



Title	Association Between Speech Intelligibility and Tongue Perception in Patients With Malignant Tongue Tumors
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Citation	Oral Science International. 2025, 22(3), p. e70017
Version Type	AM
URL	https://hdl.handle.net/11094/102842
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Title: Association between speech intelligibility and tongue perception in patients with malignant tongue tumors

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Abstract

Aim: This study aimed to evaluate the association between pre- and postoperative changes in objective speech intelligibility and tongue perception in patients with malignant tongue tumors.

Methods: The study included a total of 20 patients with malignant tongue tumors. Objective speech intelligibility was assessed using UDTalk, a speech recognition software. Speech intelligibility was calculated at a maximum of 100%. Objective tongue perception was evaluated using an electrical stimulator. Perceptual thresholds for the tongue apex, margin, and dorsum on the nontumor and tumor sides were also evaluated. Each parameter was examined pre- and postoperatively (1, 3, 6, and 12 months).

Results: In the forearm flap (AF) group, which included patients who underwent tongue resection and reconstruction with a radial forearm free flap, speech intelligibility 1 month postoperatively was significantly lower than that preoperatively ($P < 0.01$). However, postoperative speech intelligibility improved over time, and speech intelligibility 12 months postoperatively was significantly better than that 1 month postoperatively ($P < 0.01$). In the AF group, tongue perception on the nontumor side 1 month postoperatively tended to decrease and, gradually improved over time. Perception 12 months postoperatively recovered to the preoperative level. In the AF group, speech intelligibility change and tongue perception on the nontumor side changed 12 months postoperatively showing a significant correlation when compared with that preoperatively (tongue apex, $r = 0.6781$, $P < 0.05$; tongue margin, $r = 0.7276$, $P < 0.05$)

Conclusion: In the AF group, changes in tongue perception on the nontumor side may influence speech intelligibility.

KEY WORDS: Tongue cancer, speech recognition software, speech intelligibility, tongue perception.

1 INTRODUCTION

Tongue cancer is more common among oral cancers and is encountered more frequently in clinical practice. Treatment for tongue cancer mainly involves surgery. Such surgical treatment affects patients' oral and maxillofacial functions, such as swallowing, chewing, and speech. In particular, patients who have undergone flap reconstruction after tongue cancer resection experience a significant decrease in oral and maxillofacial functions¹⁻⁸, as well as a significant decrease in tongue perception. In an interview, patients with tongue cancer reported decreased swallowing and chewing function with decreased postoperative tongue perception³. Therefore, in our interviews with patients diagnosed with tongue cancer, many of them complained that chewing and speech function were diminished because of decreased tongue perception⁹. Previously, we investigated the effects of tongue perception changes on the oral and maxillofacial function of patients with tongue cancer. The results showed that tongue perception changes on the nontumor side were associated with chewing function changes in patients who underwent less than hemiglossectomy and reconstruction with radial forearm free flap⁹. However, the association between changes in tongue perception and articulatory function was not examined in these patients, which needs to be investigated. The articulatory function of patients with tongue cancer has mainly been evaluated subjectively by speech therapists or people with normal hearing function^{1,10-13}.

In recent years, the objective evaluation of articulatory function using speech recognition software has been attracting attention in various fields. In patients with central dysarthria, articulation has been evaluated using speech recognition software, and the usefulness of the evaluation has been reported¹⁴⁻¹⁷. However, only a few objective evaluations using speech recognition software have been reported in patients with oral cancer^{18,19}. In Japan, a study conducted postoperative articulatory evaluation using speech recognition software in patients with maxillary cancer¹⁹, however, objective articulatory evaluation using speech recognition software in those with tongue cancer has not been reported. Our study focused on UDTalk, speech recognition software developed to assist communication between people with hearing loss and those with normal hearing. UDTalk allows people with hearing loss to understand the speaker's words. Yamaguchi et al.¹⁵ compared speech intelligibility using UDTalk between a group of healthy participants and a group with dysarthria and reported a clear difference in speech intelligibility between the two groups¹⁵.

In the present study, objective speech intelligibility assessed using UDTalk was evaluated before and after surgery in patients with tongue cancer, as well as the association between changes in objective speech intelligibility and tongue perception in those patients before and after surgery.

