

# Fiber arrangements of the vertical lingual muscle in human adult subjects

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## SUMMARY

This study identified the anatomy of the vertical lingual muscle and functional relationships between the vertical lingual and the other lingual muscles in the human tongue. Three whole tongues were obtained from adult human cadavers and were used for histological study by the serial section method. At the tip of the tongue, the fibers of the vertical lingual muscle cross with the transverse lingual muscle, and extend inferiorly to the fibers of the inferior longitudinal lingual muscle. At the body of the tongue, the fibers of the vertical lingual muscle are located between the fibers of the superior longitudinal lingual and inferior longitudinal lingual muscle, crossing the fibers of the transverse lingual muscle, instead of crossing the fibers of the extrinsic lingual muscles. At the base of the tongue, the fibers of the vertical lingual muscle start by the fibers of the superior longitudinal lingual muscle, and connect with the fibers of the posterior muscle bundle of the styloglossus muscle. The average diameters of the vertical lingual muscle fibers increased gradually as they approached the base of the tongue. These findings suggest that postero-superior movement of the tongue body may be accomplished with downward movement of

the tip of the tongue by contractions of both the vertical lingual and the styloglossus muscle. The inferior longitudinal lingual muscle may also play a supporting role for the vertical lingual muscle at the tip of the tongue.

**Key words:** Vertical lingual muscle – Styloglossus muscle – Inferior longitudinal lingual muscle – Human tongue

## INTRODUCTION

The musculature of the human tongue consists of both four extrinsic and four intrinsic lingual muscles (Boden and Harris, 1934; Kaneko, 2000). The fibers of extrinsic lingual muscles are attached structures outside of the tongue (the mandible, the hyoid bone, the styloid process, and the soft palate) and insert into the tongue. The fibers of intrinsic lingual muscles were contained entirely within the tongue without external attachments. It has been suggested that the movements of the tongue body are accomplished by the contraction of the extrinsic lingual muscles, while the shape of the tongue surface is determined by the contraction of the intrinsic lingual muscles (Boden and Harris, 1934; Hardcastle, 1976). In reality, the extrinsic lingual muscle

and the intrinsic lingual muscle function together to accomplish finer and more efficient movement of the tongue, i.e., articulation, mastication, and swallowing. It had been believed that the neuromotor control of all extrinsic lingual muscles and intrinsic lingual muscles (except the palatoglossus muscle) were innervated by the hypoglossus nerve alone (Sadler, 2000). Recently, Saigusa et al. (2006) reported that the superior longitudinal and the inferior longitudinal lingual muscles were innervated by motor fibers of the trigeminal nerve in the human adult subjects. And Saigusa et al. (2004) reported that the posterior part of the transverse lingual muscle in the human adult tongue may not originate from the myotome in occipital somite. These findings suggested that each intrinsic lingual muscle was derived from inside the body of the tongue as an "intrinsic lingual muscle", but had each own origin with distinctive muscle fibers with their own nerve supplies.

In this study, the total structure of the vertical lingual muscle and anatomical relationship with the other lingual muscles were examined using the serial section method. In accordance with the findings, the function and the origins of the vertical lingual muscle are postulated.

## MATERIAL AND METHODS

All research was approved and conducted according to the institutional ethical committee guidelines at Nippon Medical School.

### *Specimens*

Three whole tongues were obtained from human adult cadavers that had been fixed by a 10% formaldehyde solution for more than 3 months. All tongue samples were removed by total glossectomy using the subperiosteal pull-through technique.

### *Study of Fiber Arrangement of the Vertical Lingual Muscle*

The three cadaver samples were cut in half sagittally, and embedded in paraffin. Three half-cut samples were sectioned frontally in series into 30  $\mu\text{m}$  thick slices from the apex of the tip of the tongue to the base of the tongue. Each sectioned specimen was stained with hematoxylin and eosin for light microscopy.

