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# Craniomandibular status and function in patients with habitual snoring and obstructive sleep apnoea after nocturnal treatment with a mandibular advancement splint: a 2-year follow-up

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SUMMARY The aim of the investigation was to evaluate the status and function of the temporomandibular joint (TMJ) and masticatory system in patients with habitual snoring and obstructive apnoea after 2 years nocturnal treatment with a mandibular advancement splint.

Thirty-two patients participated in the study, ranging from 43.0 to 79.8 years of age (mean 54.4 years, SD 8.78) at the start of treatment. All patients had been referred from the ENT department for treatment with a mandibular advancement splint. The acrylic splint advanced the mandible 50–70 per cent of maximal protrusion, opened 5 mm vertically, and was used 6–8 hours per night and 5–7 nights per week. Overjet, overbite, and molar relationship were measured on dental casts. The patients were asked to answer a questionnaire concerning symptoms of craniomandibular dysfunction (CMD). They were also clinically examined in a standardized manner, including registration of range of mandibular movements, TMJ sounds, pain on movement, and palpatory tenderness of the TMJ and the masticatory muscles.

None of the patients showed more than five symptoms of dysfunction either at the start of or after 2 years of treatment. A decrease in the frequency of headache was found for nine of those 18 patients that reported headache ($P = 0.004$). A minor, but significant decrease in overjet and overbite was found and the molar relationship was also changed.

It was concluded that 2 years' treatment with a mandibular advancement splint had no adverse effects on the craniomandibular status and function, but the observed occlusal changes requires further evaluation.

## Introduction

Upper airway respiratory disorders, such as habitual snoring and obstructive sleep apnoea (OSA), are relatively common in the general population. Men are more commonly affected than women and complete polygraphic sleep registration has shown a prevalence of OSA of approximately 1–3 per cent in adult males (Lavie, 1983). The prevalence of OSA increases with age, and is most often identified in mid-life with the development of loud snoring and excessive daytime sleepiness. OSA has attracted significant attention because of an increased risk of diurnal hypertension, nocturnal dysrhythmias, pulmonary hypertension, right and left ventricular failure, myocardial infarction, and stroke (Yamashiro and Kryger, 1994; Strollo and Rogers, 1996).

The data on the effectiveness of oral appliances/mandibular advancement splints in the treatment of OSA are conflicting (Clark and Nakano, 1989; Lowe, 1994; O'Sullivan *et al.*, 1995; Schmidt-Nowara *et al.*, 1995; Bernhold and Bondemark, 1998). Nevertheless, their use in the treatment of habitual snoring and mild OSA has gained increased attention and acceptance.

The pathogenesis of snoring, and the pharyngeal narrowing and obstruction in OSA is still unclear. Skeletal relationships, muscle tone, soft tissue structure, and volume have been proposed as important factors to maintain airway patency during sleep (Riley *et al.*, 1983; Davies and Stradling, 1990). The effect of the mandibular advancement splint in the treatment of OSA is based on creating an anterior displacement of the mandible causing anatomical alterations of hard, as well as soft tissue in the oro-pharyngeal region resulting in a widening of the pharynx (Athanasiou *et al.*, 1994; Mayer and Meier-Ewert, 1995). Recently, it has also been reported that absence or abnormality of EMG-response of the oro-pharyngeal muscles to the negative inspiratory pressure found in OSA subjects, seem to be normalized by splint therapy (Ono *et al.*, 1996; Mortimer and Douglas, 1997). Thus, the narrowing and closure of the unstable upper airway may be counteracted.

In clinical investigations of patients with craniomandibular disorders (CMD), the most commonly reported subjective symptoms are pain from the temporomandibular joint (TMJ) and/or masticatory muscles, pain on movement, and locking of the TMJ (Rieder *et al.,* 1983; Mejersjö, 1984; Agerberg and Helkimo, 1987; Wedel, 1988). Although dysfunction and pain from the stomatognathic system are considered multifactorial, the treatment of snoring and OSA by repositioning the mandible in a considerably more forward position may place a strain upon the orofacial structures, causing adverse effects on the TMJ and masticatory system. However, studies on the functional status in OSA-patients treated with advancement splints or the effect of such treatment on the TMJs and mandibular function are lacking or limited.

