Does Conservative Temporomandibular Therapy Affect Tinnitus Complaints? A Systematic Review

Sarah Michiels, PhD
Department of Rehabilitation Sciences and Physiotherapy
Department of Otorhinolaryngology
Department of Translational Neurosciences

Evelien Nieste, MSc
Department of Rehabilitation Sciences and Physiotherapy
Department of Otorhinolaryngology

Paul Van de Heyning, PhD, MD
Department of Otorhinolaryngology
Multidisciplinary Motor Centre Antwerp
Department of Translational Neurosciences

Faculty of Medicine and Health Sciences,
University of Antwerp, Antwerp, Belgium

Marc Braem, PhD
Lab Dental Materials
Faculty of Medicine and Health Sciences
University of Antwerp, Antwerp, Belgium;
Special Care Dentistry
University Hospital Antwerp
Edegem, Belgium

Corinne Visscher, PhD
Department of Oral Health Sciences
Academic Centre for Dentistry Amsterdam
University of Amsterdam and VU University Amsterdam
Research Institute MOVE
Amsterdam, The Netherlands

Vedat Topsakal
Department of Otorhinolaryngology
Antwerp University Hospital
Edegem, Belgium
Department of Translational Neurosciences
Faculty of Medicine and Health Sciences
University of Antwerp, Antwerp, Belgium

Annick Gilles, PhD
Department of Translational Neurosciences

Laure Jacquemin, MSc
Department of Translational Neurosciences

Willem De Hertogh, PhD
Department of Rehabilitation Sciences and Physiotherapy

Faculty of Medicine and Health Sciences
University of Antwerp, Antwerp, Belgium

Correspondence to:
Dr Sarah Michiels
Universiteitsplein 1 - 2610 Wilrijk, Belgium
Email: sarah.michiels@uantwerpen.be

Submitted September 14, 2017;
accepted October 17, 2018.

Aims: To investigate whether temporomandibular disorders treatment can positively influence tinnitus complaints. **Methods:** Four online databases (PubMed, Web of Science, Scopus, and the Cochrane Library) were searched up to August 2018 for relevant studies. Two independent reviewers extracted the data and performed a risk of bias assessment. **Results:** A total of 11 studies were included. These studies showed an overall positive effect of the combination of splint therapy and exercise treatment on tinnitus severity and intensity (as measured on a visual analog or numeric rating scale), as well as on global perceived effect. One study specified that the treatment effect was only present in patients with severe to very severe tinnitus, while the others found an effect in the overall study group. The risk of bias in the included studies was high, mainly due to lack of statistical analyses between groups and before vs after treatment, incomplete presentation of the data, and selective reporting. Additionally, most included studies showed a lack of information concerning blinding of the subjects, therapists, and investigators. The heterogeneity of the inclusion criteria, outcome measurements, and treatments made data pooling and meta-analysis impossible. **Conclusion:** There is low-quality evidence for a positive effect of conservative temporomandibular disorders treatment on tinnitus complaints. The combination of splint therapy and exercise treatment is currently the best investigated treatment approach, showing a decrease in tinnitus severity and intensity. Despite the low level of evidence and the methodologic issues in the included studies, it is noteworthy that all included studies show positive treatment effects. *J Oral Facial Pain Headache 2019;33:308–317. doi: 10.11607/ofph.2055*

Keywords: *occlusal splints, physical therapy modalities, somatic, somatosensory, temporomandibular joint disorders*

Tinnitus, the perception of sound in the absence of a corresponding external auditory stimulus,[1] occurs in a large portion of the adult population, with a prevalence ranging from 10% to 15%.[2,3] Tinnitus may affect patients' quality of life (QoL), is associated with depression, can result in reduced productivity at work, and may cause sleeping difficulties.[2,4] Various types of tinnitus exist, with two main subtypes: objective and subjective tinnitus. In some cases, internal somatosounds can cause the tinnitus; eg, turbulences of the blood flow. In these cases, the underlying generator is often measurable or detectable by the physician, and objective tinnitus can be considered. In the absence of any acoustic stimulus (internal or external), it is called subjective tinnitus, which is the most common form of tinnitus.[2]

Subjective tinnitus can additionally be classified based on its etiology. Most tinnitus complaints derive from underlying otologic pathology, such as age-related hearing loss and noise trauma. In other cases, tinnitus can be attributed to the somatosensory system of the cervical spine or temporomandibular area.[2,5,6] This type of tinnitus is called somatic or somatosensory tinnitus (ST) and has been described in 36% to 43% of the population with subjective tinnitus.[7,8] Vice versa, tinnitus was found to be eight times more prevalent in patients with temporomandibular disorders (TMD) compared to patients without TMD.[9]

