Acta Odontologica Scandinavica, 2006; 64: 89–96

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

Long-term effect on tinnitus by treatment of temporomandibular disorders: A two-year follow-up by questionnaire

MARIE TULLBERG & MALIN ERNBERG

Department of Clinical Oral Physiology, Institute of Odontology, Karolinska Institutet, Huddinge, Sweden

Abstract

Objective. The aim of the study was to investigate the presence of symptoms and signs of temporomandibular disorders (TMD) in patients with tinnitus and to evaluate the effect of TMD treatment on tinnitus in a long-term perspective in comparison with a control group of patients on a waiting list. ***Material and Methods***. One-hundred-and-twenty patients with tinnitus were subjected to a clinical examination of the masticatory system and whether they had co-existing TMD to TMD treatment. Ninety-six patients had TMD, most frequently localized myalgia. Seventy-three of these completed the treatment and responded to a questionnaire 2 years later. Fifty patients with tinnitus who were on the waiting list served as a control group. ***Results***. Eighty percent of the patients had signs of TMD, most commonly myofascial pain. Forty-three percent of the patients reported that their tinnitus was improved at the 2-year follow-up, 39% that it was unchanged, and 17% that it was impaired compared to before the treatment. Twelve percent of the subjects in the control group reported that their tinnitus was improved compared to 2 years previously, 32% that it was unchanged, and 56% that it was impaired. The difference between groups was significant (χ^2: $p < 0.001$). ***Conclusion***. The results of this study showed that TMD symptoms and signs are frequent in patients with tinnitus and that TMD treatment has a good effect on tinnitus in a long-term perspective, especially in patients with fluctuating tinnitus.

Key Words: *Clinical examination, control group, questionnaire, temporomandibular joint disorders, treatment outcome*

Introduction

Tinnitus could be described as a subjective sound in the ears or head without any external source of the sound [1]. It is estimated that approximately 10–15% of the general population suffer from tinnitus [2–4]. It is reported that 20% of tinnitus patients are affected by their tinnitus to a degree that their quality of life is impaired and about 60% report depression [2,5]. Tinnitus is therefore a widespread conditions and a major health problem in many countries.

There are many theories about the etiology and pathophysiology of tinnitus. The most common theories are that tinnitus is caused by otological pathology, such as hearing-loss [6,7], cochleovestibular disorders, and endolymphatic disorders [8], or psychological factors, including, e.g., psychiatric disorders and depression [9,10]. It is suggested that if tinnitus is unilateral or pulsating it can indicate a serious underlying pathological condition and this should be out ruled by audiometric and radiologic examination [11]. However, fluctuating tinnitus has been associated with temporomandibular disorders (TMD) [12].

As early as 1934, ear pain, tinnitus, impaired hearing, and dizziness were reported in patients with TMD, which was suggested to be caused by badly fitted dental prosthesis or lack of molar support [13]. Other authors have also reported that tinnitus may be associated with TMD. For example, Rubinstein & Erlandsson [12] reported that awareness of diurnal bruxism and feeling of jaw tenderness/fatigue may be related to fluctuating tinnitus, vertigo, and hyperacusis, and Parker & Chole [14] reported that tinnitus and vertigo were more prevalent in TMD patients than in healthy controls. More recently it was reported that 60% of patients with chronic tinnitus had more than two symptoms of TMD compared to 36.5% of healthy controls [15]. The incidence of tinnitus in 989 consecutive TMD patients during the years 1981 to 1990 was found to be 7% [3], but other studies have reported that as

Correspondence: Marie Tullberg, Brahekliniken, Brahegatan 36, SE-114 36 Stockholm, Sweden. Tel: +468 660 20 23. E-mail: marie.tullberg@brahekliniken.se

(Received 30 June 2005; accepted 27 September 2005)

ISSN 0001-6357 print/ISSN 1502-3850 online
DOI: 10.1080/00016350500377842

many as 60% of TMD patients suffer from tinnitus [14,16]. One might expect that temporomandibular joint (TMJ) disorders, i.e. disk displacement or osteoarthrosis, would be the most frequent TMD subgroup. However, although TMJ disk degeneration is reported to be associated with tinnitus [17], masticatory muscle pain is the most frequent TMD symptom in tinnitus patients [12,15,18]. Conversely, myofascial pain patients show the highest prevalence of tinnitus [19].