The aim of the present investigation was to evaluate the status and function of the TMJ and masticatory system in patients with habitual snoring and OSA after 2 years' nocturnal treatment with a mandibular advancement splint.

## Subjects and methods

Thirty-two consecutive patients with socially handicapping snoring or OSA participated in the study. Twenty-three were male and nine were female, and the patients' ages ranged from 43.0 to 79.8 years of age with a mean of 54.4 years (SD 8.78) at the start of therapy. All patients had been referred from the ENT department for treatment with a mandibular advancement splint.

The monobloc mandibular advancement splint was fabricated from acrylic and with full tooth coverage in both arches. A special instrument, the George Gauge™, was used to select the desired forward and vertical position of the mandible (George, 1992). The splint advanced the mandible 50–70 per cent of maximal protrusion with 5 mm opening vertically between the incisal edges in all 32 patients. To increase the mechanical retention of the splint to the teeth, it was supplemented with eight posteriorly placed stainless steel clasps. Furthermore, the splint was designed with an open anterior space through the acrylic to ensure adequate air flow.

### *Anamnestic examination*

The patients were asked to answer a questionnaire concerning different symptoms of CMD (Helkimo, 1974; Agerberg and Helkimo, 1987; List *et al.*, 1992) at the start and after 2 years of treatment. The severity of the reported symptoms was expressed as an anamnestic index ($A_i$; Helkimo, 1974). With the aid of this index, the symptoms before and after 2 years of treatment were classified into one of three groups: $A_i0$, no symptoms; $A_iI$, mild symptoms, including a feeling of tired jaws, jaw stiffness, and TMJ sounds; and $A_iII$, severe symptoms, including one or more of the following: difficulty in opening wide, jaw locking or dislocation, pain on movement of the mandible, and pain in the TMJ region and/or masticatory muscles. Since headache is not included in the Helkimo's anamnestic index, a question regarding headache frequency, graded on a four-point scale (never, monthly, weekly, daily) was added.

### *Clinical examination*

The patients were clinically examined in a standardized manner (Zarb and Carlsson, 1988),

which included measurement of the range of movement of the mandible, the function of the TMJ, pain on movement of the mandible, and pain on palpation of the TMJ and the masticatory muscles. From these registrations, the clinical dysfunction score, ranging from 0 to 25 points, was determined (Helkimo, 1974).

*Measurements on dental casts*

Sliding calipers measuring to the nearest 0.1 mm were used to measure the following occlusal parameters on dental casts before and after 2 years of treatment:

*Overbite:* the vertical distance in millimetres between the tips of the upper and lower incisors.

*Overjet:* the horizontal distance in millimetres between the labial surface of the most prominent upper incisor and the lower tooth directly behind this point.

*Molar relationship:* on the right and left sides the distance in millimetres was measured between the mesiobuccal cusp tip of the maxillary first molar and the buccal groove of the mandibular first molar. In a Class I molar relationship this value will be approximately 0 mm. Positive values indicate a Class II relationship and negative values a Class III relationship.

The measurements on the dental casts and the clinical examination were carried out by the same investigator before as well as after 2 years of treatment.

*Statistical procedures*

For measurements of mandibular movement capacity and measurements on dental casts the paired *t*-test was used for differences within samples and for differences between samples the unpaired *t*-test was used after *F*-tests for equal or unequal variances. For variables measured on an ordinal scale, the Wilcoxon matched-pairs signed-rank test was used. Differences with probabilities of less than 5 per cent ($P < 0.05$) were considered to be statistically significant.

## Results

All patients easily accepted the mandibular advancement splint and were very motivated towards treatment. They used the splint 6–8 hours per night and 5–7 nights per week throughout the 2-year treatment period.

No significant differences were found between the sexes. Recordings from men and women were therefore pooled and analysed together.

*Anamnestic examination*

During the first nights of use eight patients reported transient symptoms such as slight tenderness in the teeth and/or increased salivary secretion. Two patients reported increased jaw stiffness for approximately half-an-hour after removal of the appliance in the morning.

