Journal of Cranio-Maxillo-Facial Surgery (1992) **20**, 203–210

JOURNAL OF CRANIO-MAXILLO-FACIAL SURGERY

Articulatory function in glossectomized patients with immediate reconstruction using a free jejunum flap

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SUMMARY. **Postoperative articulation in 18 glossectomized patients was investigated. The subjects were: 5 cases of tongue tumour, 7 cases of tumour of the anterior part of the floor of the mouth and 6 cases of tumour of the lateral part. A new modification of the *Freiburger* test for speech audiometry was used as test material. Then the articulatory function was assessed according to an overall score based on 180 monosyllables, the manner of production of 171 initial consonants and the place of production of 85 glossal sounds. The cases of tumour of the tongue and the lateral part of the floor of the mouth had excellent scores in all classes of sounds, which were compatible with the normative data. The subjects of tumour of the anterior part of the floor of the mouth had low overall scores, low scores for plosive and affricative sounds, and very low scores for sounds produced with the rear of the tongue. The relation between the site or amount of resection and subsequent articulation was significantly poor in all categories of sounds for the cases of anterior tumour, particularly in the movement of the posterior portion of the tongue even though it was not involved in the operation. In all groups there was a weak negative relation between the amount of resection and postoperative articulation. In reviewing the literature, reconstruction with a free jejunum flap was considered to lead to better articulation than reconstruction by other techniques. The need to assess postoperative function objectively was stressed, to compare the postoperative functions and to determine the indications for the reconstructive technique.**

KEY WORDS:
Glossectomy – Intraoral reconstruction – Free jejunum flap – Postoperative articulation

INTRODUCTION

Surgical advances enable the treatment and cure of many patients with seriously progressive cancer who could not have a radical operation because of potential postoperative complications or mortality. Oral cancer patients, however, who have undergone major ablative surgery and then live free from cancer, suffer from subsequent functional impairment of mastication, swallowing and speech. Among such dysfunctions, the speech disorder occurs most often and isolates patients due to the difficulty of communication with others, so they cannot return to society and good quality of life.

Such speech impairment may result from tissue loss or alteration of structure, impairment of motility, or loss of coordination of articulators, that prevent or distort the production of sounds. There are now a few treatment methods for the rehabilitation of articulatory disorders: these include surgery, prostheses and speech training. Reconstructive surgery, when performed immediately after the primary operation, is probably the first and most effective means of relieving dysfunction due to tissue loss. There are many techniques developed to correct the tissue defects, but their functional effects or indications are controversial because of few reports of objective examination of postoperative function.

The purposes of the present study were 3-fold: the first was evaluation of the articulatory functions of glossectomized patients whose tongue was reconstructed with a microvascularized intestinal jejunum flap, the second was to clarify site-specific damage to articulation, so relations between articulation disorders and site or type of tissue loss could be confirmed, and thirdly to evaluate the functional effects of reconstruction using a free jejunum flap, and compare the speech functions with those of patients in the literature who have been examined by objective articulation tests.

MATERIAL AND METHODS

Subjects for this study were 18 patients who were glossectomized because of squamous cell carcinoma in the mouth. The patients were from the Department of Oral and Maxillofacial surgery of the Medical University, Hannover, Germany. The criteria for inclusion were: (1) the sites of the lesions were the

