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Case Report

Structure of a New Palatal Plate and the Artificial Tongue for Articulation Disorder in a Patient with Subtotal Glossectomy

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A palatal augmentation prosthesis (PAP) is used to facilitate improvement in the speech and swallowing functions of patients with tongue resection or tongue movement disorders. However, a PAP's effect is limited in cases where articulation disorder is severe due to wide glossectomy and/or segmental mandibulectomy. In this paper, we describe speech outcomes of a patient with an articulation disorder following glossectomy and segmental mandibulectomy. We used a palatal plate (PP) based on a PAP, along with an artificial tongue (KAT). Speech improvement was evaluated by a standardized speech intelligibility test consisting of 100 syllables. The speech intelligibility score was significantly higher when the patient wore both the PP and KAT than when he wore neither ($p = 0.013$). The conversational intelligibility score was significantly improved with the PP and KAT than without PP and KAT ($p = 0.024$). These results suggest that speech function can be improved in patients with hard tissue defects with segmental mandibulectomy using both a PP and a KAT. The nature of the design of the PP and that of the KAT will allow these prostheses to address a wide range of tissue defects.

Key words: palatal augmentation prosthesis, artificial tongue, articulation disorder, glossectomy, mandibulectomy

A palatal augmentation prosthesis (PAP) is used to facilitate improvement in the speech and swallowing functions of patients with tongue resection or tongue movement disorders. Many studies have described PAP's effectiveness for patients with impaired tongue function, and its efficacy for dysphagia and articulation disorder has been widely recognized. Using tests for articulation disorder, Cantor *et al.* and Leonard *et al.* have reported improvements in speech

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and conversational intelligibility with the use of a PAP [1, 2]. However, PAP's effect is limited for patients with severe articulation disorders associated with wide glossectomy and/or segmental mandibulectomy. Few studies have demonstrated the effectiveness of PAP in patients with hard tissue defects with segmental mandibulectomy [3]. This clinical report describes the positive outcomes of a patient with an articulation disorder following glossectomy and segmental mandibulectomy. The report describes the structure and use of a palatal plate (PP) based on a PAP in conjunction with an artificial tongue (KAT).

Case Report

A 50-year-old man, complaining of pain on the right margin of his tongue, was assessed at the Department of Oral and Maxillofacial Reconstructive Surgery, Okayama University Hospital, in April 2014. He was diagnosed with tongue cancer (cT4aN2bM0 Stage IV) by a CT scan and biopsy, and was treated the following month using combination chemotherapy with fluorouracil and Acpra. After that treatment, surgical intervention took place in June of that year, involving subtotal glossectomy, right cervical dissection, right cricopharyngeus muscle amputation and laryngeal elevation. After the cancer recurred in August 2014, the patient received oropharyngeal carcinoma removal surgery, segmental mandibulectomy, mesopharyngeal tumor resection, mandibular bone debridement, and reconstruction with an anterolateral thigh flap. The cancer recurred again in October 2014, leading to right mandibulectomy, left cervical dissection, and left neck dissection with reconstruction using the left-front outside thigh free flap. The patient started rehabilitation in June 2015.

Fig. 1 shows a panoramic X-ray following the three operations. The right mandibular jaw defect, right buccal mucosa, base of the tongue, floor of the mouth, soft palate, oropharyngeal sidewall, and reconstruction using the rectus abdominis muscle free flap are shown. In this case, the patient lost oral soft tissue because his weight markedly decreased due to ill health and the recurring cancer. The patient was referred to the Department of Oral Rehabilitation and Occlusion, Okayama University, for treatment with a PAP. We applied a PP to the patient's maxilla and a KAT to his mandibule to improve his articulation abilities (Fig. 2).

