

COMPARATIVE ELECTROMYOGRAPHIC ANALYSIS OF MASTICATORY MUSCLES BETWEEN BILATERAL AND UNILATERAL MASTICATORS

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There are several variations in normal mastication. In them, unilateral mastication is chewing, predominantly on a preferred side of the dentition and hardly on the non-preferred side. Continual unilateral mastication may alter the coordination of masticatory muscles. Although they studied about these EMG of masticatory muscles, there were no information about characteristics of masticatory muscle activity in unilateral mastication. Therefore, In this study, we investigated the activity of the masseter and anterior temporal muscles during rest, clenching in maximum intercuspation and gum chewing in habitually unilateral mastication group compared with normal group and tried to know effects of continual unilateral mastication on activity of masticatory muscles.

The results of this study were as follows

1. In electromyographic activity during rest, in bilateral mastication group pattern of muscle activity of right and left side was symmetrical. But, in unilateral mastication group, records of anterior part of temporal muscle was higher than that of bilateral mastication group ($p < .01$) and patterns of muscle activity of right and left side in both muscle were asymmetrical. ($p < .05$)
2. In electromyographic activity during clenching in maximum intercuspation, records of superficial part of masseter muscle were higher than anterior part of temporal muscle in both group. Muscle activity of temporal muscle in unilateral mastication group was a little higher than bilateral mastication group and asymmetry of activity pattern in temporal and masseter muscle was shown but these differences were not statistically significant. ($p < .05$)
3. In electromyographic activity during gum chewing, temporal muscle was activated earlier than masseter muscle and maximum bite force is derived from masseter muscle in both group. In unilateral mastication group, electromyographic activity of masseter and temporal muscle of preferred chewing side, regardless of right or left side chewing, was higher than that of bilateral mastication group and especially, difference in masseter muscle was statistically significant. ($p < .01$)

Based on the above results, our study suggested that recording of masticatory muscle activity will be helpful in the effective diagnosis and treatment of some types of the parafunctional habits.

Key Words

Bilateral mastication, Electromyographic, Masseter, Temporal, Unilateral mastication

One of the most important functions of the stomatognathic system is mastication¹. Mastication is a rhythmic movement which depends on coordination of the masticatory apparatus, the afferent sensory receptors and the central nervous system. Sensory feedback from receptors of the trigeminal nerve affects chewing behaviour by modifying the output of the central nervous system. The inter-relations among occlusion, masticatory muscles and temporomandibular joints are intricate and must be precisely coordinated for functional mastication.² The mechanism of mastication is highly flexible, and system deficiencies are readily compensated for.¹ Mastication consists of vigorous alternating contractions, in which the elevator muscles produce both forces and movement while the depressor muscles contract only to move the mandible.³

There are several variations from normal mastication. Among them, unilateral mastication is chewing, predominantly on a preferred side of the dentition and hardly on the non-preferred side.⁴ Continual unilateral mastication may alter the coordination of masticatory muscles. It produces strain in a single muscle unlike bilateral mastication and contributes to more severe damage to the stomatognathic system.⁴ Therefore, the balance between left and right masticatory muscle activities is important to the normal function of the jaw musculature. Pathophysiology of the stomatognathic dysfunction are complex, but can be separated into masticatory muscle disorders. Furthermore, epidemiological studies of the disorder suggested that large numbers of the population have clinically detectable dysfunctions. However, they exhibit no significant symptoms and did not require any treatment. Therefore, to study these disorders, various pathophysiologic conditions of stomatognathic dysfunction must be considered.

The anterior and posterior temporal muscles and superficial and deep masseter muscles start their activity at the point around first tooth contact. The contralateral masseter muscle is activated before the deep masseter and anterior temporal muscle is activated at the onset of tooth contact.⁵ Coordination and timing of the muscles during mastication in fully dentate subjects has been evaluated previously. In general, the ipsilateral anterior temporal muscle is activated before the contralateral temporal muscle is activated, whereas masseter muscle is activated on the contralateral side and shows greatest strength on the ipsilateral side.⁵

Thus recording electromyographic activity during mastication is a very useful tool to evaluate the functional integrity of the masticatory system. Surface electromyography(EMG) of the masticatory muscles has been widely used in the diagnosis of the stomatognathic disorder.⁵ Although its role as an evaluation instrument in the diagnosis of stomatognathic disorder has been questioned by a couple of groups, it has substantially increased the knowledge of function and dysfunction of the masticatory system(Dahlstrom,1989), with some value in the investigation of clinical problems (Schroeder *et al*,1991). For example, EMG is useful for physiotherapists, with its application to the study of the muscular function, in the characterization of muscular unbalance and in the evaluation of treatment.⁶

Many researchers have described in detail the kinematics events associated with chewing.⁷ Jaw tracking and electromyography(EMG) have been essential tools for documentation of these events.⁸ More specially, the use of the chewing pathway and shape and timing of the EMG signal during chewing have been used to classify these behaviors into normal and abnormal.⁷ Unfortunately, by its very nature, chewing movements include substantial randomness and, therefore, have low

reproducibility and limited diagnostic usefulness when attempts are made to apply a group-derived definition for bilateral mastication chewing. The study of muscle action in humans has been limited to an estimation of the contractile force by recording electromyographic activity.

