

# Surface electromyographic patterns of masticatory, neck, and trunk muscles in temporomandibular joint dysfunction patients undergoing anterior repositioning splint therapy

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**SUMMARY** The aim of this study was to investigate the surface electromyographic (sEMG) activity of neck, trunk, and masticatory muscles in subjects with temporomandibular joint (TMJ) internal derangement treated with anterior mandibular repositioning splints. sEMG activities of the muscles in 34 adult subjects (22 females and 12 males; mean age 30.4 years) with TMJ internal derangement were compared with a control group of 34 untreated adults (20 females and 14 males; mean age 31.8 years). sEMG activities of seven muscles (anterior and posterior temporalis, masseter, posterior cervicals, sternocleidomastoid, and upper and lower trapezius) were studied bilaterally, with the mandible in the rest position and during maximal voluntary clenching (MVC), at the beginning of therapy (T0) and after 10 weeks of treatment (T1). Paired and Student's *t*-tests were undertaken to determine differences between the T0 and T1 data and in sEMG activity between the study and control groups.

At T0, paired masseter, sternocleidomastoid, and cervical muscles, in addition to the left anterior temporal and right lower trapezius, showed significantly greater sEMG activity ( $P = 0.0001$ ;  $P = 0.0001$ ; for left cervical,  $P = 0.03$ ; for right cervical,  $P = 0.0001$ ;  $P = 0.006$  and  $P = 0.007$  muscles, respectively) compared with the control group. This decreased over the remaining study period, such that after treatment, sEMG activity revealed no statistically significant difference when compared with the control group. During MVC at T0, paired masseter and anterior and posterior temporalis muscles showed significantly lower sEMG activity ( $P = 0.03$ ;  $P = 0.005$  and  $P = 0.04$ , respectively) compared with the control group. In contrast, at T1 sEMG activity significantly increased ( $P = 0.02$ ;  $P = 0.004$  and  $P = 0.04$ , respectively), but no difference was observed in relation to the control group. Splint therapy in subjects with internal disk derangement seems to affect sEMG activity of the masticatory, neck, and trunk muscles.

## Introduction

Mono or bilateral temporomandibular joint (TMJ) disk displacement is found in the majority of patients with symptoms of temporomandibular disorders (TMD; Okeson, 1993). In approximately 50 per cent of these patients, the displaced disk can be held in a normal (reduced) relationship with the condyle by positioning the mandible anteriorly (Okeson, 1993). With the mandible held in this anterior position, clicking and locking are eliminated, and pain relief is usually obtained within a few days (Okeson, 1993). Consequently, anterior mandibular repositioning using maxillary splints has been undertaken to treat TMJ disk displacement (Visser *et al.*, 1992; Okeson, 1993). This form of treatment has proved superior to the use of flat occlusal splints in reducing or eliminating joint noise (clicking), joint pain, and associated muscle symptoms (Farrar, 1971; Farrar and McCarty, 1979; Lundh *et al.*, 1985; Okeson, 1988; Zamburlini and Austin, 1991; Paesani *et al.*, 1992; Orenstein, 1993; Tecco *et al.*, 2004).

Several researchers have investigated surface electromyographic (sEMG) activity of masticatory and neck muscles after splint therapy (Lundh *et al.*, 1985; Dahlström and Haraldson, 1989; Williamson *et al.*, 1993;

Visser *et al.*, 1995; Ormeno *et al.*, 1997; Canay *et al.*, 1998). However, most of these studies focused on the use of flat relaxation splints and on their effects on sEMG activity of the masticator muscles alone. Lundh *et al.* (1985) investigated the immediate influence of stabilization splints and bite plates on masticatory muscle sEMG activity in patients with TMD compared with controls. With the mandible held in the rest position, no statistically significant change in muscle activity was registered with either appliance. Activity during maximal voluntary clenching (MVC) with stabilization splints was not statistically different from that of control subjects, while bite plates caused a statistically significant decrease in sEMG activity of the masticatory muscles in both groups. This decrease, observed during MVC activity, was probably associated with the smaller number of occlusal contacts and with their exclusively anterior position on the bite plate.