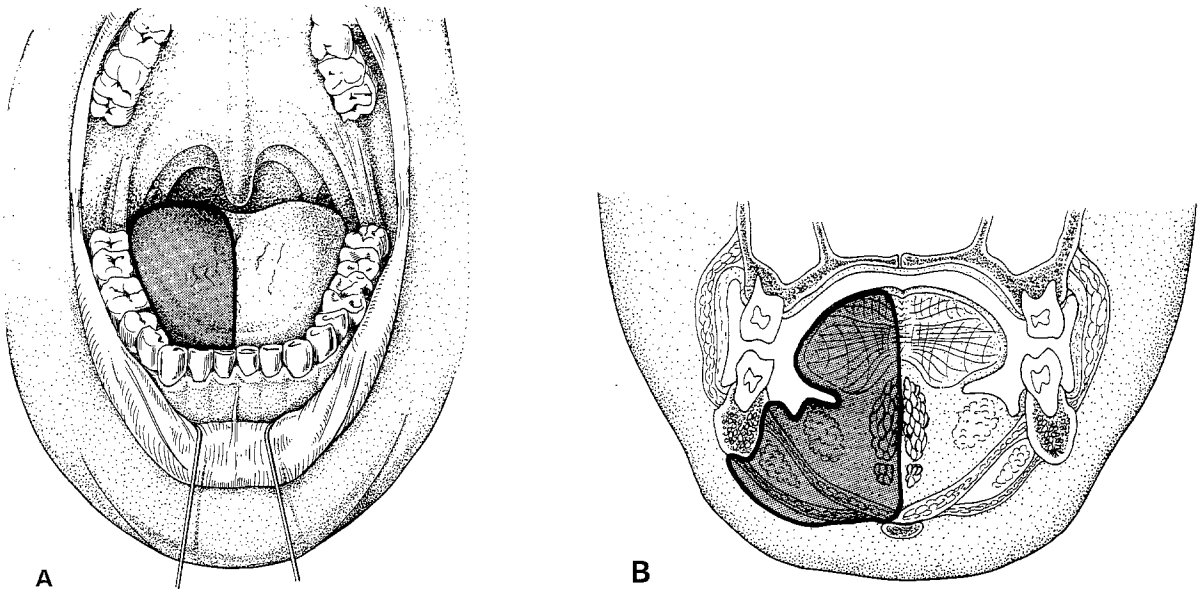


Fig. 1 – Resected areas typical of cases in group 1. Operative procedures: (**A**) hemiglossectomy including the root of the tongue and floor of the mouth, (**B**) frontal section (pull-through technique) (presented for individual cases in Table 1).

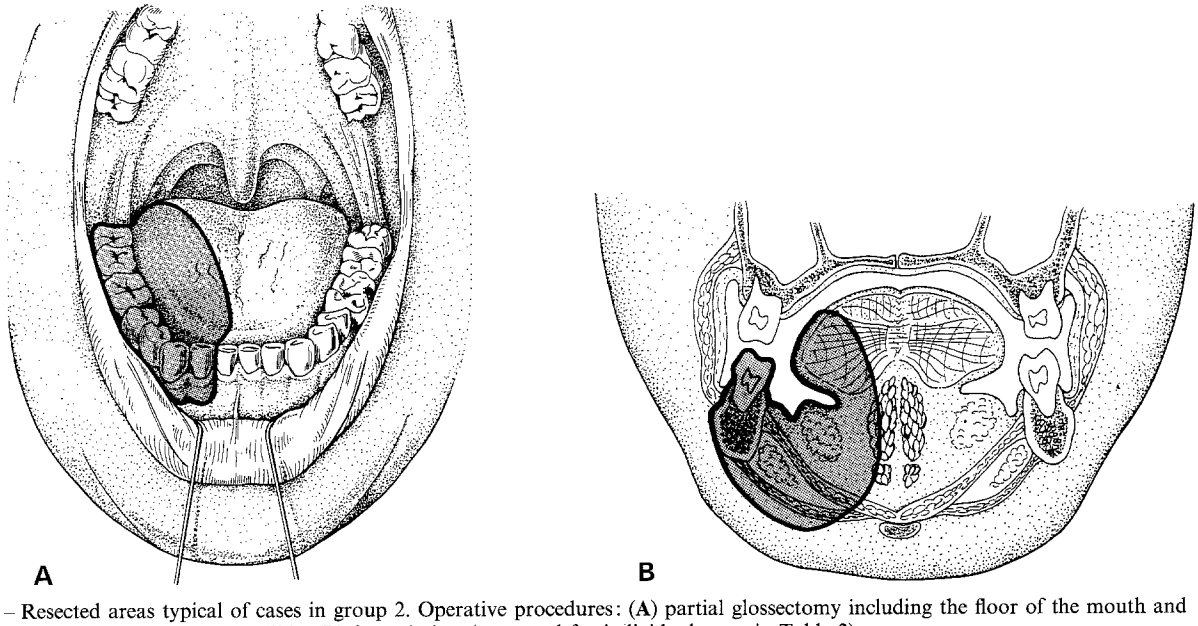


Fig. 2 – Resected areas typical of cases in group 2. Operative procedures: (**A**) partial glossectomy including the floor of the mouth and in-continuity resection of the mandible, (**B**) frontal view (presented for individual cases in Table 2).

floor of the mouth or the tongue with or without mandibular gingiva, (2) the subjects had been treated radically at least 6 months previously by ablative surgery and immediate intraoral reconstruction using a free intestinal jejunum transfer, and had not received other adjunctive skin flaps (e.g. pectoralis major myocutaneous flap, delto-pectoral flap). However, patients treated by primary or secondary mandibular reconstruction, were included, and (3) the patients had no recurrence of the tumour.

