Research Paper

Effect of Tempromandibular Joint Sounds on Timing of the Masseter Muscle Activity in the Open-close-clench Cycle

B. Hafez, S. Talebain, G.R. Oliyae and H. Bagheri

The aim of the present study was to investigate the effect of tempromandibular joint (TMJ) sounds and distribution of malocclusion on the timing pattern of the masseter muscle in the open-close-clench (OCC) cycle. A total of 39 adult women were participated in two part of study. They completed OCC cycles in the functional condition, with 80 cycles in a minute. Two separated recording for 15 sec with an interval 2-3 min from each side were done. The results of comparing the synchronized signals of motion in sagittal plan and electromyography in first part demonstrated the earlier onset of masseter activity in two side and longer duration of right masseter in group with TMJ sounds (21 subjects) compare to controled group (18 subjects). In second part ten subjects were selected which they had only one joint with sound, the ipsilateral masseter (side with TMJ sound) contracted sooner and for a longer duration in comparison with contralateral side. Also in the first part that distribution of occlusion was significantly different between two groups, the two-way ANOVA showed that it had an interaction effect on the increase of the duration of masseter activity. In conclusion, TMJ sounds in accompany with malocclusion without obvious symptoms such as pain and limitation can change timing pattern of masseter activity in the functions same a mastication. This abnormal pattern may affect TMJ and other structures to produce vicious cycle and other problems.

Key words: TMJ sounds, EMG, masseter, timing pattern, motor control

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INTRODUCTION

It is well known that peripheral input of muscles, joints and other tissues around them can influence the controlling action of Central Nervous System (CNS) that design and product functional pattern of muscular activity (Kandel et al., 2000).

Electromyography studies in some painful disorders such as Tempromandibular Disorder (TMD), headache and other craniomandibular muscle pain, has often demonstrated an increase in the resting amplitude and a decrease in maximal contraction of involved muscles such as masseter muscle (Jersen et al., 1994; Bodere et al., 2005; Liu et al., 1999; Nielsen et al., 1990; Pfoh et al., 2000 and Yamaguchi et al., 2002). However a little is known about pattern of muscle activation in TMD (Chong-Shan and Heri-Yun, 1989; Murno et al., 1975; Vegt et al., 2003 and Graven-Nielsen et al., 1995). It is argued that Pattern of muscle activation can better identify involvement of muscles in disorders rather than amplitude (Lahman, 2002).

There are few evidences showing change of amplitude and pattern of masticatory muscles activity in pain free subjects with biomechanical dysfunction such as malocclusion and Tmj sounds (Murko et al., 1975; Yoshida, 1995; Riise, 1984). It means that several factors effect motor activity.

Electromyography of masseter muscle activity is an appropriate choice to study the effect of internal sensory feedback on motor control, because 1) Tempromandibular Joint (TMJ) continually experience cyclic loading in mastication or speech, 2) brain stem and cortical centers control these functions (McDevitt, 1989), 3) masseter muscle is a jaw closer and a surface muscle with many muscle spindles and it has an out standing dynamic role in mastication (Scutter and Turkler, 2001).

The purpose of this study was to investigate effect of the TMJ sounds and distribution of the malocclusion on the timing pattern of masseter muscle in OCC cycle in subjects with no pain in cephalic and cervical regions and no limitation in Mandibular Range of Motion (ROM). We recorded masseter EMG activity simultaneously with OCC cycles of mandibular in sagittal plane. This investigation consisted two part. In first part, subjects with TMJ sounds versus subjects without TMJ sounds. In second part, ipsilateral comparison in same subject (those subjects were chosen who had only one TMJ sound). The aim of second part was to understand direct and indirect effect of TMJ sounds on the pattern of masseter activation, it means that if only one joint had sound, changes in masseter of both sides will be equal. We hypothesize that few dysfunctions in TMJ regularity such as malocclusion and abnormal tracking of mandibular motion that cause sound, would elicited disturbance sensory signal to CNS and may be effect neuromuscular controlling of craniomandibular region specially in the same side.

MATERIALS AND METHODS

Subjects and examination: The present study was a case-control study, which was carried out of 2003 at Tehran University of Medical Science and Health Services on 39 healthy adult female, aged between 19-32. All subjects were consisted students and employees of rehabilitation department. They were fully informed of the nature of the study. All subjects satisfied the following criteria: 1) no history of any pain, limitation and locking in TMJ and surgery or trauma in the craniomandibular region, 2) no history of orthodontic treatment, 3) no frequent taking of drugs that may effect on neuromuscular system, 4) no missing tooth except for the third and/or second molar. In first part were considered twenty-one subjects had single or both joints with sound (Group 1) and eighteen subjects had joint without sound (Group 2). In second part ten subjects were selected who had only one joint with sound. Thus in this part ipsilateral masseter (a side with TMJ sound) was compared with contralateral masseter (a side without TMJ sound).