2 MATERIALS AND METHODS

2.1 Patients

A total of 20 patients with malignant tongue tumors were included in this study. Details of the patients are shown in **Table 1**. Of the 20 patients, 11 were male and 9 were female, with an average age of 61.8 (range, 31–81) years. In all 20 patients, the tumor was found in the anterior 2/3 of the tongue. The patients were classified into the primary closure (PC) group, who underwent partial tongue resection and primary suture, and the forearm flap (AF) group, who underwent tongue resection and reconstruction with a radial forearm free flap. Tumor resection and reconstruction were performed independently by one surgeon familiar with the technique. In reconstructive surgery, the flap was sutured to the tongue using absorbable thread to avoid interfering with its movements. **Figure 1** shows the postoperative intraoral photographs of two cases in the AF group. One case shows the tongue margin reconstructed with a flap (**Figure 1-a**) and the other with the tongue apex reconstructed with a flap (**Figure 1-b**). No tooth extraction was performed in any of the patients, and no change in the number of teeth was observed between the pre- and postoperative periods. The PC and AF groups included 10 patients each. In the PC group, all 10 patients had squamous cell carcinomas. Seven had undergone resection, including the floor of the mouth. None of the patients in this group received preoperative chemotherapy and radiation therapy. The tongue apex and lingual nerve on the tumor side were preserved in all 10 patients. Of the 10 patients in the AF group, 2 had histopathological evidence of nerve invasion on the tumor side. None of the patients in the PC group received postoperative chemotherapy and radiation therapy. Of the 10 patients in the AF group, 9 had squamous cell carcinoma and one had myoepithelial carcinoma. Moreover, 4 patients received preoperative chemotherapy, nine underwent partial tongue resection including the oral floor, and 1 underwent hemiglossectomy. In addition, 3 underwent resection from the tongue apex and 8 from the lingual nerve on the tumor side. All patients underwent unilateral neck dissection on the tumor side, and the omohyoid muscle on the neck dissection side was preserved in four patients. 1 patient received postoperative radiation therapy. Three exhibited histopathological evidence of nerve invasion on the tumor side. In both groups, no patient had a history of cerebrovascular disease, central nervous system disorders, treatment for head and neck cancer, glossodynia, or

lingual nerve palsy. In both groups, no patient was prescribed vitamins for nerve restoration postoperatively. In the AF group, all patients received postoperative oral rehabilitation to restore oral and maxillofacial function.

2.2 Objective speech intelligibility in patients with malignant tongue tumors

2.2.1 Speech intelligibility using UDTalk

Figure 2 shows the evaluation method of speech intelligibility using UDTalk.

The microphone (iQ6 Microphone ®, Zoom Video Communications, Inc., USA) is connected to a tablet device (iPad ®, Apple Inc., USA). The microphone was set at approximately 45° down and 20 mm away from the patient's mouth.

Patients were asked to read aloud the text, "The North Wind and the Sun,"²⁰ which is commonly used in oral cancer articulation assessment, at their own normal conversational speed (**Figure 2-1**).

Each patient's voice was recorded in a quiet and identical room and captured on a personal computer using an application installed on the tablet (Handy Recorder App ®, Zoom Video Communications, Inc., USA). (**Figure 2-2**).

Each patient's voice was transcribed through iRig2 from a personal computer to UDTalk ® (Shamrock Records) installed on a tablet. UDTalk used a speech recognition engine (Ami Voice Cloud ® 2020 version, Advanced Media Corporation, Japan, 2020). (**Figure 2-3**).

Voice evaluations were conducted in similar settings to ensure that there would be no differences in speech recognition algorithms as UDTalk and Ami Voice Cloud grew.

One evaluator judged each of the letter words if they were correct. The percentage of correct answers (up to 100%) was calculated as the speech intelligibility of each patient. (**Figure 2-4**).

Speech intelligibility was evaluated in each patient preoperatively and 1, 3, 6, and 12 months postoperatively. Changes over time for each case by group were evaluated, and statistical comparisons were made between the groups over the same period.

Statistical analysis was performed using the Friedman test (post-hoc test Dunn test) ($P < 0.05$) for each group, and the Mann-Whitney U test ($P < 0.05$) for comparison between the groups at the same period.

