

## Clinical Evaluation of the Speech Following Maxillectomy<sup>\*)</sup>

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### ABSTRACT

The influence of maxillectomy on speech sound articulation and intelligibility were studied by ten cases. These cases were anatomically classified into Type I (unilateral), II (unilateral), and III (bilateral) in maxillectomy type. Pressure consonants, such as plosives [p, b, t, d, k, g], fricatives [s, ç] and affricates [ts, dz, tç, dç], were defective in maxillectomized patients. Vowels [i, u] were inclined to be hypernasal. Nasal consonants [m, n] and fricatives [F, h; j, w] were rarely misarticulated. Dental obturator, denture or maxillo-dental prosthesis for unilateral maxillectomy produced effective recovery of speech in most of cases, but did not so much for bilateral maxillectomy. When patients with unilateral maxillectomy (Type I or II) obtained intraoral pressure ratio of 0.8 or more with the use of such prosthesis, their speech became intelligible. The patients with bilateral maxillectomy (Type III), however, could not attain to such acceptable speech level. Articulation test composed of eight consonants [p, b, t, d, k, g, s, ç] and five vowels [a, o, e, u, i] is recommended for such patients conclusively in consideration of this experimental result.

### INTRODUCTION

Many patients with a partial or subtotal resection of maxilla for the treatment of their tumor have been suffered from speech disorders<sup>3-7,9,11,14-16</sup>. It is not well known, however, what is the best method to evaluate their speech problems. It will be of great use for the treatment of such patients, if it is predicted before surgery, how deviated the speech will be under the influence of their maxillectomy. Maxillectomized patients are generally older than the cleft palate patients. Most of them are adult, and usually they have not any speech disorders before the operation. They also have not any defects or deformities in their oral structures. So if their resected maxillae can be recovered in form by prosthesis as good as possible, their speech will be different from the articulation of the cleft palate patients with innate nasopharyngeal incompetence. In short,

the former needs rehabilitation program, while the latter needs habilitative speech therapy.

Cleft palate speech is now analyzed by many measures, such as oral inspection, articulation test, intelligibility estimation, intraoral pressure test, X-ray film analysis, fiberoptics, sound spectrography and so on. But for the appraisal of the communicative disorders derived from partial to total maxillectomy, modified convenient tests are required. Up to date there are, however, hardly any reports on the problems. So new estimation method of speech for this purpose must be developed and discussed.

In this article, study on the clinical evaluation of the speech following maxillectomy was made to look for the best tool of evaluating communicative disorders and to apprehend the grade of speech recovery by the use of prosthesis after partial, subtotal or total resection.

<sup>\*)</sup> 武内和弘, 石川武憲, 下里常弘: 上顎骨切除患者における構音の臨床評価法

**SUBJECTS AND METHODS**

1. *Subjects*

Subjects were ten patients who went through maxillectomy at the Department of Oral & Maxillofacial Surgery II, Hiroshima University Dental Hospital, between May 1975 and November 1977, and followed by the Division of Speech Disorders. They have no communicative disorders before the surgery.

Articulation disorders caused by maxillectomy were derived from the impossibility of impounding breath pressure in oral cavity. It has been reported that the speech problems of such patients do not depend on the width of the maxillectomy, but the position and the shape

of the resected maxillae. Therefore, the conditions of maxillectomy were classified into three types as follows:

Type I (unilateral maxillectomy): complete opening between oral cavity and unilateral maxillary sinus, but only natural anatomical opening between nasal cavity and sinus.

Type II (unilateral maxillectomy): complete opening among oral cavity, unilateral nasal cavity and unilateral maxillary sinus, as a result of non-resected nasal septum.