Based on the site of the primary lesion, subjects were divided into three groups; a group of patients with tumours of the tongue (group 1), a group of patients with tumours of the lateral part of the floor of the mouth (group 2), and a group of patients with tumours of the anterior part of the mouth floor (group 3). Typical resected areas of cases in group 1 are demonstrated in Figure 1. Tissue loss in group 2 was unilateral, involving essentially one side of the tongue, the floor of the mouth, and the mandible mainly from the incisor tooth to the retromolar region (Fig. 2). The resection in group 3 was the anterior portion of the mouth, which could include both sides of the tongue, the floor of the mouth and the mandible (Fig. 3). The soft tissue area resected was described from pre- and postoperative medical reports, surgical notes and

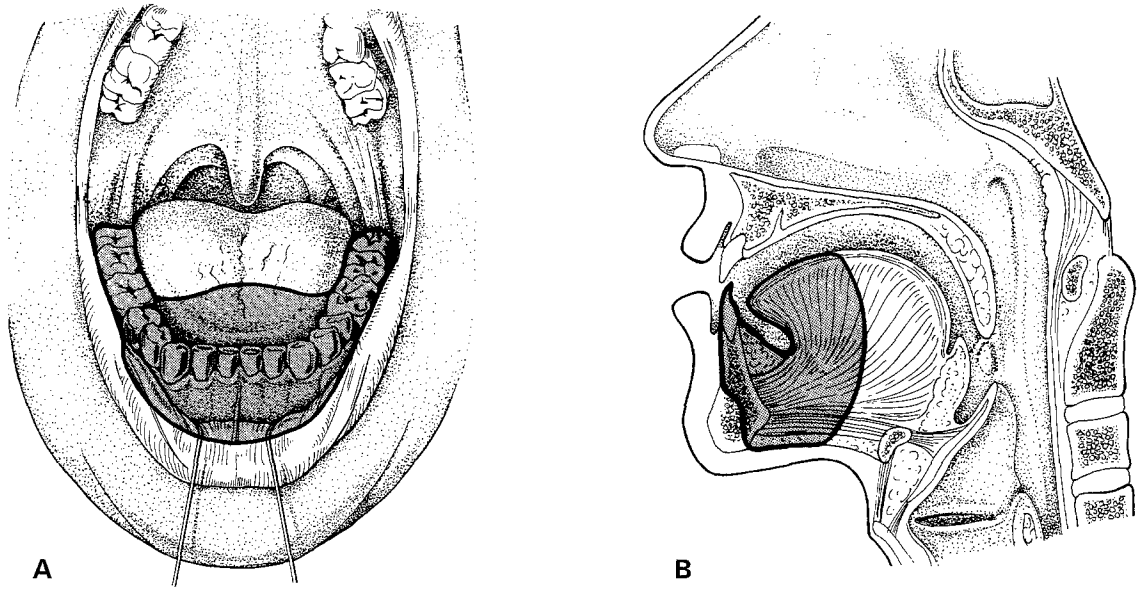


Fig. 3 – Resected areas typical of cases in group 3. Operative procedures: (**A**) partial glossectomy including the floor of the mouth and marginal resection of the mandible, (**B**) sagittal view (presented for individual cases in Table 3).

