

Title:

Relationship between facial asymmetry and masseter reflex activity

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## Structured abstract

**Purpose:** This study evaluated the tonic vibration reflex (TVR) of the masseter muscles in patients with facial asymmetry.

**Subjects and Methods:** The experiment was performed on 10 volunteers without facial asymmetry and 12 orthognathic patients with facial asymmetry. Subjects were seated in a chair, and held a stimulator composed of an electric motor and an acrylic bite block between the upper and lower dentitions at facial midline, in order to elicit TVR. EMG activity was recorded using a pair of silver electrodes affixed bilaterally with adhesive tape to the skin over the superficial masseter. The amount of mandibular deviation was measured on the frontal cephalogram. The reflex response was evaluated by the TVR index (%) =  $\int \text{TVR} \times 100 / \int \text{maximum voluntary contraction (MVC)}$  and the TVR ratio ( $\int \text{TVR on the high MVC side} / \int \text{TVR on the low MVC side}$ ).

**Results:** In the patient group, the average TVR index on the deviated side was significantly higher than on the non-deviated side. In all subjects, including the control and patient groups, a negative correlation between the amount of mandibular deviation and the side-to-side difference in TVR index was seen ( $r = -0.536$ ,  $p < 0.05$ ,  $n = 22$ ). Also, patients with lower MVC on deviated side than on the non-deviated side, showed a significantly higher TVR ratio than that of the control group.

**Conclusions:** These results suggested that the difference between the right and left reflex response elicited by TVR might be related to frontal craniofacial morphology.

The mandible is unique in its structure; i.e., 1) it consists of a body with its ascending ramus on each side, 2) it is only connected with the other bones of the skull by synovial joints, and 3) masticatory muscles, such as masseter and temporal muscles, attach themselves to it symmetrically. By the time of appearance of the mammals, powerful masticatory muscles had developed that were capable of utilizing the mechanical leverage made available by the ossified craniofacial structures and the joint. These changes were associated with appropriate evolutionary changes in the dentition to provide these mammals with the ability for eating either a carnivorous or an herbivorous diet.

Until recently, it was believed that the mandible grows symmetrically in the craniofacial system. Therefore, there have been reports about facial morphology and muscle function, but no attention to facial asymmetry.<sup>1-3</sup> However, malocclusion and/or mandibular dysfunction due to asymmetry in the craniofacial morphology are being increasingly reported on.<sup>4-7</sup> In patients with mandibular deviation, it is important to understand the relationship between craniofacial morphology and voluntary muscle activity, in order to estimate mandibular growth and possible reactions to orthodontic treatment. Thus, the relationship between them has been extensively studied.

It has been reported that in growing animals, either unilateral destruction of the trigeminal motor nucleus or unilateral resection of the masticatory muscle caused an asymmetrical morphological change in the mandible.<sup>8,9</sup> The results strongly suggested an influence of muscle activity on craniofacial morphology. Since then, electromyographic (EMG) studies have been done to seek a possible relationship between craniofacial asymmetry and masticatory muscle activity at maximum clenching.<sup>4-7</sup> However, they have yielded contradictory results, and in fact only a small

fraction of the day is spent with maximum voluntary contraction of the masticatory muscle. Since during the major part of the day, the posture of the mandible is reflexly maintained based on various peripheral sensory inputs, the relationship between mandibular deviation and reflex activity in the masticatory muscle could be considered worth investigating.

Muscle spindles, which are proprioceptors, are deeply involved in the reflex control of masticatory muscles, and it has been assumed that their sensitivity is controlled by the gamma-motor drive.<sup>10,11</sup> It is also known that the primary endings of muscle spindles are sensitive to and respond vibration over 150 Hz, which elicits continuous muscle contraction.<sup>12</sup> This phenomenon has been termed the tonic vibration reflex (TVR). Muscle activity induced by TVR may be regarded as an activation of the gamma-motor drive controlling the primary endings.<sup>13-15</sup> In the present study, reflex muscle activity was measured during TVR in bilateral masseter muscles, in order to investigate the relationship between mandibular deviation and reflex activity in the masticatory muscle.

