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Electromyographic and Histological Studies of Passavant's Ridge

Eiichi FUJIMURA[1], Iwao HONJO[2], Kazunori MORI[2]
and Michio KAWANO[2]

A horizontal bar which is formed at the retropharynx during phonation is called Passavant's ridge[1]. With regard to the significance of the ridge in cleft palate speech, two concepts have been proposed ; one is that the ridge compensates for velopharyngeal insufficiency and the other is that it actually plays little role in velopharyngeal closure. On the other hand, concerning the process of the ridge formation, there have been also two concepts ; either the ridge is a fold of mucous membrane or a muscular prominence. In order to clarify both the process of the ridge formation and its significance in cleft palate speech, electromyographic and histological studies of the ridge were conducted.

1) Electromyographic study

To clarify whether the ridge has any muscular activity or not, an electromyogram (EMG) from the ridge during phonation was picked up. Then, in order to determine the relationships among the various movements at the velopharynx including those of the ridge, electromyographic activity from the ridge, the levator velli palatini muscle, and the lateral pharyngeal wall was evaluated in relation to the degree of velopharyngeal competence.

Subjects

The subjects were 6 cleft lip palate patients, 1 patient with congenital velopharyngeal insufficiency and 4 normal controls with velopharyngeal competence (Table 1). The degree of Passavant's ridge formation and velopharyngeal competency are shown in Table 1. EMGs from the Passavant's ridge, the levator velli palatini muscle and the lateral pharyngeal wall were examined in 7 out of 11 subjects. In the other subjects, only the EMGs from the ridge and the levator velli palatini muscle were recorded.

Electromyographic Methods

Based on the fiberscopic and fluorovideoscopic observation, the degree of the

Eiichi FUJIMURA[1](藤村英一), Iwao HONJO[2] (本庄　巖), Kazunori MORI[2] (森　一功), Michio KAWANO[2] (川野通夫),
1) Department of Otorhinolaryngology, Kansai electric hospital, Fukusimaku, Osaka, 563 Japan.
2) Department of Otorhinolaryngology, Faculty of Medicine, Kyoto University, Sakyoku, Kyoto, 606 Japan.

Table. 1 Type of Cleft, ages, degree of Passavant's ridge, and velopharyngeal function of 11 subjects.

	case	age	sex	type	Passavant's ridge	VPI
1	K. Y	34	male	CLP	++	+
2	T. Y	13	male	CVPI	+	+
3	K. I	10	male	CLP	−	+
4	K. M	13	male	CLP	++	+
5	M. I	24	female	CLP	++	+
6	T. N	15	male	CLP	++	+
7	T. Y	16	female	CLP	++	−
8	M. K	51	male	NORMAL	−	−
9	K. K	39	female	NORMAL	++	−
10	N. K	26	male	NORMAL	+	−
11	A. I	28	male	NORMAL	++	−

CLP : cleft lip and palate
CVPI : congenital velopharyngeal insufficiency
VPI(+) : velopharyngeal incompetence
VIP(−) : velopharyngeal competence

ridge were classified into 3 types: no formation of the ridge(−), inconsistent formation (+) and consistent formation (++) of the ridge during phonation of vowels and consonants syllables.

EMGs were recorded during the phonation of 5 Japanese vowels (a, i, ɯ, e, o) under surface anesthesia with 4 % lidocaine.

A stainless steel wire electrode with a diameter of 100 μm was introduced through the nasal cavity into the nasopharynx, and was inserted into the levator velli palatini muscle at the levator eminence medial to the tubal orifice, thus entering Passavant's ridge at the center of the retropharynx. For the lateral