### *Study of the Muscle Fiber Diameter of the Vertical Lingual Muscle*

The other two half-cut samples were sectioned horizontally at the superior-mid portion of the tongue into 30  $\mu\text{m}$  thick slice. Each sectioned specimen was stained with hematoxylin and eosin for light microscopy. Average diameters of the vertical lingual muscle fibers were measured at three different portions of the tongue: the tip of the tongue (VT-tip), in which the fibers ran near the tip of the tongue; the anterior portion (VT-ant), in which the fibers ran lateral to the genioglossus muscle at the anterior portion; the posterior portion (VT-post), in which the fibers ran lateral to the genioglossus muscle near the base of the tongue. One hundred fibers were selected from each of the three portions and their diameters were calculated from the circumference measurement by the NIH imaging system as described previously (Ryu, 1981; Hizawa et al., 1987; Saigusa et al., 2001).

## RESULTS

### *Fiber Arrangement of the Vertical Lingual Muscle*

All samples in this study showed similar results. All three samples demonstrated the common fiber arrangement of the vertical lingual muscle and fibers of the other lingual muscles along the six serial frontal sections from the tip of the tongue to the base of the tongue (Fig. 1). At the very tip of the tongue (Fig. 2A), the fibers of the vertical lingual muscle are surrounded by loose connective tissue with the fibers of the inferior longitudinal and transverse lingual muscles. No fiber of the

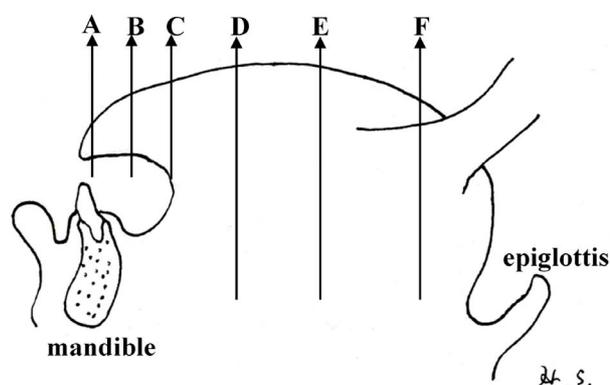


Fig. 1. Locations of six typical serial frontal sections in the tongue. **A:** anterior portion of the tip of the tongue. **B:** posterior portion of the tip of the tongue. **C:** anterior portion of the tongue body. **D:** middle portion of the tongue body. **E:** posterior portion of the tongue body, **F:** the base of the tongue.