Although they studied about these EMG of masticatory muscles, there were no information about characteristics of masticatory muscle activity in unilateral mastication. Therefore, in this study, we investigated the activity of the masseter and anterior temporal muscles during rest, clenching in maximum intercuspation and gum chewing in habitually unilateral mastication group compared with normal group and tried to know effects of continual unilateral mastication on activity of masticatory muscles.

MATERIAL AND METHODS

SUBJECTS

To check the masticatory habit, existence of TMD, past dental history and other dental condition, 350 students in Chosun University answered questionnaires designed by the author. And then, they were interviewed for verification. Final 20 subjects based on interview results were selected. All participants were male aged between 20 and 27years old. They were composed of two groups, bilateral mastication group(10) and unilateral mastication group(10) by questionnaire answer and oral examination result. The subjects of bilateral mastication group were selected when they fulfill all the following conditions.

- Angle class I molar relations with complete permanent dentitions
- No pain on masticatory muscle palpation
- No sign and symptom in TMJ
- No limitation of mandibular movement

All of unilateral mastication group had right-side

preference during mastication which was derived from habit.

ELECTRODES POSITION AND PLACEMENT

Electromyographic activity was recorded using BIO-PAK system(Bio-Research Associates Inc. USA). Calibration was $200\mu V$ and a speed of 2000ms/division depending on the recordings.⁹ The instrument was directly connected to a computer which presented the data graphically and recorded them on a magnetic media for later reference and analysis. Disposable bipolar surface disc electrodes made of Ag/AgCl(Myotronics Research Inc, USA) were used to record EMG.¹⁰ To locate the areas for electrode placement the subjects were asked to clench the jaws and the most prominent part of the major muscle mass of the anterior temporal was located superior and posterior to the lateral part of the orbital rim and the superficial masseter muscle was palpated. The long axis of each muscle was located by palpation during clenching. Each pair of electrodes were placed at a distance of 22mm(from electrode center to electrode center) which was parallel to the main direction of the bilateral anterior temporal and masseter muscles by anatomic landmarks.³¹¹ The ground electrode was placed on the front of neck. The skin area, where the electrodes are to be placed, was cleaned with alcohol or an appropriate cleanser, to reduce the impedance and to enhance signal conductivity. Recordings were done 5~6minutes later to allow the conductive paste to adequately moisten the skin surface. The electrodes were placed on an area without hair to minimize noise on the electromyographic recording. The electrodes were attached with adhesive strips and were pressed firmly in place. The subjects were sitting straight on an ordinary upright chair without head support. All the recordings were done three times.

There was short rest between each recording to avoid muscular fatigue. Resting periods were recorded before and during the experiment.

RECORDING PROCEDURE

The subjects sat relaxed and upright in a straight-backed chair without head support and were asked not to look at the monitor. The patients were asked to make no head and body movement which doing the asked tasks which includes only the mandibular movement.

To measure the electromyographic activity during rest, subjects were asked to relax and keep maxillary and mandibular teeth remain uncontacted. Recording was done three times successively, with 3-minutes interval between each recording. To measure the electromyographic activity during clenching, subjects were asked to bite maximally bilaterally. Subjects were asked to clench as hard as possible and maintain it for 2seconds. Recording was done three times successively, with 3- minutes interval between each recordings to avoid muscle fatigue. To measure the electromyographic activity during chewing, Subjects were asked to chew half a stick of chewing gum(2 × 3cm) until it gets homogeneous consistency. The subjects were asked to chew the gum on one side for 30seconds. Recordings were done three times successively on both the right side and on the left side, with 3- minutes interval between each recording.