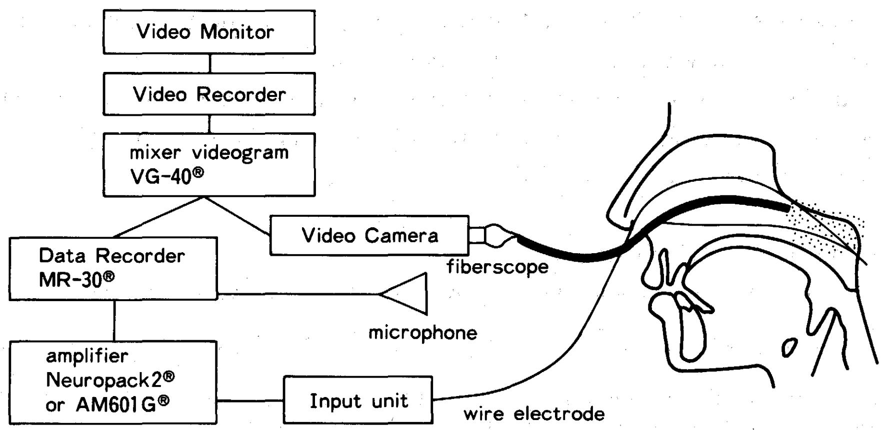

Fig. 1 Endonasal recording of the EMG from the velopharynx.

pharyngeal wall EMG, the electrode was inserted into the wall posterior to the torus tubarius at the level of Passavant's ridge. In subjects with no formation of the ridge, the insertion points for the retropharynx and the lateral pharyngeal wall were determined with reference to the level of the inferior end of the torus tubarius. The electromyogram was amplified using a Neuropack2® or an EMG amplifier AM-601G®, recorded on a data recorder MR30®, and superimposed on a video monitor (Fig. 1). Electromyographic signals were digitalized with an A/D converter at a sampling rate 10 KHz using Wave Master®. These data were processed by a personal computer (PC-9801®), saved in symbolic link format (SYLK), and averaged by Lotus 1-2-3®.

Results of EMG

The EMGs which were recorded simultaneously with endoscopy of the velopharynx are shown in the Fig. 3. Averaged voltages of the EMGs for 5 vowels are given in Fig. 4.

A prominent EMG was noted from Passavant's ridge during phonation, which was synchronous with the EMGs from the levator velli palatini and the lateral pharyngeal wall (Fig. 3). On the other hand, it was found that EMG activity from the ridge was similar to that from the lateral pharyngeal wall in 6 of 7 subjects (85 %) (Fig. 4. cases 1, 4, 5, 6, 8, 11), and in 6 of 11 subjects (55 %) (Fig. 4. cases 2, 5, 6, 7, 8, 10) the average EMG values from the ridge were similar to those from the levator velli palatini. Interestingly, there was a certain amount of EMG activity from the retropharvnx in cases with velopharyngeal incompetence (Fig. 4. case 3) or in case without ridge formation (Fig. 4. case 8).

Discussion on EMG Findings

There have been several methods used for quantitative analysis of the EMG; for example, the maximum level of the EMG envelope[2] or the averaged voltage of EMG[3][4]. We adopted the latter method in the present study. To determine the averaged voltage, Lubker[4] measured the slope of the accumulated voltage envelope, but we determined the averaged voltage at one sampling point of the EMG.

Although there are some reports on the activity of levator muscles in connection with the posterior pharyngeal wall or the superior constrictor muscle, no EMG study on Passavant's ridge has been previously reported.

In the present study we found the synchronous muscle activity in the ridge and the levator veli palatini muscle. Fritzell's report[3] suggests that the activity of superior conptrictor muscle is synchronous with that of the levator velli palatini muscle during phonation. Regardless of the degree of velopharyngeal insufficiency, the activities of both muscles during phonation of 5 vowels generally coincided well with each other, indicating that these two muscles moved synchronously to

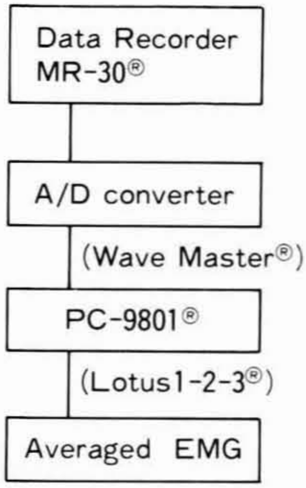

Fig. 2 Averaging of EMG.