Visser *et al.* (1995) investigated the short-term (3–6 weeks) effects of stabilization splints in a group of 35 myogenous TMD patients. In subjects who experienced a statistically significant decrease in temporal sEMG activity during splint therapy, there was a greater decrease in the amount of static pain compared with patients who showed a

significant increase in temporal sEMG activity. This suggested an important role of the temporal muscles in perception of static pain in the masticatory system.

Canay *et al.* (1998) investigated the effectiveness of relaxation splint therapy on sEMG activity of masticatory muscles (anterior temporal and masseter) before and after 6 months use. Following treatment, there was no evident difference in sEMG of these muscles during maximal biting and the changes observed in both the involved and non-involved sides were not statistically significant.

The effects of anterior repositioning splints on sEMG activity of head muscles were first investigated by Williamson *et al.* (1993), who compared the use of an anterior repositioning and centric relation splints on masseter and temporal muscles in 26 patients with TMJ internal derangement, equally divided between the two treatments. After therapy, the results showed a statistically significant reduction in masseter and temporal muscle sEMG activity in subjects treated with an anterior repositioning splint. Anterior repositioning splints proved to be superior to flat occlusal splints in reducing and improving sEMG activity in masticatory muscles, in patients with TMJ internal derangement.

To date, no study has evaluated the effects of anterior repositioning splints on trunk and neck muscles, despite the accepted functional connection between the stomatognathic system and body posture. Thus, the aim of the current investigation was to examine the sEMG activity of neck and trunk muscles in subjects treated with anterior repositioning splints.

The investigated hypothesis is that sEMG activity of neck and trunk muscles could be affected by this type of therapy, due to their neurological connection with the masticatory muscles (Marfurt and Rajchert, 1991).

## Subjects and methods

### Study population

From a total cohort of 205 subjects examined in the Department of Oral Science, University G.d'Annunzio, Chieti, from January to September 2003, 68 patients (42 females and 26 males) with a mean age of 31.3 (range 18–56) years were diagnosed with bilateral TMJ internal disk derangement. The diagnosis was based on the presence of signs (intra-articular sounds and pain) and symptoms (pain during function) and confirmed using magnetic resonance imaging. The diagnostic criteria applied have been previously described (Tecco *et al.*, 2004).

The subjects were assigned by age and gender to either a study group, who received treatment with an anterior repositioning splint, or a control group, who remained untreated and were observed for a period of 4 months. The study group included 34 subjects (22 females and 12 males),

with a mean age of 30.4 (range 20–48) years and the control group 34 subjects (20 females and 14 males), with a mean age of 31.8 (range 18–56) years. There was no significant difference between the groups in terms of mean age or gender distribution.

### Anterior repositioning splint

The study groups were all treated by a single operator (ST) using an anterior mandibular repositioning splint. No adjunctive drug or physiotherapy was prescribed. The anterior repositioning splint (Figure 1) is commonly used in the management of anterior disk displacement with reduction to establish a normal condyle–disk relationship and thus eliminate joint sounds by recapturing the disk. A smooth, co-ordinated, painless range of motion can often be obtained if the disk is recaptured. Thus, mandibular deviation, joint noises, and pain can be eliminated (Visser *et al.*, 1992; Okeson, 1993).

A full coverage splint was constructed for the maxillary arch using clear self-curing acrylic resin, as described by Okeson (1993). An acrylic ramp was incorporated in the anterior palatal area so that during normal closure the mandibular anterior teeth were guided into a protrusive position and posterior teeth retained in occlusal contact. The amount of anterior repositioning in the construction bite averaged 4.5 mm, with a range of 2–6 mm, measured at the anterior teeth. The later the click occurred during opening, the greater the degree of mandibular protrusion required to obtain an acceptable condyle–disk relationship. The subjects were instructed to wear the splint 24 hours a day for a period of 10 weeks (Okeson, 1988). The splint was then modified to allow the mandible to gradually return to its original and more posterior position.