Table 1 – Subjects (1). Cases with tumour of the tongue (group 1)

No.	Sex	Age	TNM	Time lapse (yr)	Extent of resection		
					Tongue	Floor of the mouth	Mandible
1*	M	40	T3N0M0	5	Hemi	Hemi	Partial
2	F	71	T2N0M0	2	Hemi	Partial	—
3	F	21	T3N1M0	2	Hemi	Hemi	—
4	F	64	T3N0M0	0.8	Hemi	Hemi	—
5*	M	40	T2N0M0	0.5	Two thirds	Subtotal	Marginal
$\bar{x}$		47		2.1			

* Preoperative radiotherapy and chemotherapy

Table 2 – Subjects (2). Cases with tumour of the lateral part of the floor of the mouth (group 2)

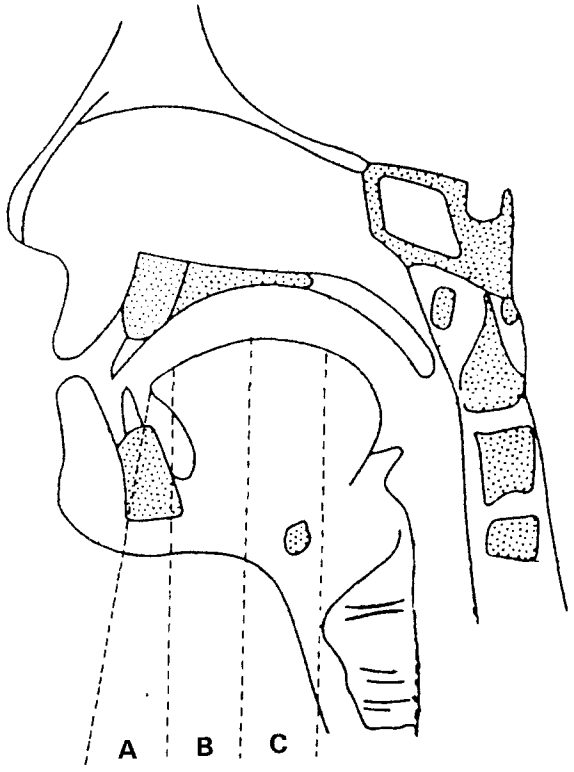
No.	Sex	Age	TNM	Time lapse (yr)	Extent of resection		
					Tongue	Floor of the mouth	Mandible
1**	M	68	T3N2M0	7	Partial	Hemi	Continued
2**	M	63	T3N1M0	5	Partial	Partial	Partial
3#	F	65	T3N1M0	3	Partial	Partial	Partial
4*	F	48	T3N2M0	3	Partial	Subtotal	Continued
5*	M	60	T3N1M0	3	Hemi	Hemi	Continued
6*	F	47	T3N2M0	2	Two thirds	Subtotal	Continued
$\bar{x}$		59		3.8			

* Preoperative radiotherapy and chemotherapy
** Pre- and postoperative radiotherapy and chemotherapy
# Preoperative radiotherapy

Table 3 – Subjects (3): Cases with tumour of the anterior part of the floor of the mouth (group 3)

No.	Sex	Age	TNM	Time lapse (yr)	Extent of resection		
					Tongue	Floor of the mouth	Mandible
1##	M	48	T3N1M0	6	Partial	Total	Continued
2*	M	59	T3N1M0	5	Hemi	Total	Marginal
3	M	48	T3N1M0	4	Partial	Subtotal	Marginal
4*	M	58	T3N3M0	3	Partial	Total	Continued
5*	F	43	T3N1M0	3	Two thirds	Total	Marginal
6	M	51	T3N1M0	3	Partial	Subtotal	Marginal
7	M	68	T3N1M0	3	Subtotal	Subtotal	Partial
$\bar{x}$		54		3.9			

* Preoperative radiotherapy and chemotherapy
Postoperative radiotherapy and chemotherapy



Manner of Articulation	Site of Articulation			Site of Articulation	Main Articulator
	A	B	C	Site A	Blade of the tongue
Plosive	t, d		k, g		
Fricative	s, z	sch	ch[2]	Site B	Middle of the tongue
	l	ch[1]			
		j		Site C	Rear of the tongue
Vibrant	r		R[1]		
Nasal	n		ng		

('ch' and 'R' can be produced in two different sites)

Fig. 4 – Relation between divisions of the tongue and glossal sounds (translated from *Wulff*, 1983).

postoperative direct inspection. The region operated on in the mandible was determined from radiographic examinations immediately after the operation.

