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Review

Effect of Palatal Augmentation Prosthesis on Speech and Swallowing in Tongue Dysfunction: A Literature Review

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Abstract：

Purpose: Palatal augmentation prosthesis (PAP) is used on patients with dysphagia and dysarthria. While several studies have evaluated the effects of PAP, evidence regarding the adaptation criteria, effects, and limitations of PAP are not well organized. This review aims to summarize its functions, limitations, and applications.

Procedure: To investigate the adaptation criteria, effects, and limitations of PAP, we searched the English language literature published in PubMed from its inception through April 20, 2022. The leading search terms included "palatal augmentation prosthesis."

Main findings: The primary search used keywords that reflected 31 studies. Finally, nine cross-sectional studies and nine case reports were selected for full-text assessment after applying the inclusion criteria. Eleven studies described the efficacy of speech function: two for motility factors and nine for organic factors (with overlap). Thirteen studies described the effectiveness of swallowing function, four related to motility factors, and ten for organic factors (with overlap). Several studies have demonstrated that PAP effectively restores articulation and swallowing in patients with impaired tongue function after glossectomy for oropharyngeal cancer, sequelae of cranial nerve disease, or neuromuscular disease. However, few papers describe the scope of glossectomy and tongue movement restrictions, so it is impossible to describe the adaptation criteria, effects, and limitations. In this review, most case reports and cross-sectional studies did not provide information on the fabrication methods of PAP or the dentists' experience. Thus, the effect of bias on palatal morphology in PAP patients remains unclear.

Conclusions: The number of patients with dysarthria and dysphagia is increasing worldwide, similar to what is already occurring in Japan. Therefore, additional high-quality studies on the effects of PAP are required.

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1. Introduction

Palatal augmentation prosthesis (PAP) is used on patients with dysphagia or dysarthria due to tongue dysfunction caused by surgical resection of tongue cancer, sequelae of cerebrovascular disorders, and neuromuscular diseases. There are many reports on the effects of PAP on dysphagia or dysarthria caused by organic factors such as glossectomy[1-7] and motility factors such as sequelae of cerebrovascular or neurological disorders[8-11].

Marunick et al.[12] reviewed the efficacy of palatal augmentation prostheses for speech and swallowing in patients undergoing glossectomy in 2004; nine articles evaluating the efficacy of PAP on speech and swallowing for patients undergoing glossectomy were selected. However, because of inconsistent methods of participant selection and nonuniform objective measurement of function across studies, the results of these nine studies could not be combined statistically.

Furthermore, the Japanese Society of Gerodontology and the Japan Prosthodontic Society investigated the effects of PAP on dysphagia and dysarthria and published it as a clinical practice guideline in the Medical Information Distribution Service Guidelines library in 2020. This guideline describes the effects of PAP, but only in Japanese.

Thus, PAP is an effective prosthesis for dysphagia and dysarthria caused by organic and motility factors. However, regardless of the factors of tongue dysfunction, evidence regarding the adaptation criteria or effects and limitations of PAP has not been well organized.

Therefore, we have reviewed the literature on PAP and summarized its functions, limitations, and applications.

2. Material and Methods

2.1 Data Sources and Searches

To investigate the adaptation criteria, effects, and limitations of PAP, we searched the English language literature published in PubMed from its inception through April 20, 2022. The leading search terms included "palatal augmentation prosthesis." Electronic database searches were performed using the following keywords: "palatal augmentation prostheses" [All Fields] OR "palatal augmentation prosthesis" [All Fields]. A manual search was also performed.

2.2 Inclusion Criteria

Articles were selected based on the following inclusion criteria: 1) articles describing the effectiveness and benefits of using PAP and 2) full-text articles written in English. The exclusion criteria were literature review, *in vitro* and animal studies, and questionnaire survey reports.

2.3 Study Selection

Figure 1 illustrates the literature search strategy used in this study. Three reviewers (K.N., K.F., and H.S.) contributed to this review. Two reviewers (K.N. and K.F.) determined the criteria and independently performed the literature search. Any discrepancies were evaluated by the other reviewer (H.S.) and discussed by all three reviewers. First, the titles and abstracts were selected based on their purpose and criteria. After confirming that the results of the two examiners were identical, a complete examination of the manuscripts was performed, and the articles were screened again.