One suggested explanation for the relation between tinnitus and TMD is that hyperactivity of masticatory muscles is conveyed to the tensor tympani and tensor veli palatine [15]. Other explanations are that the sensory signal from the trigeminal nerve could be affected during tooth-grinding, since the trigeminal ganglion also innervates the ventral cochlear nucleus and superior olivary complex [20], and psychological distress, which is suggested in the etiology of both conditions [14]. However, the exact mechanism is unknown.

Because of the lack of clear etiology of tinnitus, various treatments are proposed, i.e. hearing aids and maskers [11,21], pharmacological treatment [22], physiotherapy [23], acupuncture, and/or cognitive behavioral therapy [24]. A few studies have reported that TMD therapy, such as occlusal bite splints, may improve tinnitus [25–27]. Given the reports of a co-existence of tinnitus and TMD, this might not be surprising. However, few studies have investigated this is in a controlled manner. Our hypothesis was that TMD treatment would alleviate tinnitus in patients with co-existing TMD.

The aim of the study was to investigate the presence of TMD symptoms and signs in a group of patients with tinnitus and to evaluate the effect of TMD treatment in a long-term perspective in comparison with a control group of patients on a waiting list.

Material and methods

Study group

One-hundred-and-twenty patients who suffered from tinnitus were referred to the Specialist Clinic at the Institute of Odontology, Karolinska Institutet between the years 1997 and 2001. The patients were referred by specialists in otorhinolaryngology or audiology when medical causes to the tinnitus, such as acusticus neuroma or Meniere's disease could be excluded. After an initial clinical examination, 21 patients were excluded, 19 since they did not have any signs of TMD or malocclusion that possibly could influence their tinnitus, one because of a diagnosis of Meniere's disease and one because of a viral infection of the statoacusticus nerve. The remaining 99 patients were offered TMD treatment. Five of these patients resigned from the treatment and 10 did not complete it. Two years after completion of the treatment, the patients were evaluated by questionnaire. Of the 84 patients that had completed the treatment two years previously, 11 did not return the questionnaire, although they received a reminder. Thus, of the initial 120 patients, 73 completed the study, and formed the study group (Figure 1A). They had a mean (SD) duration of tinnitus of 7.5 (9.6) years. The 45 patients who were not included did not differ significantly from the study group regarding the distribution of gender, age, or duration of tinnitus.

Control group

Eighty-two patients with tinnitus that were referred from the same specialists in otorhinolaryngology or audiology as the patients in the study group and were on the waiting list in June 2002 received the same questionnaire as the study group. A reminder was sent to those who had not returned the questionnaire after one month. Fifty-six of the patients returned the questionnaire, giving a response rate of 68%. Of these, 6 were excluded, since the duration of their tinnitus was less than 2 years. The remaining 50 subjects formed the control group (Figure 1B). They had a mean (SD) duration of tinnitus of 7.6 (6.1) years. The 32 patients that were excluded did not

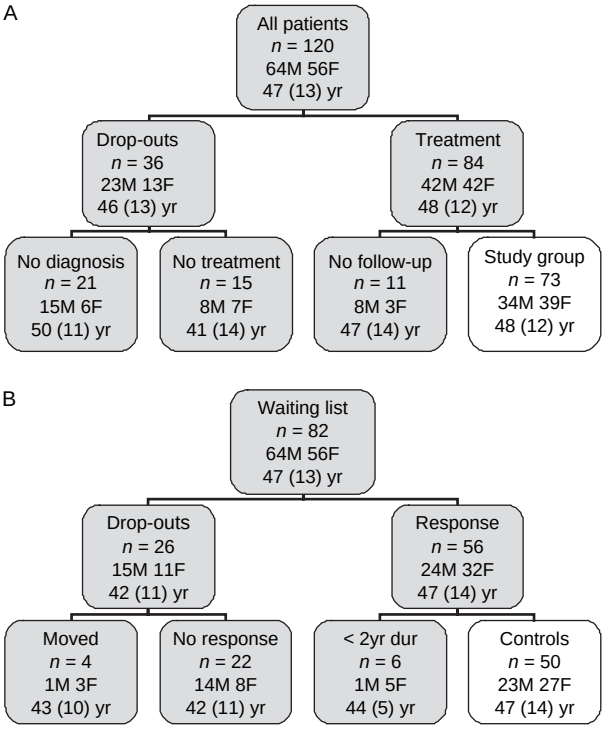

Figure 1. Patients with tinnitus referred to the Specialist Clinic at the Institute of Odontology in the period 1997 to 2002. A. The study group comprised patients with tinnitus and co-existing temporomandibular disorders (TMD) that had completed TMD treatment before 30 June 2002 and returned the questionnaire 2 years later. B. The control group comprised patients that were on the waiting list for an appointment in June 2002 and returned the questionnaire.

differ significantly from the control group regarding age or gender.