2.2.2 Association between speech intelligibility evaluated by UDTalk and that by the speech therapist

With regard to the speech intelligibility assessment by the speech therapist, one speech therapist familiar with test assessed the degree of naturalness of oral reading^{21,22} using a 5-point scale: 1, it is totally natural; 2, some unnaturalness is always felt; 3, unnaturalness is always felt; 4, a pronounced unnaturalness is always felt; 5, it is totally unnatural. The degree of naturalness of oral reading was assessed in 5 cases (24 samples) in the PC group and 8 cases (38 samples) in the AF group. This evaluation was performed preoperatively and 1, 3, 6, and 12 months postoperatively. Spearman's rank correlation coefficient ($P < 0.05$) was used to analyze the relationship between speech intelligibility assessed using UDTalk and the degree of naturalness of oral reading assessed by a speech therapist.

2. 3 Tongue perception in patients with malignant tongue tumors

2.3.1 Evaluation of tongue perception using an electrical stimulator

Tongue perception was assessed with an electrical stimulator (STG4002R, Multichannel Systems, Germany) using the same method as Suzuki et al⁹. A total of six sites (1, 2, and 3 for the tongue apex, margin, and dorsum on the nontumor side and 1', 2', and 3' for the tongue apex, margin, and dorsum on the tumor side, respectively) were evaluated. Preoperatively, to avoid the tumor, the site near the tumor side was evaluated. Postoperatively, sites replaced by the flap were assessed as the flap, and sites that were not replaced by the flap were evaluated as the residual tongue.

A counterplate was fixed to the patient's left wrist, and a 2-mm-diameter spherical probe was placed on the tongue surface lightly. The stimulation time was 0.2 ms, and tongue stimulation was started at 200 μ A, which was increased every 100 μ A. The value that the patient could recognize was set as the upper threshold, which was measured thrice, and the average value was used as the tongue perception threshold and scored. Considering the changes over time, perceptions noted at < 500 , 500 to < 1000 , 1000 to < 1500 , 1500 to < 2000 , 2000 to < 2500 , and 2500 to < 3000 μ A, were scored 5, 4, 3, 2, and 1 point, respectively. If no perception was observed at > 3000 μ A, the score was 0. Evaluations were performed preoperatively and 1, 3, 6, and 12 months postoperatively.

2.3.2 Association between speech intelligibility using UDTalk and tongue perception in the AF group

In the AF group, the association between changes in speech intelligibility and tongue perception 12 months postoperatively in comparison with that preoperatively was evaluated. Statistical analysis was performed using Spearman's rank correlation coefficient ($P < 0.05$).

2.4 Tongue movements in patients with malignant tongue tumors.

2.4.1 Tongue movement in the AF group

Tongue movements were evaluated using forward, lateral, and elevation movement items (total of 7 points)⁸. Tongue movements were evaluated on three items: forward protrusion (3, tongue over the lower lip; 2, tongue touching the lower lip; 1, tongue over the dentition but not touching the lower lip; 0, tongue not over the dentition), lateralization (1, tongue touching the corners of the mouth; 0, tongue not touching the corners of the mouth), and elevation (2, tongue touching the palate; 1, tongue elevated but not touching the palate; 0, tongue not elevated). The evaluation was performed preoperatively and 1, 3, 6, and 12 months postoperatively. The Friedman test (using post-hoc Dunn test) ($P < 0.05$) was used for statistical analysis.

2.4.2 Association between changes in speech intelligibility and tongue movements in the AF group

The association between changes in speech intelligibility and tongue movements 12 months postoperatively in comparison with that preoperatively was evaluated in the AF group. Statistical analysis was performed using Spearman's rank correlation coefficient ($P < 0.05$).

3 RESULTS

3.1.1 Changes over time in preoperative and postoperative speech intelligibility using UDTalk in each group

Changes over time in speech intelligibility using UDTalk in the PC and AF groups are shown in **Figure 3**. In the PC group, speech intelligibility 1 month postoperatively was significantly lower than that assessed preoperatively ($P < 0.05$); however, it tended to improve over time (**Figure 3-a**). Cases 3 and 4 with low speech intelligibility 12 months postoperatively were older patients who had undergone resection that included the floor of the mouth (**Figure 3-a**).