EMG DATA ANALYSIS

Three data were analysed in the following fashion visual investigation was done to find any characteristic pattern during rest, clenching in maximum intercuspatation and gum chewing EMG of each group. The EMG data were analysed by finding the total cumulative EMG level from the onset to the offset of the rest, clenching in max-

imum intercuspatation and gum chewing period for each recorded muscle. During rest and clenching, these electromyographic data were then used to calculate the asymmetry index of right and left side and the activity index of temporal to masseter muscle of each group, During gum chewing, these electromyographic data were then used to calculate the activity index of temporal to masseter muscle and an asymmetry index to determine the work efforts of chewing side versus non-chewing side activity for each muscle. To evaluate the muscle activity balance of the left and right side, the asymmetry index(AI), advocated by Naeije, McCarroll & Weijs(1989), was modified for this study. When the subject did not have a preferred chewing side(PCS), the asymmetry index was calculated replacing PSC electromyographic activity with right electromyographic activity and non-preferred chewing side (NPCS) electromyographic activity with left electromyographic activity. The absolute asymmetry index was used during investigation of deteriorating muscle symmetry regardless of whether the PCS or NPCS was originally dominant. These values were statistically tested by using the independent sample t-test. To avoid Type II errors, all probability levels below 5% and 1% were accepted as statistically significant.

RESULTS

The electromyographic activities of left, right masseter and anterior temporal muscle during rest, clenching in maximum intercuspatation were illustrated in table I -1, I -2. Twenty subjects were asked to relax and clench maximally three times and the mean of 3 recordings was illustrated.

In order to quantitatively analyze the degree of asymmetry in temporal and masseter muscle, asymmetry index(%)¹¹⁻¹³ in masticatory muscles was introduced which is mathematically equivalent to the activity index.

Table I-1. The electromyographic activity during rest(Unit: μV)

		1		2		3		4		5		6		7		8		9		10	
		Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt
A	temporalis	0.9	1.3	1.1	1.7	2.1	1.8	0.7	0.8	0.9	1.2	1.1	1.2	1.3	1.4	1.1	1.3	1.7	1.6	1.0	1.2
	masseter	1.0	1.0	1.2	1.6	1.2	1.2	0.6	0.8	0.7	1.0	0.8	1.0	0.8	0.9	1.0	1.0	1.2	1.1	0.7	0.8
B	temporalis	1.9	2.8	0.8	4.5	2.1	2.8	2.0	2.7	1.0	3.8	0.3	0.6	1.5	2.4	2.1	2.6	2.2	3.1	1.3	2.5
	masseter	1.0	0.7	0.8	1.1	1.0	0.8	1.0	0.7	0.9	1.3	0.3	1.1	0.9	0.7	1.2	1.5	1.0	0.7	0.8	0.8

(A: bilateral mastication group, B: unilateral mastication group)

Table I-2. The electromyographic activity during clenching in maximal intercuspation(Unit: μV)

		1		2		3		4		5		6		7		8		9		10	
		Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt
A	temporalis	55.2	57.0	54.6	51.8	58.5	52.4	29.0	31.4	40.5	41.7	38.5	38.3	55.5	57.1	42.0	37.1	40.2	51.3	42.7	47.0
	masseter	70.2	67.2	64.3	57.2	81.4	83.9	59.8	61.3	54.4	55.1	52.3	53.1	60.7	64.4	55.1	51.4	69.8	54.1	67.9	75.3
B	temporalis	31.0	42.2	32.1	40.0	16.2	21.5	34.0	56.3	37.4	63.7	39.5	57.2	11.4	21.3	30.0	37.7	28.9	40.3	50.0	57.4
	masseter	26.8	47.7	26.0	47.2	34.3	39.6	50.0	93.8	87.4	99.4	73.3	93.8	27.9	48.8	26.4	44.7	26.3	46.0	54.9	60.9

(A: bilateral mastication group, B: unilateral mastication group)

Table II-1. The asymmetry index(%) of masseter and temporal muscle electromyographic activity between left and right side during rest(Unit: %)

		1	2	3	4	5	6	7	8	9	10
AI in temporalis muscle	A	-8.18	-11.43	+7.69	-6.67	-14.29	-4.35	-3.70	-8.33	+3.03	-9.09
	B	+19.15	+9.81	+4.29	+14.89	+8.33	+33.33	+23.08	+10.64	+16.98	+31.58
AI in masseter muscle	A	0.00	+4.29	0.00	+10.29	+7.65	+11.11	-5.88	0.00	-4.35	+6.67
	B	-17.65	+15.79	-11.11	-17.65	+18.18	+53.85	-12.50	+11.11	+35.48	+46.67

(A: bilateral mastication group, B: unilateral mastication group)

Table II-2. The asymmetry index(%) of masseter and temporal muscle electromyographic activity between left and right side during clenching in maximum intercuspation(Unit: %)

		1	2	3	4	5	6	7	8	9	10
AI in temporalis muscle	A	-1.60	+2.63	+5.50	-3.97	-1.46	+0.26	-1.42	+6.19	-12.13	-4.79
	B	+15.30	+10.96	+14.06	+24.70	+26.01	+18.30	+30.28	+11.37	+16.47	+6.89
AI in masseter muscle	A	-2.18	-5.84	+1.51	+1.24	+0.64	+0.76	+2.96	-3.47	+12.67	+5.17
	B	+28.05	+28.96	+15.63	+30.46	+11.18	+12.27	+56.95	+25.74	+27.25	+5.18