### Clinical outcomes

All subjects were examined following a 10 week treatment or observation period. The presence of joint noise (clicking) was investigated using a stethoscope by the same clinician

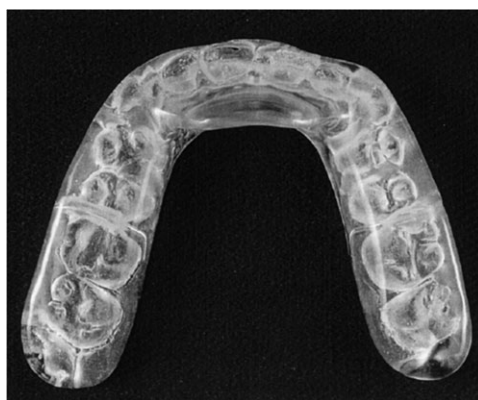


Figure 1 The anterior repositioning splint used in this study.

(FF), blind to the grouping and recorded as present or absent. Each subject was then assessed for the presence of TMJ pain alone or associated with chewing or biting.

#### *sEMG recordings*

sEMG recordings were obtained, blind to the grouping, prior to the beginning of the study (T0) and after 10 weeks of treatment observation (T1). sEMG evaluation was performed using a Key-Win 2.0 surface electromyograph (Biotronic s.r.l., S.Benedetto Tronto, Ascoli Piceno, Italy) with disposable electrodes (DUO F3010 bipolar—10 mm, Ag-AgCl, lithium chloride gel, unit distance 22 mm, LTT FIAB Vicchio, Firenze, Italy). Key-Win 2.0 is a 60-channel electromyograph with a 15–430 Hz band-pass filter, containing a special 60 Hz notch filter to eliminate any electrical noise from the recording environment that exceeds the capabilities of the common mode rejection scheme. All monitoring was performed with the patients in a standing position. The subjects were asked to make themselves comfortable, with their arms by their sides, and to look straight ahead and make no head or body movements during the test. The electrodes, which determine to a large extent the quality of the recordings, were placed according to the electrode atlas described by Cram and Kasman (1997). Before the electrodes were applied, the skin was thoroughly cleaned with ethanol. sEMG activity of seven muscles: masseter, anterior and posterior temporalis (masticatory muscles), and the sternocleidomastoid, posterior cervical, upper and lower trapezius (postural muscles) were studied bilaterally, with the mandible in the rest position (teeth not in contact) and during MVC, applying the protocol developed by Donaldson and Donaldson (1990). In order to avoid occlusal interference during maximal voluntary isometric contraction, the MVC recordings were carried out with cotton wool rolls placed between the dental arches. sEMG recording time was 15 seconds. The raw electromyograms were rectified, the root mean square integrated over time, and the peaks measured in microvolt seconds (Van der Bilt *et al.*, 2001).

#### *Statistical analysis*

The Statistical Package for Social Sciences (SPSS Inc., Chicago, Illinois, USA) was used to perform data analysis. The differences in the frequency distribution of the various clinical outcomes (clicking, chewing/biting pain, and spontaneous pain) were tested for significance using the chi-square test.

sEMG data were tested for normality by means of the Kolmogorov–Smirnov test. As the sEMG data had a markedly skewed distribution, a root square transformation was required to produce a normal distribution. Since the root square transformation was successful, transformed

values were used for significance testing. For each muscle and test situation, a Student's *t*-test was then performed to assess the significance of the differences in sEMG activities between the study and control groups. A paired sample *t*-test was used to determine differences between T0 and T1 data in each group. A probability of  $P < 0.05$  was applied in order to reject the null hypothesis.

## **Results**

#### *Clinical outcomes*

The clinical outcomes obtained in the present investigation are summarized in Table 1. No subject in the test group reported discomfort in relation to their splint. A statistically significant improvement in all the clinical parameters investigated was observed after treatment.

