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Effect of temporomandibular joint sensory receptors on functional jaw movements following intra-articular anesthesia during gum-chewing

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We attempted to clarify the role of the temporomandibular joint (TMJ) sensory receptors on jaw movement. Eight young healthy volunteers participated in this study. All volunteers had a full complement of teeth, optimal occlusion and an absence of any symptoms of TMJ or masticatory muscle dysfunction. Functional jaw movements were monitored before and after saline was injected into the right superior temporomandibular joint cavity. On a different day, functional jaw movements were monitored before and after 2% lidocaine was injected into the right superior temporomandibular joint cavity for sensory deprivation. Recordings of jaw movement were made by monitoring movements of the lower incisors using a model K 7 Mandibular Kinesiograph (MKG ; Myotronics Research, Seattle, WA, USA) during unilateral gum-chewing.

Following anesthsia to the TMJ on one side, the jaw movements of the chewing path had a more variable pattern in the frontal plane, and the cycle time of each stroke after anesthsia was longer than normal. These findings suggest that sensory receptors in the TMJ contribute to functional jaw movements. (J Osaka Dent Univ 2014 ; 48(1) : 67–73)

Key words : Jaw movement ; Temporomandibular joint sensory receptors

INTRODUCTION

Basic patterns of masticatory rhythm are generated by the intrinsic neuronal network, so called masticatory central pattern generator, in the brain stem, and are fine tuned in response to both peripheral feedback and central afferent inputs.[1–4] It is well known that peripheral receptors responsible for the regulation of masticatory rhythm are distributed in the periodontium, lips, oral mucosa, jaw muscles and temporomandibular joint (TMJ), and that they play an important role in adjusting the movements of the jaw.[1–4] There are many reports about mechanoreceptors in periodontium,[5–7] lips, oral mucosa[4] and jaw muscles. However, the effect of mechanoreceptors in the TMJ on functional jaw movements has not been clarified clinically, even though there is abundant neurohistological evidence of TMJ innervation in animals and man.[9–11] We attempted to establish the effect of TMJ sensory receptors on functional jaw movements in humans.

MATERIALS AND METHODS

Subjects

Eight healthy young, volunteers, 4 males and 4 females, between 23 and 32 years of age (mean 27 years) were included in this study. All volunteers had a full complement of teeth, optimal occlusion and an absence of any symptoms of TMJ or masticatory muscle dysfunction. Informed consent was obtained from each subject prior to the experiment. The Committee of Medical Ethics, Osaka Dental University, approved the protocol of this study (No.100708).

Recording method

This experiment was done over two days (Fig. 1). On the first day, we recorded the subject's occluding force in order to confirm that it would not physically in-

First day measurements after saline injection

Before : Without anesthesia as a control for the first day

After : Following injection of saline into the right superior TMJ cavity

Second day measurements after TMJ anesthesia

Before : Without anesthesia as a control for the second day

After : Following injection of 2% lidocaine into the right superior TMJ cavity

Fig. 1 Experimental design.

terfere with injection of liquid into the right superior TMJ cavity. The subjects were seated in an upright position on a dental chair. Occluding force was measured using pressure sensitive film (Type R, Dental Prescale 50 H ; Fuji Photo Film, Tokyo, Japan) during maximum voluntary clenching (100% MVC) at intercuspal position. The film was placed between the maxillary and mandibular dental arches. The subjects were then asked to occlude on the film with maximum force for 3 seconds. The area and color density of the contacts imprinted on the film were measured using an Occluzer FPD709 (GC Corporation, Tokyo, Japan) image scanner, and the force (N) was computed. The average of three trials was used as 100% MVC.

Subjects were seated upright in a chair with the head lightly supported and the Camper plane horizontal. They were then requested to chew gum that had fully softened 30 times on the right side. The movements were recorded and repeated 5 times, allowing adequate rest between each of the measurements. Recordings of jaw movement were made by monitoring movements of the lower incisors using a Model K7 Mandibular Kinesiograph (Myotronics Research, Seattle, WA, USA).

After analysis of normal chewing, the location of the needle tip in the superior joint cavity was confirmed by backflow of saline and the superior joint cavity volume was measured. Then 1–1.5 mL of saline, which was the same volume as the subject's superior joint cavity, was injected into the right superior TMJ cavity by a dentist trained in the pumping manipulation technique of the TMJ. This technique is used to avoid the spread of the solution to the superior and inferior heads of the lateral pterygoid muscles antero-medially, and to the deep masseter muscle fibers antero-laterally. After 30 min, the 100% MVC occluding force was determined, and the functional jaw movements of chewing gum were obtained. On the second day, the 100% MVC occluding force and functional jaw movements were monitored before and after 2% lidocaine was injected into the right superior TMJ cavity for sensory deprivation. After 30 min, when the effect of the right TMJ sensory deprivation by local anesthesia had been confirmed, the 100% MVC occluding force and the functional jaw movements of chewing gum were obtained.