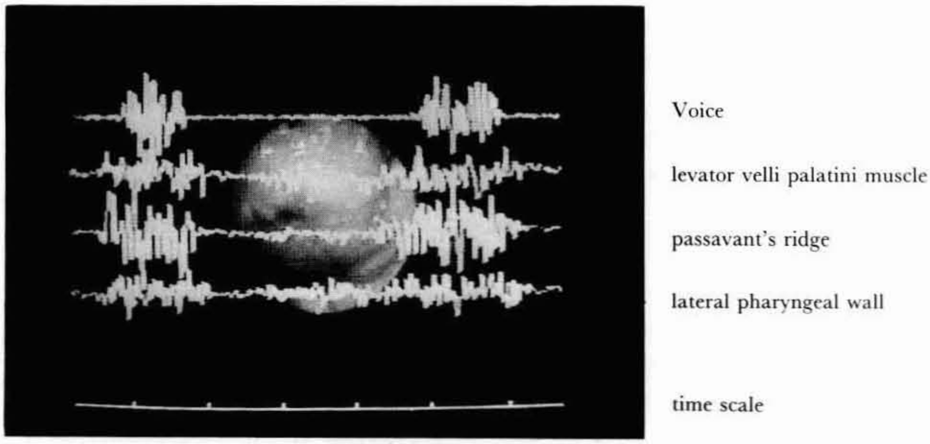

Fig. 3 Simultaneous recording of the EMG, voice signals, and velopharyngeal movements.

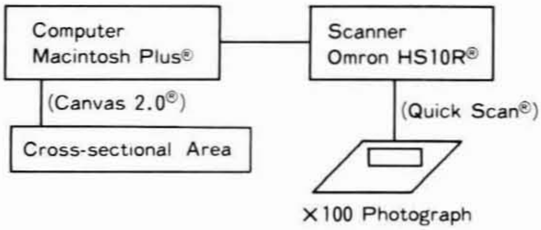

Fig. 5 Measurement of cross-sectional area of the muscle fibers in Passavant's ridges.