#### *sEMG evaluations*

The sEMG evaluations obtained in the present study are summarized in Tables 2 and 3.

#### *Mandibular rest position*

At T0, all the investigated muscles, in the control group, showed statistically significantly lower sEMG activity compared with the study group. At T1, the bilateral masseter, sternocleidomastoid, and cervical muscles in the study group showed a statistically significant decrease in sEMG activity but no significant difference compared with the control group. Moreover, at T0, sEMG activities of the masseter muscles demonstrated statistically significant differences between the right and left sides, with the latter being greater; this difference disappeared after the therapy. Only the left anterior temporalis and right lower trapezius showed a statistically significant decrease after splint therapy, with both these muscles showing significantly different sEMG activity between the right and left sides. All the investigated muscles in the study group continued to show statistically significantly higher sEMG activity in the mandibular rest position compared with the control subjects.

#### *Maximal voluntary clenching*

The anterior and posterior temporalis, masseter, and upper trapezius muscles at T0 showed a statistically significant difference in sEMG activity compared with the control group. During MVC, while the masseter and the anterior temporalis showed a statistically significant increase in sEMG activity following splint therapy (for both the right and left sides) compared with the T0 values, no such difference was observed when compared with the control group at T1. In addition, bilateral upper trapezius activity was significantly higher in the study group compared with the control group at T0 and T1.

**Table 1** Frequency distribution of clinical outcomes, before (T0) and after (T1) treatment, in the study and the control groups and level of significance group differences.

Temporomandibular joint (TMJ)	Study group (n = 34)			Control group (n = 34)		
	T0 (%)	T1 (%)	Intra-group difference (significance)*	T0 (%)	T1 (%)†	Intra-group difference (significance)
TMJ spontaneous pain	90	10	<i>P</i> < 0.05	80	80	NS
Pain during chewing/biting	70	20	<i>P</i> < 0.05	90	95	NS
TMJ sound	100	10	<i>P</i> < 0.001	100	100	NS

NS, no significant difference in the intra-group comparisons.

\*Significant difference in intra-group comparisons.

†Significantly different from the study group in the inter-group comparisons.

**Table 2** Surface electromyographic (sEMG) activities ( $\mu\text{V/s}$ ) of the different monitored muscles at the mandibular rest position.

Muscles	Study group (n = 34)			Control group (n = 34)		
	T0 (mean $\pm$ SD)	T1 (mean $\pm$ SD)	Difference	T0 (mean $\pm$ SD)	T1 (mean $\pm$ SD)	Difference
Left anterior temporalis	19.9 $\pm$ 7.5	5.42 $\pm$ 7.5*	<i>P</i> < 0.01†	6.2 $\pm$ 3.2‡	5.2 $\pm$ 2.2	NS
Right anterior temporalis	19.6 $\pm$ 7.0	19.5 $\pm$ 8.09	NS	6.6 $\pm$ 2.2‡	6.5 $\pm$ 1.8‡	NS
Left posterior temporalis	46.2 $\pm$ 9.8	43.5 $\pm$ 8.2	NS	7.3 $\pm$ 2.2‡	6.9 $\pm$ 2.1‡	NS
Right posterior temporalis	47.3 $\pm$ 8.6	42.1 $\pm$ 9.1	NS	6.9 $\pm$ 1.8‡	6.8 $\pm$ 1.3‡	NS
Left masseter	16.4 $\pm$ 2.8*	2.3 $\pm$ 2.6	<i>P</i> < 0.001†	4.4 $\pm$ 1.7‡	4.1 $\pm$ 1.2	NS
Right masseter	35.9 $\pm$ 2.2	2.2 $\pm$ 1.8	<i>P</i> < 0.001†	4.2 $\pm$ 2.6‡	5.4 $\pm$ 1.5	NS
Left sternocleidomastoid	17.5 $\pm$ 2.6	7.4 $\pm$ 2.5	<i>P</i> < 0.001†	6.2 $\pm$ 1.4‡	6.2 $\pm$ 2.1	NS
Right sternocleidomastoid	17.2 $\pm$ 2.42	6.8 $\pm$ 2.4	<i>P</i> < 0.001†	7.1 $\pm$ 1.6‡	5.6 $\pm$ 2.2	NS
Left upper trapezius	40.3 $\pm$ 14.2	38.3 $\pm$ 13.2	NS	15.2 $\pm$ 1.3‡	13.6 $\pm$ 1.4‡	NS
Right upper trapezius	40.2 $\pm$ 15.1	39.3 $\pm$ 12.1	NS	13.2 $\pm$ 1.5‡	15.6 $\pm$ 1.4‡	NS
Left lower trapezius	21.7 $\pm$ 4.5	24.7 $\pm$ 4.5	NS	8.4 $\pm$ 2.7‡	12.6 $\pm$ 2.2‡	NS
Right lower trapezius	28.5 $\pm$ 4.1	8.1 $\pm$ 4.02*	<i>P</i> < 0.01†	10.6 $\pm$ 2.4‡	9.1 $\pm$ 2.4	NS
Left posterior cervicals	24.3 $\pm$ 6.2	10.3 $\pm$ 5.1	<i>P</i> < 0.05†	9.3 $\pm$ 2.4‡	8.2 $\pm$ 2.3	NS
Right posterior cervicals	32.3 $\pm$ 6.1	9.4 $\pm$ 3.3	<i>P</i> < 0.001†	8.6 $\pm$ 2.3‡	10.4 $\pm$ 3.5	NS