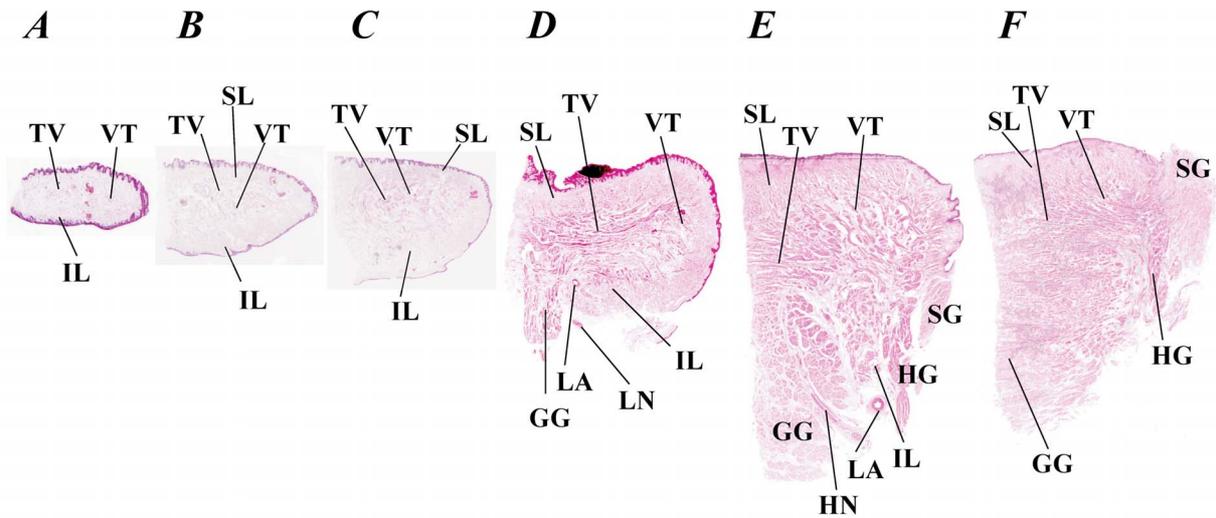


Fig. 2. Light micrographs (H & E) and schematic depictions of frontal sections of the tongue at the six sectional planes. The upper column is light micrographs and the lower column is schematic depictions. *A*: anterior portion of the tip of the tongue. *B*: posterior portion of the tip of the tongue. *C*: anterior portion of the tongue body. *D*: middle portion of the tongue body. *E*: posterior portion of the tongue body, *F*: near the base of the tongue. GG, genioglossus muscle; HG, hyoglossus muscle; HN, hypoglossal nerve; IL, inferior longitudinal lingual muscle; LA, lingual artery; LN, lingual nerve; SG, styloglossus muscle; SL, superior longitudinal lingual muscle; TV, transverse lingual muscle; VT, vertical lingual muscle.

superior longitudinal lingual muscle was located there. At the posterior portion of the tip of the tongue (Fig. 2B), a small amount of fine fibers of the superior longitudinal lingual muscle were seen in the superior portion and joined with the fibers of the inferior longitudinal lingual muscle at the lateral side, forming a muscular cover at the tip of the tongue beneath the mucosal layer. The fibers of the vertical lingual muscle coursed from the superior surface of the superior longitudinal lingual muscle to the inferior surface of the inferior longitudinal lingual muscle. At the anterior portion of the tongue body (Fig. 2C), the fibers of the genioglossus muscle were seen at the inner lateral side of the inferior longitudinal lingual muscle. The fibers of the superior longitudinal lingual muscle were larger than those of the tip of the tongue and spread laterally as the fibers reach posteriorly in the tongue body. The fibers of the vertical lingual muscle coursed from the superior surface of the superior longitudinal lingual muscle to the inferior surface of the inferior longitudinal lingual muscle, and they were lateral to the genioglossus muscle. At the middle portion of the tongue body (Fig. 2D), the fibers of the styloglossus muscle were seen as a border between the superior and inferior longitudinal muscles beneath the mucosal layer. And the fibers of the hyoglossus muscle were seen at the inner lateral side of a muscular cover con-

sisting of the superior, inferior longitudinal lingual, and styloglossus muscles. The fibers of the vertical lingual muscle coursed inferolaterally from the superior surface of the superior longitudinal lingual muscle and ended at the inner lateral side of the hyoglossus muscle. At the posterior portion of the tongue body (Fig. 2E); the fibers of the superior longitudinal lingual muscle and the inferior longitudinal lingual muscle were completely separated by the styloglossus and the hyoglossus muscles. The fibers of the inferior longitudinal lingual muscle did not connect with the mucosal layer; instead, they were surrounded by the genioglossus and hyoglossus muscle. The fibers of the vertical lingual muscle coursed inferolaterally from the superior surface of the superior longitudinal lingual muscle, and reached the upper side of the hyoglossus muscle and the lateral side of the styloglossus muscle. At the base of the tongue, (Fig. 2F) the fibers of the superior longitudinal lingual muscle were detected, but no fibers of the inferior longitudinal lingual muscle were seen. The fibers of the vertical lingual muscle connected with the fibers of the styloglossus muscle which tunned anteromedially. Figure 3 is a schematic representation of the fiber arrangements of the musculature of the tongue.