(A: bilateral mastication group, B: unilateral mastication group)

$$\text{Asymmetry index(\%)} = \frac{\text{EMG(right)} - \text{EMG(left)}}{\text{EMG(right)} + \text{EMG(left)}} \times 100$$

$$\text{Activity index(\%)} = \frac{\text{EMG(masseter)} - \text{EMG(temporal)}}{\text{EMG(masseter)} + \text{EMG(temporal)}} \times 100$$

Mean values of asymmetry index(%) of temporal and masseter muscle in each group during rest were shown in table II-1 and during clenching in table II-2.

Table II-1 and II-2 represented the average of the index in each condition. When an index score is close to 0%, this means that muscles on the right and left sides were activated symmetrically. Index score close to +100%, means that is activated the right muscle solely and index score close to -100%, means that is activated in the left muscle solely. Table II-1 and II-2 showed substantially large asymmetry indices of masseter muscle and anterior temporal muscles in unilateral mastication group than bilateral mastication group in both conditions.

In order to quantitatively compare the contribution of the masseter and anterior temporal muscles to the bite force the average masseter muscle and temporal muscle activity were calculated in each subject. The following activity index(%)^{7,12} was used to indicate the relative contribution of the masseter muscle and temporal muscle to the contraction effort.

Mean values of asymmetry index(%) of temporal and masseter muscle in each group during rest were shown in Table III-1 and during clenching in Table III-2.

When an index score is close to 0%, this means that temporal and masseter muscles were activated symmetrically on the right and left sides respectively. Index score close to +100%, means that is activated in the masseter muscle solely and index

Table III-1. The Activity index(%) of temporal to masseter electromyographic activity during rest (Unit:%)

		1	2	3	4	5	6	7	8	9	10
in right side	AI A	-13.04	-3.03	-20.00	0.00	-9.09	-9.09	-27.27	-13.04	-18.52	-20.00
	B	-60.00	-60.71	-55.56	-58.82	-49.02	-25.00	-54.84	-26.83	-19.23	-6.38
in left side	AI A	+5.26	+4.35	-27.27	-7.69	-12.50	-15.79	-18.18	-4.76	-17.24	-17.65
	B	-31.03	0.00	-35.48	-33.33	-5.26	0.00	-25.00	-27.27	-37.50	-23.81

(A: bilateral mastication group, B: unilateral mastication group)

Table III-2. The Activity index(%) of temporal to masseter electromyographic activity during clenching in maximum intercuspation (Unit: %)

		1	2	3	4	5	6	7	8	9	10
in right side	AI A	+8.21	+4.95	+23.11	+32.25	+13.84	+16.19	+6.01	+16.16	+2.66	+23.14
	B	+6.12	+8.26	+4.62	+24.98	+26.40	+24.24	+14.97	+8.50	+6.60	+2.96
in left side	AI A	+11.96	+8.16	+16.37	+34.68	+14.65	+15.20	+4.48	+13.49	+26.91	+22.78
	B	-7.27	-10.50	-6.23	+19.05	+40.06	+29.96	-18.13	-6.38	-4.71	+4.67

(A: bilateral mastication group, B: unilateral mastication group)

score close to -100%, means that is activated in the temporal muscle solely.

Table III-1 showed negative values of activity index predominantly in bilateral mastication group, therefore remarkable negative values of activity index in unilateral mastication group and this means tonus of temporal muscle is far more than masseter muscle during rest. Table III-2 revealed relatively somewhat positive values of activity index in bilateral mastication group, therefore activity indices in unilateral mastication

group are not uniformed. This means that majority of contraction effort during clenching in maximal intercuspation is derived masseter muscle than temporal muscle. But this characteristics is not clear in unilateral mastication group.

The electromyographic activities of left, right masseter and anterior temporal muscle during chewing at left and right sides were illustrated in Table IV. All of subjects with unilateral mastication habit to participate in this study were unilateral masticators on right. Therefore, that is to say,

Table IV. The electromyographic activity during chewing in left and right side(Unit: μV)