A Student's *t*-test was used to assess the significance of the differences in sEMG activities between the study and control group. A paired sample *t*-test was then used to determine the significant level of differences between T0 and T1 data in each group. NS, no significant difference in the intra-group comparisons.

\*Significantly different from the corresponding contralateral muscle.

†Significant difference in intra-group comparisons.

‡Significantly different from the study group in the between-group comparisons.

## Discussion

### Clinical outcomes

The findings of the present study are in agreement with those of Tecco *et al.* (2004) who also demonstrated a statistically significant improvement in clinical symptoms after treatment with anterior repositioning splints in subjects with anterior disk displacement.

### sEMG data

The current study objectively monitored, using sEMG activity, the effects of splint therapy in subjects with internal disk derangement. The use of sEMG is based on extracellular recording of the motor unit action potentials by means of surface sensors, and the magnitude of energy recorded is in the microvolt range (Cram and Kasman, 1997). Reflecting muscle activity,

the sEMG signal is lower at rest and greater under isometric contraction; therefore, when a muscle is affected by some dysfunction, the signal at rest generally increases and the sEMG activity decreases during isometric contraction (Cram and Kasman, 1997). In this study, the bilateral masticatory, neck, and trunk muscles were monitored during mandibular rest position and under MVC. The trunk muscles were monitored to determine the effects of therapy on these muscles and on their possible interactions with the masticatory muscles.

### Mandibular rest position

Bilateral sEMG activity of the masseters at rest showed a statistically significant decrease after therapy as compared with the baseline value. The left anterior temporalis muscle also showed a statistically significant decrease in sEMG activity. Moreover, at T0, sEMG activity of the masseter was

**Table 3** Surface electromyographic activities ( $\mu\text{V/s}$ ) of the different muscles investigated in maximal voluntary clenching.