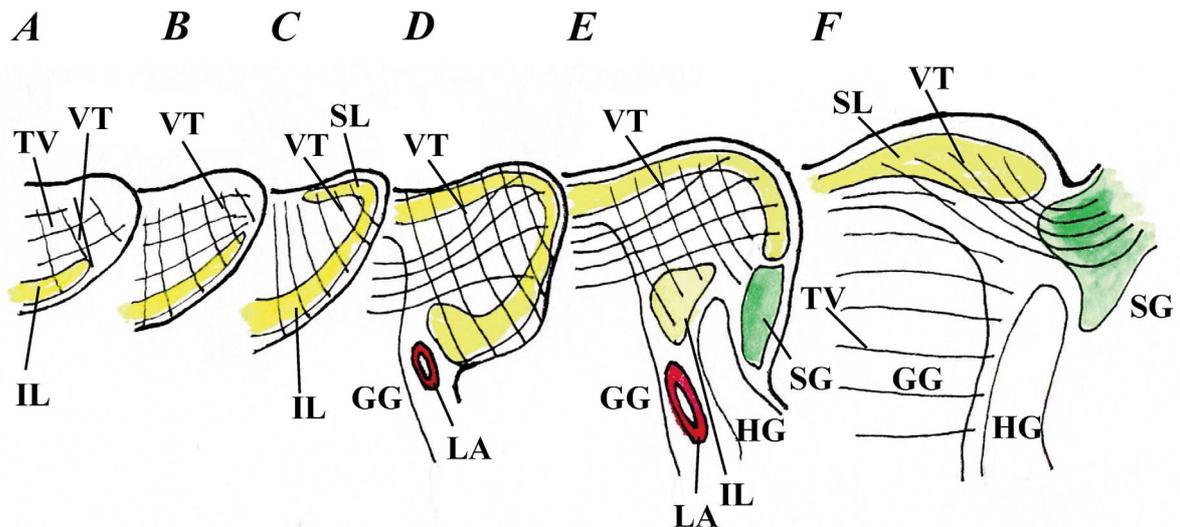


Fig. 3. A diagram showing the tongue musculature of the six frontal serial sections. A: anterior portion of the tip of the tongue. B: posterior portion of the tip of the tongue. C: anterior portion of the tongue body. D: middle portion of the tongue body. E: posterior portion of the tongue body, F: the base of the tongue. GG, genioglossus muscle; HG, hyoglossus muscle; HN, hypoglossal nerve; IL, inferior longitudinal lingual muscle; LA, lingual artery; LN, lingual nerve; SG, styloglossus muscle; SL, superior longitudinal lingual muscle; TV, transverse lingual muscle; VT, vertical lingual muscle.

#### Muscle Fiber Diameters of the Vertical Lingual Muscle

The two samples examined in this study showed similar results. Light microscopic morphometry showed a clear difference in the diameters of the three portions (Fig. 4). Figure 5 is a histogram of the distribution of fiber diameters for the three portions in the two samples. The total number of fibers for each portion was 200. The fibers of the VT-tip had smaller diameter fibers ( $2.05 \pm 0.22 \mu\text{m}$ ). The VT-ant had slightly larger diameter fibers ( $4.08 \pm 0.83 \mu\text{m}$ ). The VT-post had the largest diameter fibers ( $4.33 \pm 0.97 \mu\text{m}$ ). The differences in diameter at the three locations were statistically significant ( $p < 0.05$ ).

#### DISCUSSION

The general functions of the vertical lingual muscle are thought to flatten the tongue

out sideways (Kaneko, 2000; Hardcastle, 1976), to narrow the frontal cross section of the tongue (Hardcastle, 1976), and to produce a ridge on the dorsum of the tongue (Strong, 1956). However, the function of the vertical lingual muscle based on fine fiber arrangements of the vertical lingual muscle of the human tongue (Barnwell, 1976) has not been reported. In order to better understand the function of the vertical lingual muscle of the human tongue, we examined the entire fiber arrangement and the structure of the vertical lingual muscle in the human adult subjects by serial section method.

We found that the posterior part of the vertical lingual muscle joined the fibers of the posterior muscle bundle of the styloglossus muscle. It was previously reported that the styloglossus muscle separated into two parts after coursing inferiorly to reach the edge of the tongue (Barnwell, 1977; Saito, 2007).



Fig. 4. Lightmicrographs of 30  $\mu\text{m}$  thick sections of vertical lingual muscle from three portions (H&E, original  $\times 50$ ). A: Vt-tip, B: VT-ant, C: Vt-post.