			1		2		3		4		5		6		7		8		9		10	
			Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt
left side chewing (NPCS)	A	temporalis	16.5	20.1	29.1	36.5	26.3	32.6	30.4	34.1	22.4	29.8	20.1	34.7	20.4	30.8	30.1	30.0	29.1	36.2	15.0	20.1
		masseter	37.0	14.9	55.3	30.7	52.1	21.7	43.1	39.1	33.7	23.2	39.4	29.0	38.2	30.2	41.4	28.9	54.7	29.0	30.8	23.4
	B	temporalis	15.4	8.8	19.5	10.2	7.7	16.2	7.8	14.7	15.4	8.8	31.6	20.8	21.6	10.0	14.4	7.3	20.1	9.7	16.2	8.6
		masseter	19.7	27.2	23.7	32.7	11.1	10.1	11.5	11.6	19.7	27.2	35.8	45.5	25.2	34.4	15.1	23.5	23.7	32.2	19.1	30.1
right side chewing (PCS)	A	temporalis	15.0	28.8	20.2	33.1	11.6	18.9	9.4	20.9	11.5	23.0	36.2	22.2	32.0	24.7	25.0	18.4	19.8	10.4	30.0	16.2
		masseter	16.9	32.7	21.5	35.1	6.9	21.8	16.5	23.1	17.2	26.0	37.0	47.2	39.2	50.4	29.0	32.0	28.2	29.8	42.0	51.4
	B	temporalis	18.0	24.8	10.3	21.4	10.1	20.4	11.6	25.8	11.4	24.9	11.7	26.0	10.6	23.8	19.8	34.0	13.5	29.0	6.7	14.9
		masseter	19.7	20.8	16.5	20.1	14.7	20.1	12.5	24.4	13.5	23.8	23.8	10.6	12.7	22.9	20.8	34.9	17.7	29.3	9.5	14.3

(A: bilateral mastication group, B: unilateral mastication group)

Table V. The asymmetry index of masseter and temporal muscle electromyographic activity during chewing in left and right side(Unit: %)

			1	2	3	4	5	6	7	8	9	10
left side chewing	AI in temporal muscle	A	-9.84	-11.28	-10.70	-5.74	-14.18	-26.64	-20.31	-0.17	-5.67	-14.53
		B	+27.27	+31.31	+35.56	+30.67	+27.27	+20.61	+36.71	+32.72	+34.90	+30.65
	AI in masseter muscle	A	+42.58	+28.60	+41.19	+4.87	+18.45	+15.20	+11.70	+17.78	+30.70	+13.65
		B	-15.99	-15.96	-4.72	-0.43	-15.99	-11.93	-15.44	-21.78	-15.36	-22.36
right side chewing	AI in temporal muscle	A	+31.51	+24.20	+23.93	+37.95	+33.33	+23.97	+12.87	+15.21	+31.13	+29.87
		B	+15.89	+35.02	+33.77	+37.97	+37.19	+37.93	+38.57	+26.39	+36.47	+37.96
	AI in masseter muscle	A	+31.85	+24.03	+51.92	+16.67	+20.37	+12.11	+12.50	+4.92	+2.76	+10.06
		B	+2.72	+9.84	+15.52	+32.25	+27.61	+38.37	+2.65	+25.31	+24.68	+20.17

(A: bilateral mastication group, B: unilateral mastication group)

right side was preferred chewing side(PCS) and left side was non-preferred chewing side(NPCS) in unilateral mastication groups. 20 subjects were asked to chew in left and right side three times and the mean of 3 recordings was illustrated.

Mean values of asymmetry index (%) of anterior temporal and masseter muscle in each group were shown in table V.

The asymmetry index ranges from +100% (higher activity of chewing side muscle) to -100% (higher activity of chewing side muscle). When an index score is close to 0%, this means that muscles on the right and left sides were activated symmetrically.

Mean values of the activity index (%) of anterior temporalis and masseter muscle in each group on left and right side respectively were shown in table VI.

Table VI revealed that the values of activity index in bilateral mastication group are positive substantially in same side of chewing side, that is to say, masseter muscle of chewing side is more active than temporal muscle. Therefore, the values of activity index in bilateral mastication group are negative substantially in same side of chewing side, preferred chewing side, and this means temporal muscle in preferred chewing side is more active than masseter muscle.

To the difference of these values of asymmetry index and activity index during rest, clenching and chewing between bilateral and unilateral mastication group. Table VII represents the results of the independent sample t-test for all index values. The T- test was done in each conditions, at the $p < .05$ and $p < .01$ level of significance.