The distribution of age, sex and TNM of the subjects in group 1 is presented in Table 1, including a summary of the treatment. Hemiglossectomy with resection of the ipsilateral side of the floor of the mouth was carried out in 4 of the 5 cases. The other had extirpation of two thirds of the tongue and marginal resection of the entire body of the mandible.

A summary of the subjects in group 2 is presented in Table 2. 4 cases underwent partial resection, 1 had half, and another had a subtotal glossectomy. The areas of the mandibles resected are indicated in Table 2.

4 of the patients in group 3 underwent partial resection, and the other 3 had one half, two thirds or subtotal extirpation of the tongue, as shown in Table 3. In addition, 4 had total removal and 3 underwent subtotal resection of the floor of the mouth. The extent of the mandibular resection in each case is presented in Table 3.

The test material for articulation was a modified version of the *Freiburger* audiometry test (German Industrial Standard 45621), which is a test for speech audiometry for German adults that consists of 400 meaningful German monosyllables. Though these 400 words are subdivided into 20 groups, the difficulty in understanding each group is known to vary. Based on results by *Banget* (1990) and *von Wedel* (1986), 9 groups that are equally difficult to understand, were accepted for the present study. Among these words 163 monosyllables have a phonemic form composed of a consonant-vowel-consonant (CVC) combination, nine have VC, and the other eight have CV combinations. The test was performed in the usual manner (*Michiwaki* et al., 1990).

Overall scores and scores for glossal sounds were estimated from the results obtained. Focussing on the initial consonants of 171 monosyllables with CV or CVC combinations, errors were divided into two

Table 4(b) – Scores for glossal sounds (group 1): (cases with tumour of the tongue)

No.	Portion of the tongue Blade (%)	Middle (%)	Rear (%)
1	99.4	99.3	86.4
2	80.0	92.6	81.8
3	97.2	99.3	100
4	91.1	100	68.2
5	96.1	100	91.8
$\bar{x}$	92.8	98.2	85.6

Table 4(a) – Scores of the articulation test (group 1): (cases with tumour of the tongue)

No.	Overall score (%)	Plosive (%)	Fricative (%)	Affricative (%)	Nasal (%)	Vibrant (%)	Lateral (%)
1	94.0	91.9	97.9	92.5	100	89.1	100
2	82.4	82.6	92.1	77.5	96.7	98.2	97.5
3	95.3	97.1	99.1	92.5	100	98.2	95.0
4	89.2	85.8	96.8	95.0	100	100	97.5
5	96.1	96.1	98.5	100	100	100	92.5
$\bar{x}$	91.4	90.7	96.9	91.5	99.3	97.1	96.5

Table 5(a) – Scores of articulation test (group 2): (cases with tumour of the lateral part of the floor of the mouth)

No.	Overall score (%)	Plosive (%)	Fricative (%)	Affricative (%)	Nasal (%)	Vibrant (%)	Lateral (%)
1	73.3	78.7	83.2	57.5	91.7	89.1	80.0
2	84.7	88.7	87.4	95.0	100	90.9	95.0
3	84.5	86.1	90.9	72.5	88.3	94.5	95.0
4	97.8	98.7	98.8	95.0	100	98.2	100
5	93.5	93.5	96.8	92.5	91.7	96.4	100
6	74.6	67.4	81.5	82.5	95.0	100	95.0
$\bar{x}$	84.8	85.5	89.8	82.5	94.5	94.9	94.2

classes: the manner of production of the sound, and the place of production relevant to the glossal sound (Fig. 4).

In the literature, there are no normative data of articulation of German people who were tested by the method described here. To obtain control data on articulation related to this system, 17 healthy native speakers of German were screened and requested to perform the task. 9 subjects were relatively young (mean age, 25 years ranging from 19–28) and had all teeth and good occlusion; the other 8 were older (mean age 65 years, ranging from 47–85) and had lost some or all of their teeth. The subjects without teeth were asked to perform the test while not wearing a prosthesis.

RESULTS

The overall score was $98.0 \pm 1.0\%$ ranging from 95.8–99.4% in the control group with all teeth, and $93.9 \pm 3.7\%$ ranging from 86.5–97.5% in the control group without some or all teeth.