In the AF group, speech intelligibility 1 month postoperatively was significantly lower than that evaluated preoperatively ($P < 0.01$); however, it tended to improve over time, and the speech intelligibility at 12 months postoperatively improved significantly compared with that 1 month postoperatively ($P < 0.01$) (**Figure 3-b**). Compared with the eight patients in whom the lingual nerve was resected, the two patients (Case 12 and 19) in whom the nerve on the tumor side was preserved tended to have higher speech intelligibility at 12 months postoperatively (**Figure 3-b**). Case 18 with low speech intelligibility 12 months postoperatively was an older patient who had undergone resection of the anterior part of the tongue including the tongue apex (**Figure 3-b**). No significant difference was found in postoperative speech intelligibility between patients in whom the omohyoid muscle was preserved and those in whom it was resected (**Figure 3-b**).

3.1.2 Comparison of speech intelligibility using UDTalk between the two groups

Figure 4 shows a comparison of speech intelligibility between the PC and AF groups at the same period. Preoperatively, speech intelligibility was not significantly different between the two groups (**Figure 4-a**); however, 1 month postoperatively, speech intelligibility in the AF group was significantly lower than that in the PC group ($P < 0.05$, **Figure 4-b**). From the third postoperative month onward, the speech intelligibility of the AF group improved but, was not significantly different between the two groups (**Figure 4-c to 4-e**).

3.1.3 Correlation between speech intelligibility using UDTalk and that by the speech therapist

As shown in **Figure 5**, speech intelligibility evaluated using UDTalk and that assessed by a speech therapist showed a significant positive correlation ($r = 0.5279$, $P < 0.001$).

3.2.1 Changes over time in the preoperative and postoperative tongue perception scores in the two groups

Changes in the tongue perception scores over time in the PC group are shown in **Figure 6**. Based on the preoperative standard, +, 0, and – indicate improvement, no change, and a decrease postoperatively, respectively. The upper numbers in each graph show the percentage (%) at each period.

In the PC group, the perceptions of the tongue apex, margin, and dorsum on the nontumor side 12 months postoperatively were unchanged compared with those preoperatively in more than half of the patients (**Figure 6-1** to **6-3**). Tongue apex perception on the tumor side showed various changes from the third postoperative month onward when compared with that in the preoperative period (**Figure 6-1'**). The perception of the tongue margin and dorsum on the tumor side 12 months postoperatively were improved or unchanged compared with that assessed preoperatively in more than half of the patients (**Figure 6-2'** and **6-3'**). **Figure 7** shows changes in the tongue perception scores in the AF group over time. In the AF group, the tongue apex perception on the nontumor side 1 month postoperatively decreased in 40% of all patients compared with that postoperatively, and perception from the third postoperative month onward recovered or improved compared with that in the preoperative period in 70.0% of all patients (**Figure 7-1**). In approximately half of the patients, the perception of the tongue margin on the nontumor side 1 month postoperatively decreased compared with that preoperatively, and the perception 6 months postoperatively improved with compared with that measured preoperatively (**Figure 7-2**). Moreover, in half of the patients, the perception of the tongue dorsum on the nontumor side 1 month postoperatively decreased compared with that assessed postoperatively, and the perception 6 months postoperatively was improved compared with that assessed preoperatively (**Figure 7-3**). Among them, case 18, who received postoperative radiation therapy, had the lowest perception of tongue margin and dorsum on the nontumor side postoperatively compared with other patients (**Figure 7-2** and **7-3**). The perception of the tongue apex on the tumor side at all postoperative periods decreased compared with that evaluated postoperatively in more than half of patients (**Figure 7-1'**). With regard to the margin and dorsum of the tongue, very few patients had improved perception over time postoperatively (**Figure 7-2'** and **7-3'**).

3.2.2 Association between changes in speech intelligibility and tongue perception on the nontumor side in the AF group.

In the AF group, changes in speech intelligibility and tongue perception on the nontumor side demonstrated the same trend. Therefore, the association between changes in speech intelligibility and tongue perception on the nontumor side was examined. **Figure 8** shows the correlation between

changes in speech intelligibility and tongue perception on the nontumor side 12 months postoperatively compared with that assessed preoperatively. Changes in speech intelligibility and tongue perception at the three sites (tongue apex, margin, and dorsum) on the nontumor side showed a positive correlation (**Figure 8-a to 8-c**). In particular, changes in the perception of the tongue apex and margin on the nontumor side showed a significantly strong correlation with changes in speech intelligibility (apex; $r=0.6781$, $P < 0.05$; margin, $r = 0.7276$, $P < 0.05$ **Figure 8-a and 8-b**).

