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An Evaluation by High-Resolution Manometry of the Dynamics of Swallowing in Healthy Individuals Using a Palatal Augmentation Prosthesis: Mini Review

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Abstract

Objective: This study aimed to elucidate and evaluate the dynamics of swallowing when using different thickness palatal augmentation prosthesis (PAP) in healthy individuals. We observed changes in pharyngeal pressure during the swallowing process according to the wearing of PAP which was different thickness in healthy individuals using high-resolution manometry (HRM).

Materials and methods: Ten healthy subjects (average age 34.2 ± 9.5 years) wearing a PAP of three thicknesses ingested water jelly and thin rice porridge. Maximum swallowing pressure and timing events were recorded with a 20-sensor HRM catheter.

Results: Healthy individuals that wore the PAP of 10 mm and swallowed jelly and thin rice porridge showed significantly increased maximum pressure at the tongue base and significantly decreased maximum pressure at the lower pharynx.

Conclusion: The thickness of PAP as 10mm enhanced the anchor of the tongue and increased the maximum pressure at the base of the tongue.

Keywords: Palatal augmentation prosthesis; High-resolution manometry; Dynamics of swallowing

Introduction

The Palatal Augmentation Prosthesis (PAP), which is fabricated so the palatal vault is lowered to provide increased linguopalatal contact, improves deglutition, and speech potential in patients with reduced tongue volume and movement. It was described the effect of PAP on the management of dysphagia in patients with cerebral palsy [1], cerebrovascular disease [2,3] and Amyotrophic lateral sclerosis [4] as consequence of its treatment. In order to evaluate the pharyngeal swallowing dynamics of PAP, swallowing videoendoscopic and video fluoroscopic (VF) were often used. As a quantitative evaluation method, Manofluorography, which synchronizes the VF image and the swallowing pressure waveform, was used [5-7]. Swallowing pressure measurement, which is one of the swallowing function evaluations, can quantitatively assess abnormalities in swallowing dynamics caused by abnormalities in muscle tone and contraction timing from the aspect of pressure and time, and to know the pathogenesis of dysphagia. It can get very useful information [8]. In the case of Manofluorography, several (2 to 4) pressure sensors were mounted at intervals of several centimeters, and the pressure receiving part is unidirectional, and only partial evaluation can be made.

The advent of high resolution manometry (HRM) offers a drastically improved method to evaluate pressure during swallowing along the length of the entire pharynx and esophagus. HRM uses 36 sensor arrays spaced one centimeter apart and is capable of recording pressure in asymmetrical structures, offering the spatial and temporal resolution necessary to accurately capture rapidly changing pressures throughout the pharynx without concern for anatomic variation or moving structures. This allows for a comprehensive evaluation of the pharyngeal swallow. Analyzing pressures across the entire length of the pharynx should reveal additional and perhaps subtle findings that were previously undetectable using traditional manometry.

This study aimed to elucidate and evaluate the dynamics of swallowing when using different thickness palatal augmentation prosthesis in healthy individuals. We observed changes in pharyngeal pressure during the swallowing process according to the wearing of palatal augmentation prosthesis (PAP) which was different thickness in healthy individuals using 20-sensor HRM.

Materials And Methods

Ten males aged 34.2 ± 9.5 years, each participant in this study provided informed consent, and the protocol was approved by the local Institutional Review Board of the University of Asahi. All participants were without swallowing, neurological, or gastrointestinal disorders. Participants were instructed not to eat for four hours and not to drink liquids for two hours prior to testing to avoid any potential confounding effect of satiety.

Wearing a PAP was fabricated three type's thicknesses (2 mm, 5 mm, 10 mm) and augments the palate using tissue conditioning material [9].

Pressure and timing events were recorded with a 20-sensor HRM catheter. The Starlet HRM system (Star Medical, Inc, Tokyo, Japan) has a catheter with 20-channel solid-state sensors spaced at 1-cm intervals (Unisensor AG, Attikon, Switzerland) [10]. The sensors were unidirectional and were covered by circumferential soft membranes with fluid inside. The luminal pressure acted on the membrane and was transferred to the fluid, so the sensors actually perceived the average luminal pressure in situ. The outer diameter of the thinnest part of the

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catheter was 3.8 mm by 5.4 mm of each transducer site. The catheter was connected to polygraph recording equipment, and the manometric data were collected on a personal computer using a sampling frequency of 25 Hz [11].