We made a PP to provide increased linguopalatal contact. The PP was made of hard thermoplastic resin with a thickness of 0.5 mm (Fig. 3). The posterior edge was left open to enhance speech quality. The KAT consisted of hard thermoplastic resin covering part of the lower teeth and a resin plate over the dorsum of the tongue (Fig. 4). Each part was connected with Ni-Ti wire (0.016 inch diameter). Silicone (SOFRELINER S, Tokuyama Dental Corporation, Tokyo, Japan) covered the surface of the resin plate of the KAT to fill up the space between the PP and the resin plate in the tongue position when the patient raised the KAT. Because Ni-Ti wires are flexible, the

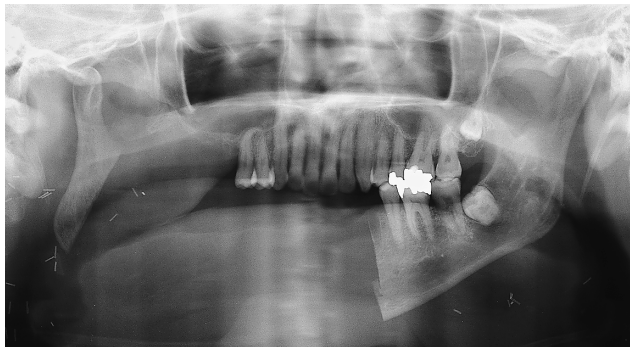

Fig. 1 Panoramic X-ray following three operations including right mandibulectomy.

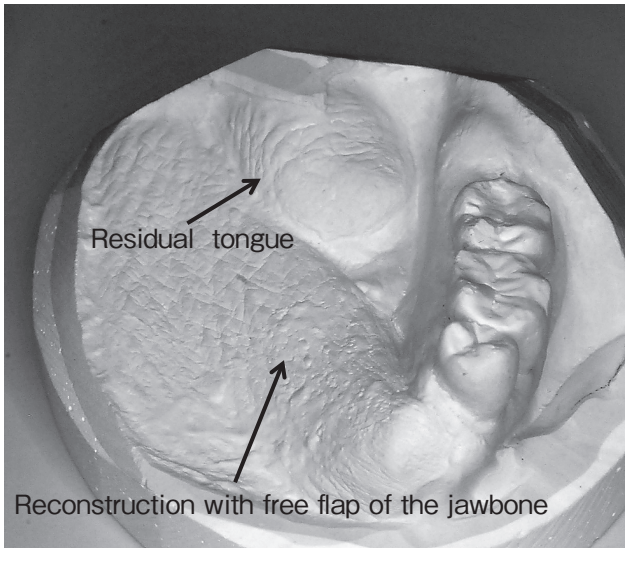

Fig. 2 Photograph of the plaster model of the patient's mandibular.

silicone part of the KAT can be raised with a little tongue power (Fig. 5A) and returned to the resting position as needed (Fig. 5B). The KAT is designed to produce a plosive/p/when a patient presses their tongue, and a nasal/n/or a tap or flap/r/when they push and slowly raise their tongue. Fig. 6 shows photographs of states inside the patient's mouth with and without a KAT. The patient wears neither the PP nor the KAT during meals.

The patient started wearing the PP and KAT in April 2015. In June, we evaluated his ability to produce speech in single syllables and in conversation. The patient trained with both the PP and KAT for a month and a half. In the following section, we describe the evaluation method used to monitor his speech outcomes. Speech improvement was evaluated using a standardized speech intelligibility test consisting of 100 syllables. Five naive listeners, people who had no knowledge of speech therapy, and whose hearing was within normal limits, were recruited as examiners. For the speech intelligibility test, the patient was asked to produce 100 syllables, which were recorded to an IC recorder (RR-XS455-W, Panasonic, Osaka, Japan) and then played back to the 5 examiners. For the conversational assessment, the patient was instructed to read sentences, which were also recorded and then played back to the same 5 examiners. The examiners evaluated each utterance using a 5-point Likert scale comprising the phrases: 1-understand well; 2-sometimes I can't understand; 3-if I know the story/context, I can recognize what is being said; 4-sometimes I can understand; 5-I can't understand at all.