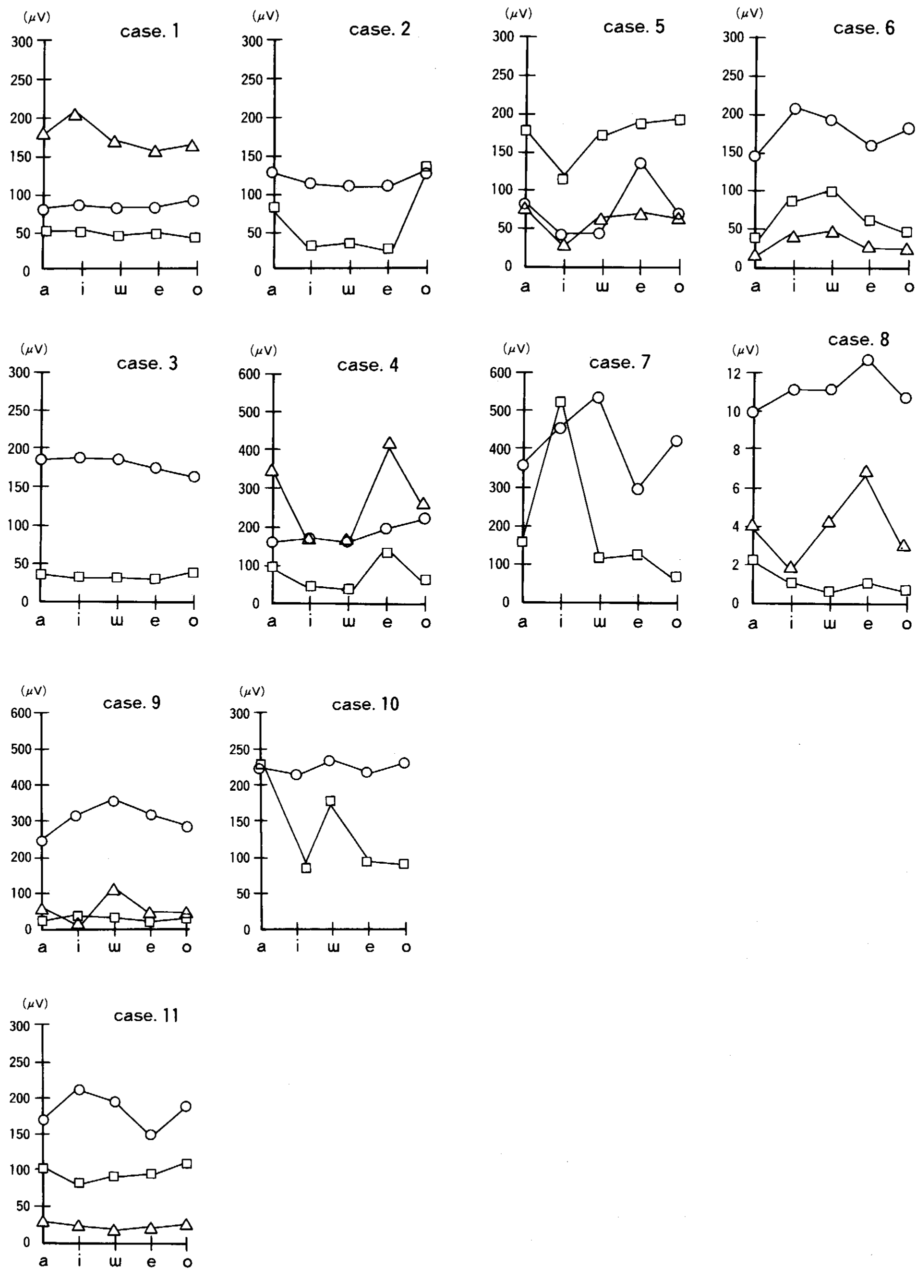

Fig. 4 Averaged voltages of EMGs.

○ levator velli palatini muscle

□ Passavant's ridge

△ lateral pharyngeal wall

complete velopharyngeal closure. Synchronous changes of muscle activity in Passavant's ridge and the lateral pharyngeal wall appeared to indicate that a single muscle which runs in a circular fashion around the pharynx produced both the ridge formation and medial movement of the lateral pharyngeal walls.

Activity observed in the cases without Passavant's ridge may have been due to weak muscle contraction which could not overcome the local tissue resistance.

It appeared likely that the Passavant's ridge was formed by the circular muscle around the pharynx, and had a significant part in velopharyngeal closure by acting synchronously with the levator velli palatini.

2) Histological study

In order to determine histological nature of the ridge, microscopic examination of the tissue obtained from the retropharynx of cleft palate patients during pharyngeal flap surgery was performed.

Subjects for Histological Study

Table. 2 Type of Cleft, ages, degree and averaged cross-sectional muscle area of 8 Passavant's ridge.

	case	age	sex	type	Passavant's ridge	averaged area (μm^2)
1	A. O	6	male	CLP	−	275
2	K. T	6	male	CLP	−	430
3	A. N	5	female	SMCP	−	257
4	S. K	6	female	CLP	−	174
5	O. Y	5	male	CLP	+	374
6	T. Y	13	male	CVPI	+	375
7	M. K	24	female	SMCP	++	616
8	M. I	25	female	CLP	++	1158

CLP : cleft lip and palate
SMCP : submucous cleft plate
CVPI : congenital velopharyngeal insufficiency

Five patients with cleft palate, 2 patients with submucous cleft, and 1 patient with congenital velopharyngeal insufficiency were examined. Degree of Passavant's ridge formation in each case is shown in Table 2

Method of Histological Study

Before pharyngeal flap surgery, Passavant's ridge was marked with blue dye (pyoctanin®), and during surgery the specimen was obtained from the retropharynx at the level of Passavan's ridge. Specimins were stained with hematoxylin-eosin and investigated by light microscopy. The cross-sectional area of the muscle fibers was determined using a scanner (Omron HS10R®), and the CAN-

VAS[R] software package (Fig. 5).