Analysis

The records of jaw movement were amplified with AC amplifiers and were stored in a computer memory through a Biopac MP 150 converter (Biopac Systems, Santa Barbara, CA, USA). Sampling rate of the recordings was fixed at 100 Hz. Data was analyzed by special AcqKnowledge software (Biopac Systems). The data sampling began with the fifth cycle from the start of chewing and continued for 10 cycles. Using the centric occlusion (CO) of each cycle as a starting point, the amount of the maximum opening and the amount of lateral movement at maximum opening were calculated in the frontal plane (Fig. 2). Kobayashi[12] classified masticatory patterns. The opening

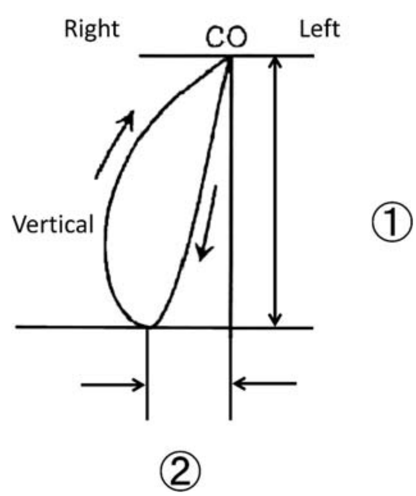

Fig. 2 Jaw movements on the chewing side in the frontal plane.
① Maximum opening, ② Lateral movement at maximum opening, CO : Centric occlusion.

path was roughly divided into three types : a linear or concave path ; a path first inclined to the non-working side and then to the working side ; and a convex path.

The closing path was roughly divided into two types : a convex path and a concave path. The path of movement of the mandibular incisal point was then divided into seven patterns, Six of which are based on the combinations of three opening paths and two closing paths, and the seventh pattern is where the opening and closing paths cross (Fig. 3). These movements are based on the classification of Kobayashi. Based on vertical movement, the duration of a single cycle during chewing was measured as the interval from one point of maximum opening to the next, and is called the total cycle duration (TC). A single masticatory cycle was further divided into three phases : opening phase (Op), closing phase (Cl) and occlusion phase (Oc) based on directional changes in vertical movement as defined by Shiga *et al*.[13] (Fig. 4). The average and standard deviation of these parameters were calculated and all data were evaluated with a

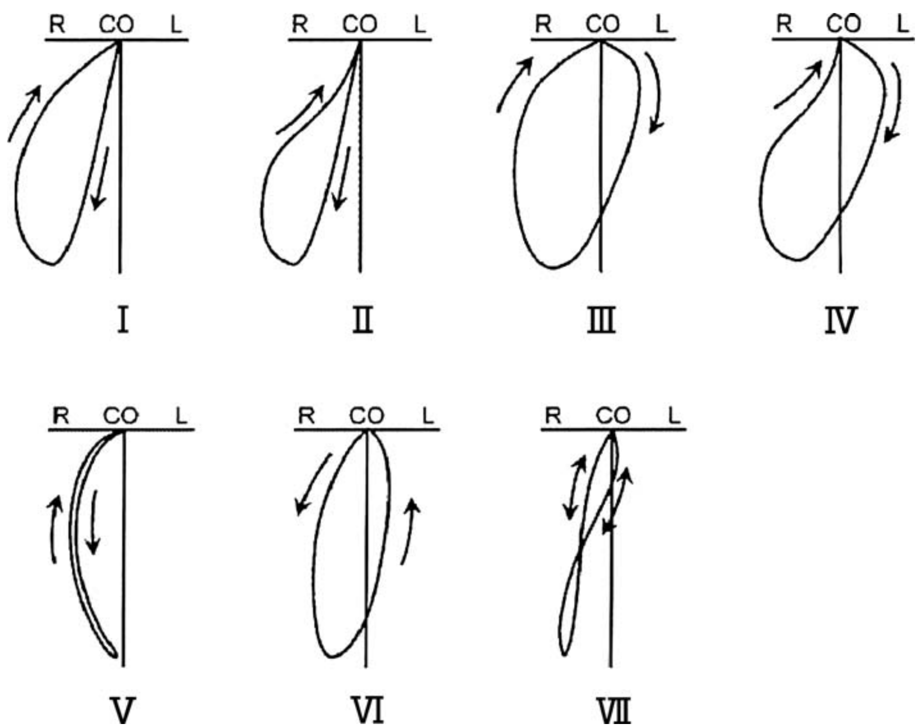

Fig. 3 Patterns of the jaw movement path from Kobayashi *et. al*.[12]