3.3.1 Changes over time in preoperative and postoperative tongue movements in the AF group

In the AF group, changes over time in tongue movements are shown in **Figure 9**. Tongue movements 1 month postoperatively were significantly decreased (** $P < 0.01$) compared with that assessed preoperatively but showed a trend toward improvement 6 months postoperatively (**Figure 9**). No significant difference was observed in postoperative tongue movements between patients in whom the omohyoid muscle was preserved and those in whom it was resected (**Figure 9**).

3.3.2 Association between changes in speech intelligibility and tongue movements in the AF group.

In the AF group, changes in tongue movement were similar to that in speech intelligibility. Therefore, the association between changes in speech intelligibility and tongue movements in this group was examined. **Figure 10** shows the correlation between changes in speech intelligibility and tongue movements in this group 12 months postoperatively relative to that preoperatively. Changes in speech intelligibility and tongue movements showed positive correlation (**Figure 10**).

4 DISCUSSION

4. 1 Objective assessment of speech intelligibility in patients with malignant tongue tumors.

Stelzle et al.¹⁸ evaluated pre- and postoperative speech intelligibility using speech recognition software in patients with oral cancer and reported that it decreased when the floor of the mouth or gingiva was resected with the tongue, when a large part of the tongue was resected, and when postoperative radiation

therapy was administered. Furthermore, Hattori et al.¹⁹ evaluated postoperative speech intelligibility using speech recognition software in patients with maxillary cancer and found lower speech intelligibility in the non-prosthetic group than in the prosthetic group. The articulatory evaluation in patients with tongue cancer has been reported mainly as a subjective evaluation by speech therapists and people with normal hearing^{1,10-13}. In Japan, no study has conducted speech intelligibility evaluations using speech recognition software in patients with tongue cancer. Thus, this study focused on UDTalk, which has been reported to show clear differences in speech intelligibility between the healthy group and the dysarthric group¹⁵. Initially, to establish the method for evaluating speech intelligibility using UDTalk, speech intelligibility was evaluated in 17 healthy individuals (6 male and 11 female participants, aged 28 – 66 years). The results showed that the speech intelligibility of the normal group (n = 17) was > 90%, and no significant difference in speech intelligibility was noted in multiple assessments. Therefore, we thought that the same method could be used to assess speech intelligibility in patients with tongue cancer.

Ming et al.¹⁴ examined the correlation between speech intelligibility using speech recognition software and by humans in 32 patients with motor dysarthria and reported a positive correlation with respect to articulatory accuracy. This study also examined the association between objective speech intelligibility using UDTalk and subjective speech intelligibility by humans in patients with tongue cancer. The results showed a positive correlation between the objective speech intelligibility using UDTalk and the subjective speech intelligibility by a speech therapist. Therefore, speech intelligibility assessed using UDTalk could be considered equivalent to speech intelligibility evaluated by a speech therapist.

In the study by Kumakura et al.¹¹, speech intelligibility in patients who had undergone flap reconstruction after tongue cancer resection was evaluated by speech therapists, and the results revealed that their speech intelligibility was significantly reduced immediately after surgery but improved 6 months postoperatively. In the present study, speech intelligibility 1 month postoperatively in the AF group was significantly lower than that in the PC group. Thus, the replacement of the excised tongue with a flap and the swelling of the remaining tongue was suggested to result in limited tongue movements and decreased speech intelligibility immediately after the surgery. Conversely, 3 months postoperatively, speech intelligibility in the AF group improved and was

not significantly different from that in the PC group. This result demonstrated an improvement in the swelling of the residual tongue and edema of the flap and restoration of the flexibility characteristic of the forearm flap, making it easier for patients to speak.

Speech intelligibility tended to decrease if a larger part of the tongue is resected^{10, 23, 24}, and speech function was significantly reduced in patients with tongue resected beyond the midline¹². Furthermore, patients who had undergone resection the tongue apex had significantly decreased speech function than those who had preserved tongue apex¹. In this study, a patient whom speech intelligibility was still reduced 12 months postoperatively was an older patient who underwent a large anterior tongue resection. Therefore, the ability or inability to preserve the tongue apex is one of the factors that significantly affect speech intelligibility.