No significant difference was found in the anamnestic index after the 2-year treatment period. Twenty-nine patients showed no change in anamnestic index. In two patients, an improvement from $A_i$II to $A_i$I was found, while in one patient the index increased from $A_i$0 to $A_i$I (Table 1).

Figure 1 summarizes the patients' replies to the question concerning headache at the start and after the 2-year treatment period. As will be seen from Figure 1, a decrease in the frequency of headache was found for nine of those 18 patients who reported headache monthly or more often ($P = 0.004$).

*Clinical examination*

The change in mandibular mobility during the 2-year period was negligible (Table 2), and none

**Table 1** Anamnestic pain-dysfunction index ($A_i$, see Methods for definitions). Severity of symptoms at the start and after 2 years' nocturnal treatment with a mandibular advancement splint ($n = 32$).

| $A_i$ | Start | After 2 years | Probability |
|---|---|---|---|
| 0 | 23 | 22 | NS |
| I | 7 | 10 | NS |
| II | 2 | 0 | NS |

NS = not significant.

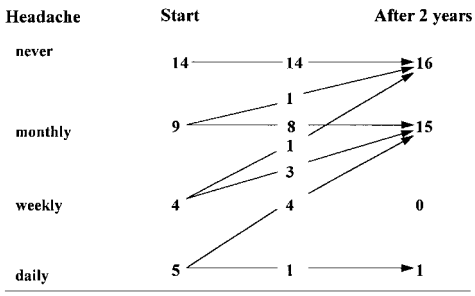


**Figure 1** Distribution of reported frequency of headache at the start and after 2 years' nocturnal treatment with a mandibular advancement splint, as well as the changes during the 2-year period given separately for the patients ($n$ = 32). A significant decrease in the frequency of headache was found in the group, $P$ = 0.004 (Wilcoxon matched-pairs signed-rank test).

of the patients complained of pain provoked by mandibular movements.

Tenderness to palpation of the TMJ and different masticatory muscles is reported in Table 3. The temporal muscle most commonly showed tenderness to palpation, but only minor and insignificant changes in muscle tenderness to palpation were found. The TMJ remained almost unchanged in tenderness to palpation during the 2-year treatment period.

The function of the TMJ showed only minor differences when the status before and after 2 years treatment was compared. Joint sounds were found in nine patients before treatment and in 12 patients after the 2-year treatment period (Table 4). Deviation of the mandible more than 2 mm was found in two patients, while none of the patients showed locking or luxation (Table 4).

The distribution and changes of the clinical dysfunction score for the patients in the Helkimo dysfunction index are presented in Figure 2. Minor and insignificant changes occurred among the patients during the 2-year treatment period. None of the patients showed more than five symptoms, either at the start of treatment or after 2 years of treatment with the mandibular advancement splint.

### *Measurements on dental casts*

The measurements on the dental casts at the start and after 2 years treatment are shown in Table 5. A significant decrease in overjet and overbite was found, as well as a significant change in molar relationship, thus indicating a more mesial sagittal relationship and/or change in incisor inclination.

## Discussion

Treatment of habitual snoring and mild OSA using mandibular advancement splints has gained increased attention and acceptance. However, a major concern when repositioning the mandible in a considerably more forward position several hours per night has been that it may place a special strain upon the orofacial structures, causing adverse effects on the TMJ and masticatory system. The present study, however, has shown that 2 years' nocturnal treatment with a mandibular advancement splint in patients

**Table 2** Mandibular movement capacity (mm) at the start and after 2 years' nocturnal treatment with a mandibular advancement splint ($n$ = 32).

| Mandibular movement | Start | | | After 2 years | | | |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Range | Mean | SD | Range | Probability |
| Opening | 51.5 | 3.64 | 42.0–59.0 | 51.3 | 4.08 | 42.0–59.0 | NS |
| Right lateral | 8.6 | 1.24 | 6.0–11.0 | 8.7 | 1.18 | 5.0–11.0 | NS |
| Left lateral | 8.2 | 1.06 | 6.0–10.0 | 8.3 | 1.01 | 5.0–10.0 | NS |
| Protrusion | 7.8 | 1.08 | 5.0–10.0 | 7.7 | 1.02 | 5.0–10.0 | NS |

NS = not significant.