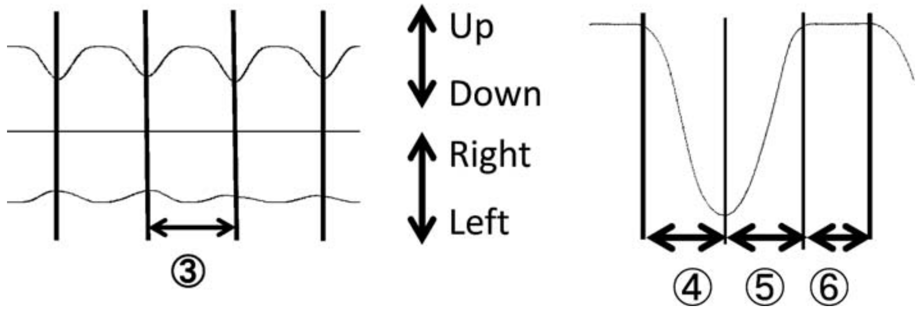

Fig. 4 The chewing cycle.
③ Total cycle duration (TC), ④ Opening phase (Op), ⑤ Closing phase (Cl), ⑥ Occlusion phase (Oc)

two-tailed t-test with $p < 0.05$ considered statistically significant.

RESULTS

Occlusal force

Immediately after injection of saline or 2% lidocaine, the occlusal force was significantly less than in that of the controls (Fig. 5). However, there were no differences in the values of occlusal force before injection and 30 minutes after injection into the right superior TMJ cavity.

Jaw movements

The results of the experiment for the jaw movement of subject 1 are shown in Fig. 6. The functional jaw movements after injection of saline into the right superior TMJ cavity were similar in shape and size for repetitive chewing gum before the injection. However, the functional jaw movements after injection of 2% lidocaine had a variety of shapes and shifted to the left side.

Patterns of the jaw movement path

The results for maximum opening are shown in Table 1 a. The effect of sensory deprivation by local anesthesia varied with the chewing path range. The results for the amount of lateral movement at the maximum opening are shown in Table 1 b. There was no significant difference before and after the injection of the 2% lidocaine. The results for each chewing pattern are shown in Table 2. The effect of sensory deprivation by local anesthesia varied with the chewing path.

Chewing rhythm

The times for TC, Op, Cl and Oc are shown in Table 3. Injection of 2% lidocaine tended to increase TC. TC, Op and Oc were significantly increased compared with the controls. However, there were no significant differences between in the normal joint and that with saline except for Cl. The time for Cl after injection of

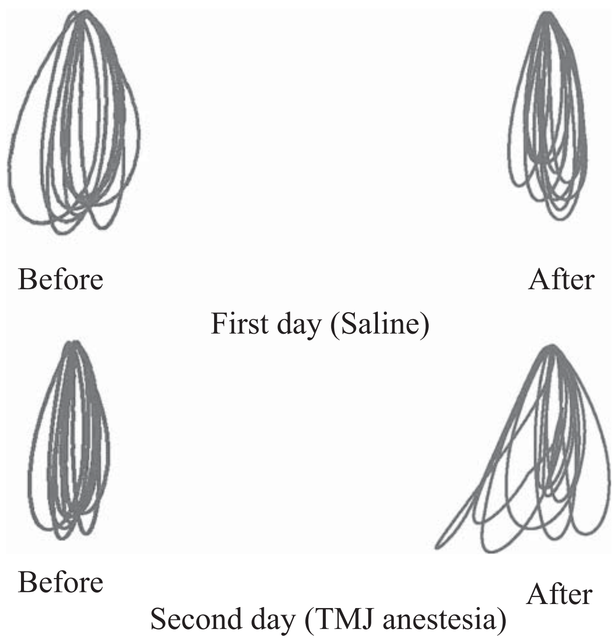

Fig. 6 Frontal plane of the chewing cycle of subject 1.