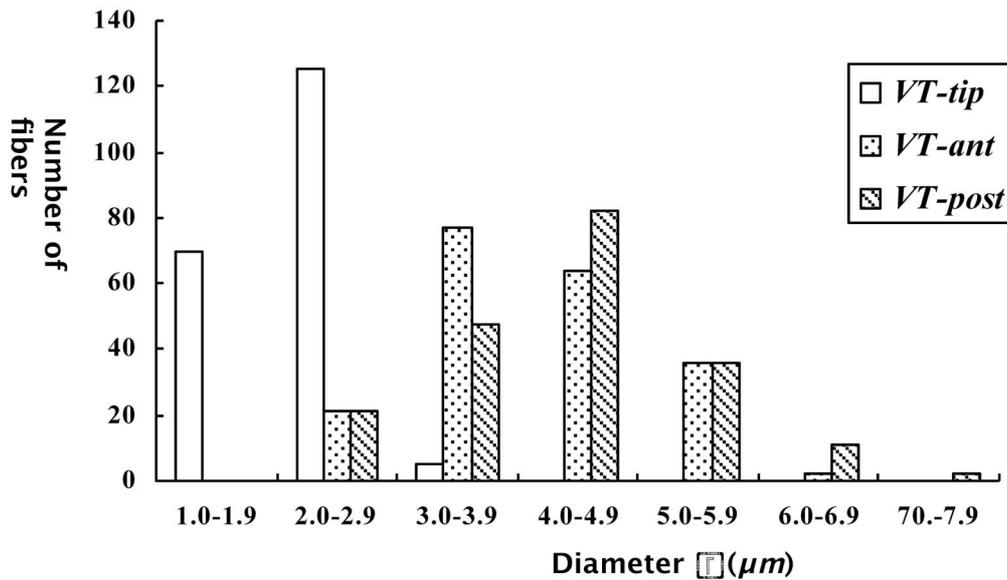


Fig. 5. Distribution of fiber diameters in three portions of vertical lingual muscle. The Vt-tip has smaller-diameter fibers in general. Fibers of the Vt-post are larger and the diameters of the Vt-ant are intermediate in diameter.

One fiber turned anteromedially and ran further medially (posterior muscle bundle). The other fiber coursed along the lateral margin of the tongue (anterior muscle bundle) (Abd-El-Malek, 1949; Barnwell 1977; Saito, 2007). Barnwell (1977) estimated that 75 % of the fibers of the styloglossus muscle were composed of the posterior muscle bundle and 25 % was the anterior muscle bundle. Saito (2007) noted that the contraction of the posterior muscle bundle of the styloglossus muscle might contribute to the posterosuperior movement of the base of the tongue, and the contraction of the anterior muscle bundle could contribute to the movement of the anterior part of the tongue posteriorly or, by working unilaterally, to turn the anterior part of the tongue laterally. However, in order to achieve more refined and efficient movement of the tongue, the simultaneous contraction of the styloglossus muscle with the fibers of intrinsic lingual muscle may be considered, instead of the contraction of the styloglossus muscle alone. Simultaneous contraction of both the vertical lingual and styloglossus muscles at the base of the tongue may contribute, not only to the posterosuperior movement of the tongue body, but also the shaping of the posterior part of the tongue (Fig. 6B).

The fibers of the vertical lingual muscle were detected from the apical tip of the tongue to the base of the tongue, and coursed from the superior portion to the inferolateral portion of the tongue, eventually reaching the

lateral side of the styloglossus muscle at the posterior portion of the tongue body. And the fibers of the inferior longitudinal lingual muscle were detected from the apical tip of the tongue to the posterior portion of the tongue body, mixing with the fibers of the vertical lingual muscle, and were surrounded by the genioglossus, hyoglossus, and styloglossus muscles from the middle portion of the tongue body to the posterior portion of the tongue body. The fibers of the superior longitudinal lingual muscle were not found in the apical tip. They started from the posterior portion of the tip of the tongue to the base of the tongue beneath the mucous layer, combining with the fibers of the vertical lingual muscle. Considering these anatomical features, contractions of the vertical lingual muscle may also accomplish downward movement of the tip of the tongue, since the inferior longitudinal lingual muscle was surrounded and restricted by the genioglossus, hyoglossus, and styloglossus muscles in the tongue body. Additionally, the inferior longitudinal lingual muscle may contribute to control a degree of downward movement of the tip of the tongue as a supporting muscle for the vertical lingual muscle (Fig. 6A).