## Subjects and methods

### Subjects

Participating in this experiment were 10 facially symmetrical volunteers (mean age 27.0 years), and 12 patients with facial asymmetry (mean age 19.5 years) who displayed unilateral posterior crossbite and a midpoint deviation of 4 mm or more from the facial midline at the menton, as seen on their frontal cephalograms. Written informed consent was obtained from the subjects before the experiment.

## Recording of EMG

Subjects were seated in a chair with headrest, and their eyes were closed so as to avoid environmental information. The Frankfurt horizontal plane was set parallel to the ground. EMG activity was recorded using a pair of silver electrodes (8 mm in diameter, 15 mm apart) affixed with adhesive tape to the skin over the superficial masseter bilaterally, parallel to the muscle fibers. The signals obtained were amplified with biophysical amplifiers and were recorded using a personal computer. After digitizing (12-bit resolution, sampling rate of 500 Hz), signals were displayed on a computer screen and analyzed using an application program (Wave Master; Canopus electronic Co., Kobe, Japan).

## Stimulation

A vibrating device composed of an electric motor and an acrylic bite block, which generated a micro-vibration of 180 Hz, was used as a stimulator. Subjects held the stimulator between the upper and lower dentitions at facial midline, in order to stimulate bilateral masseter muscles simultaneously. The surface of the vibrator block, where made contact with the teeth, was altered for each subject according to previously-taken impressions, so that the vibrator block attached to the dentition was in a stable condition. Vibration of the mandible was monitored with an accelerometer fixed on a lower first molar, and we confirmed that the vibratory stimulus been conducted to the masseter muscles.

To avoid voluntary contraction, subjects were instructed and trained not to actively bite the vibrator block. After sufficient practice, the measurement was performed. The stimulation period was for a total of 20 seconds, but muscle activity was analyzed for a

period of 4 seconds, starting 15 seconds after the onset of stimulation and terminating at 19 seconds.

## Data analysis

### Frontal cephalometric analysis

Frontal cephalograms were obtained with vertically adjustable head holders.<sup>16</sup> All frontal cephalograms were obtained from subjects in intercuspal position and were traced by one of the authors. The amount of mandibular deviation was measured on the frontal cephalogram (Fig. 1).<sup>17</sup> First, the Lo-Lo' line, i.e., joining the two points located at the intersections of the right and left orbital margins with the greater wings of the sphenoids, was determined as the horizontal base line. Second, the line which intersected perpendicularly the Lo-Lo' line at its midpoint, was designated as the vertical base line. Finally, the horizontal distance from Me to the vertical base line was calculated as the amount of mandibular deviation, with right-deviation defined as positive and left-deviation as negative.

### Analysis for muscle activity

The reflex response was evaluated by the TVR index as defined by Takata et al. (1996).<sup>18</sup> In the present study, the evaluation of the reflex response was obtained by a modified TVR index obtained as follows:

TVR index (%) =  $\int \text{TVR} / \int \text{MVC} \times 100$ , where  $\int \text{TVR}$  was 4 seconds of full-wave rectified and integrated EMG activity during stimulation and  $\int \text{MVC}$  was 4 seconds of rectified and integrated EMG activity during maximum voluntary contraction (Fig. 2, Table 1).

The average value of 5 trials was used as the TVR index.

Since TVR index is influenced by  $\int$ MVC and  $\int$ TVR, an effort was made to determine which had a greater contribution on the TVR index,  $\int$ MVC or  $\int$ TVR. First, subjects in the patient group were further divided into two groups in order to take into account the influence of mandibular deviation and MVC activity: one group with lower MVC activity on the deviated side than on the non-deviated side (group P1), and another group with lower MVC activity on the non-deviated side than on the deviated side (group P2). Second, the side with lower MVC was always used as the reference side in each of the groups (control, P1, and P2) and the right/left ratio of MVC activity (MVC ratio) and the right/left ratio of TVR activity (TVR ratio) were individually calculated as well (Table 1).