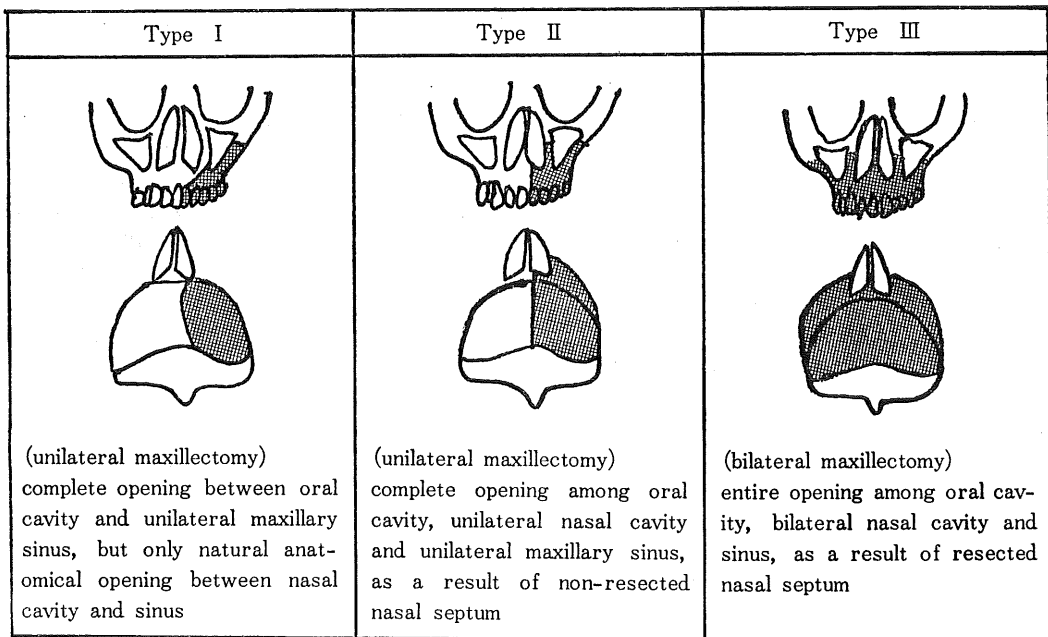
Type III (bilateral maxillectomy): entire opening among oral cavity, bilateral nasal cavity and sinus, as a result of resected nasal septum.

The grade of maxillary resection are assorted with narrow (N) and wide (W). Figure 1

**Table I.** Classification of patients (sex, age, side, and width) of maxillectomy

Type I			Type II			Type III		
unilateral maxillectomy			unilateral maxillectomy			bilateral maxillectomy		
case	side	width	case	side	width	case	side	width
1. K.H.(m, 37)	R	W	1. Y.S.(f, 48)	R	W	1. I.S <sub>1</sub> .(m, 64)	R, L	W
2. T.U.(m, 59)	L	W	2. T.K.(m, 56)	L	W	2. I.S <sub>2</sub> .(m, 64)	R, L	W
3. K.O.(m, 75)	R	W	3. K.N.(m, 41)	L	W			
4. U.Y.(f, 65)	L	N						
5. T.S.(f, 73)	R	W						

R: right side, L: left side, N: narrow, W: wide



**Fig. 1.** Anatomical classification of the maxillectomy

represents the types and the grades of maxillectomy. Table I shows the distribution of case, age and sex of the subjects. Partial denture or modified maxillo-dental prosthesis was setted after the healing of wounds. Obturator-typed acrylic denture was used for the bilateral maxillectomy. Those patients with the removal of all soft palate including the posterior border were excluded from this study.

2. Instrumentation and Procedure

Intraoral breath pressure was measured by polygraph (Nihon Kohden Kogyo RM-85) and pressure transducer (Nihon Kohden Kogyo MFP-1T). The connecting tube was placed and supported in the middle of the oral cavity. Intraoral pressure was recorded seven times in pronouncing [pa] by every two seconds in the course of both open nares and closed nares. A mean intraoral pressure was calculated with the preclusion of maximum and minimum intraoral pressure scores. Intraoral pressure ratio was then computed as follows:

$$OPR = NO/NC$$

OPR=intraoral pressure ratio

NO=A mean intraoral pressure within pronouncing [pa] in open nares

NC=A mean intraoral pressure within pronouncing [pa] in closed nares

Nasal air flow rate and volume were recorded at the same time (Fig. 2).