The study was performed according to the treatment practice outlined by the Declaration of Helsinki, and informed consent was obtained from all participating subjects.

Written questionnaires

Before the clinical examination, the patients in the study group were asked to fill in two questionnaires. The first included questions about (1) subjective symptoms from the temporomandibular system including aural symptoms and (2) oral parafunctions. The second questionnaire included questions regarding their tinnitus, including (1) the duration of tinnitus; (2) the temporal pattern of the tinnitus, i.e. if it was fluctuating or constant; (3) the severity of their tinnitus, with the alternatives: none, minor, moderate, severe, and very severe; and (4) which treatments they had received for their tinnitus, with the alternatives: physiotherapy, bite splint/occlusal adjustment, medical laser therapy, jaw exercises, acupuncture, masking of the tinnitus sound, pharmacotherapy, and others (describe which). The last question (5) concerned the impact of tinnitus on quality of life, i.e. if their tinnitus affected them to such a degree that: they were currently on sick leave, they had sleep disturbances, it influenced their private life, or it influenced their studies/work.

Clinical examination

After the patients had filled in the questionnaires a clinical examination was performed which included digital palpation of the TMJ and masticatory muscles, recording of joint sounds, maximal unassisted mouth opening ability, occlusion and articulation, and deviations in the sagittal, lateral, and vertical plane, e.g. crossbite, over jet, and anterior open bite.

Treatment

According to the diagnosis and clinical findings, an individual treatment plan was made for each patient. This included information about the association between tinnitus and TMD and means of self care, e.g. to relax the jaw and to avoid tooth contacts when not chewing and to refrain from frequent use of chewing gum. An occlusal bite splint adjusted according to Ramfjord & Ash [28] was performed for patients with localized myalgia or TMJ pain and subjective morning stiffness in jaw muscles (68% of the patients). When splints were already used by the patients, they were adjusted if needed. Minor occlusal adjustment was performed on pre-contacting teeth during mouth closing and articulation in 81% of the subjects. The majority (84%) of the patients were instructed in jaw exercises, including isotonic and isometric exercises. In addition, medical laser therapy was given to 88% of the patients with a medical gallium-aluminium-arsenide laser (GaAlAr; Soft power laser Med-700, Lasotronic AG, Baar, Switzerland) operating at a wavelength of 820 nm. A total dose of 1 J was given at each visit to the TMJ and masticatory muscles that were tender upon digital palpation. The number of visits varied between 1 and 6, with an average (SD) of 3.7 (1.3).

At the final visit the patients were asked if their tinnitus was: resolved, reduced, unchanged, or increased (compared to before the treatment).

Follow-up

Two to 3 years after completion of the treatment, a questionnaire was sent to the patients by mail. The questionnaire consisted of questions B3–B5 from the tinnitus questionnaire. They were also asked if their tinnitus had changed compared to 2 years previously (see above).

The same questionnaire was sent to the control group. They were also asked about the duration of their tinnitus and about its temporal pattern (questions 1–2 from the tinnitus questionnaire), and whether their tinnitus had changed compared with 2 years previously, similar to the patients in the study group.

Statistics

Data are presented as mean (SD) unless otherwise stated. The difference between patient groups regarding variables with percentage distribution was tested for statistical significance with the chi-squared or the Fisher exact test, while differences before and after treatment were tested with the McNemar test. Yates correction factor was used for the chi-square and McNemar's tests. The Mann-Whitney U-test was used to test the significance of the difference between groups in categorical data, e.g. rating of severity of symptoms, while the Wilcoxon test was used to test the difference before and after treatment in the patient group. Correlations between variables were tested with the Spearman rank correlation test. The significance level was set to $p < 0.05$.