We conducted a literature review based on the following research question: Does wearing PAP improve speech and swallowing function in people with tongue dysfunction caused by motility or organic factors?

3. Results

3.1 Study selection

As shown in Figure 1, the primary search using the keyword "palatal augmentation prostheses" presented 31 studies. After reviewing the titles and abstracts, 10 studies were excluded based on the inclusion and exclusion criteria, and 21 were selected. In addition, three articles were manually searched. Six studies that were not written about the benefits of using PAP or the evaluation criteria were excluded. Finally, nine cross-sectional studies and nine case reports were selected for full-text assessment after applying the inclusion criteria.

Eleven studies described the effectiveness of speech function, two for tongue dysfunction caused by motility factors and nine for organic factors (with overlap). Thirteen studies described the effectiveness of swallowing function, four by motility factors and ten by organic factors (with overlap).

3.2 Effects of PAP on speech for tongue dysfunction caused by motility factors

Table 1 shows the effects and limitations of PAP on speech in individuals with tongue dysfunction caused by motility factors.

Esposito et al.[9] investigated the effect of PAP on hypernasality, articulation, volume, and clarity of speech in 10 amyotrophic lateral sclerosis (ALS) patients who were treated with a combination of palatal lift prosthesis (PLP) and PAP and reported that 6 (60%) patients demonstrated improvement in articulation. Ono et al.[11] reported that the Japanese single-word intelligibility score increased from 58% before prosthodontic treatment to 79% after placement of PLP and PAP and then to 84% after behavioral management in a 71-year-old stroke patient.

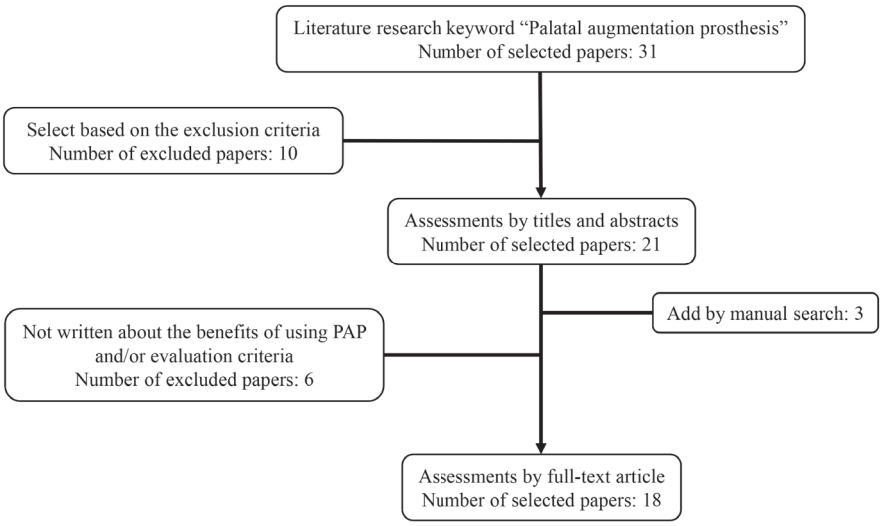

Fig. 1 Literature review strategy

Table 1 Effects and limitations of PAP on speech for the people with tongue dysfunction caused by motility factors

Author	Year	Research type	Subjects No.	Etiology of dysarthria and subject’s oral condition	Evaluation	Effects
Esposito SJ	2000	Cross-sectional	10	ALS patients PLP and PAP	Hypernasality, articulation, volume, clarity of speech, satisfaction and comfort	6/10 (60%) patients demonstrated improvement in articulation after placement of PLP and PAP
Ono T	2005	Case report	1	71-year-old man after stroke PAP and PLP	Conversation speechi ntelligibility	Japanese single word intelligibility improved after placement of PLP and PAP

Table 2 Effects and limitations of PAP on speech for the people with tongue dysfunction caused by organic factors