Table VI. The activity index(%) of temporal to masseter electromyographic activity during chewing in left and right side(Unit:%)

			1	2	3	4	5	6	7	8	9	10
left side chewing	AI	A	-14.86	-8.63	-20.07	+6.83	-12.45	-8.95	-0.98	-1.87	-5.84	+7.59
		B	+51.11	+52.45	+23.19	+11.79	+51.11	+37.25	+54.95	+52.60	+53.81	+55.56
		A	+38.32	+31.04	+32.91	+17.28	+20.14	+32.44	+30.38	+15.80	+30.55	+34.50
		B	+12.25	+9.72	+18.09	+19.17	+12.25	+6.23	+7.69	+2.37	+8.22	+8.22
right side chewing	AI	A	+6.34	+2.93	+7.13	+5.00	+6.12	+36.02	+34.22	+26.98	+48.26	+52.07
		B	-8.77	-3.13	-0.74	-2.79	-2.26	-4.42	-1.93	-1.31	+0.51	-2.05
		A	+5.96	+3.12	-25.41	+27.41	+19.86	+1.09	+10.11	+7.14	+17.50	+16.67
		B	+4.51	+23.13	+18.55	+3.73	+8.43	+4.93	+9.01	+2.46	+13.46	+17.28

(A: bilateral mastication group, B: unilateral mastication group)

Table VII. The difference in asymmetry index and activity index between bilateral and unilateral mastication group

	Asymmetry index in temporal m.	Asymmetry index in masseter m.	Activity index in right side	Activity index in left side
rest	0.053	0.005**	0.002**	0.211
clenching in maximum intercuspatation	0.228	0.051	0.632	0.027*
chewing in preferred side(right)	0.016*	0.111	0.023*	0.147
chewing in non-preferred side(left)	0.000**	0.520	0.000**	0.383

* indicates significant difference ($P < .05$)

** indicates significant difference ($P < .01$)

First of all, the differences between bilateral and unilateral mastication group were the most distinct in the asymmetry indices of temporal muscle and the activity indices in right side chewing (PCS) during chewing in non-preferred side (left) and these differences were significant at the $p < .01$ level. Also, asymmetry indices of masseter muscle and activity indices in right side during rest were differed between bilateral and unilateral mastication group at the $p < .01$ level of significance. And, asymmetry indices of temporal muscle and the activity index in right side chewing (PCS) during chewing in preferred side (right) were differed between bilateral and unilateral mastication group at the $p < .05$ level of significance. But, except activity indices in left side, the differences between bilateral and unilateral mastication group during clenching were not significant.

DISCUSSION

The stomatognathic system is consisted of occlusion, masticatory muscles and temporomandibular joints. The stomatognathic apparatus develops in an almost symmetric pattern, with two paired bones (the maxillae) and a single symmetric bone (the mandible) bearing two symmetric joints, several pairs of muscles, and two symmetric rows of teeth.¹⁴ The inter-relationship among occlusion, masticatory muscles and temporomandibular joints are intricate and must be precisely coordinated for functional mastication and alterations of this symmetric arrangement are most usually found in the dental arches or in the supporting bones, but the effects of such an alteration are likely to involve the apparatus as a whole.¹⁴ Nevertheless, several compensatory adaptations to the altered anatomical situations may be found, and assessment of the patient should be aimed mostly at the functional impairment.¹⁴ For instance, continual unilateral mastication may alter the coordination of masticatory muscles

it produce strain in a single muscle unlike bilateral mastication. Therefore contributes to more severe damage to the stomatognathic system. Habitual unilateral mastication is related to stomatognathic dysfunction. The analysis of the masticatory muscle activity in subjects with altered masticatory functions could, therefore, provide useful data on the functional impact of masticatory system. These activities can be investigated using surface EMG, which allows the monitoring of some of the main masticatory muscles (masseter, temporal muscle), with results that do not significantly differ from those obtained with intramuscular recordings. Results from a bio-feedback study suggested that equalization of masticatory muscle activity may be important in the successful treatment of some types of the stomatognathic dysfunction.¹⁵

Since electromyography (EMG) was introduced by Moyers in 1949 for dental research, several investigation have examined jaw muscle electrical activity in the diagnosis of mandibular dysfunction.^{4,9,10,16} In the present study, the influence of continual unilateral mastication on masticatory muscle activity was tested in a group of unilateral masticators and irregular muscular coordinations were found.

The initial recordings at rest showed very light activity in the muscles, with similar values for all subjects. The average values ($1.08 \mu V$) from all the muscles supports the presence of basal tonus.¹⁰ Present studies represent very symmetric rest position values, i. e. $1.0 \mu V$ to $1.5 \mu V$ for the temporal muscle and $0.5 \mu V$ to $1.0 \mu V$ respectively, in the bilateral mastication group.

The electromyographic analysis of this study generally exhibited positive values in asymmetry indices for all recorded muscles and the larger asymmetry indices were observed in masseter muscle. These results reveal higher activity level in chewing side masticatory muscle than non-chewing side, particularly in masseter muscle.¹¹ Even

though the electromyographic analysis exhibited clear differences between the bilateral mastication group and the unilateral mastication group.