The percentage of correct answers obtained on the speech intelligibility tests was used as the speech intelligibility score. We further detailed the speech intelligibility score according to the place and manner of articulation. The place of articulation was described using 6 categories: bilabial, alveolar, alveopalatal,

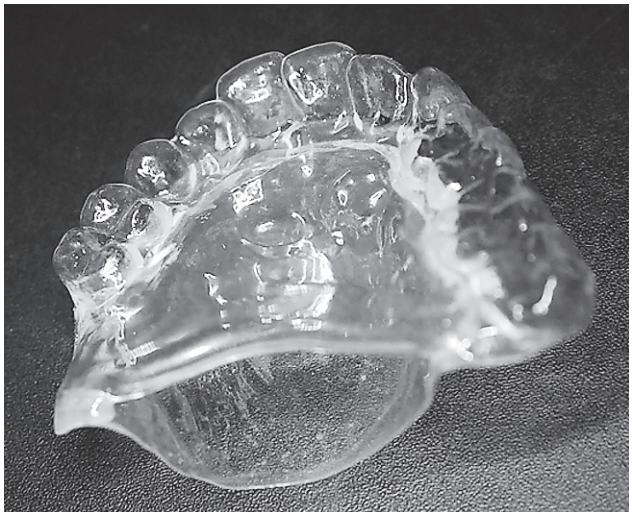

Fig. 3 Palatal plate showing the open posterior edge.

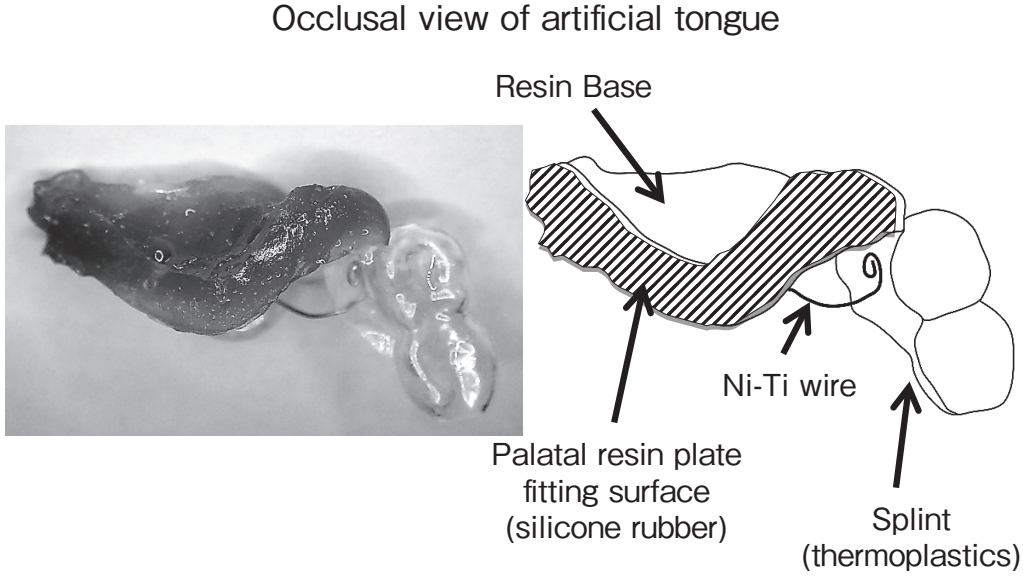

Fig. 4 Photograph (left side) and schematic diagram of the artificial tongue in occlusal view.