Results

Tinnitus

Seventy-nine percent of the patients had tinnitus on the right side and 85% on the left side. Bilateral tinnitus was reported by 63%. The majority of patients (89%) rated their tinnitus as moderate to very severe (Figure 2) and 36% that the debut of their tinnitus was associated with periods of increased stress or stressful events, such as exposure to loud noise. Seventy-eight percent described the

Table I. The frequency (%) of self reported TMD symptoms in 73 patients with tinnitus

	Never	1–2 days/month	1–2 days/week	Several days/week	Daily
Pain in the face and/or jaws	38	18	15	13	15
Headache	15	33	18	16	18
Pain during chewing	61	24	7	2	7
Difficulties to open mouth wide	75	8	0	4	13
Tiredness in the jaws	23	17	21	17	21
Joint sounds/locking	34	22	12	6	26
Vertigo	40	33	15	4	8
Hyperacusis	11	9	9	27	44
Ear stuffiness	24	17	20	17	22

temporal pattern of their tinnitus as fluctuating, while 28% described it as continuous.

Fourteen percent reported that their tinnitus started after exposure to loud noise, 10% in combination with stress, and 8% after trauma. The remaining patients reported various or unknown causes.

In the control group, 74% of the patients reported fluctuating and 26% continuous tinnitus.

Subjective symptoms and oral parafunctions

The frequency of self-reported symptoms is indicated in Table I. Pain-related symptoms were frequent. For example, 43% of the patients reported pain in the face or jaws at least 1–2 days per week, 52% headache, and 59% fatigue in the jaws. Also symptoms from the ear/TMJ region occurred frequently, with 44% reporting joint sounds or locking of the jaw, 59% ear stuffiness, 80% hyperacusis, and 27% vertigo at least 1–2 days per week. Reduced hearing on any side was reported by 80% of the patients and was related to tinnitus on the same side (Spearman: $r_s = 0.59$, $n = 37$, $p < 0.001$ right side, and $r_s = 0.47$, $n = 37$, $p = 0.002$ left side).

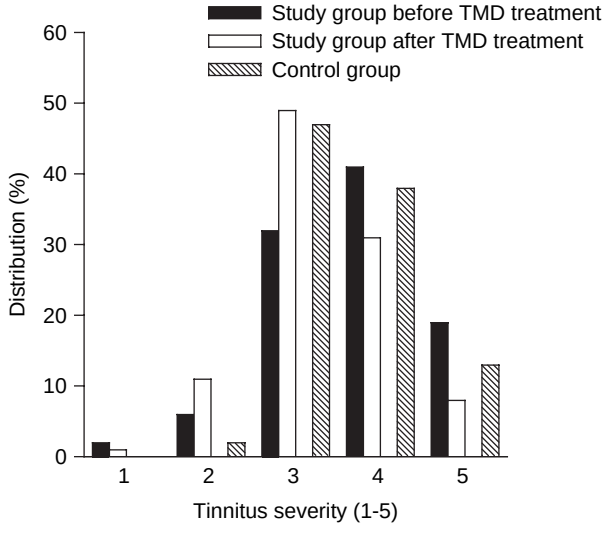

Figure 2. Self-report of the severity of the tinnitus before and after TMD treatment in patients with tinnitus and co-existing TMD (study group) as well as in a group of untreated tinnitus patients on a waiting list (control group). The following scale was used: 1 = none, 2 = minor, 3 = moderate, 4 = severe, and 5 = very severe. The severity of tinnitus in the study group was decreased at follow-up (Wilcoxon: $p = 0.004$), but did not differ from the control group before treatment.

Seventy-six percent of the patients reported frequent tooth-clenching, 51% grinding, 35% tongue thrusting, 48% cheek biting, and 17% nail biting. Almost all of the patients (98%) reported that their oral parafunctions were associated with periods of increased stress.

Clinical examination

The clinical examination confirmed the subjective symptoms for many of the patients. Forty-five percent had palpatory tenderness over the TMJ and 44% had joint clicking, while only 8% had joint crepitation. The median (IQR) number of temporomandibular muscles with pain upon palpation was 6 (8), and 80% of the patients had at least 3 muscles that were painful upon palpation. The voluntary mouth opening capacity was 50 mm (7). Thirteen percent had anterior open bite, 26% had posterior crossbite, 13% were postnormal, and 4% were prenormal.

Treatment result

Directly after treatment, 73% of the patients reported that their tinnitus was reduced, while 27% reported that it was unchanged. None reported an increase of their tinnitus.

Result at follow-up

Forty-three percent of the patients in the study group reported that their tinnitus was reduced at the follow-up 2 years after treatment, 39% that it was unchanged, and 18% that it was increased. Twelve percent of the patients in the control group reported that their tinnitus was reduced compared to 2 years previously, 32% that it was unchanged, and 56% that it was increased. The difference between groups was significant (χ^2: $p < 0.001$).