To detect type of occlusion, relationship of upper and lower first molar and upper and lower canine had been considered (Jaggr et al., 1994). For examination of TMJ sounds, bilateral posterior palpation of TMJ through the external auditory meatus was performed by fingertips and the participant was requested to open and close her jaw rhythmically in functional range (2-3 cm) while teeth did not contact. Those joints, which had repeatable sound or abnormal grinding, were recognized as TMJ sound. For confirming, this test was done several times even in lateral deviation and history of hearing sounds by subjects was also noticed (Jaggr et al., 1994; Boyling et al., 1997; Hertling and Kessler, 1996).

Electromyography recording: The skin was cleaned by alcohol and bipolar surface electrodes (Ag/Ag-Cl), with 20 mm inter-electrode distance, were filled with specific gel and were placed on a line parallel to the masseter muscle fibers (bulk of masseter muscle was prominence by strong clench) (Burnett et al., 2000; Panchez et al., 1986). Then electrodes were fixed by adhesive tapes until impedance of skin did not become more than 5 kΩ (Burdette and Gale, 1990). Ground electrode was attached around the wrist. The electromyography signal of masseter muscle was recorded using a 4-channel Amplified differentially
Electromyograph (Medelec, Premiere model) with CMRR > 100 db. The parameters of record were: Gain: 500 µV/Div., Sweep: 1 sec/Div., Bandpass filter: 10-500 Hz.

**Motion recording:** Mandibular motion cycles in sagittal plane were recorded with mandibular recorder switch which is a simple electrical circuit with output voltage of 3 V. The switch of this circuit had two parts, first part was fixed by adhesive tape) on mandible and the second part was placed on the opposite side of the first part. The unit was set in a way which jaw could be opened and closed for only 2 cm (Fig. 1). When the participant moved her jaw, the first part alternately contacted and separated from upper and lower plate of the second part. Thus, the switch turned on and off following the change in voltage of output signal. In fact, the unit detected the starting point and duration of the closing and opening of jaw motion in any cycles (Fig. 2a).

**Exercise protocol**

**Reliability of EMG recording:** Electromyography of the right and left masseter muscles of seven women (20-27 years), without any painful problem in the mandibulocraniofacial region and orthodontic therapy were taken under the condition of this study for two times with one week interval. Intraclass correlation coefficient of the timing factors (duration and onset latency) of masseter EMG between two sessions was significant and had well to excellent correlation (Table 1).

**Accuracy of mandibular recorder switch:** To study the accuracy of the unit we used digital camera (Mercury, CyberPix, E-560 M) and Ulead video studio software (version 7). This test was done on 5 women (20-27 years) who had no pain in the mandibulocraniofacial region and orthodontic therapy. Interval time between start of jaw closing and turn on of upper plate of switch detected by video was compared with recorded signal of same cycle. This method was also used from the beginning of jaw opening to switch closing of the lower plate. Maximum delay time of switch (measurement error) for detection of start jaw closing was 49±12 m sec and maximum delay time of switch (measurement error) to detect beginning of jaw opening was 32±18 m sec in study's condition (80 cycles of OCC in minute). Although jaw motion was limited by apparatus for 2 cm and mandibular part was sticked perfectly on the subject's mandible, these delays was due to 1) adhesive attachment of mandibular part on the skin and 2) subjects usually opened their mouths more than 2 cm, but this delay was technical error and did not differ in Groups. For minimizing this error we analyzed cycles with similar pattern in each subject.

Table 1: Intraclass correlation coefficient between two sessions

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Onset latency (msec)</th>
<th>Duration (msec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right masseter</td>
<td>ICC = 0.89</td>
<td>ICC = 0.77</td>
</tr>
<tr>
<td>Sigf = 0.007</td>
<td>Sigf = 0.04</td>
<td></td>
</tr>
<tr>
<td>Left masseter</td>
<td>ICC = 0.87</td>
<td>ICC = 0.91</td>
</tr>
<tr>
<td>Sigf = 0.01</td>
<td>Sigf = 0.003</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1: The set up for synchronizing electromyography and mandibular recorder switch records
Testing procedures: Subjects were asked to sit on a chair with arm rest and without head rest. They were instructed to maintain their head in Frankfort to horizontal position (the line parallel horizontal from anterior cartilage of ear to inferior prominence of orbit) and did not change this position during the recording (Fig. 1). After placing the instruments, they were requested to do cycles of OCC same as in chewing gum until near to its functional movement. Speed of motion was standardized with metronome (80 cycles/minute). We tried to create peer conditions for all subjects, because the position of head, speed and power of motion influence on onset of masseter activity (Uchida et al., 1999; Winnberg et al., 1988; Ahlgren, 1967). Masseter is a phasic muscle and fast fatigable (almost 5000 m sec mastication) (Buzinella and Berzin, 2001), so we recorded EMG before reaching this fatigue point. Total duration of each session was around 45 min.