**Table 3** Areas tender to palpation according to the clinical examination at the start of treatment and after 2 years' nocturnal treatment with a mandibular advancement splint ($n$ = 32).

| | Start | After 2 years | Probability |
|---|---|---|---|
| Temporalis | | | |
| No | 28 | 32 | NS |
| Yes, right | 2 | 0 | |
| Yes, left | 2 | 0 | |
| Masseter | | | |
| No | 29 | 31 | NS |
| Yes, right | 1 | 0 | |
| Yes, left | 2 | 1 | |
| Medial pterygoid | | | |
| No | 32 | 32 | NS |
| Yes, right | 0 | 0 | |
| Yes, left | 0 | 0 | |
| Lateral pterygiod | | | |
| No | 31 | 31 | NS |
| Yes, right | 1 | 1 | |
| Yes, left | 0 | 0 | |
| TMJ, right | | | |
| No | 31 | 30 | NS |
| Yes, laterally | 0 | 1 | |
| Yes, posteriorly | 1 | 1 | |
| TMJ, left | | | |
| No | 32 | 31 | NS |
| Yes, laterally | 0 | 1 | |
| Yes, posteriorly | 0 | 0 | |

NS = not significant.

**Table 4** TMJ function according to the clinical examination at the start of treatment and after 2 years' nocturnal treatment with a mandibular advancement splint ($n$ = 32).

| | Start | After 2 years | Probability |
|---|---|---|---|
| Clicking | | | |
| No | 24 | 21 | NS |
| Yes, right | 5 | 7 | |
| Yes, left | 3 | 4 | |
| Crepitation | | | |
| No | 31 | 31 | NS |
| Yes, right | 1 | 1 | |
| Yes, left | 0 | 0 | |
| Deviation | | | |
| No | 30 | 30 | NS |
| Yes, to the right | 1 | 1 | |
| Yes, to the left | 1 | 1 | |
| Locking or luxation | | | |
| No | 32 | 32 | NS |
| Yes | 0 | 0 | |

NS = not significant.

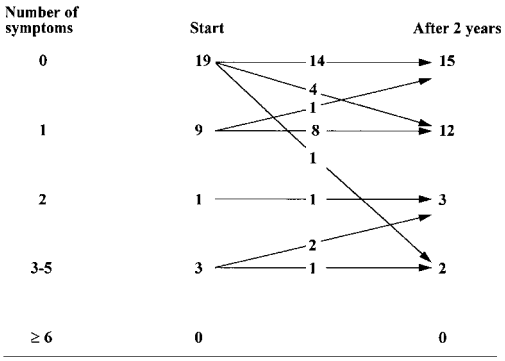


**Figure 2** Distribution and changes in clinical dysfunction score according to the Helkimo dysfunction index (Helkimo, 1974) given separately for the patients at the start and after 2 years' nocturnal treatment with a mandibular advancement splint ($n$ = 32). No significant change was found in the group (Wilcoxon matched-pairs signed-rank test).

with habitual snoring and OSA has no clinically recordable adverse effects on craniomandibular status and function. In a previous study, Bernhold and Bondemark (1998) found that 6 months treatment of snoring and OSA patients with a two-piece magnetic mandibular advancement splint also caused negligible changes of the anamnestic and clinical pain-dysfunction index. Thus, treatment of snoring and OSA with an advancement splint seems to be well tolerated by the stomatognathic system in subjects with healthy TMJs and muscles at the start of treatment.