The severity of tinnitus was significantly decreased at follow up (Figure 2) and the patients reported a significant improvement regarding quality of life variables (Table II). An increased number of patients

Table II. The frequency (%) of perceived effect by tinnitus on quality of life parameters reported by the patients in the study group before and 2 years after treatment as well as in the control group

	Study group				
	Before	After	*p*	Control group	*p*
Due to my tinnitus:					
I am currently on sick leave	38	21	0.025	30	0.500
I have disturbed sleeping	65	45	0.009	68	0.998
My private life is affected	74	49	0.019	60	0.194
My work/studies is affected	72	43	0.029	54	0.070

p = p-value. The McNemar's test was used to compare patients before and after tretament and chi-square test was used to compare patients before treatment with controls.

reported that they had received occlusal therapy, jaw exercises, medical laser therapy, and masking of the tinnitus sound at follow-up (Table III).

Split of study group into subgroups

Since almost half of the patients in the study group reported an improvement of their tinnitus at the follow-up (subgroup 1), while the other half reported that their tinnitus was unchanged or impaired (subgroup 2), we decided to investigate whether these two subgroups differed in self-reported symptoms or clinical signs before treatment.

The groups did not differ with respect to severity of tinnitus before treatment, but differed significantly at follow-up (Mann-Whitney: $p < 0.001$). Eighty-seven percent in subgroup 1 and 62% in subgroup 2 reported an improvement of their tinnitus directly after treatment. The difference between groups was significant (χ^2: $p = 0.034$). Subgroup 1 reported fluctuating tinnitus significantly more often than subgroup 2; 95% compared to 66% (Fisher exact test: $p = 0.017$). There were no significant differences between subgroups regarding any other variable.

Differences between the study group and the control group in background variables

The duration of tinnitus was significantly longer in the patient group than in the control group (Mann-Whitney: median 5 and 3 years, respectively; $p = 0.013$). A larger proportion of patients in the control group had received masking therapy compared to the study group (Table III), but there were no differences between groups regarding age, the proportion of patients with fluctuating tinnitus, the severity of tinnitus (Figure 2), or the impact of tinnitus on quality of life (Table II).

Discussion

The major findings of the present study were that TMD symptoms and signs were frequent in our group of patients with tinnitus, that TMD treatment alleviates tinnitus in a long-term perspective, and that the effect is most beneficial in patients with fluctuating tinnitus.

The co-existence of tinnitus and TMD is well described previously. Rubinstein et al. [18] found that pain on palpation of masticatory muscles, impaired mandibular mobility, and signs of parafunctions were more prevalent in tinnitus patients than in epidemiologic samples. Bernhardt et al. [15] reported that 60% of tinnitus patients, but only 36% of healthy subjects from the general population, had TMD symptoms, and Lam et al. [29] reported that 64% of patients with tinnitus had TMD. Of the 120 patients referred to our clinic 101 (82%) showed signs of TMD. The higher prevalence of TMD signs in our study compared to previous studies [15] could be due to a more selected patient sample. Self-reported pain-related symptoms were also frequent.

Table III. The frequency (%) of treatments that the patients in the study group reported that they had received at the first visit and 2 years after TMD treatment and that the non-treated controls reported that they had received

	Study group				
	Before	After	*p*	Controls	*p*
Physiotherapy	47	48	0.502	50	0.911
Occulsal therapy	35	84	<0.001	48	0.277
Medical laser therapy	17	68	<0.001	7	0.275
Jaw exercises	31	72	0.003	43	0.397
Acupuncture	47	47	0.683	38	0.539
Masking	10	29	0.001	36	0.004

p = p-value. The McNemar's test was used to compare patients before and after tretament and chi-square test was used to compare patients before treatment with controls.

TMD questionnaires are reported to be a good predictor of TMD signs [30], which is supported by the findings in this study.

Most of the patients described their tinnitus as fluctuating, which may not be surprising since it is the type of tinnitus that has been associated with TMD [12]. Similar to previous studies [9], left-sided tinnitus was a little more prevalent than right-sided tinnitus, although most patients had bilateral tinnitus. Furthermore, tinnitus was associated with subjective hearing loss on the ipsilateral side. This could indicate a relationship between tinnitus and hearing loss. However, a recent study in TMD patients found no relation between TMD patients' subjective report of hearing loss and objectively assessed hearing loss by audiometry [19].