Author	Year	Research type	Subjects No.	Etiology of dysarthria and subject’s oral condition	Evaluation	Effects
Lofhede H	2020	Cross-sectional	20	Post-surgery for head and neck cancer PAP	Speech intelligibility	Velar sounds improved significantly and easier or better speech for 12 of 19 patients with PAP.
de Carvalho-Teles V	2008	Cross-sectional	36	partial or total glossectomy PAP	Conversation intelligibility	Spontaneous speech intelligibility and the average number of correctly identified syllables significantly improved with PAP
Robbins KT	1987	Cross-sectional	10	partial or total glossectomy PAP	Speech intelligibility	Immediate and long-term improvement in articulation with PAP
Weber RS	1991	Cross-sectional	27	Partial glossectomy: 13 Total glossectomy: 14 PAP: 18 (without PAP: 9) Speech rehabilitation	Communication and speech quality	7 of 18 patients with PAP demonstrated improvement in speech quality All patients without PAP didn’t demonstrated improvement in speech quality
R L Wheeler	1980	Cross-sectional	10	Partial glossectomy PAP Speech and swallowing rehabilitation	Conversation intelligibility	Speech intelligibility improved with PAP
Kozaki KI	2016	Case report	1	50-year-old man Post-surgery for tongue and oropharyngeal cancer PAP and artificial tongue	Speech intelligibility	Speech and conversational intelligibility significantly improved with PAP and artificial tongue
Okuno K	2014	Case report	1	64-year-old man Partial glossectomy PAP+LAP	Speech intelligibility	Speech intelligibility improved with PAP+LAP
Aramany MA	1982	Case report	2	Partial glossectomy PAP	Speech intelligibility	Articulation and resonance are improved with PAP
J W Davis	1987	Case report	1	45-year-old man Partial glossectomy PAP	Speech intelligibility	Intelligibility of /t/ and /d/ was improved 20% and that of /k/ and /g/, 33% with PAP Compromises must be effected in prosthesis design to facilitate improvement in both speech and swallowing

3.3 Effects of PAP on speech for tongue dysfunction caused by organic factors

Table 2 shows the effects and limitations of PAP on speech in individuals with tongue dysfunction caused by organic factors.

Weber et al.[6] investigated the effect of PAP on

Table 3 Effects and limitations of PAP on swallowing for the people with tongue dysfunction caused by motility factors

Author	Year	Research type	Subjects No.	Etiology of dysphasia and subject's oral condition	Evaluation	Effects
Yoshida M	2019	Cross-sectional	15	Stroke: 9 Disuse syn.: 6 PAP	VF Laryngeal penetration or aspiration Pyriform sinus residue Pharyngeal delay time Pharyngeal transit time	Disappearance of laryngeal penetration or aspiration in 2 (disuse, stroke) and pyriform sinus residue in 3 (stroke) with PAP Pharyngeal delay time and pharyngeal transit time were significantly shortened with PAP
Ohno T	2017	Case report	1	61-year-old man Bilateral hypoglossal nerve palsy PAP+LAP	VF Swallowing	Dysphagia improved with PAP and LAP
Ohno T	2017	Case report	1	53-year-old man Postoperative bilateral Hypoglossal nerve injury PAP	VF Pharyngeal swallowing pressure Clearance of oral and pharyngeal residue	Bolus transportation, pharyngeal swallowing pressure, and clearance of oral and pharyngeal residue was improved with PAP
Kikutani T	2006	Case report	1	ALS PAP	Food test Tongue pressure to palate Subjective evaluation of patient	Oral and pharyngeal residue was decreased and tongue pressure was increased with PAP

communication and speech quality in 13 patients who underwent subtotal glossectomy and 14 patients who underwent total glossectomy for locally advanced tongue carcinoma. All patients underwent speech rehabilitation. Eighteen patients used PAP, and seven patients didn't use PAP. Seven of the 18 patients with PAP demonstrated improvement in speech quality, but no improvement in speech quality was observed in all patients without PAP.

In four other cross-sectional studies (subjects:10-36) [1, 3, 13, 14], patients who used PAP after glossectomy demonstrated an improvement in speech intelligibility compared to those who did not. Similar effects were reported in four case reports of patients undergoing partial glossectomy[2, 15-17].

3.4 Effects of PAP on swallowing for tongue dysfunction caused by motility factors

Table 3 shows the effects and limitations of PAP on swallowing in patients with tongue dysfunction caused by motility factors.