The dental cast measurements showed that the overjet and overbite was decreased and the molar relationship was changed towards a more mesial sagittal relationship, indicating a conceivable forward movement of the mandible and/or change in incisor inclination. These changes, albeit at a smaller magnitude, are similar to those occurring in the dentition after treatment with functional bite jumping appliances in growing individuals. However, no signs of change in the dentition or movement of teeth could be observed at the clinical examination and none of the patients reported any permanent sense of altered occlusion. If an individual tooth had been moved during treatment, it should have been observed since the appliance, with full-arch

**Table 5** Occlusal parameters (see Methods for definitions): measurements in millimetres on dental casts at the start and after 2 years' nocturnal treatment with a mandibular advancement splint ($n = 32$).

| Measurements | Start | | | After 2 years | | | |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Range | Mean | SD | Range | Probability |
| Overjet | 4.5 | 2.66 | 0.0–13.5 | 4.1 | 2.59 | 0.0–12.0 | *** |
| Overbite | 3.6 | 2.14 | –1.0–7.0 | 3.5 | 2.13 | –1.0–0.0 | * |
| Molar relationship right | 0.7 | 1.36 | –2.0–5.0 | 0.5 | 1.23 | –3.0–5.0 | ** |
| Molar relationship left | 0.8 | 1.42 | –1.5–5.5 | 0.5 | 1.41 | –3.5–5.0 | ** |

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

occlusal coverage to tie all the teeth firmly together, would then not have fitted.

The nature of the possible occlusal changes is of importance due to the requirement for life-long treatment. Conceivably, these changes are related to remodelling of the TMJs or, more likely, to a neuromuscular adaptation, which may have an influence on the posture of the mandible. Additional cephalometric, radiographic, and clinical studies are needed, and are in progress, to elucidate the nature and the magnitude of these changes.

The methods used in this study to detect changes in status and function of the craniomandibular system included a questionnaire combined with a clinical examination. The reliability of the answers concerning subjective symptoms can always be discussed, but the questions were the same as or only slightly modified from those used in other studies (Helkimo, 1974; Agerberg and Helkimo, 1987; List *et al*., 1992) and the clinical investigation was performed by one of the investigators before, as well as after 2 years of treatment. Several studies have investigated the reliability in assessing clinical signs of CMD (Carlsson *et al*., 1980; Kopp and Wenneberg, 1983; Dworkin *et al*., 1988) and the intra-observer reliability for parametric and non-parametric variables has been found to be acceptable. Many different scoring systems have been used in order to quantify the severity of clinical signs and symptoms of CMD (Helkimo, 1979; Gross and Gale, 1983; Fricton and Schiffman, 1986). As the index devised by Helkimo in 1974 is the most widely used system epidemiologically (Wännman, 1987; Salonen *et al*., 1990; DeKanter, 1990), as well as clinically (Magnusson, 1981; Mejersjö, 1984; Tegelberg, 1987; Wedel, 1988), it was the index of choice for the present investigation.

An increased prevalence of morning headaches has been found among patients with heavy snoring and OSA (Aldrich and Chauncey, 1990; Jennum *et al*., 1994). Frequent headache is also a common symptom in patients with craniomandibular disorders or hyperfunctional activity of the masticatory muscles (Magnusson, 1981; Agerberg and Helkimo, 1987; Wedel, 1988). One important result of this study was that the splint therapy had a beneficial effect on headache. All patients reported improved sleep quality, possibly due to fewer micro-arousals and less sleep fragmentation, and nearly all had an improved oxygen saturation according to the medical records. As the patients showed no or only mild symptoms of mandibular dysfunction before treatment, one would expect that headache in the patients before treatment was more related to the decrease in oxygen saturation and/or impaired sleep quality than to functional disturbances of the craniomandibular system.

There was a tendency towards an increase in recorded joint sounds after the 2 years of treatment. This increase was not significant, however, and is most likely related to a normal fluctuation of symptoms as previously reported in other studies (Heikenhiemo *et al.,* 1990). As the status and function of the TMJ, and its

response to this type of treatment are essential, especially as the treatment can be considered life-long, this issue must be further evaluated.

## Conclusions

The study showed no adverse effects on the temporomandibular joints or stomatognathic system after 2 years' nocturnal use of a mandibular advancement splint, indicating that this treatment is well tolerated. However, minor occlusal changes were found and as the treatment is considered to be life-long, the benefit of treatment of habitual snoring and OSA with mandibular advancement splints must be further evaluated. Therefore, additional long-term studies of possible side effects on the temporomandibular joints, dentofacial morphology, tooth movements, and periodontal tissues are required, and must be correlated to studies on treatment modalities and effects.

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