Many patients reported that their tinnitus occurred in conjunction with stressful events, although they did not report high psychological distress at the time of examination. Similar to the study by Rubinstein et al. [18], oral parafunctions frequently occurred and these were reported to be associated with periods of increased stress. Stress is suggested as an etiologic factor to tinnitus [31], but is also frequently associated with TMD [32]. Although the pathophysiological mechanism that could explain the co-existence of tinnitus and TMD is unknown, stress seems to be one possible factor that links the two disorders.

Previous studies have reported that patients with co-existing tinnitus and TMD may benefit from TMD treatment [25–27,33]. In view of this, the positive treatment result in the present study is not surprising. Despite the severity of tinnitus before treatment not differing from the severity in the control group, the study group reported a significant improvement of their tinnitus after 2 years and a concomitant decrease of tinnitus severity, while most patients in the control group reported that it was increased or unchanged compared to 2 years previously. The patients in the study group also reported improved quality of life. Although no single treatment could be held responsible for the positive result, occlusal splint therapy could have been important, since there is evidence that it has a positive effect on TMD [34,35]. The use of medical laser deserves some explanation. We are aware that this is not a widely used treatment for TMD, but there is some evidence that it may be effective for treatment of musculoskeletal disorders [36,37]. Although the mechanism of action is vastly unknown, it is proposed that it has a pain modulatory effect on peripheral sensory nerves [38], enhances the release of β-endorphins from the spinal cord [39], and increases muscle metabolism [40]. On the other hand, in all pain treatment there is a considerable placebo effect and factors such as the patient's expectations of the treatment and wish to satisfy the therapist also influence the result [41]. As judged from the questionnaire, the patients in both groups had received several treatments for their tinnitus with only minor effect before the TMD treatment. At follow-up, few patients reported additional therapy apart from TMD treatment. We therefore believe that the positive treatment effect on tinnitus was due to the latter treatment.

This study did not aim to investigate the prognostic value of specific symptoms and signs for the treatment outcome. However, it is striking that most patients had fluctuating tinnitus, which previously has been reported to be associated with a better prognosis [12,16]. In addition, when the patient group was divided into subgroups the proportion of patients with fluctuating tinnitus was twice as high in the subgroup that reported improvement at the follow-up. Since this was the only factor that differed significantly between subgroups, it strongly supports fluctuating tinnitus being an important prognostic factor for the outcome of TMD treatment in patients with tinnitus.

The present study has several methodological limitations that need to be addressed. First, the patients were not examined clinically at the follow-up and we therefore lack knowledge about TMD signs, such as palpatory pain on this occasion. This is unfortunate. However, if we consider tinnitus as a sign of TMD the positive result regarding tinnitus might indicate that other TMD symptoms were also improved, although subjective and objective treatment results could be disparate [42].

Secondly, the patients were asked if their current tinnitus had changed compared to 2 years previously. It is possible that the patients in the control group might wish to report impairment in order to receive an appointment more quickly. Another possibility is that the subjects' memory of their tinnitus 2 years previously is not reliable, since the memory is prone to error and bias [38,43]. On the other hand, the patients in the study group scored their current severity of tinnitus lower at the 2-year follow-up than before treatment. This may indicate that the improvement of tinnitus that they reported was not biased by lack of memory. In addition, the influence of memory on reported tinnitus would probably be similar in both groups. Furthermore, the choice of control group might not be the most adequate. In all treatment studies, two parallel groups, one receiving active treatment and one receiving placebo treatment, is preferable. However, for ethical reasons we consider such a design inappropriate when studying long-term treatment effects. Therefore a control group of patients on a waiting list is the only option at hand and, indeed, better than no control group.

Thirdly, despite the fact that questionnaires similar to those used in the present study are commonly used in the clinic, many of them are not validated. This is a concern, since their reliability is therefore unknown. Future research should either validate

these or use other questionnaires that are already validated.