We analyzed the maximum swallowing pressure, duration of contraction, and time of contraction to peak, at the level of the velopharynx, tongue base, and lower pharynx. We analyzed the duration of relaxation of the upper esophageal sphincter (UES), maximum pre-opening UES pressure, and maximum post-closure UES pressure [9].

The manometric catheter was lubricated with gel to ease passage of the catheter through the pharynx. The Starlet HRM system (Star Medical, Inc, Tokyo, Japan) catheter was inserted transnasally until UES. The catheter was then taped to participants nose and videoendoscope was inserted from another nose to observe pharynx to evaluation of swallowing. Once the catheter was positioned within the pharynx, participants sat quietly for 5-10 minutes to adjust to the catheter prior to performing swallowing tasks.

In the neutral head position, the participant's received, 3 ml water, 3 g jelly and 3 g thin rice porridge three times for the analysis of different texture with wearing each different thicknesses PAP and without PAP.

Statistical Analysis

The measurement was performed three times each, and the average value was used for the analysis. Friedman test was used for the comparison values of each parameter between no wearing PAP and wearing different thickness PAP (2 mm, 5 mm, and 10 mm) different texture swallow with each thickness PAP. For multiple comparisons, the Wilcoxon signed-rank test was used with Dunnett's correction for the comparison of values the first study. Wilcoxon signed-rank test was used with Bonferroni correction for the comparison of values the second study. Spearman's rank correlation coefficient was used for the relationship between the maximum tongue base pressure and the maximum hypopharyngeal pressure when PAP was used at each thickness. Differences were regarded as statistically significant at p<0.05.

Result

Effect of different thickness PAP for the dynamics of swallowing

Maximum velophary nx pressure was significantly higher 3ml water swallow with a thickness of 10mm PAP when compared to the without PAP (p=0.00585). Maximum tongue base pressure was significantly higher jelly 3g swallow with a thickness of 10mm PAP when compared to the without PAP (p=0.01758) and significantly higher thin rice porridge 3g swallow with a thickness of 10mm PAP when compared to the without PAP (p=0.0411). Low pharynx pressure was significantly lower jelly 3g swallow with a thickness of 10mm PAP when compared to the without PAP (p=0.00585), significantly thin rice porridge swallow with a thickness of 2mm PAP when compared to the without PAP (p=0.02931) and significantly lower thin rice porridge swallow with a thickness of 10mm PAP when compared to the without PAP (p=0.01758) (Table 1).

No differences were found among duration of contraction, or time of contraction to peak, at the level of the velopharynx, tongue base, or lower pharynx, and duration of relaxation of UES when comparing those with PAP and without PAP.