Articulation and voice of the subjects were evaluated according to Kamiyama's test items for the standard Japanese articulation test. Five vowels and 20 consonants were tested (Table II)<sup>8)</sup>. Overall speech efficiency was estimated

Table II. Articulation test items

I. phonemes
A. vowels: a, o, e, u, i
B. consonants: m, n; p, b, t, d, k, g; F, w, s, j, ç, j, h; ts, dz, tʃ, dʒ, r
II. words (initial position and final position)
A. plosives: p, b, t, d, k, g
B. fricatives: F, ç, h
C. affricates: ts, dz, tʃ, dʒ
D. flapped: r
III. sentence
"Jack and his beans"
IV. voluntary speech
A. story-telling
B. free talking

Table III. Criteria for intelligibility in patients with maxillectomy

I. intelligible
II. intelligible, but some words are not clear
III. understandable if the topic is limited
IV. some words can be followed
V. unintelligible

by the criteria, as shown Table III<sup>10)</sup>. All the procedure was performed in the sound proof room of the Hospital, where background noise level was always under 40 dB. Pronunciation of patients were recorded by the taperecorder (Sony TC-357A) using a microphone (Sony F-96) and open reel tape (Sony A5-90). The microphone was placed at approximately 20 cm before the patient's mouth. Patients are ordred to speak in natural pitch and loudness. The tape was playbacted in the quiet room

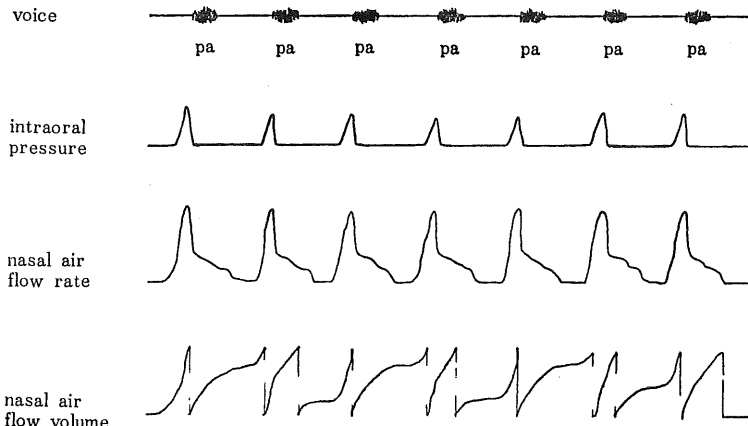


Fig. 2. A recording sample of voice, intraoral pressure, nasal air flow rate and volume (case: I. S., with the use of maxillary prosthesis)

with the same taperecorder. In assessing the articulation of the patients, careful attention was paid on the manner and place of articulation.

### RESULTS

#### 1. Improvement of Intelligibility

Intelligibility was improved by the aid of prosthesis, as shown in Fig. 3. Namely the unilateral maxillectomized patients became better in speech to Grade I (intelligible) or Grade II (intelligible, but some words are not clear), and most of them could communicate without difficulty in their daily lives. On the other hand, bilateral maxillectomized patients showed

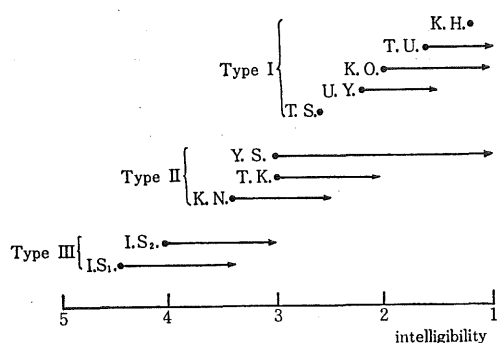


Fig. 3. Improvement of speech intelligibility with the use of maxillo-dental prosthesis

only a little effect in intelligibility, and the recovery of their speech was raised only to Grade III (under standable if the topic is limited).

#### 2. Estimation of Articulation

Results of articulation test for the whole patients are exhibited in Table IV. Plosives [p, b, t, d, k, g], fricatives [s, ç], and affricates [ts, dz, tʃ, dʒ] were more defective than nasals [m, n], fricatives [F, h, w, j] and vowels [a, o, e]. Fricatives [ʃ], flapped [r] and vowels [i, u] were slightly defective (Fig. 4). Articulation test with syllabic level was similar to word level.

#### 3. Intelligibility and Intraoral Pressure

Intelligibility and intraoral pressure of the three types in patients are indicated in Table V. Unilateral maxillectomized patients (Type I and Type II) improved to Grade I or Grade II in intelligibility, if intraoral pressure ratio increased with excess of 0.8 with the use of prosthesis. Such cases could produce acceptable speech after the maxillectomy. On the other hand, in the case of bilateral maxillectomy, intelligibility was not recovered contently and was worse than Grade III, even if intraoral pressure rised higher than 0.9 or more.