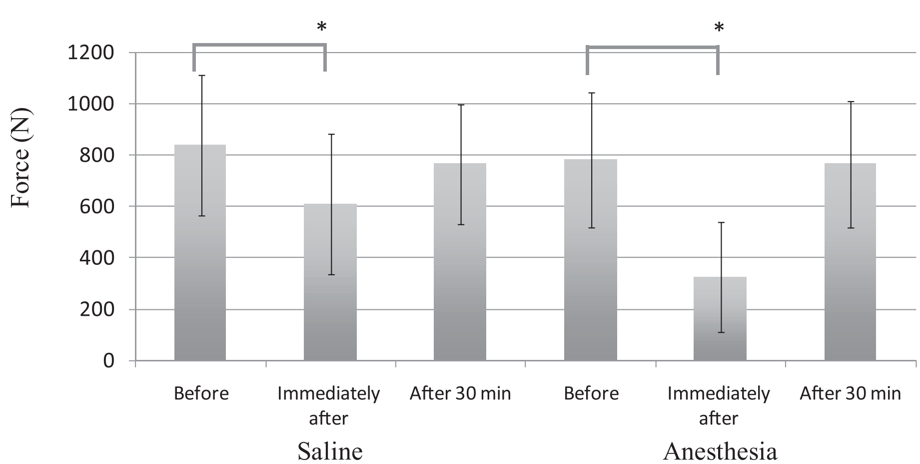

Fig. 5 The 100% MVC occluding force (*$p < 0.05$).

Table 1 a Maximum opening

	First day (Saline)				Second day (TMJ anesthsia)			
	Before		After		Before		After	
Subject	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	13.7	0.6	14.4	0.7	14.0	0.5	15.5	1.3
2	12.5	0.6	12.5	0.8	12.7	1.4	10.5	4.1
3	12.5	0.5	11.4	0.4	12.6	0.8	7.2	2.2
4	10.3	1.0	8.7	1.2	11.6	0.7	10.7	1.8
5	11.6	1.3	12.9	1.2	12.1	1.3	12.3	1.6
6	11.1	0.8	10.8	1.6	10.8	1.4	11.8	1.7
7	12.3	0.4	14.5	0.6	11.5	0.5	16.4	2.4
8	12.6	0.6	11.4	0.5	14.0	0.7	8.2	1.3

(mm)

Table 2 Movement path patterns in this experiment

Experiment		Pattern						
		I	II	III	IV	V	VI	VII
First day (Saline)	Before	335	5	43	0	16	0	1
	After	336	2	37	0	23	0	2
Secondday (TMJ anesthsia)	Before	322	2	43	1	14	0	3
	After	129	3	160	16	67	0	25

(n)

Table 1 b Lateral movement at maximum opening

	First day (Saline)				Second day (TMJ anesthsia)			
	Before		After		Before		After	
Subject	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	0.0	0.6	0.3	1.0	0.1	0.8	−3.0	0.7
2	3.1	1.1	2.5	0.9	5.8	1.2	4.1	1.7
3	−3.7	1.3	−0.3	1.3	−1.8	1.1	0.8	0.4
4	2.2	0.7	1.2	0.5	3.4	1.3	−4.1	1.2
5	−2.4	1.3	−4.6	1.2	−2.5	1.2	−4.8	1.2
6	1.5	0.8	3.1	0.8	1.5	0.8	3.1	0.8
7	5.5	1.1	3.8	0.8	6.3	1.2	9.5	1.1
8	1.5	0.8	2.9	1.1	3.3	0.6	−0.5	1.1

(mm)

Table 3 a Total cycle duration (TC)

	First day (Saline)				Second day (TMJ anesthsia)			
	Before		After		Before		After	
Subject	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	0.46	0.01	0.45	0.02	0.47	0.02	0.56	0.04
2	0.44	0.04	0.37	0.03	0.46	0.04	0.53	0.06
3	0.64	0.05	0.56	0.03	0.64	0.03	0.55	0.08
4	0.66	0.09	0.61	0.02	0.58	0.02	1.01	0.13
5	0.67	0.06	0.59	0.05	0.78	0.11	0.88	0.14
6	0.56	0.02	0.55	0.03	0.47	0.02	0.55	0.03
7	0.51	0.02	0.51	0.02	0.46	0.01	0.59	0.03
8	0.59	0.02	0.68	0.07	0.53	0.06	0.50	0.03
Avg	0.57		0.54		0.55		0.65*	

*$p < 0.05$ (sec)

Table 3 b Times for the opening phase (Op), closing phase (Cl) and occlusion phase (Oc)