Maximum pre-opening UES pressure was higher with PAP than

		Maximum Pressure(mmHg)				Duration of contraction(msec)					Time of contraction to peak(msec)				
		Saliva	Water	Jelly	Thin rice porridge		Saliva	Water	Jelly	Thin rice porridge		Saliva	Water	Jelly	Thin rice porridge
Velopharynx	Without PAP	225.0 ± 74.9	236.9± 64.6*	223.5 ± 77.5	225.5 ± 68.2	Without PAP	460 ± 200	418 ± 191.1	510 ± 229.4	524.2 ± 260.2	Without PAP	174.2 ± 51.4	177.5 ± 48.9	200.8 ± 46.9	181.7 ± 62.3
	2 mm	197.1 ± 77	194 ± 69.2*	190.8± 78.4	204.4 ± 80	2 mm	398.3 ± 192.6	411.7 ± 187.5	478.3 ± 188.1	442.5 ± 190.8	2 mm	170 ± 68.9	185 ± 70.1	223.3 ± 86	185 ± 72.6
	5 mm	214.7 ± 91.5	221.2± 85.1	213.8± 78	219.2 ± 92.2	5 mm	463.3 ± 201.3	465 ± 186.1	592.5 ± 156.5	490 ± 173	5 mm	169.2 ± 52.7	170.8 ± 40.9	250.8 ± 93.7	231.7 ± 179.6
	10 mm	217 ± 56.8	214.9± 52	219.1 ± 55	218.5 ± 55.2	10 mm	482.5 ± 177	501.7 ± 201.7	486.7 ± 150	253.3 ± 141.9	10 mm	181.7 ± 36	181.7± 37.2	205.8 ± 73.8	186.7 ± 76.3
Tongue base	Without PAP	213.8 ± 48.9	230.1± 59.5	205.8± 39.6*	219.3 ± 34.3*	Without PAP	472.5 ± 91.9	472 ± 89.7	487.5 ± 85	410.8 ± 67	Without PAP	290 ± 92.6	301.7 ± 106.9	242.5 ± 80	230.0 ± 49.6
	2 mm	233.7 ± 44.8	228.4± 54.4	259.9± 62.6*	260.9± 70.3*	2 mm	426.7 ± 116.8	455 ± 80.3	422.5 ± 82.4	430.8 ± 70.7	2 mm	237.5 ± 80.1	276.7 ± 65.7	234.2 ± 63.9	233.3± 63.7
	5 mm	270.5 ± 82.4	256 ± 67.2	247.1 ± 49.2*	252.2± 50*	5 mm	404.2 ± 84.6	450.8 ± 140.4	460 ± 111.4	455.8 ± 95.3	5 mm	246.7 ± 70.4	290.8 ± 99.2	243.3 ± 87.6	246.7± 99.4
	10 mm	246.9 ± 76.6	266.9 ± 102.1	275.3 ± 82.9*	295.4± 102.7*	10 mm	431.7 ± 110.4	451.7 ± 139.8	415.8 ± 139.8	447.5 ± 136	10 mm	260 ± 62.7	266.7 ± 119.4	245 ± 112.9	262.5 ± 108.3
Lowerpharynx	Without PAP	213.2 ± 74.2	250 ± 90.7	297.2 ± 93.3*	315.1 ± 105.4	Without PAP	367.5 ± 115.4	347.5 ± 120.3	350.8 ± 95.8	315.7 ± 115.7	Without PAP	211.7 ± 73.7	190.8 ± 65.2	190.8 ± 63.8	197.5 ± 58.4
	2 mm	246 ± 65.7	236.9 ± 59.6	268.6 ± 84.6*	246± 48.2	2 mm	345.8 ± 98.6	357.5 ± 125.5	340 ± 118.2	376.7 ± 146.9	2 mm	197.5 ± 61	190.8 ± 57.8	195.8 ± 73.7	191.7 ± 61.2
	5 mm	227.9 ± 76.2	231.7 ± 62.1	256.2 ± 92.8*	268.6± 75.9	5 mm	392.5 ± 135.7	366.7 ± 107.8	343.3 ± 85.6	360 ± 88.6	5 mm	223.3 ± 77.3	199.2 ± 61	190.8 ± 47.7	1916.7 ± 35.6
	10 mm	233.7 ± 111.5	240.5 ± 107.7	248.6 ± 75*	261.8± 61.2	10 mm	332.5 ± 104.6	315.8 ± 99	315.7 ± 126.2	341.7 ± 93.7	10 mm	189.2 ± 50	180.8 ± 63.5	196.7 ± 66.5	185.5 ± 45
		Duration of relaxation of the upper esophageal sphincter (msec)				Maximum pre-opening UES pressure(mmHg)					Maximum post-closure UES pressure(mmHg)				
		Saliva	Water	Jelly	Thin rice porridge		Saliva	Water	Jelly	Thin rice porridge		Saliva	Water	Jelly	Thin rice porridge
UES	Without PAP	554.2 ± 160.5	660.8 ± 118.5	576.7 ± 128	663.3 ± 179.6	Without PAP	186.8 ± 92.2	154.5 ± 53.6	158.6 ± 84	160.6 ± 70.4	Without PAP	329.4 ± 138.8	353.6 ± 123	369.5 ± 142.3	376.6 ± 138.9
	2 mm	563.3 ± 198.8	646.7 ± 175.5	589.2 ± 165.3	633.3 ± 179.6	2 mm	156.5 ± 60.2	163.3 ± 51.9	153.6 ± 75.2	144.9 ± 62.6	2 mm	320.2 ± 124.4	375.2 ± 126.1	316.8 ± 123	352.2 ± 126.5
	5 mm	582.5± 203.8	727.5 ± 243.4	652.5 ± 204.6	617.5 ± 133.4	5 mm	159 ± 58.9	131.9 ± 49	169.3 ± 49.6	175 ± 54.7	5 mm	359.4 ± 119.1	396 ± 110.2	316.8 ± 123	377.5 ± 110.1
	10 mm	580.8 ± 147	598.3 ± 183.4	576.7 ± 217.2	567.5 ± 51.7	10 mm	161.3 ± 83.2	174 ± 53.2	190.4 ± 108.5	191.7 ± 74	10 mm	330.3 ± 138.3	311.4 ± 122.9	311.4 ± 109.7	325.1 ± 119.6

Note: Mean ± SE *P<0.05

Table 1: Comparison of HRM parameters between without PAP and different thickness PAP (2 mm, 5 mm, 10 mm)

without, and maximum post-closure UES pressure was lower with PAP than without, but neither was statistically significantly different.