#### Statistical analysis

A paired t-test was performed to compare intra-individual differences in the muscle activity between right and left sides. An unpaired t-test was performed to compare the difference between the patient group and control group, and a paired t-test was used to compare the difference between the deviated and non-deviated sides in the patient group. Differences with a p-value of less than 0.05 were regarded as significant. Pearson's correlation coefficients were calculated to evaluate the relation between the right and left sides of the TVR index.

## Results

In this study, a vibrator with a built-in block was used as a stimulator. Although an accelerometer confirmed that the jaw was indeed vibrated in every case, TVR was not always induced in all the subjects. Subjects with a distinct TVR response showed reproducible and stable reflex activities; however, others showed small or poor responses. We thus excluded the latter from the study. Hence, the final number of subjects was 10 (62.5%) in the control group and 12 (60%) in the patient group.

### Comparison of TVR index between control and patient groups

The average TVR indices of the control group and patient group were  $10.2 \pm 2.4$  (mean  $\pm$  SE,  $n = 10$ ) and  $12.4 \pm 2.1$  (mean  $\pm$  SE,  $n = 12$ ) respectively. Differences in the absolute TVR index value between the sides were  $3.6 \pm 1.04$  (mean  $\pm$  SE,  $n = 10$ ) in the control group and  $5.6 \pm 1.2$  (mean  $\pm$  SE,  $n = 12$ ) in the patient group. Although the difference was larger in the patient group than the control group, there was no significant difference between them. In the patient group, the average TVR index was  $10.0 \pm 2.0$  (mean  $\pm$  SE,  $n = 12$ ) on the deviated side, whereas it was  $14.8 \pm 2.5$  (mean  $\pm$  SE,  $n = 12$ ) on the non-deviated side. The average index was significantly higher on the non-deviated side than on the deviated side (Fig. 3).

### Correlation of mandibular deviation with side-to-side difference in TVR index

Since a statistically significant difference in TVR index between the deviated and non-deviated sides was found, the correlation between the amount of mandibular deviation and the side-to-side difference in TVR index was calculated in all subjects, including the control and patient groups. A negative correlation was found between

them ( $r = -0.536$ ,  $p < 0.05$ ,  $n = 22$ ) (Fig. 4).

#### Comparison of MVC ratio and TVR ratio between the control and patient groups

As for MVC, neither the P1 nor P2 group showed a significant difference in this ratio compared with that of the control group. In case of TVR, however, the P1 group showed a significantly higher ratio than that of the control group ( $p < 0.05$ ) (Table 2).

## Discussion

Although mandibular deviation has been reported to be from 0 – 1.3 mm in adults with normal occlusion, there still is no standardized criteria for classification of facial asymmetry patients.<sup>19</sup> We therefore classified facial asymmetry patients with 2 mm or more mandibular deviation and cross bite at the canine or molar region on the deviated side. To determine the amount of mandibular deviation, lateral deviation at the menton from the craniofacial-midline was measured on the frontal cephalogram.

Concerning the clinical method for assessing the reflex condition of masticatory muscles, Takata et al. (1996) elicited TVR in the masticatory muscles and devised a TVR index that showed the ratio of TVR activity against MVC activity. We also considered the TVR index to be a clinically useful parameter in assessing the reflex condition of masticatory muscles at rest. Since subjects in the present study included orthodontic patients at the Niigata University Dental Hospital, measurements had to be quick and non-invasive. We therefore modified the stimulator originally used by Takata et al. (1996). In the present study, a vibrator with a bite block built-in was developed to stimulate the masticatory muscle, which could be held lightly so as not to give rise to voluntary contraction between the upper and lower teeth at the cranial midline.