4. 2 Changes over time in preoperative and postoperative tongue perception scores in patients with tongue cancer

Monofilament-based tactile sensation is generally applied in the evaluation of pre- and postoperative tongue perception evaluation methods in patients with tongue cancer. Maeda et al.²⁵ evaluated the tongue apex perception in healthy individuals and patients with lingualgia using monofilament baroreceptor, discriminator, and electrical stimulation and reported that the electrostimulation perception test provided a more precise evaluation of perception than the other tests²⁵. Therefore, we reported changes in tongue perception over time before and after surgery using an electrical stimulator in patients with tongue cancer⁹. In the present study, changes in tongue perception using an electrical stimulator were evaluated preoperatively to 12 months postoperatively in the PC group and the AF group. As a result, tongue perception on the nontumor side 1 month postoperatively tended to decrease, whereas perception 6 months postoperatively tended to recover or improve compared with that postoperatively. Tongue perception assessment using an electrical stimulator was performed mainly for assessing pain sensation on the tongue and as an accessory assessment for cold/warmth sensation for measuring the sensation of A δ and C fibers²⁶. In the AF group, tongue perception on the nontumor side 1 month postoperatively tended to decrease. An electrocautery scalpel is used in tumor resection. The electric current generated during electrocautery may have damage temporarily sensory receptors of A δ and C fibers on the nontumor side.

However, the sensation in those nerve fibers may have been restored 6 months postoperatively.

4. 3 Association between changes in speech intelligibility and tongue movements in the AF group.

In this group, the tongue perception on the nontumor side and speech intelligibility demonstrated the same extent of change, suggesting the need to further investigate the association between the changes in tongue perception and speech intelligibility.

Isberg et al.²⁷ reported on the case of a patient with a severely displaced articular disk of the temporomandibular joint that caused compression of the lingual nerve, resulting in decreased tongue perception and articulatory function, and noted that tongue perception was associated with speech function. In this study, a positive correlation was found between changes in speech intelligibility and the tongue perception on the nontumor side in the AF group, and a significant and strong correlation was found between changes in speech intelligibility and the perception of the tongue apex and margin on the nontumor side. This finding suggests an association between changes in tongue perception and speech intelligibility on the nontumor side.

Furthermore, a strong correlation was reported between speech intelligibility and tongue movements in patients with tongue cancer²⁸. In this study, the association between changes in speech intelligibility and tongue movements in the AF group was also examined. The results showed that changes in tongue movements were similar to changes in speech intelligibility, and a positive correlation was noted between changes in speech intelligibility and tongue movements in the AF group. In conclusion, the results of this study suggest that in patients who underwent tongue resection and forearm flap reconstruction, pre- and postoperative changes in speech intelligibility may be related to changes in tongue perception on the nontumor side, in addition to changes in tongue movements. Thus, analyzing more cases and performing statistical are crucial in determining whether tongue perception on the nontumor side or tongue movement greatly affects speech intelligibility

4. 4 Limitations of this study

In this study, speech intelligibility was evaluated using UD Talk among the speech recognition software. Many speech recognition software are available besides UDTalk, each with different evaluation criteria. Therefore, the outcomes

regarding speech intelligibility may also vary depending on the software used. In addition, the AmiVoice Cloud used by UDTalk contains some unclear algorithms. Therefore, potential slight differences in judgments should be considered if the performance of the AmiVoice Cloud differs depending on the time of the evaluation. To achieve a more reliable and objective speech intelligibility using speech recognition software, it must be evaluated using different speech recognition software in the future.

Moreover, a positive correlation was found between objective speech intelligibility using UDTalk and subjective speech intelligibility by the speech therapist. However, the evaluation criteria were different because objective speech intelligibility using UDTalk was rated on a 100-point scale, whereas subjective speech intelligibility by the speech therapist was rated on a five-point scale. Therefore, a future task is to compare the two evaluations using the same scoring system to establish a reliable correlation.

This study also compared speech intelligibility and tongue perception between the PC and AF groups. In the AF group, some patients received preoperative chemotherapy and postoperative radiation therapy, resulting in notable differences between the AF group and the PC group in these respects. To accurately compare the two groups, standardizing the pre- and postoperative treatments is necessary.