Yoshida et al.[18] evaluated the effect of PAP using VF in 15 patients who were diagnosed with dysphagia (stroke, 9; disuse syndrome from pneumonia, 6) and reported that laryngeal penetration or aspiration disappeared in two patients (disuse and stroke) pyriform sinus residue also disappeared in three patients (stroke). Pharyngeal delay time and pharyngeal transit time were significantly shortened with PAP.

Furthermore, three other case reports[19-21] showed improvement in swallowing function with PAP in patients with ALS or bilateral hypoglossal nerve palsy.

3.5 Effects of PAP on swallowing for tongue dysfunction caused by organic factors

Table 4 (a, b) shows the effects and limitations of PAP on swallowing in people with tongue dysfunction caused by organic factors.

Lofhede et al.[14] evaluated the effect of PAP in 20 patients with dysphagia after surgery for head and neck cancer. They reported that 7 of 20 patients self-reported better transport of food or saliva, but PAP was not used/ did not help with oral transport in 10 of 20 patients. Weber et al.[6] investigated the effect of PAP on swallowing in 18 patients who underwent partial or total glossectomy for tongue carcinoma and reported that 13 of the 18 patients achieved oral alimentation with PAP from tube feeding.

Robbins et al.[3] investigated oral cavity residue, tongue movement, the volume of swallowing, gargling voice quality, the timing of hyoid/larynx elevation, and evaluated the effect of PAP during swallowing in 10 patients who underwent partial or total glossectomy. They reported improvements in swallowing function in the oral preparatory and oral propulsive stages and immediate and long-term improvements in swallowing. In other cross-sectional studies and case reports, similar effects were observed, such as the reduction of meal time and pharynx transit time or pyriform sinus residue in patients undergoing partial glossectomy[1, 4, 15, 16, 18, 22, 23].

4. Discussion

Dysfunction of the tongue, due to glossectomy or sequelae of cerebrovascular disorders, and neuromuscular diseases result in reduced contact pressure between the tongue and the palate, leading to dysarthria and dysphagia. PAP is a device that restores contact between the tongue and the palate by thickening the palate of the maxillary denture for such patients. The denture palate is thickened according to the range of movement of the patient's tongue to restore the tongue contact pressure during function.

4.1 Effects of PAP on dysarthria

Evaluation of Speech

Conversations and speech intelligibility are often used to

Table 4-a Effects and limitations of PAP on swallowing for the people with tongue dysfunction caused by organic factors (Cross-sectional study)

Author	Year	Research type	Subjects No.	Etiology of dysphasia and subject's oral condition	Evaluation	Effects
Lofhede H	2020	Cross-sectional	20	Post-surgery for head and neck cancer PAP	Transport of food or saliva Functional oral intake scale(FOIS)	7 of 20 patients self-reported better transport of food or saliva and 10 of 20 patients reported that the PAP was no use/no help with oral transport
Yoshida M	2019	Cross-sectional	3	Bone fracture: 3 Disuse syn.: 6 PAP	VF Laryngeal penetration or aspiration Pyriform sinus residue Pharyngeal delay time Pharyngeal transit time	Disappearance of laryngeal penetration or aspiration with PAP: 1 Pharyngeal delay time and pharyngeal transit time were significantly shortened with PAP
Okayama H	2008	Cross-sectional	7	Post-surgery for tongue cancer PAP	US lingual movement dynamics of the center of tongue during swallowing RSST	Duration of lingual-palatal contact decreased significantly in patients with PAP RSST showed no significant difference between subjects with and without PAP in swallowing PAP was effective for lingual movement on Swallowing
Weber RS	1991	Cross-sectional	27	Partial glossectomy: 13 Total glossectomy: 14 PAP: 18 (without PAP: 9) Speech rehabilitation	VF	13 of 18 patients achieved oral alimentation with PAP
J A Logemann	1989	Cross-sectional	4	Post-surgery for tongue cancer PAP and pharyngeal obturator: 2 PAP: 2	VF Oropharyngeal transit time Duration of tongue contact to pharyngeal wall Speed of movement of bolus	Duration of tongue contact to the pharyngeal wall and speed of movement of the bolus from the valleculae to the pyriform sinus were improved with PAP (and pharyngeal obturator)
Robbins KT	1987	Cross-sectional	10	Partial or total glossectomy PAP	VF Oral cavity residue Tongue movement Volume of swallowing Gargling voice quality Timing of hyoid/larynx elevation	Improvement in oral preparatory stage and oral propulsive stage of swallowing with PAP Immediate and long-term improvement in swallowing with PAP
R L Wheeler	1980	Cross-sectional	10	Partial glossectomy Speech and swallowing rehabilitation PAP	VF Oropharyngeal transit time	Oral transit times decreased for all patients with PAP Pharyngeal transit times decreased except for the patients who had resections of the anterior floor of the mouth with PAP