Although stimulus intensity generated by the new stimulator was not enough to elicit the reflex for some of the subjects, it was small and easy enough to use in the clinic.

For EMG recording, non-invasive surface electrodes were chosen, but it was then difficult to compare EMG activity between different muscles and between subjects. Because there were many factors influencing the EMG signals, such as contact resistance between the electrode, and skin and distance between the electrode and target muscle. Therefore, Takata et al. (1996) compared the reflex EMG activity in different muscles by means of a TVR index, which was normalized to the MVC. The present study assessed reflex EMG activity using three parameters; the TVR index, MVC ratio (the ratio of MVC in the muscle with larger activity to that in the muscle with smaller activity at maximum clenching) and TVR ratio.

In comparison with average and side-to-side differences in TVR index between control and patient groups, no statistically significant difference was found. However, comparison of deviated and non-deviated sides in the patient group revealed a significantly larger TVR index in the non-deviated side (Fig. 3). A significantly negative correlation between mandibular deviation and side-to-side difference in the TVR index was also seen (Fig. 4). These results suggested that the difference in the reflex activity between right and left masseter muscles was larger in proportion to the amount of mandibular deviation.

Since the MVC might be closely related to TVR index, assessment of the TVR index using MVC activity in subjects with mandibular deviation may be confounded by a relationship between mandibular deviation and MVC activity. In fact, Akimoto (1994) reported larger masseter MVC activity in the non-deviated side in patients with facial asymmetry. Others, however, reported that masseter MVC was larger in the deviated

side in patients with mandibular protrusion.<sup>4,5</sup> Kondoh (1991) reported that the side-to-side difference in MVC activity correlated with mandibular deviation. As seen in the conflicting results, the relationship between masseter MVC activity and mandibular deviation still remains unclear. It seems to be thus necessary to investigate which has a greater effect on the TVR index, i.e., MVC or TVR. Therefore, we compared the right/left ratio of MVC activity “MVC ratio” and that of TVR activity “TVR ratio” between control and patient groups. There were no significant differences in the MVC ratio between group P1 and the control group, or between group P2 and the control group (Table 2). This may thus suggest no correlation between MVC and mandibular deviation. On the other hand, the TVR ratio in group P1 was significantly larger than that of control group. This suggests that subjects with larger MVC in the non-deviated side have larger TVR activity in that side.

Facial asymmetry is influenced by a variety of causes including heredity, special cases (syndromes and congenital anomalies, trauma, infections), functional factors (airway, allergies, occlusal interferences, imbalances of masticatory muscle, habits) and dysfunctional remodeling of condyles.<sup>20</sup> Based on the results of the present study, it can only be concluded that reflex muscular activity is simultaneously associated with mandibular deviation: since the present study is cross-sectional, the cause-effect relation still remains unclear. Further longitudinal studies will be necessary to completely determine just what kind of relationship exists between reflex muscular activity and craniofacial morphology.

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## Figure legends

FIGURE 1. Planes and landmarks in the frontal cephalogram

Lo, Lo' - Intersection points between the external orbital contours laterally and the oblique orbital line; Nc - Neck of crista galli: the most constricted point of the projection of the perpendicular lamina of the ethmoid; Me – the lowest point of the contour of the chin; d - distance of deviation

FIGURE 2. Measurement of TVR index.

a: EMG of MVC, b: EMG of TVR, c: Fullwave-rectified and integrated EMG of MVC ( $\int$ MVC), d: Fullwave-rectified and integrated EMG of TVR ( $\int$ TVR)

FIGURE 3. Comparison of TVR indices between deviated and non-deviated sides in the patient group (Mean  $\pm$  SE, \* $p < 0.05$ , paired t-test)

FIGURE 4. Correlation between amount of mandibular deviation and TVR indices

Negative numbers on the x-axis indicate mandibular deviation to the left and positive numbers on the x-axis indicate mandibular deviation to the right.