The association among tongue perception, speech intelligibility, and tongue movements in the AF group has not been examined through multiple correlation coefficient analysis due to the limited number of cases. Therefore, it is necessary to accumulate and report more cases in the future.

5 CONCLUSION

In patients who underwent tongue resection and forearm flap reconstruction, pre- and postoperative changes in speech intelligibility may be related to changes in tongue perception on the nontumor side, in addition to changes in tongue movements.

AUTHOR CONTRIBUTIONS

Hiroko Kinosada: Evaluation and analysis. Kazuhide Matsunaga: Planning, analysis and supervision. Shihoko Koyama: Analysis and guidance. Mao Suzuki: Evaluation. Yoshihiro Morita: Guidance. Chihiro Sugiyama: Evaluation and guidance. Yuko Ogata: Guidance. Hiroki Nishikawa: Evaluation and

guidance. Ittetsu Taniguchi Evaluation and guidance. Akinori Takeshita: Evaluation. Narikazu Uzawa: Planning and supervision

Acknowledgments

The authors would like to thank Enago (www.enago.jp) for the English language review.

Conflict of interest

All authors have no conflict of interest to disclose.

Funding statement

The authors declare that no funding was provided for the performance of this study.

Ethics approval statement

This study was approved by the Ethics Committee of Osaka University (Approval No. R1-E49).

Patient consent statement

Informed consent was obtained from all patients included in the study.

Clinical trial registration

None

12 Animal Studies

None

13 Data availability statement

None

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FIGURE Legends

FIGURE 1 Postoperative intraoral photographs of two cases in the forearm (AF) group.

- a: A case of reconstruction of the tongue margin with a flap
- b: A case of reconstruction of the tongue apex with a flap

FIGURE 2 Evaluation of speech intelligibility using UDTalk.

- 1: Recording setup and methods
- 2: Capturing each patient's voice on a personal computer
- 3: Transcribing from a personal computer to UD Talk through iRig2
- 4: Calculation of each patient's voice as speech intelligibility

FIGURE 3 Changes in speech intelligibility with UDTalk in both groups over time. In the primary closure (PC) group, speech intelligibility 1 month postoperatively was significantly lower than that preoperatively ($P < 0.05$). In the forearm flap (AF) group, speech intelligibility 1 month postoperatively was significantly lower than that preoperatively ($P < 0.01$), and speech intelligibility 12 months postoperatively improved significantly compared with 1 month postoperatively ($P < 0.01$).

FIGURE 4 Statistical comparison of speech intelligibility between the two groups at the same period. Preoperatively, speech intelligibility was not significantly different between the two groups. One month postoperatively, speech intelligibility in the AF group was significantly lower than that in the PC group ($P < 0.05$). Three months postoperatively or later, speech intelligibility was not significantly different between the two groups

FIGURE 5 Correlation between speech intelligibility using UDTalk and that by a speech therapist. A significant positive correlation was found between speech intelligibility using UDTalk and speech intelligibility by a speech therapist ($r = 0.5279$, $P < 0.001$).

FIGURE 6 Changes in tongue perception scores in the PC group over time. Based on the preoperative standard, +, 0, and – indicate improvement, no change, and a decrease postoperatively, respectively. Tongue perception on the nontumor side 12 months postoperatively was unchanged compared with that

preoperatively in more than half of the patients.

FIGURE 7 Changes in tongue perception scores in the AF group over time. Based on the preoperative standard, +, 0, and – indicate improvement, no change, and a decrease postoperatively, respectively. Tongue perception on the nontumor side 1 month postoperatively tended to decrease and gradually improved over time. The perception level 12 months postoperatively recovered to the preoperative level.

FIGURE 8 Correlation between changes in speech intelligibility and tongue perception on the nontumor side in the AF group 12 months postoperatively relative to that preoperatively. A positive correlation was found between changes in speech intelligibility and tongue perception at the three sites (tongue apex, margin, and dorsum) on the nontumor side.

FIGURE 9 Changes in tongue movements in the AF group over time. Tongue movements 1 month postoperatively were significantly decreased ($P < 0.01$) when compared with that preoperatively but showed a trend toward improvement 6 months postoperatively.

FIGURE 10 Correlation between changes in speech intelligibility and the tongue movements in the AF group 12 months postoperatively relative to that preoperatively. A positive correlation was noted between changes in speech intelligibility and tongue movements.