The coordination of muscle activity during mastication is thought to be a measure of dysfunction. It has been suggested that the contralateral masseter muscle initiates activity before the ipsilateral muscle, and the ipsilateral anterior temporal muscle initiates activity before the contralateral temporal muscle.⁵

Our data indicate that, during chewing, the masseter acts asymmetrically, both in firing level and in timing. The chewing side masseter was always more active than the non-chewing side, and EMG peaks appeared earlier at the non-chewing side than at the chewing side. Similar results were reported previously.¹⁷ The latter report also showed a decrease of the chewing / non-chewing side ratio with increasingly powerful mastication. A further increase in chewing force will probably lead to asymmetrical contraction. Such contractions were found in a study where maximal effort unilateral bite forces were produced. The full contribution of both masseters is then required for the high level of force to be produced.¹⁷

The present study shows that the electromyographic values during rest were clearly asymmetric in subjects with unilateral mastication group than in bilateral mastication group and muscle tonus of temporalis was higher than in bilateral mastication group and that the activity and asymmetry index during maximal clenching were slightly higher in subjects with unilateral mastication group than in bilateral mastication group, but no significant difference was found between the two groups.

In bilateral masticators, the AI did not equal zero. This indicates that bilateral masticators have a deterioration on the symmetry of muscle activity, as reported previously.¹⁸

In the present study, the AI of the masseter muscles detected the asymmetry of muscle activ-

ity and was relative to parafunctional habit.⁴

The difference between the masseter and anterior temporal muscle activities was considered dependant on differences in the functional role of each muscle. The anterior temporal muscle activity could be due in part to stabilization of the jaw and in part to the requirements of generating biting forces. The masseter muscle has a long-moment arm length favouring its biting capabilities.¹⁹ If the symmetry of masseter muscle activity is impaired, the temporal muscles may correct the imbalance. Therefore, even when there is an apparent asymmetry in the activity of temporal muscles, this asymmetry should be interpreted as a correction of the masseter muscle asymmetry and hence not abnormal by itself.

Unilateral mastication is thought to impair the symmetry of masseter muscles, leading to various disturbances of the stomatognathic system. Therefore, an analysis of mastication habits was included in the study. Using Kendall's ranked correlation coefficient, a significant correlation between mastication habits and stomatognathic dysfunction was demonstrated ($p < 0.01$).⁴ Developmentally, masticatory organs are normally symmetric. Natural mastication is performed bilaterally without shifting to one side.¹²

It is possible that unilateral mastication affects the symmetry of muscle activity, or, conversely, it is possible that the asymmetry of muscle activity induces unilateral mastication. The muscle activity level during maximal clenching reflects the maximal contractility of these muscles.¹³ Because even normal subjects show some degree of asymmetry of muscle activity, some difference in the contractibility between right and left muscle and is accepted as physiological asymmetry. The masticatory muscles usually exert their function when the clenching level is about 20% of maximum.²⁰ Therefore, the slight imbalance observed between left and right muscle activities of bilateral mastication subjects will not cause any imbal-

ance in the masticatory function. However, if the asymmetry index of the masseter muscle is great, the masticatory function can be adversely affected, probably leading to unilateral mastication. Unilateral mastication and the asymmetry index during maximal clenching are related. That is, pain or muscle fatigue due to stomatognathic dysfunction syndrome can induce habitual unilateral mastication.⁸

The unbalance of the masticatory musculature can lead to cervical pains, headaches, earaches, clicking, discal degeneration, breaking and lateral deviations of the mandible. These symptoms can be attributed to an involuntary alteration of the muscular activity of one or more muscles producing an unbalance in the mouth opening and closing mechanism.³

CONCLUSIONS

The purpose of this study was to obtain basic data which is electromyographic activity in unilateral masticators.

Twenty subjects, ranging from 21 to 27 years of age without symptoms of stomatognathic system, were selected from dental students in Chosun University by the questionnaire and oral examination. Among the twenty subjects, ten bilateral mastication subjects and ten unilateral mastication subjects were divided.

The electromyographic activities of anterior temporal and masseter muscle were investigated by BIO-PAK system (Bio-Research Associates Inc. USA). Each subjects were measured three times during rest, clenching in maximum intercuspation and gum chewing and the mean of 3 recordings were compared and analyzed.