Table 4-b Effects and limitations of PAP on swallowing for the people with tongue dysfunction caused by organic factors (Case report)

Author	Year	Research type	Subjects No.	Etiology of dysphasia and subject's oral condition	Evaluation	Effects
Okuno K	2014	Case report	1	64-year-old man Partial glossectomy PAP+LAP	Oral cavity residue	Amount of residual food remained after swallowing was reduced withP AP+LAP
Meyer JB Jr	1990	Case report	1	69-year-old man Partial glossectomy	VF Swallowing reflex Pyriform sinus residue Degree of linguopalatal contact	Pyriform sinus residue and aspiration was reduced with PAP
J W Davis	1987	Case report	1	45-year-old man Partial glossectomyP AP	VF Oral and pharyngeal transit time Oral cavity residue Pyriform sinus residue Aspiration	Oral transit time was extended and pharyngeal transit time was reduced with PAP Oral cavity and pyriform sinus residue was reduced with PAP Aspiration was reduced with PAP

evaluate speech. In many studies, evaluators included not only speech pathologists but also dentists[1, 2, 6, 9, 15-17]. Speech intelligibility tests require high proficiency; therefore, they should be evaluated by speech professionals or experts in this field.

Effects of PAP on dysarthria

Expectations of PAP in improving articulation function include the recovery of articulation points of consonants produced mainly in the hard palate and assistance of the tongue during articulation. In addition, it is expected that some vowels can be improved by reducing the volume of the oral cavity as a resonant cavity. Most cross-sectional studies and case reports have reported that PAP affects articulatory function[1-3, 6, 9, 11, 13-17]. However, patients' motility and organic conditions vary widely, and it is not clear why PAP is ineffective in some patients. In addition, there are few reports on the effect of PAP on dysarthria caused by motility factors; therefore, further research is required.

In patients with dysarthria caused by organic factors, PAP has been reported that PAP was effective with lingual augmentation prosthesis (LAP)[16] or an artificial tongue[17]. However, the underlying physiological and anatomical mechanisms remain unclear. Future research on adaptation criteria for prostheses that fill the mandibular space created by glossectomy is expected. However, the effects of training were ambiguous in this study.

4.2 Effect of PAP on dysphagia

Evaluation of swallowing function

Screening tests for dysphagia diagnosis included repetitive saliva swallowing test (RSST), water-swallowing test (WST) , modified water-swallowing test (MWST), food test (FT), and questionnaires. In addition, to swallowing videofluorography (VF) and videoendoscopic evaluations of swallowing (VE) were used for a definitive diagnosis. In this review, many items were used to evaluate dysphagia; however, VF was the most frequently used[1, 3, 4, 6, 15, 18, 20-22]. Although VF has disadvantages, such as the lack of testing equipment in small facilities, radiation exposure to the operator and patient, and the complexity of testing, it is easy to evaluate dysphagia objectively. In addition, pharyngeal swallowing pressure[21], FT[19], post-swallowing oral cavity residue[3, 21], ultrasonography (US)[23], RSST[23], the time required to eat[16], functional oral intake scale (FOIS)[14], subjective patient assessment such as visual analog scale[19], which are used to evaluate swallowing function in daily clinical practice, were used as evaluation methods. These examinations can be performed relatively quickly but are inferior to VF and VE in terms of reproducibility and objectivity. There is also a relatively new evaluation method using tongue pressure[19]. However, the drawback is that measuring equipment is not widely used. On the other hand, Okayama et al.[23] reported that RSST was not possible because of interindividual variation in post-surgery patients with tongue cancer and recommended the need for food testing or other tests to secure more detailed data.