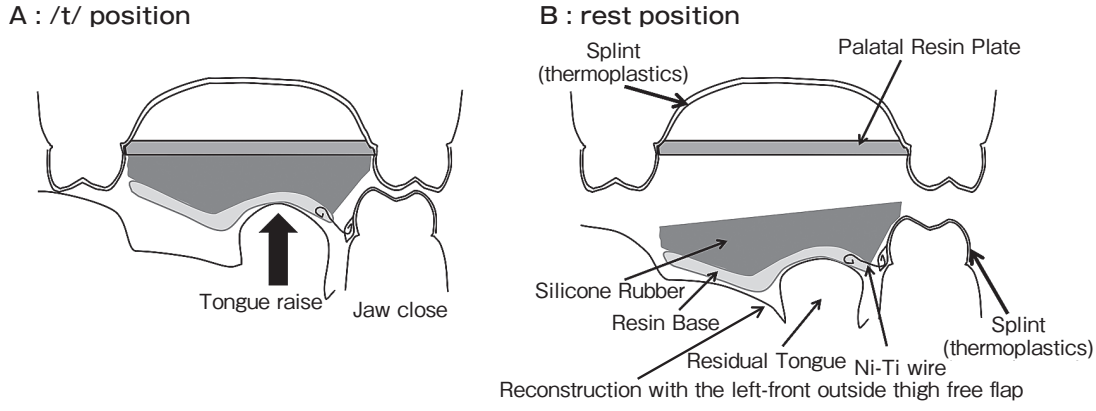

Fig. 5 Schematic diagram of the palatal plate and artificial tongue. The silicone part of the artificial tongue can be raised up with minimal tongue power such as in the/t/position (**A**), and can be returned to the original rest position afterwards (**B**).

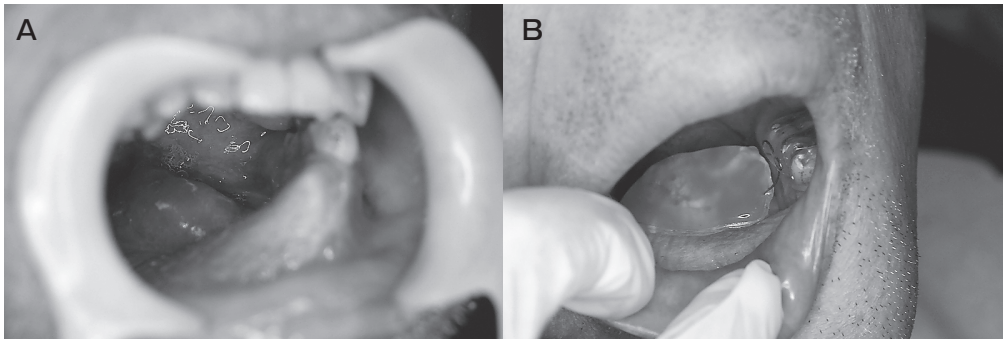

Fig. 6 Photographs of the patient's mandibular without the artificial tongue (**A**) and with it (**B**).

Table 1 Classification of Japanese consonants by place and manner of articulation

	Plosive	Fricative	Affricate	Tap or flap	Nasal	Approximant
Bilabial	p (a, ɯ, e, o, ja, ji, jɯ, jo) b (a, ɯ, e, o, ja, ji, jɯ, jo)	ɸɯ			m (a, ɯ, e, o, ja, ji, jɯ, jo)	β̞a
Alveolar	t (a, e, o) d (a, e, o)	s (a, ɯ, e, o)	tsɯ dz (a, ɯ, e, o)	r (a, ɯ, e, o, ja, ji, jɯ, jo)	n (a, ɯ, e, o, ja, ji, jɯ, jo)	
Alveopalatal		ɕ (a, i, ɯ, o)	tɕ (a, i, ɯ, o) dʑ (a, i, ɯ, o)			
Palatal		ç (a, i, ɯ, o)				ja, jɯ, jo
Velar	k (a, ɯ, e, o, ja, ji, jɯ, jo) g (a, ɯ, e, o, ja, ji, jɯ, jo)					
Glottal		h (a, e, o)				

palatal, velar, and glottal. The manner of articulation was classified as either plosive, fricative, affricate, tap or flap, nasal, or approximant. The classification of Japanese consonants is described in Table 1. We also evaluated the patient's vowel production. The Likert scale rating was used to evaluate sentences spoken in the conversational intelligibility assessment and gave the conversational intelligibility score. One-way analysis of variance (ANOVA) and Tukey's *post-hoc* test were used. These statistical analyses were performed using the statistical software package SPSS Statistics, Release 22.0 (IBM Japan Ltd., Tokyo, Japan). A significance level of 0.05 was adopted.

This study was conducted in accordance with the Declaration of Helsinki. The patient gave his informed written consent to participate in the project.