	First day (Saline)						Second day (TMJ anesthsia)					
	Before			After			Before			After		
Subject	Op	Cl	Oc	Op	Cl	Oc	Op	Cl	Oc	Op	Cl	Oc
1	0.18	0.18	0.15	0.14	0.16	0.15	0.16	0.16	0.15	0.20	0.20	0.16
2	0.14	0.13	0.17	0.12	0.12	0.13	0.16	0.15	0.14	0.19	0.16	0.18
3	0.24	0.16	0.23	0.23	0.16	0.17	0.24	0.18	0.22	0.18	0.16	0.21
4	0.22	0.20	0.24	0.20	0.19	0.22	0.18	0.20	0.21	0.28	0.35	0.37
5	0.26	0.20	0.21	0.23	0.19	0.17	0.25	0.32	0.21	0.37	0.20	0.31
6	0.19	0.16	0.21	0.19	0.16	0.20	0.16	0.12	0.19	0.20	0.16	0.20
7	0.15	0.17	0.19	0.16	0.16	0.19	0.11	0.17	0.18	0.19	0.19	0.22
8	0.21	0.16	0.22	0.24	0.16	0.28	0.23	0.18	0.13	0.17	0.15	0.17
Avg	0.20	0.17	0.20	0.19	0.16*	0.19	0.19	0.18	0.18	0.22*	0.20	0.23*

*$p < 0.05$ (sec)

the saline was significantly less than for normal chewing.

DISCUSSION

This study took into consideration the physical influence of injection into the right superior TMJ cavity. We injected both saline and 2% lidocaine without epinephrine. Kakudo *et al*.[14] reported that the transport of lidocaine from the artictular cavity into the capillary lumen was slow and that maximum concentration occurred 30 minutes after injection. Therefore, we confirmed the physical influence of injection by measuring the occlusal force 30 minutes after the injection. There were no differences in the occlusal force before and 30 minutes after injection. We believe that the physical influence of the injection on the TMJ was not significant. Many reports have analyzed the functional jaw movements of chewing gum. Several attempts have been made to analyze the degree of vertical and lateral displacement,[15, 16] the rhythm,[15, 17–19] the velocity,[15, 18] and the patterns of masticatory movements.

In this study, the effect of sensory deprivation by local anesthesia was observed for various chewing patterns. We found that the point of maximum opening of the chewing path shifted to the non-working side. However, there were no significant differences before and after the injection of saline and 2% lidocaine.

The chewing path of the mandibular incisal point along the frontal plane has been classified into between 3 and 8 patterns by different investigators.[20–24] These classifications are very detailed and complex, requiring high skill to evaluate. However, Kobayashi's classification is a simplified catalog that lists the types of movements used to classify the paths of the mandibular incisal point. In this study we classified the chewing patterns into 7 types based on Kobayashi's classification.[12] Patterns I and III are considered as representative patterns during mastication of softened chewing gum in healthy subjects.

There have been reports that have evaluated chewing movement in patients with malocclusion.[15, 16, 24, 25] In individuals with unilateral crossbite, the pattern on the contralateral side was similar to that in individuals with normal occlusion, while the pattern on the crossbite side differed from that in individuals with normal occlusion.[24] Correction of malocclusion resulted in a more frequent appearance of the pattern seen in individuals with normal occlusion.[25] Sato *et al*.[26, 27] observed that chewing movement and masticatory efficiency are impaired in patients who have non-reducing disk displacement without reduction of the TMJ. Although the chewing movements of the patients showed deviation to the chewing side while chewing on the TMJ-affected-side, there was no deviation while chewing on the side where the TMJ was not affected. In contrast, in normal volunteers, chewing movements showed deviation to the chewing side.

These reports noted that the chewing movements of patients with clinical abnormalities in the masticatory system were different from normal subjects. It has been suggested that peripheral receptors responsible for the regulation of masticatory rhythm which are distributed in the periodontium, lips, oral mucosa, jaw muscles and TMJ, play an important role in modulating chewing movements. The role of periodontal mechanoreceptors are well known. The absence of sensory input results in reduced masticatory force and distorted spatial control of jaw movements during chewing.[28]

In our results, the chewing patterns after the injection of saline were almost all patterns I and III. However, various chewing paths resulted when 2% lidocaine was injected for sensory deprivation. Patterns V and VII increased after the injection of the lidocaine, indicating that the chewing movements were disrupted by the sensory deprivation created in the TMJ.

The fact that individual chewing rhythm is very stable indicates that it is subconscious and reflectory.[24, 29, 30] However, chewing rhythm slows with malocclusion and mandibular disfunction. The results for TC, Op and Oc were increased after injection of 2% lidocaine, indicating that sensory deprivation of the TMJ disrupted and destabilized chewing movement patterns.

We found that functional jaw movements experienced a partial loss of reflex motor control as a result of sensory deprivation of the TMJ. It would appear that this was likely caused by incapacitation of peripheral mechanoreceptors, particularly those located in the

TMJ. However, it can be seen that chewing movement was still possible with a high degree of precision. We concluded that mechanoreceptors in the TMJ play an important role in reflex control of functional jaw movements.

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