Results of Histological Study

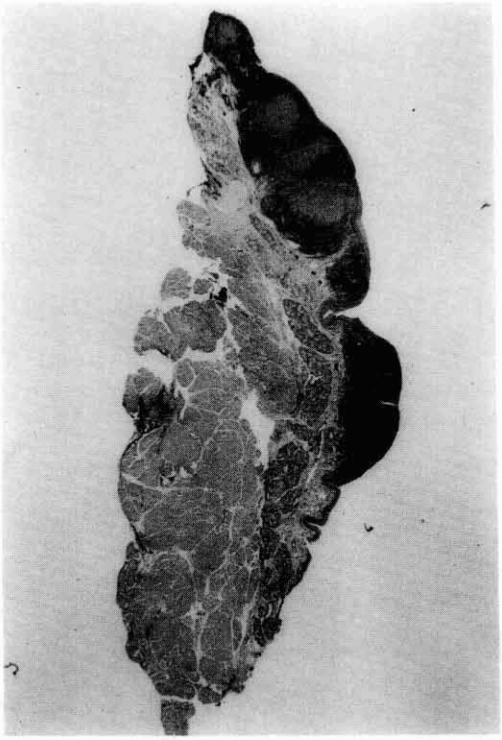

Fig. 6. Histological appearance of the retropharynx at the level of Passavant's ridge (×5).

The histological appearance of the retropharynx at the level of Passavant's ridge in case 2 is presented in Fig. 6. Although this subject had an inconsistent formation of the ridge, a muscular layer was found to run horizontally, just under the mucous membrane at the level of the ridge. In the upper part of the ridge, however, there was no muscular layer, but only adenoid lymphoid tissue. The other 7 subjects examined showed similar histological findings.

The relationship between the degree of Passavant's ridge and the presence of muscular hypertropy was investigated (Fig. 7 and Fig. 8.). In case 1, Passavant's ridge was not present ; the average diameter of the muscle fibers was about 20 μm, and the average cross-sectional area was about 275 μm^2 (Fig. 7). On the other hand, muscular hypertrophy was noted in case 8, in whom a marked Passavant's ridge was present. The average diameter of the muscle fibers was about 40 μm, and the average cross-sectional area was about 1157 μm^2 in this case (Fig. 8). The relationship between the degree of Passavant's ridge and the average cross-sectional area of the muscle fibers is shown in Fig. 9. The muscle fibers were larger in the cases with a prominent Passavant's ridge.

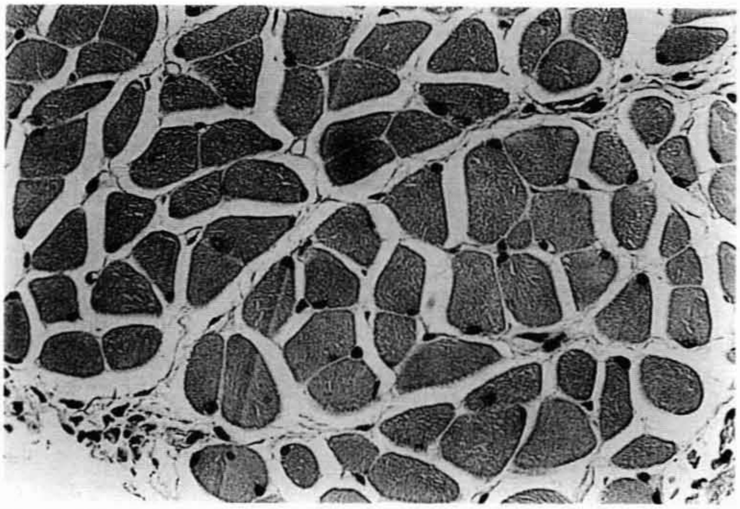

Fig. 7 Histological appearance of the retropharynx at the level of Passavan's ridge (no ridge formation, case 1, ×100).