The speech intelligibility score was 29.0% with neither the PP nor the KAT, 32.8% with the PP, and 39.0% when the PP and KAT were used together (Fig. 7). The score was significantly higher with the PP and KAT than with the PP alone ($p = 0.013$). The conversational intelligibility score was 2.2 with neither the PP nor the KAT, 1.6 with the PP, and 1.2 with the PP and KAT together (Fig. 8). The conversational intelligibility score was significantly higher with the PP and KAT than when neither was worn ($p = 0.024$). The percentages of correct answers for all of the manner-of-articulation categories were higher when the PP and KAT were worn (Fig. 9). In particular, plosives and taps/flaps were noted to have increased accuracy. The speech intelligibility scores for alveolars increased from 3% to 20% correct in the plosive category. Scores for taps/flaps were slightly lower

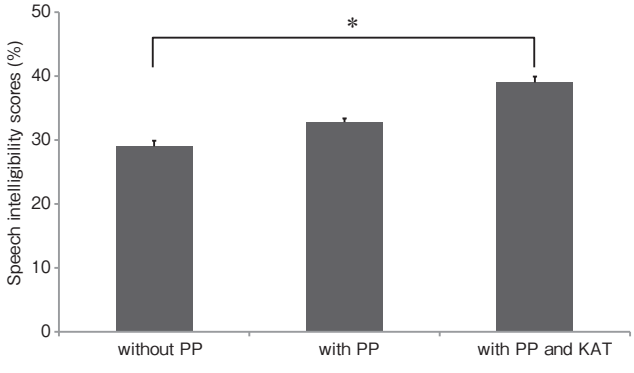

Fig. 7 Speech intelligibility scores with neither the palatal plate nor the artificial tongue (29%), with the palatal plate alone (32.8%), and with the palatal plate and artificial tongue together (39.0%).

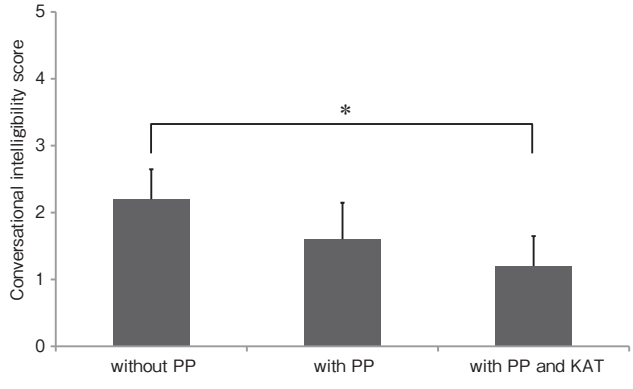

Fig. 8 Conversational intelligibility scores with neither prosthesis (2.2), with the palatal plate only (1.6), and with the palatal plate and the artificial tongue together (1.2).

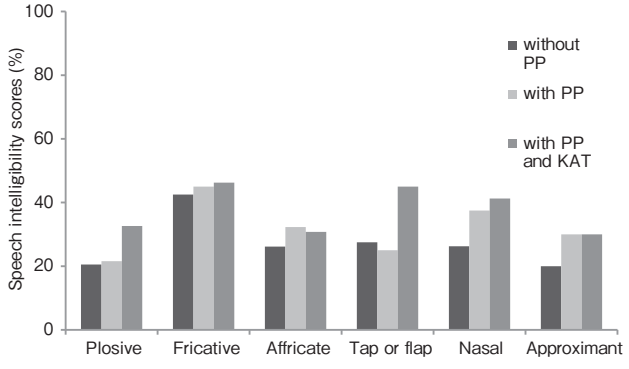

Fig. 9 Speech intelligibility scores for all categories of manner of articulation. Percentages of correct answers of plosives and taps/flaps were notably increased with the palatal plate and the artificial tongue together.