Muscles	Study group ( $n = 34$ )			Control group ( $n = 34$ )		
	T0 (mean $\pm$ SD)	T1 (mean $\pm$ SD)	Difference	T0 (mean $\pm$ SD)	T1 (mean $\pm$ SD)	Difference
Left anterior temporalis	192.5 $\pm$ 38.8	202.1 $\pm$ 35	$P < 0.01^*$	278.1 $\pm$ 22.1†	290.4 $\pm$ 34.2	NS
Right anterior temporalis	204.9 $\pm$ 32.9	270.7 $\pm$ 45.7	$P < 0.01^*$	280.9 $\pm$ 32.2†	290.7 $\pm$ 45.5	NS
Right posterior temporalis	102.6 $\pm$ 24.6	206.7 $\pm$ 23.3	$P < 0.05^*$	203.1 $\pm$ 44.6†	209.7 $\pm$ 26.1	NS
Left posterior temporalis	107.1 $\pm$ 32.4	104.1 $\pm$ 28.9	$P < 0.05^*$	197.1 $\pm$ 21.4†	203.4 $\pm$ 27.4	NS
Left posterior cervicals	24.5 $\pm$ 4.3	28.5 $\pm$ 5.1	NS	23.5 $\pm$ 8.2	24.2 $\pm$ 7.1	NS
Left masseter	190.6 $\pm$ 27.8	299.6 $\pm$ 47.31	$P < 0.05^*$	298.6 $\pm$ 37.5†	309.2 $\pm$ 27.1	NS
Right masseter	179.7 $\pm$ 27.4	307.4 $\pm$ 59.3	$P < 0.05^*$	301.7 $\pm$ 37.4†	299.4 $\pm$ 39.7	NS
Left sternocleidomastoid	20.4 $\pm$ 5.8	19.9 $\pm$ 4.8	NS	22.6 $\pm$ 3.4	22.3 $\pm$ 5.3	NS
Right sternocleidomastoid	21.9 $\pm$ 4.2	21.3 $\pm$ 4.4	NS	23.9 $\pm$ 5.7	25.9 $\pm$ 5.1	NS
Left upper trapezius	43.2 $\pm$ 4.3	42.8 $\pm$ 4.7	NS	13.2 $\pm$ 2.3†	15.8 $\pm$ 4.7†	NS
Right upper trapezius	38.4 $\pm$ 3.7	38.5 $\pm$ 3.8	NS	18.4 $\pm$ 2.2†	18.5 $\pm$ 3.8†	NS
Left lower trapezius	10.40 $\pm$ 4.09	10.19 $\pm$ 4.33	NS	8.2 $\pm$ 2.9	9.1 $\pm$ 3.3	NS
Right lower trapezius	10.25 $\pm$ 4.3	10.18 $\pm$ 4.20	NS	10.5 $\pm$ 3.3	9.1 $\pm$ 4.1	NS
Right posterior cervicals	26.7 $\pm$ 6.2	27.7 $\pm$ 8.6	NS	24.7 $\pm$ 6.2	28.3 $\pm$ 8.6	NS

A Student's *t*-test was carried out to assess the significance of the differences in sEMG activities between the study and the control groups. A paired sample *t*-test was then used to test the significant level of differences between T0 and T1 data in each group. NS, no significant difference in the intra-group comparisons.

\*Significant difference in intra-group comparisons.

†Significantly different from the study group in the between-group comparisons.

significantly different between the right and left sides, with the latter being greater. The difference was not present after therapy, suggesting the efficacy of the anterior repositioning splint to obtain equilibrium between the right and left masseter muscles. However, an inverse behaviour was observed for the anterior temporalis muscles, as their activity was equal bilaterally at T0, but showed a statistically significant difference at T1. This finding suggests that treatment could have resulted in a new sEMG pattern of the masticatory muscles, although maintaining their asymmetric activity at different levels.

The findings of the current study are consistent, at least in part, with those of Williamson *et al.* (1993) who compared sEMG response of masseter and temporalis muscles with the use of anterior repositioning and centric relation splints. Those authors reported that, after treatment, both muscles showed statistically significant lower sEMG activity in the mandibular rest position in patients treated with the anterior repositioning splint compared with those treated with the centric relation splint.

The primary aim of the current investigation was to evaluate sEMG activity in the neck and trunk muscles after therapy. The most interesting finding was that sEMG activity of the sternocleidomastoid and cervical muscles at rest showed a statistically significant bilateral decrease after treatment, suggesting that the splint could affect the function of the neck muscles. In addition, the right lower trapezius showed a statistically significant decrease in sEMG activity at rest, suggesting the existence of links between masticatory muscle activity and trunk muscle activity.