Fig. 2: The diagrams demonstrate the method used to analyze timing of the masseter EMG a) Desirable investigatory variables of masseter activity in one OCC cycle. b) a sample of signal processing in one subject
**Analyzing processing:** These two signals (EMG and mandibular motion) were transferred synchronously to computer by 12-bit A/D board with 1000 Hz sampling rate. There were two-separated recording from each side, for 15 sec with interval of 2-3 min. The mean of 10 cycles was analyzed by Excel software.

To detect onset of the activity, before starting the test, participant opened her mouth 1 cm in order to relaxed and minimized her masseter activity (Manns et al., 1981). To determine baseline of activity on-set and off-set of activity was a point where its intensity was equal to the average of 200 m sec of baseline plus two standard deviation.

By comparing the synchronized signal of motion and rectified EMG, the investigable variables were: 1) onset latency: start of masseter activity until beginning of the jaw closing. So, the muscle activity that preceded jaw closing was indicated as plus and delayed activity was indicated as minus. 2) Duration of masseter activity in OCC cycle. 3) Percentage of duration of masseter activity in OCC cycle. 4) Percentage of onset of masseter activity in OCC cycle (Fig. 2). Last two variables were measured to normalize with regard to the OCC cycle (one cycle corresponds to 100%).

**Statistical analysis:** Statistical analysis was done with SPSS software (version 11.5). Chi-square was used for comparing distribution of occlusion, which was a qualitative variable and analyses of EMG variables were performed with student t-test, because they were normally distributed (using the Kolmogorov Smirnov test). Factors analysis (two-way ANOVA) was used to study interaction of distribution of occlusion and TMJ sounds. We considered differences significant at p<0.05.

**RESULTS**

**First part of study:** In the first part, the onset of both masseter activities in OCC cycle in Group 1 was significantly earlier than the subjects in Group 2 (Table 2). The duration and duration percent of right masseter activity in OCC cycle in Group 1 was significantly more than Group 2 (p<0.001). Onset percent of right masseter activity in OCC cycle in Group 1 was significantly earlier than Group 2 (p<0.001) (Table 2).

Distribution of occlusion in left side was approximately similar in two Groups, but in right side, distribution differed and type I of occlusion in Group 2 was significantly more than Group 1 (p<0.05). Type II of occlusion in Group 1 was more than Group 2, but this difference was not significant (Fig. 3).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Non-sound</th>
<th>Sound</th>
<th>Non-sound</th>
<th>Sound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration (m sec)</td>
<td>340±34.53</td>
<td>87.6±25.63</td>
<td>334±75.5</td>
<td>81.3±39.2</td>
</tr>
<tr>
<td>Onset latency (m sec)</td>
<td>-4.8±32.3</td>
<td>19.9±26.1</td>
<td>-13.2±37.1</td>
<td>25.2±17.7</td>
</tr>
<tr>
<td>Duration percent (%)</td>
<td>46±0.73</td>
<td>50.5±6.4</td>
<td>44.6±8.5</td>
<td>53.4±4.6</td>
</tr>
<tr>
<td>Onset percent (%)</td>
<td>41.9±7.7</td>
<td>36.9±7.7</td>
<td>43.7±8.8</td>
<td>34.2±4.6</td>
</tr>
</tbody>
</table>

*Data are means(SE), *p<0.05, **p<0.01

Fig. 3: Distribution of the types of occlusion in two Groups and two side (*p<0.05)

Fig. 4: Interaction effect of occlusion on duration of masseter in two Group with and without sound. Two-way ANOVA was significant (*p<0.05) in both side.
Table 3: Duration, Onset latency, % duration and %onset of the masseter activity in OCC cycle in Ipsilateral, Contralateral masseter (N = 10)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Duration (msec)</th>
<th>Onset latency (msec)</th>
<th>Duration (%)</th>
<th>Onset (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contralateral-Masseter (Non-sound)</td>
<td>356.58±47.0</td>
<td>23.58±44.2</td>
<td>47.34±4.7</td>
<td>37.65±4.5</td>
</tr>
<tr>
<td>Ipsilateral-Masseter (Sound)</td>
<td>395.68±44.7*</td>
<td>16.86±8.6*</td>
<td>53.24±5.3*</td>
<td>35.11±4.6</td>
</tr>
</tbody>
</table>

1Data are mean±SD. *p<0.05

In factors analysis, type of occlusion had significant interaction effect with the TMJ sounds on the duration (Left masseter: F (2, 25) = 4.74; p<0.05, Right masseter: F (2, 25) = 4.62; p<0.05) (Fig. 4) and on the duration percentage (Left masseter: F (2, 25) = 6.54; p<0.005, Right masseter: F (2, 25) = 3.5; p<0.05). This interaction did not significant for onset latency and onset percentage.

