. The superior pharyngeal constrictor exhibits the greatest range and frequency of morphological variations, including anomalous muscular origins, accessory elevator bundles, external stylopharyngeus attachment, and buccopharyngeal subtypes. The middle constrictor is relatively constant, though rare vascular entrapment variants exist. The inferior constrictor, while morphologically stable in origin, shows clinically significant innervation variants involving the recurrent and external laryngeal nerves. The pharyngeal raphe in Indian cadavers is predominantly of type 3 (full-length), a pattern divergent from previously published multiracial series. Killian's dehiscence is near-universal in the elderly population studied.

These findings carry important implications for head and neck surgical practice, particularly for transoral robotic surgery, pharyngeal flap procedures, cricopharyngeal myotomy, and the management of dysphagia and aspiration. Future studies employing surgical microscopy, immunohistochemistry, and neurophysiological mapping in larger cohorts across different age groups and ethnicities would further elucidate the functional consequences of these morphological variants and their contribution to pharyngeal motor disorders.

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