Table 5(b) – Scores for glossal sounds (group 2): (cases with tumour of the lateral part of the floor of the mouth)

No.	Portion of the tongue: Blade (%)	Middle (%)	Rear (%)
1	87.2	91.9	77.3
2	92.8	84.4	81.8
3	95.0	91.9	90.0
4	98.9	100	98.2
5	96.1	98.5	96.4
6	63.3	77.8	74.5
$\bar{x}$	88.9	90.8	86.4

Table 6(b) – Scores for glossal sounds (group 3) (cases with tumour of the anterior part of the floor of the mouth)

No.	Portion of the tongue: Blade (%)	Middle (%)	Rear (%)
1	96.7	97.0	32.7
2	73.9	86.7	21.8
3	88.3	87.4	87.3
4	79.4	83.0	45.5
5	52.8	56.9	25.5
6	64.4	77.8	14.5
7	56.1	72.6	44.5
$\bar{x}$	73.1	80.2	38.8

In group 1, overall scores of cases with tumours of the tongue were excellent, ranging from 82.4–96.1% with a mean of 91.4%. The sounds that depended on the manner of production had mean scores ranging from 90.7–99.3%, and were considered to be excellent (Table 4a). The glossal sounds produced with the blade of the tongue scored 92.8% on average, the sounds produced with the middle of the tongue scored 98.2%, and those made with the rear of the tongue scored 85.6% (Table 4b).

In group 2, patients who had had tumours of the lateral part of the floor of the mouth, the average of overall scores was 84.8%. Scores for the other parts of the examination, based on the manner of production and classes of the glossal sounds, were good, from 82.5–94.9% (Table 5a, b). Generally, the articulatory functions of these patients were excellent in all of the tongue, as good as those of group 1.

Table 6(a) – Scores of articulation test (group 3): (cases with tumour of the anterior part of the floor of the mouth)

No.	Overall score (%)	Plosive (%)	Fricative (%)	Affricative (%)	Nasal (%)	Vibrant (%0	Lateral (%)
1	77.8	74.8	97.1	85.0	100	100	90.0
2	56.5	52.9	79.1	67.5	88.3	47.3	90.0
3	82.2	92.9	87.6	80.0	100	98.2	65.0
4	71.6	65.2	87.6	82.5	93.3	81.8	95.0
5	49.9	46.5	73.1	70.0	85.0	83.6	45.0
6	51.6	48.7	78.2	35.0	86.7	81.8	62.5
7	54.4	44.5	66.5	60.0	73.3	85.5	82.5
$\bar{x}$	63.4	60.8	81.3	68.6	89.5	82.6	75.7

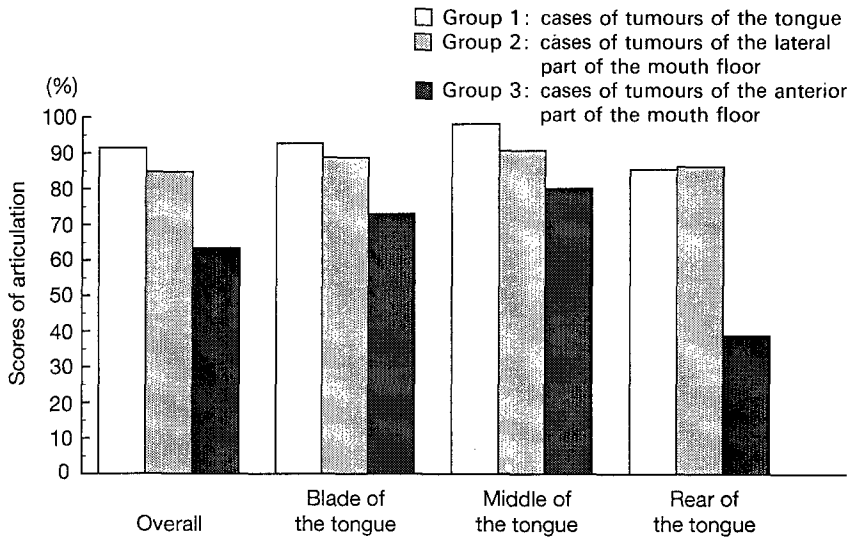


Fig. 5 – Overall scores and scores for glossal sounds.