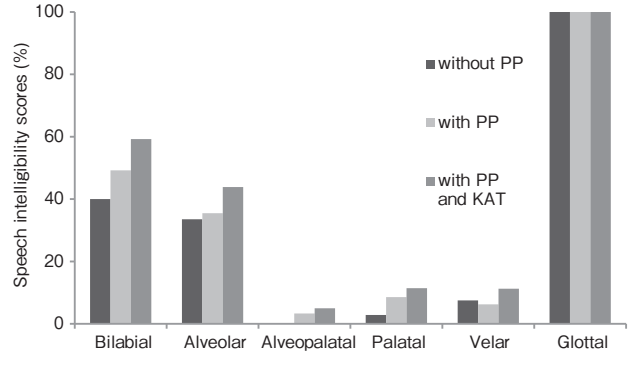

Fig. 10 Speech intelligibility scores for all places of articulation. The speech intelligibility scores for velars decreased slightly when only the palatal plate was worn.

when only the PP was worn than when neither prosthesis was worn, and were highest when both the PP and KAT were worn. All speech intelligibility scores increased in terms of accuracy of place articulation (Fig. 10). The speech intelligibility scores for velars decreased slightly when only the PP was worn than when neither was worn. Vowel production did not appear to be influenced by the PP or by the PP and KAT together, since the speech intelligibility outcomes for these sounds remained unchanged.

Discussion

Speech intelligibility outcomes are typically evaluated using standardized assessments consisting of 25–100 syllables [4]. A standardized speech intelligibility test comprising 100 syllables has been widely used because it is objective and its results can be compared to normative data. However, this type of assessment is limited when used with individuals who have severe speech difficulties because the lack of contextual cues makes conversation difficult to evaluate [5]. A speech intelligibility test consisting of 25 syllables was devised by Ohkubo *et al.*, who used it with patients following glossectomy; they found similar results on the shorter test to those obtained for the speech intelligibility test with 100 syllables [6]. Tanaka *et al.* reported similar results in their study of patients post-oropharyngeal cancer surgery [7]. However, Itoh *et al.* cautioned that speech intelligibility scores from 100-syllable assessments are typically significantly lower than the results obtained from shorter assessments, especially for patients with moderate or severe speech difficulties [8]. In this case, we used a speech intelligibility test that consisted of 100 syllables for a patient who had severe articulation difficulties due to wide glossectomy and/or segmental mandibulectomy. We used the conversational intelligibility score as an additional measure to compensate for any difficulties arising from the selection of the 100-syllable speech intelligibility test.

The speech intelligibility scores for nasals and approximants showed an increasing trend when both the PP and KAT were worn. We considered that our patient could easily use the dorsum of his tongue to touch the PP with the KAT. It was thus expected that the speech intelligibility score for these sounds would increase more when both the PP and KAT were worn. However, there was little difference compared with the PP-only condition. It is possible that our patient could easily produce nasals and approximants with the PP because of the optimal resonance effects of the oral capacity in this condition.

The speech intelligibility scores of taps or flaps decreased slightly with the PP than without it. Yokoyama *et al.* also reported that speech intelligibility scores for taps or flaps decreased when a PAP was worn [3]. However, in our study, the intelligibility scores for these sounds increased when both the PP and KAT were worn. It is considered that tongue movement is more complicated when we produce taps or flaps than any other sound. The patient may have been able to produce these with the KAT because it helped his tongue make contact with the PP. The speech intelligibility score for plosives also increased when both the PP and KAT were worn in this case. Notably, the speech intelligibility score of alveolar plosives increased from 3% to 20% when both the PP and KAT were worn. As noted above, it is thought that the patient could easily use the tip of his tongue to touch the PP with the KAT.

Cantor *et al.* reported that speech intelligibility significantly improved when a PAP was implemented together with rehabilitation, in contrast with the situation when a PAP was used without rehabilitation [1]. Curtis *et al.* noted that speech intelligibility scores were unaffected by PAP use, but improvement was linked to whether rehabilitation was offered (whether with or without a PAP) [9]. It is known that articulation function is greatly improved with rehabilitation in the first 6 months post-surgery. In the present case, it is expected that the patient's speech will improve further in the future, because our evaluation took place 6 weeks after he had been given the PP and KAT shortly after surgery. On the other hand, his conversational intelligibility test score has already improved sufficiently. The improvement was caused by the fact that the words could be recognized by analogy even if the syllables of the word could not be recognized.

The present results suggest that use of the PP and KAT together could improve speech function in patients with hard tissue defects with segmental mandibulectomy. The design of the PP and that of the KAT are flexible enough to allow modification for use with patients who have a wide range of tissue defects.

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