**Second part of study:** In second part, result of student t-test demonstrated sooner and longer muscular activity in ipsilateral as compare to contralateral masseter. The onset percentage was not sensitive same as other factors (Table 3). Distribution of occlusion between two side had no significant difference.

**DISCUSSION**

The main finding of the first part, which we compared timing factor of masseter activity in the subjects with TMJ sounds versus subjects without TMJ sounds, was the early onset of masseter in the both side. Increase of duration and its percentage and earlier onset percentage of the right masseter in the subjects with sound as compare to the subjects without sound. The second part, which ipsilateral comparison was done, showed the early onset and increase of duration and duration percent in the ipsilateral masseter (a side with TMJ sound) as compare to contralateral masseter in the subjects with only one TMJ sound. The interest finding base on factors analysis was demonstrated that distribution of occlusion had interaction effect on increasing the duration and duration percentage of right masseter activity in the first part. This finding show, that malocclusion may had more effect on the duration of masseter activity rather than onset latency.

Biomechanical dysfunction in TMJ is mostly due to disk displacement (Elving et al., 2002) which is a result of insufficiency of involved muscles such as lateral Pterygoid and digastrics muscles in disk sliding in normal motion of mandible (Liu et al., 1989) or is a result of structural variations such as abnormal functional occlusion (Liu et al., 1999). Riise and Sheikholeslam (1984) demonstrated that small occlusal interference (about 0.5 mm) in the intercuspal position in eleven normal males could reduce the intensity and prolong duration of masseter activity during natural mastication (Riise and Sheikholeslam, 1984). Accordingly, we found in first part morphological variation can affect the duration of masseter activity. Increase in duration of masseter activity may increase the time of cyclic loading on the TMJ, so when these abnormality is stabilize and don’t adjust, this can sensitize trigeminal system and can be source of other problem see in cranio-mandibulocervical region. But there is not evidence whether malocclusion is cause of long activity of masseter or these two matters exist parallel.

Without exact para-clinical studies such as CTS, MRI and arthroscopy, we cannot recognize which TMJ really has pathology. On the other hand clinical palpation for examination of click is not an accurate method because some sounds being under audibility threshold (Tallent et al., 1993) and some joints with sound are not really pathologic (Tallent et al., 1993; Gay et al., 1987). We modified the palpation method to acquire the best result from this test to differentiate normal and abnormal joints. In this study, when the subjects opened and closed or laterotrued, first, we noticed any sounds and palpable abnormal joint motion under our fingers and asked subjects about history of hearing the click in the past. Secondly, subjects were ordered to open their mouth in sub maximal range (2-3 cm) to decrease the appearance of click in the end of mouth opening which it has high probability in normal joint, also based on other studies we can say prevalence of dysfunction in TMJ with click were higher than joints without click, even the pain and limitation in mandibular range of motion did not exist, or never appear (Gay and Bertolami, 1988; Motoyoshi et al., 1994).

Our results support previous finding of Munro (1975) who had demonstrated significant increase in the duration of masseter and anterior temporari activity from start of activity until teeth contact in subjects with TMD (They had painful and limited TMJ) and potential of TMD ( they had click or criptus with or without centric slide in TMJ) in compare to controled subjets (Munro, 1975). Yoshida (1995) also showed various changes in EMG patterns, recorded during open-close movement from the superior and inferior heads of the lateral pterygoid muscle, the anterior belly of the digastrics muscle and the temporal muscle in painless TMJ sound with click (Yoshida, 1995).

In conclusion, slight abnormality in biomechanical regulation such as sound in joint could often promote muscular activity such as masseter specific in the side with TMJ sound in second part we observed that TMJ sound had more effective directly on the ipsilateral
masseter than indirectly on the contralateral masseter. Thus in the order to TMJ is a complex joint and two sides act together, but structural and functional dysfunction in one side more effect on masseter activity of same side. On the other hand structural variations such as malocclusion could often increase duration of muscles activity. These alternations of masseter activity had similar pattern to painful disorders such as TMD (Murno, 1975) and low back pain (Vogt et al., 2003). It was suggested that in painful disorder if we just notice to remove pain, other silence mechanical dysfunctions that do not have trouble signs, create constant changes in neuromuscular regularity. Thus in any successful treatment process we should consider these elements and find appropriate way to resolve them.

Further studies to investigate different muscles, in different function and disorder in the cranio-mandibulo-cervical region can be useful to know: what is the cause of altered timing pattern of muscular activity in dysfunctions, painful or not painful elements or both? Do the pattern of muscular activity alter equal in any change of sensory inputs? How much a muscle contributes to the altered pattern of function, For example masseter muscle may alter a lot in one disorder and do not change in the other one?

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