These findings could be considered to be in agreement with those of Santander *et al.* (1994) who investigated

changes in sEMG activity of sternocleidomastoid and trapezius muscles and cranio-cervical relationship, following the use of a full-arch maxillary stabilization splint in 15 subjects with spasm in the aforementioned muscles. Splint use was reported to decrease tonic and saliva swallowing EMG activity in the sternocleidomastoid muscle. However, it should be noted that there were significant differences in the treatment time in the study of Santander *et al.* (1994) and the current investigation. A further study by al-Abbasi *et al.* (1999) investigation also demonstrated that the peak isometric strength of cervical muscles could be affected by bite position and vertical occlusal dimension, suggesting a cranio-mandibular cervical masticator system.

#### Maximal voluntary clenching

During MVC, the masseter and right temporalis muscles showed a significant increase in sEMG activity at T1 compared with T0. This suggests that the effect of mandibular repositioning splints primarily acts on the masticatory muscles. These findings also suggest the importance of splint design in ensuring the mandible is repositioned anteriorly, in determining sEMG responses. A previous study found no change in sEMG activity of the masseter and temporalis muscles during MVC, after 6 weeks of therapy using a muscle relaxation splint (Canay *et al.*, 1998).

In contrast, Dahlström and Haraldson (1989) investigated the immediate sEMG response to bite plates and found a statistically significant decrease in the activity of the masseter and anterior temporalis muscles during MVC. However, this decrease was associated with the reduced number of anterior occlusal contacts on the bite plate.

With regard to neck and trunk muscle activity, splint treatment did not produce the same levels of change, as there was with no detectable difference in sEMG activity. The different results observed within the stomatognathic area may be explained by the existence of different synaptic connections for the temporal, masseter, sternocleidomastoid, and trapezius muscles (Marfurt and Rajchert, 1991). It should be noted that muscle sEMG activity can be affected by several factors, for example, psychological stress. A negative stress profile may have a specific influence on muscular activity that may be of importance for musculoskeletal disorders (Rissen *et al.*, 2000). Ruf *et al.* (1997) found that sEMG activity of the masticatory muscles during stress situations was significantly higher and that females had significantly higher ratings than males. However, those investigations deliberately induced experimental stress which was not present in this study.

### Conclusions

1. Anterior mandibular repositioning splint therapy improved clinical outcomes in subjects with TMJ internal derangement.
2. Masticatory muscles showed a statistically significant change in sEMG activity at rest and during MVC, following splint therapy, although the clinical impact of these changes has not been investigated.
3. Splint therapy seemed to have an impact on sEMG activity of the neck muscles (sternocleidomastoid, cervicals, and lower trapezius) in the mandibular rest position, although the clinical importance of this impact has still to be clarified.
4. The results demonstrate that sEMG should be more extensively used in research in order to better understand the complex body posture system and the relationship between the stomatognathic system and the neck and trunk muscles.