The following results were obtained:

1. In electromyographic activity during rest, records of anterior part of temporal muscle in bilateral mastication group were ranged 1.0-

1.5V and superficial part of masseter muscle were ranged 0.5-1.0V and pattern of muscle activity of right and left side was symmetrical. But, in unilateral mastication group, records of anterior part of temporal muscle was higher than that of bilateral mastication group ($p < .01$) and patterns of muscle activity of right and left side in both muscle were asymmetrical. ($p < .05$)

2. In electromyographic activity during clenching in maximum intercuspation, records of superficial part of masseter muscle were higher than anterior part of temporal muscle in both group. Muscle activity of temporal muscle in unilateral mastication group was a little higher than bilateral mastication group and asymmetry of activity pattern in temporal and masseter muscle was shown but these differences were not statistically significant. ($p < .05$)
3. In electromyographic activity during gum chewing, temporal muscle was activated earlier than masseter muscle and maximum bite force is derived from masseter muscle in both group. The order of muscle activating time in bilateral mastication group was masseter muscle of chewing side, contralateral masseter muscle, temporal muscle of chewing side and contralateral temporal muscle. But, in unilateral mastication group, electromyographic activity of masseter and temporal muscle of preferred chewing side, regardless of right or left side chewing, was higher than that of bilateral mastication group and especially, difference in masseter muscle was statistically significant. ($p < .01$)

Based on the above results, our study suggested that recording of masticatory muscle activity will be helpful in the effective diagnosis and treatment of some types of the parafunctional habits.

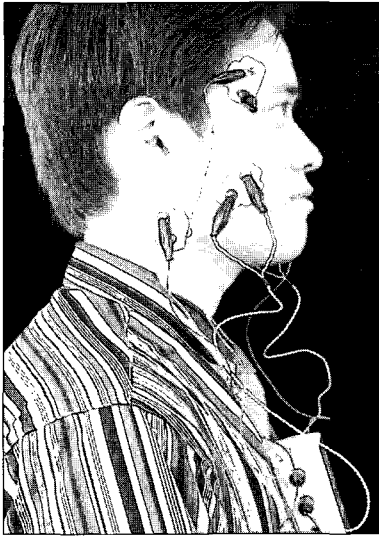


Fig. 1. Electrode placed in recorded position (BIO-PAK system, Bio-Research Associates Inc. USA)

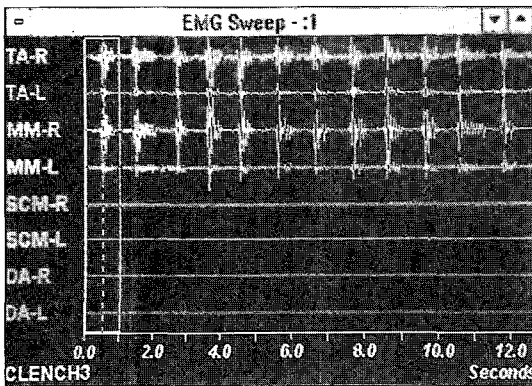


Fig. 2. The electromyographic activity during rest

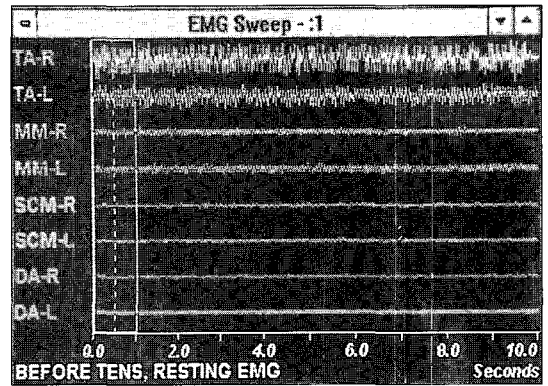


Fig. 3. The electromyographic activity during clenching

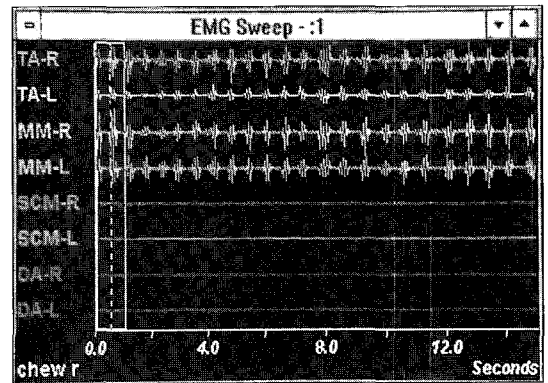
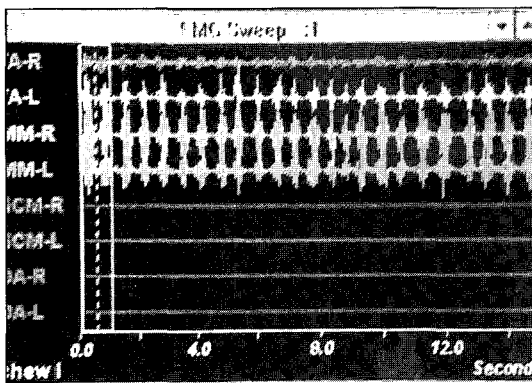


Fig. 4. The electromyographic activity during chewing (left : during left side chewing, right : during right side chewing)

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