In group 3, those who had had tumours of the anterior part of the floor of the mouth, the average overall score was 63.4%. This was significantly lower than the others. They had moderately low scores for the plosive and affricative sounds (Table 6a). Those consonants were omitted or distorted, resulting in severely reduced intelligibility. Those glossal sounds produced with the rear of the tongue had scores of 38.8% on average. The other two classes had satisfactory scores of 73.1% and 80.2% (Table 6b).

Comparing the classes of glossal sounds for the individual groups showed groups 1 and 2 to have excellent scores, but, group 3 had relatively poor scores in all classes. In particular, the scores for sounds produced by group 3 with the rear of the tongue were significantly lower than the scores of the other groups (Fig. 5).

DISCUSSION

Usefulness of the articulation test

Patients with articulatory impairment due to oral surgical resection have had few available procedures or alternatives that were effective enough to restore their dysfunction. The delay in the development of the treatment of articulatory impairment seemed to be caused fundamentally by the lack of objective evaluation. To relieve the dysfunction, the degree of impairment should be investigated objectively and quantitatively to clarify the characteristics of the distortions, and factors contributing to the impairment. The modality of treatment of articulatory impairment, including the indications for reconstructive surgery must then be determined.

There are two major methods of assessing speech function, one is articulation testing and the other is speech intelligibility testing. In the present study, articulation testing was used to evaluate the functions of major articulators, such as lips, tongue and palate by analyzing results in relation to the manner and site of articulation. The *Freiburger* test was chosen because of its popularity for speech audiometry in German (*Boehme* and *Schneider*, 1960; *Zenner* and *Pfrang*, 1986), its meaningful words that coincide with everyday usage, and the careful arrangement of the words (*Hahlbrock*, 1970).

In our study here, the results of the articulation test were analyzed not only for the manner of articulation but also for the glossal sounds. The glossal sounds have been categorized into three groups based on palato-lingual contact (*Wulff*, 1983). Each of the three groups has a particular site that is most important in the production of those sounds. The three sites are the blade, middle and rear of the oral tongue. After glossectomy, the tongue will be functionally impaired consistent with the site of the operation. Each function of each of the three individual sites of the tongue should be evaluated relative to its respective sound, to clarify relations between the site or extent of tissue loss and subsequent functional impairment. With these considerations, analysis of the glossal sounds was carried out.

Relation between the site or extent of resection and the degree or character of articulatory dysfunction

The site (organ) of resection, extent of ablation (degree of tissue loss), and a technique of reconstruction are all important factors relevant to surgical rehabilitation. But exact relations between such factors are still in doubt (*Hufnagle* et al., 1978).

Teichgraeber et al. (1985) reported little relation between the site of resection and degree of articulatory distortion in 51 cases of oral cavity cancer. But the treatment modality, reconstructive technique and the site of the tumours varied. The heterogeneity of the cases made it very difficult to establish relations between the site or amount of ablation and the degree of dysfunction.

Comparing overall scores in our series, the patients who had anterior tumours of the floor of the mouth had the worst articulatory function, although the amount of resection was almost equal to that of the other groups. The reason why patients in groups 1 and 2 had better articulation can be explained as follows.

There was a difference in the type of tissue loss between groups 1 or 2 and group 3. In group 3 the tongue and the floor of the mouth were removed in the frontal direction as shown in Figure 3, while in the others it was resected on one side and the contralateral side remained (Figs. 1 and 2). It is considered in patients of groups 1 and 2, that the residual side of the tongue, even if it is only one third, works well enough to compensate for the loss of intrinsic muscles on the other side, when reconstructed with a free jejunum flap.

In relating the site of operation to the character of articulatory impairment, patients who had had a tongue tumour (group 1) had excellent scores for all types of sounds. In cases with lateral tumours of the floor of the mouth (group 2), the scores were generally excellent also. Cases with an anterior tumour of the floor of the mouth (group 3) had apparently lower scores for the plosive and affricative sounds and poor scores for sounds produced with the rear of the tongue.

To produce the plosive or affricative sounds, the tongue should touch or approach the palate to make a valve to create a sudden burst of air in the vocal tract. The low scores of those sounds were certainly caused by insufficient elevation of the tongue. Cases in group 3 also had significantly low scores for sounds made with the rear of the tongue. The initial consonants /k/ and /g/ are produced with the rear of the tongue and these sounds are plosive sounds. These results indicate that the posterior part of the tongue cannot rise sufficiently to create the valve, although that part was not involved in the operative trauma. The reason why the tongue cannot make the valve against the palate in patients of group 3 can be explained as follows.