Although TMD often co-exists with tinnitus, the patients seldom inform their dentist about their tinnitus. The most probable reason for this is that the relation between tinnitus and facial pain has never occurred to them. However, the beneficial effect on tinnitus by TMD treatment found in this and previous studies [25–27,33] is remarkable in view of the fact that many patients had suffered from tinnitus for many years and had moderate to severe tinnitus. In addition, the proportion of patients that were on sick leave was reduced by almost 30% at the follow-up, which is a significant positive effect for both the individual patient and the society. This suggests that patients with tinnitus should be referred to a dentist when medical causes of their tinnitus have been ruled out. Furthermore, dentists could also aid by asking their patients about the presence of fluctuating tinnitus and examine the masticatory system more thoroughly in patients with a positive answer.

Within the limitations of this study, we conclude that TMD symptoms and signs are frequent in patients with tinnitus and that TMD treatment has a good effect on tinnitus in a long-term perspective, especially in patients with fluctuating tinnitus.

Acknowledgment

This study was supported by grants from the Swedish Dental Society.

References

[1] Hiller W, Goebel G. Assessing audiological, pathophysiological, and psychological variables in chronic tinnitus. A study of reliability and search for prognostic factors. Int J Behav Med 1999;6:312–31.

[2] Axelsson A, Ringdahl A. Tinnitus – a study of its prevalence and characteristics. Br J Audiol 1989;2:53–62.

[3] Upton LG, Wijeyesakere SJ. The incidence of tinnitus in people with disorders of the temporomandibular joint. Int Tinnitus J 2004;10:174–6.

[4] Hannaford PC, Simpson JA, Bisset AF, Davis A, McKerrow W, Mills R. The prevalence of ear, nose and throat problems in the community: results from a national cross-sectional postal survey in Scotland. Fam Pract 2005;22:227–33.

[5] Robinson SK, McQuaid JR, Viirre ES, Betzig LL, Miller DL, Bailey KA, et al. Relationship of tinnitus questionnaires to depressive symptoms, quality of well-being, and internal focus. Int Tinnitus J 2003;9:97–103.

[6] Lindberg P, Lyttkens L, Melin L, Scott B. Tinnitus-incidence and handicap. Scand Audiol 1984;13:287–91.

[7] Hazell JW, Jastreboff PJ. Tinnitus. I: Auditory mechanisms: a model for tinnitus and hearing impairment. J Otolaryngol 1990;19:1–5.

[8] Cohen H, Ewell LR, Jenkins HA. Disability in Meniere's disease. Arch Otolaryngol Head Neck Surg 1995;121:29–33.

[9] Erlandsson SI, Rubinstein B, Axelsson A, Carlsson SG. Psychological dimensions in patients with disabling tinnitus and craniomandibular disorders. Br J Audiol 1991;25:15–24.

[10] Holgers KM, Erlandsson SI, Barrenas ML. Predictive factors for the severity of tinnitus. Audiology 2000;39:284–91.

[11] Crummer RW, Hassan GA. Diagnostic approach to tinnitus. Am Fam Phys 2004;69:120–6.

[12] Rubinstein B, Erlandsson SI. A stomatognathic analysis of patients with disabling tinnitus and craniomandibular disorders (CMD). Br J Audiol 1991;25:77–83.

[13] Costen JB. A syndrome of ear and sinus symptoms dependent upon disturbed function of the temporomandibular joint. 1934. Ann Otol Rhinol Laryngol 1997;106:805–19.

[14] Parker WS, Chole RA. Tinnitus, vertigo, and temporomandibular disorders. Am J Orthod Dentofacial Orthop 1995;107:153–8.

[15] Bernhardt O, Gesch D, Schwahn C, Bitter K, Mundt T, Mack F, et al. Signs of temporomandibular disorders in tinnitus patients and in a population-based group of volunteers: results of the Study of Health in Pomerania. J Oral Rehabil 2004;31:311–9.

[16] Wright EF, Bifano SL. The relationship between tinnitus and temporomandibular disorder (TMD) therapy. Int Tinnitus J 1997;3:55–61.

[17] Ren YF, Isberg A. Tinnitus in patients with temporomandibular joint internal derangement. Cranio 1995;13:75–80.

[18] Rubinstein B, Axelsson A, Carlsson GE. Prevalence of signs and symptoms of craniomandibular disorders in tinnitus patients. J Craniomandib Disord 1990;4:186–92.

[19] Tuz HH, Onder EM, Kisnisci RS. Prevalence of otologic complaints in patients with temporomandibular disorder. Am J Orthod Dentofacial Orthop 2003;123:620–3.

[20] Zhou J, Shore S. Projections from the trigeminal nuclear complex to the cochlear nuclei: a retrograde and anterograde tracing study in the guinea pig. J Neurosci Res 2004;78:901–7.