### DISCUSSION

It is well known that defects or deformities

			bilabial	dental	alveolar	palatal	velar	glottal
CONSONANTS	nasal	voiced	m		n			
	plosive	unvoiced	p		t		k	
		voiced	b		d		g	
	fricative	unvoiced	F	s	ʃ	ç		h
		voiced	w			j		
	affricate	unvoiced		ts	tʃ			
		voiced		dz	dʒ			
		flapped	voiced		r			
	VOWELS					i	u	
						e	o	
					a			

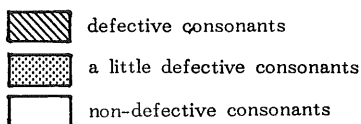


Fig. 4. Misarticulation pattern in patients with maxillectomy

**Table IV.** List of vowels and consonants pronounced correctly both without and with prosthesis (phonemic level)

Type		Type I								Type II				Type III								
case		K.H.		T.U.		K.O.		U.Y.		T.S.		Y.S.		T.K.		K.N.		I. S <sub>2</sub> .		I. S <sub>1</sub> .		
prosthesis		-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	
VOWELS	a	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	
	o	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	
	e	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	
	u	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	
	i	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	
CONSONANTS	nasal	m	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		n	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	plosive	p	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		b	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		t	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		d	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		k	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		g	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	fricative	F	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		w	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		s	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		ʃ	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		ç	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		j	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	affricate	ts	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		dz	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		tʃ	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		dʒ	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	flapped	r	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

**Table V.** Relation between intelligibility and intraoral pressure

maxillectomy	Type I								Type II				Type III							
case	K.H.		T.U.		K.O.		U.Y.		T.S.		Y.S.		T.K.		K.N.		I. S <sub>2</sub> .		I. S <sub>1</sub> .	
prosthesis	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+
intelligibility	1↓	1↓	1↓	1	2	1	2↓	2↑	3↑		3	1	3	2	3↓	3↑	4	3	4↓	3↓
intraoral pressure ratio	0.5	0.9	0.5	1.0	0.2	0.9	0.8	0.9	0.5		0.1	0.8	0.2	0.9	0.7	0.5	0.2	0.9	0.4	0.8

of oral organs cause speech disorders<sup>13)</sup>. When a part of oral organs such as maxilla or tongue, for example, was resected or lost because of tumor or trauma, man would be suffered from communication problems more or less<sup>3-7, 9, 11, 14-16)</sup>. From this point of view, some reports

about the speech disorders and prosthesis for such patients have been presented, but the details is not still obvious now. Especially mutual study of maxillectomy and speech disorders seems to be unknown and insufficient. For that reason, the types of maxillectomy

were classified according to the width and location of resection in maxilla as above-mentioned. Maxillectomy was assorted here into the three types, and the following clinical studies were performed.

### 1. *Relationship of Prosthesis and Intelligibility*

Ono<sup>16)</sup> indicated that intelligibility of maxillectomized patients was not dependent on the width, but the location of maxillectomy. He mentioned also that the patients, with resected unilateral part of maxilla or the middle of the palate, had a little damage in speech and exhibit better intelligibility.

Kamamoto<sup>7)</sup> concluded that the intelligibility of the patients, whose lateral part of hard palate was removed, was 32.1%, but 34.1% in the case of whole resection of hard palate. Intelligibility of vowels, according to Ono<sup>16)</sup>, was rated 100-72%, voiceless consonants 58-28.8%, voiced consonants 55.5-11.6% respectively, and as a whole 55.5-28.2%. Of ten maxillary cases, Masuda et al.<sup>8)</sup> revealed the mean intelligibility of 36.7%. It has been reported that maxillary prosthesis for these patients were useful to retrieve their speech function. In the report of Kamamoto<sup>7)</sup>, the intelligibility became better to 86.7% or 84.8%. In Ono's cases it was developed into 94.4-56.4% as a whole, and in Masuda's cases it was improved into 95.3%. Prosthesis, so-called temporary-typed maxillary prosthesis, were used here.