In a case of advanced squamous cell carcinoma of the anterior part of the mouth, the suprahyoid muscles, such as M. mylohyoideus, M. geniohyoideus, M. genioglossus and anterior belly of M. digastricus, must be resected radically together with the primary tumour as well as the mucosa of the floor of the mouth. The stump of the tongue then loses its anterior suspension to fall postero-inferiorly to the larynx. As a result the tongue changes its position downwards and cannot raise its posterior portion or base sufficiently to make a valve or contact against the palate. In addition the sounds of /k/ and /g/ are well known to be scarcely compensated by adjacent structures, while other sounds have a good chance of being replaced or compensated, with time, by tissue around the resected area (*Imai* et al., 1988).

On the other hand, one side of the muscles that support the tongue by their attachment to the mandible remains after an operation for tumour of the tongue or the lateral part of the floor of the mouth, excluding total glossectomy. The residual tongue position is not changed by these operations and the tongue stump, cooperating with other articulators, surely has the capacity to substitute or compensate for the lost function of its denervated part.

Good substitution or compensation by the lips, mandible and the other adjacent tissues seems to account for the sounds produced with the blade of the tongue, having a satisfactory score of 73.1% in group 3, when the part was completely removed and reconstructed with a denervated flap, as is reported by *Michiwaki* et al. (1987) and *Imai* et al. (1988).

Rentscher et al. (1980) concluded, from multiple correlation analysis in 20 glossectomized patients that the integrity of the residual oral structures as well as the amount of tissue remaining may significantly affect speech intelligibility, although the amount of lingual and adjacent tissue excised may provide a rough index of the effect. In our cases there appeared to be a weak relation between the amount of tissue removed and the articulation, although the site of resection had greater influence.

The present authors (*Michiwaki* et al., 1990) reported on the postoperative articulation of 5 patients who had had surgical reconstruction using a free radial forearm flap immediately after unilateral resection of the tongue and the floor of the mouth with or without mandibulectomy. A mean overall score was 66.3% ranging 45.6–82.1%. Comparing the results with articulation of patients in groups 1 or 2 in the present study, patients with the free jejunum flap had a significantly better score. According to *Kumakura* (1985) a mean overall score was 67.3% for 5 patients who had undergone a combined operation with hemiglossectomy and intraoral reconstruction using a pectoralis major myocutaneous flap. The jejunum flap is therefore considered to be more effective than the radial forearm flap or the pectoralis major myocutaneous flap. To determine the superiority of surgical techniques, however, many other factors should be clarified, such as operating time, complication rate, aesthetic results, and patient satisfaction. Then, we can also decide the indications for the various techniques.

The reason why the cases reconstructed with a jejunum flap have excellent or better articulatory functions can be explained as follows. Clinically we observed that the flap apparently moves together with the tongue stump, but cannot change its position voluntarily. Jejunum is essentially more pliable and moveable than a dermal or myocutaneous flap, and keeps its pliability in the mouth after being transferred (*Reuter* et al., 1984). Moreover, jejunum has many folds on the surface, and can therefore stretch extensively, so it will not disturb the voluntary movement of the residual tongue.

CONCLUSIONS

Postoperative articulation in 18 glossectomized patients with immediate reconstruction using free jejunum flaps was examined and the following points were stressed.

1. Patients with tumours of the tongue or the lateral part of the floor of the mouth had excellent postoperative articulatory function consistent with data of a healthy control group.

2. Patients with tumours of the anterior portion of the floor of the mouth had satisfactory scores, with the exception of sounds requiring the rear of the tongue.
3. The amount of resection seems to affect postoperative articulation adversely, although the influence of the site of resection was greater.
4. Reviewing the literature, the articulation in glossectomized patients with a free jejunum flap was considered to be better than those treated by other techniques.
5. It was emphasized that postoperative functions should be assessed objectively to compare the functions and determine the indications for reconstructive surgery.

Acknowledgement

This study was supported by the Alexander von Humboldt-Foundation in Germany.

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Paper submitted 26 October 1991
Accepted 15 January 1992