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### References

- al-Abbasi H, Mehta N R, Forgione A G, Clark R E 1999 The effect of vertical dimension and mandibular position on isometric strength of cervical flexors. *Journal of Temporomandibular Practice* 17: 85–92
- Canay S, Cindas A, Uzun G, Hersek N, Kutsal Y G 1998 Effect of muscle relaxation splint therapy on the electromyographic activities of masseter and anterior temporalis muscles. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* 85: 674–679
- Cram J R, Kasman G S 1997 *Introduction to surface electromyography*. Aspen Publishers, Gaithersburg
- Dahlström L, Haraldson T 1989 Immediate electromyographic response in masseter and temporal muscles to bite plates and stabilization splints. *Scandinavian Journal of Dental Research* 97: 533–538
- Donaldson S, Donaldson M 1990 Multi-channel EMG assessment and treatment techniques. In: Cram J R (ed). *Clinical EMG for surface recordings*, Vol. 2. Clinical Resources, Nevada City, pp. 143–174.
- Farrar W B 1971 Diagnosis and treatment of anterior dislocation of the articular disc. *New York Journal of Dentistry* 41: 348–351
- Farrar W B, McCarty W L 1979 Inferior joint space arthrography and characteristics of condylar paths in internal derangements of the TMJ. *Journal of Prosthetic Dentistry* 41: 548–555
- Lundh H, Westesson P-L, Kopp S, Tillstrom B 1985 Anterior repositioning splint in the treatment of temporomandibular joints with reciprocal clicking: comparison with a flat occlusal split and an untreated control group. *Oral Surgery, Oral Medicine, and Oral Pathology* 60: 131–136
- Marfurt C F, Rajchert D M 1991 Trigeminal primary afferent projections to 'non-trigeminal' areas of the rat central nervous system. *Journal of Comparative Neurology* 303: 489–511
- Okeson J P 1988 Long-term treatment of disk-interferences disorders of the temporomandibular joint with anterior repositioning occlusal splints. *Journal of Prosthetic Dentistry* 60: 611–616
- Okeson J P 1993 *Management of temporomandibular disorders and occlusion*, 3rd edn. C V Mosby, St Louis, pp. 407–413
- Orenstein E S 1993 Anterior repositioning appliances when used for anterior disk displacement with reduction—a critical review. *Journal of Temporomandibular Practice* 11: 141–145
- Ormeno G *et al.* 1997 Body position effects on sternocleidomastoid and masseter EMG pattern activity in patients undergoing occlusal splint therapy. *Journal of Temporomandibular Practice* 15: 300–309
- Paesani D, Westesson P-L, Hatala M, Tallents R H, Kurita K 1992 Prevalence of internal derangement in patients with temporomandibular disorders. *American Journal of Orthodontics and Dentofacial Orthopedics* 101: 41–47
- Rissen D, Meilin B, Sandsjö L, Dohms I, Lundberg U 2000 Surface EMG and psychophysiological stress reactions in women during repetitive work. *European Journal of Applied Physiology* 83: 215–222
- Ruf S, Cecere F, Kupfer J, Pancherz H 1997 Stress-induced changes in the functional electromyographic activity of the masticatory muscles. *Acta Odontologica Scandinavica* 55: 44–48
- Santander H, Miralles R, Jimenez A, Zuniga C, Rocabado M, Moya H 1994 Influence of stabilization occlusal splint on craniocervical relationships. Part II: electromyographic analysis. *Journal of Temporomandibular Practice* 12: 227–233
- Tecco S, D'Attilio M, Epifania E, D'Alconzo F, Festa F 2004 The treatment of joint pain and joint noises associated with a recent TMJ internal derangement. A comparison between anterior repositioning splint, a full-arch maxillary stabilization splint and an untreated control group. *Journal of Temporomandibular Practice* 22: 209–219
- Van der Bilt A, Weijnen F G, Bosman F, Ven der Glas H W, Kuks J B M 2001 Controlled study of EMG activity of the jaw closers and openers mastication in patients with myasthenia gravis. *European Journal of Oral Science* 109: 160–164
- Visser A, McCarroll R S, Naeije M 1992 Masticatory muscle activity in different jaw relations during submaximal clenching efforts. *Journal of Dental Research* 71: 372–379
- Visser A, Naeije M, Hansson T L 1995 The temporal/masseter co-contraction: an electromyographic and clinical evaluation of short-term stabilization splint therapy in myogenous CMD patients. *Journal of Oral Rehabilitation* 22: 387–389
- Williamson E H, Navarro E Z, Zwemer J D 1993 A comparison of electromyographic activity between anterior repositioning splint therapy and a centric relation splint. *Journal of Temporomandibular Practice* 11: 178–183
- Zamburlini I, Austin D 1991 Long-term results of appliance therapies in anterior disk displacement with reduction: a review of the literature. *Journal of Temporomandibular Practice* 9: 361–368