Effect of different texture swallows with thickness PAP for the dynamics of swallowing

For different texture swallow, No differences were found among maximum swallowing pressure, duration of contraction, and time of contraction to peak, at the level of the velopharynx, tongue base, and lower pharynx, duration of relaxation of the upper esophageal sphincter (UES), maximum pre-opening UES pressure, and maximum post-closure UES pressure with all PAP (2 mm, 5 mm, 10 mm) (Table 1).

Relationship between maximum pressure at tongue base and at hypopharynx with PAP of each thickness

There was no significant correlation between maximum pressure at tongue base and maximum pressure at hypopharyngeal with PAP of each thickness.

Discussion

This study investigated the effect of three different thicknesses PAP for Dynamics of Swallowing of healthy individuals by High-Resolution Manometry.

Clinically it is necessary to fabricate PAP in accordance with the form of patient tongue movement. Material is added layer to the palatal of PAP and the patient is asked to swallow several times and pronounce some letters or phonemes. Extra material is added until optimum functions are achieved. But object of study was healthy individuals, and therefore palatal form of PAP fabricated same form.

Maximum tongue base pressure was significantly higher jelly 3 g and thin rice porridge 3g swallow with a thickness of 10mm PAP when compared to the without PAP. Analysis of tongue movement during swallowing ,the contact tongue tip and hard palate plays an important role as an anchor when the central portion of the tongue propels the bolus posteriorly. PAP provides adequate tongue contact to anchor the tongue tip, enhances the pharyngeal pressure and dynamics of pharyngeal events. The stress on anchor function produced the decrease in anterior bulging of the posterior pharyngeal wall (PPW) and the increase in peek pressure at tongue base, whereas the swallow without anchor function produced an increase in PPW bulging and a decrease in peek pressure at tongue base [12] and effort swallow increased pressure on the bolus and reduce bolus Pharyngeal residual [13]. It was suggested that thickness PAP as 10 mm wearing reduced the intraoral volume and increased the force to contact the palate and tongue base, resulting caused effort swallow. As a result, the tongue's anchoring function is strengthened and the posterior movement of the tongue base is reinforced, so it is thought that the maximum pressure at tongue base rises. It was suggested that changes in the base of the tongue could not be observed unless an excessive thickness of 10 mm was added.

The hypopharyngeal maximum swallowing pressure has been reported to decrease in patients with ALS [14] and patients with tongue cancer removal by PAP [5]. Also, in this study, PAP of 10 mm decreased the hypopharyngeal maximum pressure in comparison to without PAP. In patients with partial tongue resection improved tongue anchor function and ejection of the bolus with PAP. There was no need for excessive pharyngeal contraction, resulting in a decrease in hypopharyngeal maximum swallowing pressure [5]. For receiving 3 g jelly and thin 3 g rice porridge with PAP of 10 mm, the maximum pressure at base of tongue was higher than without PAP, hypopharyngeal maximum pressure was lower than without PAP. But there was no statistically significant difference in these correlations. The anchor function is strengthened by PAP wearing in healthy adults, and the rise in the maximum pressure at the tongue base may not be a factor affecting the pharyngeal contraction in the hypopharynx.

A thick PAP affected the maximum pressure of the tongue base and hypopharynx. Particularly it was suggested that no change Pharynx maximum pressure was observed unless an excessive thickness PAP of 10 mm was added. The Pharynx pressure detected at the tongue base during swallowing has been reported to be the force to feed the bolus into the hypopharynx and esophagus [15].

If the pressure at the tongue base changes with the thickness of PAP, in patients with dysphagia, it is not only made by thickening according to tongue dysfunction, but also the thickness that changes the pressure at the tongue base is examined with HRM. Assessing may be a means to enhance the effectiveness of PAP. In the future, we will examine whether the difference in PAP thickness affects the swallowing dynamics and whether it is effective as dysphagia rehabilitation in patients with oral dysfunction, oral flail and oral dysfunction.

Conclusion

A thick PAP affected the maximum pressure of the tongue base and hypopharynx. Particularly the thickness of 10mm PAP enhanced the anchor of the tongue, and increased the maximum pressure at the base of the tongue. It was suggested that no change Pharynx maximum pressure was observed unless an excessive thickness PAP of 10 mm was added in healthy individuals.

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