Our results as shown in Fig. 3 exhibited that the grade of mutual communication between sinuses, oral cavity and nasal cavity had influence upon the intelligibility. Intelligibility of our subjects was reduced worse proportionally according to the grade of the maxillectomy. This consequence was essentially similar to that of Ono, although we had not enough patients to state this conclusively.

Adjustment of maxillary prosthesis provide the obvious improvement of the speech in the patients with unilateral maxillectomy (Type I and II). Most cases acquired acceptable speech in their daily lives. In the bilateral maxillectomy (Type III), however, the patients attained to the intelligibility Grade III (understandable if the topic is limited) at best. Eguchi et al.<sup>1)</sup> asserted that normal speech was acquired in four patients with the use of denture. Their cases seem to be similar to the Type I and II

by our classification. Their results are assumed to be equal to ours.

### 2. *Misarticulation Patterns*

Pressure consonants are defected notably, as is the case of the cleft palate patients. They are plosives, dental and alveolar fricatives and affricates, which needs intraoral pressure to produce. Alveolar fricative [ʃ] and flapped [r] are often misarticulated in cleft palate patients, but in the maxillectomized patients it is articulated more correctly. Palatal fricative [ç] is more defective in patients with maxillectomy than in cleft palate patients. The wearing of maxillary prosthesis or the oral deformities by the surgery is surely one of the main causes of articulatory deviations. Same deviations may be equally seen with the use of denture in common dental treatment.

### 3. *Intraoral Pressure*

Measures of intraoral pressure were taken with the open and occluded nares, then ratios were computed in the manner suggested by Kanntner. Spriesterbach et al.<sup>17,18)</sup> had studied the cleft palate speech and manifested that intraoral breath pressure was related to velopharyngeal competency and articulation scores, and subjects with good articulation almost invariably had high pressure scores such as 0.90 or above. Maxillectomized patients could express themselves with acceptable speech level when they had intraoral pressure in excess of 0.8. Different from the cleft palate children, maxillectomized patients with normal speech before the operation, could probably compensate for the shortage of pressure by their skill of articulation. The same compensation has been taken place at times in the adult cleft palate patients<sup>12)</sup>.

In bilateral maxillectomy, intelligibility was improved to the Grade III at best. It was sure that the resected maxillary area was too large to compensate, although patients had tried to pronounce as correctly as possible.

Nasal air flow rate and volume were not discussed here, because we could not get reliable conclusion this time<sup>10)</sup>.

### 4. *Articulation Tests*

Japanese language has about 100 original syllables. Other syllables are only used in the word of foreign derivation. Hence Furuya<sup>2)</sup> disclosed the intelligibility test composed of 100 syllables. Takayori<sup>20)</sup> disclosed the same type of test composed of 67 selected syllables (Table

**Table VI.** Frequency of vowels and consonants in the intelligibility test by Furuya and Takayori

a	1	o	1	e	1	u	1	i	1
m	8	n	8						
p	8	t	3	k	8				
b	8	d	3	g	8				
s	4	ʃ	4						
w	1	j	3						
h	3	F	1	ç	4				
ts	1	tʃ	1						
dz	4	dʒ	4						
r	8								

(Furuya's test composed of 100 syllables)

a	1	o	1	e	1	u	1	i	1
m	5	n	5						
p	5	t	3	k	5				
b	5	d	3	g	5				
s	4	ʃ	1						
w	1	j	3						
h	3	F	1	ç	1				
ts	1	tʃ	1						
dz	4	dʒ	1						
r	5								

(Takayori's test composed of 67 syllables)

VI). But it takes much time when we analyse speech sound with such test in detail. Moreover some Japanese phonemes naturally appear more frequently than others. Therefore these tests may not reflect daily Japanese articulation pattern, if the syllables are tested uniformly.

Considering the results of articulation test for the patients with maxillectomy here, examination of all Japanese syllables may be not necessary. Eight consonants (i. e. [p, b, t, d, k, g] and [s, ç]) and five vowels [a, e, i, o, u] must be estimated deeply. But it is not necessary to test other consonants, because from the results of stop consonants and fricatives, articulation of affricates [ts, dz, tʃ, dʒ] could be approximated, and other remaining consonants [m, n; F, h; j, w] are rarely misarticulated.

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