[21] Hazell JW, Wood SM, Cooper HR, Stephens SD, Corcoran AL, Coles RR, et al. A clinical study of tinnitus maskers. Br J Audiol 1985;19:65–146.

[22] Krzeska-Malinowska I, Pierchala K, Held-Ziolkowska M, Niemczyk K, Kowalska M. Intratympanic gentamycin application for the treatment of Meniere's disease]. Otolaryngol Pol 2001;55:623–6.

[23] Andersson G, Carlbring P, Kaldo V, Strom L. Screening of psychiatric disorders via the Internet. A pilot study with tinnitus patients. Nord J Psychiatry 2004;58:287–91.

[24] Andersson G, Kaldo V. Internet-based cognitive behavioral therapy for tinnitus. J Clin Psychol 2004;60:171–8.

[25] Rubinstein B, Carlsson GE. Effects of stomatognathic treatment on tinnitus: a retrospective study. Cranio 1987;5:254–9.

[26] Wright EF, Bifano SL. Tinnitus improvement through TMD therapy. J Am Dent Assoc 1997;128:1424–32.

[27] Wright EF, Syms CA 3rd, Bifano SL. Tinnitus, dizziness, and nonotologic otalgia improvement through temporomandibular disorder therapy. Mil Med 2000;165:733–6.

[28] Ramfjord SP, Ash MM. Reflections on the Michigan occlusal splint. J Oral Rehabil 1994;21:491–500.

[29] Lam DK, Lawrence HP, Tenenbaum HC. Aural symptoms in temporomandibular disorder patients attending a craniofacial pain unit. J Orofac Pain 2001;15:146–57.

[30] Braun B, Schiffman EL. The validity and predictive value of four assessment instruments for evaluation of the cervical and stomatognathic systems. J Craniomandib Disord 1991;5:239–44.

[31] Schmitt C, Patak M, Kroner-Herwig B. Stress and the onset of sudden hearing loss and tinnitus. Int Tinnitus J 2000;6:41–9.

[32] Korszun A, Young EA, Singer K, Carlson NE, Brown MB, Crofford L. Basal circadian cortisol secretion in women with temporomandibular disorders. J Dent Res 2002;8:279–83.

[33] Bjorne A, Agerberg G. Symptom relief after treatment of temporomandibular and cervical spine disorders in patients with Meniere's disease: A three-year follow-up. J Craniomandib Practice 2003;21:50–60.

[34] Forssell H, Kalso E, Koskela P, Vehmanen R, Puukka P, Alanen P. Occlusal treatments in temporomandibular disorders: a qualitative systematic review of randomized controlled trials. Pain 1999;83:549–60.

[35] Ekberg E, Nilner M. Treatment outcome of appliance therapy in temporomandibular disorder patients with myofascial pain after 6 and 12 months. Acta Odontol Scand 2004;62:343–9.

[36] Chow RT, Barnsley L. Systematic review of the literature of low-level laser therapy (LLLT) in the management of neck pain. Lasers Surg Med 2005;37:46–52.

[37] Gur A, Karakoc M, Nas K, Cevik R, Sarac J, Demir E. Efficacy of low power laser therapy in fibromyalgia: a single-blind, placebo-controlled trial. Lasers Med Sci 2002;17:57–61.

[38] Özdemir F, Birtane M, Kokino S. The clinical efficacy of low-power laser therapy on pain and function in cervical osteoarthritis. Clin Rheumatol 2001;20:181–4.

[39] Marks R, de Palma F. Clinical efficacy of low power laser therapy in osteoarthritis. Physiother Res Int 1999;4:141–57.

[40] Tam G. Low power laser therapy and analgesic action. J Clin Laser Med Surg 1999;17:29–33.

[41] Feine JS, Lavigne GJ, Dao TT, Morin C, Lund JP. Memories of chronic pain and perceptions of relief. Pain 1998;77:137–41.

[42] Vallon D, Ekberg EC, Nilner M, Kopp S. Short-term effect of occlusal adjustment therapy on craniomandibular disorders including headache. Acta Odontol Scand 1991;49:89–96.

[43] Gorin AA, Stone AA. Recall biases and cognitive errors in retrospective self-reports: a call for momentary assessments. In: Baum A, Revenson T, Singer J, editors. Handbook of health psychology. New Jersey: Erlbaum; 2001. p. 405–13.