In a previous report, posterosuperior movement of the tongue body by contraction of the styloglossus muscle could be seen with downward movement of the tip of the tongue during the production of high back vowel /u/ (Chiba and Kajiyama, 1842; Borden and

Harris, 1984). In animal models including a cat and a rhesus monkey (Schoen, 1931; Morimoto et al., 1978; Takebe, 1980), it was reported that the jaw-tongue reflex could also represent posterosuperior movement of the tongue body with downward movement of the tip of the tongue when the jaw was forced to open. In the study, the mechanism of posterosuperior movement of the tongue body during the jaw-tongue reflex should be accomplished by contraction of the styloglossus muscle (Morimoto et al., 1978; Takebe, 1980). Considering these findings, it may be suggested that there is a close relationship between posterosuperior movement of the tongue body by contraction of the styloglossus muscle and downward movement of the tip of the tongue. Based on this histological study, simultaneous contractions of both the styloglossus and the vertical lingual muscles might allow posterosuperior movement of the tongue body with downward movement of the tip of the tongue (Fig. 6B). This may suggest that the posterior part of the vertical lingual muscle may be differentiated in close proximity to the styloglossus muscle.

The average diameter of the vertical lingual muscle was significantly larger at the base of the tongue where the fibers joined the posterior muscle bundle of the styloglossus muscle. Absolute muscle strength has been reported to be proportional to the diameter of the muscle fiber (Hukunaga, 1978); thus, powerful posterosuperior movement of the tongue body

may be accomplished by contraction of both of the styloglossus and the vertical lingual muscles at the posterior part of the tongue.

Moreover, morphological and physiological studies may be warranted to elucidate the "true" neuromotor control system of the human tongue.

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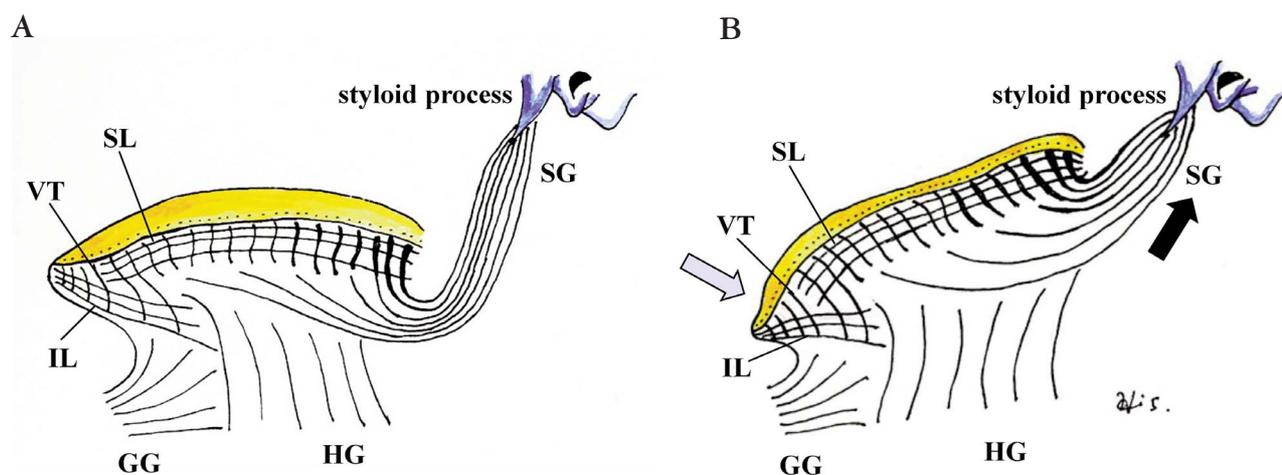


Fig. 6. Diagrams showing the mechanisms for posterosuperior movement of the tongue body with the downward movement of the tip of the tongue. Posterosuperior movement of the tongue body (black arrow) could be accomplished with downward movement of the tip of the tongue (gray arrow) by simultaneous contractions of the vertical lingual and styloglossus muscles. Inferior longitudinal lingual muscle might contribute to control a degree of downward movement of the tip of the tongue as a supporting muscle. A: On rest. B: On posterosuperior movement of the tongue body with downward movement of the tip of the tongue. GG, genioglossus muscle; HG, hyoglossus muscle; IL, inferior longitudinal lingual muscle; SG, styloglossus muscle, SL, superior longitudinal lingual muscle; VT, vertical lingual muscle.

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