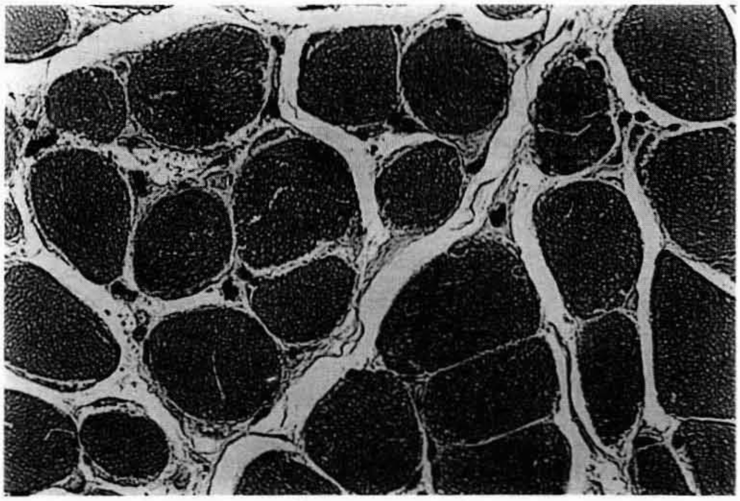

Fig. 8 Histological appearance of the retropharynx at the level of Passavant's ridge (case8, ×100).

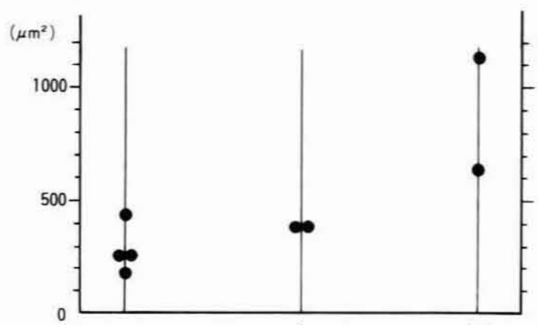

Fig. 9 Averaged cross-sectional muscle fiber area in the retropharynx at the level of Passavant's ridge.

Discussion of Histological Findings

It was confirmed by this histological study that Passavant's ridge is not a fold of mucous membrane, but is formed by the circular muscle around the pharynx.

It was also shown that the muscle fibers are hypertrophic in proportion to the degree of formation of the ridge. Hypertrophy of muscle fibers is said to be induced by exercise or physical growth[5], and by some forms of neuropathy[6]. There were no abnormal findings that suggested disuse atrophy or denervation such as central migration of nuclel and rounding of the muscle fibers. Therefore, the hypertrophy detected was considered to be physiological. Although it is not possible to determine the muscle strength from the degree of hypertrophy of the muscle fibers, the cross-sectional area increased with the degree of prominence of Passavant's ridge ($r=0.79$, $P<0.05$). It appears that muscular hypertrophy might be induced by repeated contraction during compensatory action of the velopharynx.

Discussion and Conclusion

There have been two concepts on the role of Passavant's ridge in cleft palate speech ; either the ridge compensated for velopharyngeal insufficiency or did not do so[7][8]. However fluorovideoscopic and fiberscopic studies of the velopharynx revealed that the majority of patients with the ridge showed a contact between the ridge and the palate at velopharyngeal closure[9], thus compensating for velopharygeal insufficiency. Electromyography revealed that the movement of the ridge was synchronous with movement of the lavator vei palatini muscle. These findings suggest that the ridge has an important role in compensating for in adequate velopharyngeal closure in cleft pelate patients.

By the anatomical study of cadavers, Kojima[10] and Whillis[11] both reported that the palatopharyngeal sphincter constituted Passavant's ridge. The present study revealed that EMGs from the ridge during phonation were similar to those from the lateral pharyngeal wall, and the muscle fibers from the ridge were hypertrophic in proportion to the prominence of the ridge. Thus, the circular muscle at the ridge appeared to increase its volume to compensate for velopharyngeal insufficiency.

Based on the findings of our electomyographic and histological study of the ridge, it can be concluded that passavant's ridge is formed by the contraction of the circular muscle of the pharynx synchronously with the levator muscle.

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