Effect of PAP on dysphagia

Motility factors that cause tongue dysfunction are cranial nerve diseases, such as stroke, ALS, and hypoglossal nerve palsy. Restricted tongue movement reduces pressure on the palate during swallowing. Consequently, the swallowing pressure does not increase to the value that transports the bolus to the pharynx, and dysphagia develops. PAP is a prosthesis that improves bolus transport by restoring tongue pressure to the palate. Patients with cerebrovascular disorders often restrict both the tongue and swallowing-related muscles. Individual differences in the degree of these restrictions have resulted in an evaluation bias in cross-sectional studies. In contrast, in patients with tongue dysfunction caused by organic factors, the difference in the extent of tongue resection among patients has been biased in research.

However, most studies and case reports have indicated the effect of PAP[1, 3, 4, 6, 14-16, 18-23], and these results suggest that PAP is a handy oral appliance for dysphagia. In case reports, the effects of the combined use of PAP and LAP have been reported[16, 20]; however, the adaptation criteria for LAP, manufacturing methods, and its effects are still unclear.

4.3 Adaptation criteria, effects, and limitations of PAP

Several studies have demonstrated that PAP effectively restores articulation and swallowing in patients with impaired tongue function[1, 3, 6, 14-16]. However, few papers describe the scope of glossectomy and tongue movement restrictions, so it is impossible to describe this review's adaptation criteria, effects, and limitations.

In the fabrication of PAP, palate morphology changes depending on the materials, the type of task, the timing of performing the task, and the experience of dentists, and also affects swallowing and articulation after wearing the PAP. In this review, some case reports described the fabrication methods of palate morphology[3, 9, 14]. Still, other case reports and cross-sectional studies did not provide information on the fabrication methods of PAP or dentists' experience. Thus, the effect of bias on palatal morphology in PAP remains unclear. Therefore, high-quality research studies—such as randomized controlled trials that standardize tongue disorders, PAP preparation methods, and functional evaluation methods—are required.

The greater the volume of the glossectomy area, the smaller the effects of LAP. In this review, the details of the fabrication methods for LAP have not been described[16, 20]. Therefore, the criteria for the combined use of PAP and LAP to fill the gap between the tongue and alveolar/teeth after glossectomy have not been deciphered. In addition, although several studies have combined PAP with swallowing and articulation training/guidance, no reports have demonstrated their effectiveness.

Objective functional assessments of speech and swallowing were better with PAP than without, but it did not sufficiently improve patient satisfaction or QOL in some cases[9, 19].

The ideal forms of PAP that restore speech and swallowing are contradictory. Ideally, improving both articulation and swallowing with PAP is complex, and improvement in one or both effects must be compromised[15]. It was also reported that two PAPs were produced for both purposes and used according to purpose[1].

The strength and dexterity of the tongue decline with age, even without a medical history of glossectomy or cranial nerve disease. No studies have investigated the effects of PAP in older adults. In preparation for a super-aging society worldwide, it is necessary to clarify the effects of PAP on older adults in the future.

In this review, adaptation criteria and limitations of PAP were unclear, but the benefits of PAP were clear. These results are consistent with those of Marnick et al.'s review[12] and the Minds guideline. In older adults even without a medical history of glossectomy or cranial nerve disease, we recommend evaluating articulatory and swallowing functions

and actively applying PAP, if tongue function is weak.

5. Conclusion

PAP is a prosthetic device expected to be effective in patients with dysarthria and dysphagia caused by organic or motility factors. However, this review could not elucidate the adaptation criteria, benefits, and limitations of PAP. In addition, the effects of guidance/rehabilitation and the criteria for the concomitant use of LAP are unclear.

In Japan, the number of patients with dysarthria and dysphagia after surgery for oropharyngeal cancer, sequelae of cranial nerve disease, and aging is increasing. A similar phenomenon might occur in other countries with an advanced aging population. Therefore, additional high-quality studies on the effects of PAP are required.

Conflicts of interest

The authors declare no conflict of interest.

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