A physiologic explanation for ST is found in the existence of connections between the cervical somatosensory system and cochlear nuclei (CN).[10,11] Cervical somatosensory information is conveyed to the brain by afferent fibers, the cell bodies of which are located in the dorsal root ganglia or the trigeminal ganglion. Some of these fibers also project to the central auditory system. This enables the somatosensory system to influence the auditory system by altering spontaneous rates or synchronicity of firing among neurons in the CN, inferior colliculus, or auditory cortex. In this way, the somatosensory system is able to alter the intensity and character of tinnitus.[12]

Up to 60% of patients with TMD also perceive tinnitus, which is more than in the general population.[13] Additionally, the fact that tinnitus can be triggered by altered somatosensory input from the temporomandibular area suggests that the treatment of TMD might decrease tinnitus severity. However, it is not known to date if there is any evidence for this suggestion or how strong this possible evidence is. Therefore, the aim of this review was to investigate whether TMD treatment can positively influence tinnitus complaints.

Materials and Methods

Search Strategy

A systematic search was conducted in the online databases PubMed, Web of Science, Scopus, and the Cochrane Library up to August 2018. The search strategy was based on the PICO (population, intervention, comparison, outcome) framework, and the following search was entered in the different databases:

("tinnitus"[Mesh] AND "craniomandibular disorders"[Mesh]) AND (("physical therapy modalities"[Mesh] OR "dental care"[Mesh] OR "occlusal splints"[Mesh]) OR (physical therapy modalities OR splint therapy OR TMD therapy)).

Afterwards, the reference lists of the included articles were hand searched for missed publications.

Study Selection

Studies needed to meet the following inclusion criteria: human studies; both tinnitus and TMD were present in the subjects; the studied intervention was a physical therapy treatment modality, dental care, oral appliance, or a combination of the previous; a tinnitus intensity or severity measure was one of the outcome measures; English, French, Dutch, or German language; and presenting original research. Articles not meeting all inclusion criteria were excluded.

After the initial search, all retrieved articles were screened for eligibility based on titles and abstracts. The full texts of included articles were studied.

The inclusion procedure was conducted by the first and second authors independently and supervised by the last author. In case of uncertainty about inclusion, a decision was made in a consensus meeting.

Qualifications of the Investigators

The screening of the literature and risk of bias assessment were performed independently by the first and second authors. The last author supervised the process. The first, fifth, sixth, and seventh authors provided overall expertise on tinnitus complaints, and the third, fourth, and eighth authors provided overall expertise on TMD.

Data Items and Collection Process

All relevant information extracted from the selected studies is presented in Tables 1 and 2. Table 1 describes the results of the cohort studies, and Table 2 describes the results of the randomized controlled trials (RCTs) and controlled trial.

Risk of Bias in Individual Studies

To investigate the methodologic quality of the included RCTs and the controlled trial, the PEDro scale was used, as recommended by the Physiotherapy Evidence Database. The purpose of the PEDro scale is to rapidly identify which of the (R)CTs are likely to be externally valid (item 1), internally valid (items 2 through 9), and have sufficient statistical information to make the results interpretable (items 10 and 11). The scale is comprised of 11 items with "yes" or "no" answers, and the total score is calculated by summing the number of "yes" answers for items 2 through 11 (item 1 is not considered the total score). Points are only awarded when a criterion is clearly satisfied.

The methodologic quality of the cohort studies was assessed using the quality assessment tool for before-after (pre-post) studies with no control group developed by the National Institutes of Health (NIH). This validity tool consists of 12 items scored with "yes," "no," and "other" (cannot determine [CD], not applicable [NA], or not reported [NR]) answers. The quality rating can be poor, fair, or good quality. A rating of poor quality translates to a high risk of bias, and good quality translates to a low risk of bias.

The methodologic quality assessment was performed by the first and the second authors independently. Afterwards, the results were compared, and disagreements were discussed to reach a consensus. The level of evidence was scored based on the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) system.

Table 1 Summary of the Cohort Studies

Study, country, design	Population characteristics	Intervention and control
Attanasio et al[21] (2015), Italy; Cohort	N = 55 Female: NR Male: NR Age: 18–60 y Diagnosis: Chronic subjective tinnitus (at least for the last 12 mo) Group 1: without TMD; n = 10; age: 43.9 ± 7.87 y Group 2: predisposition to TMD; n = 30; age: 44.5 ± 12.4 y Group 3: with TMD; n = 15; age: 35 ± 6.72 y	Neuromuscular occlusal splint
Buergers et al[9] (2014), Germany; Prospective cohort	N = 25 Female: NR Male: NR Age: NR Diagnosis: TMD and tinnitus	Intraocclusal stabilization appliance (all patients) and individual physiotherapeutic treatments (applied in 16 patients), including passive muscle stretching, massaging of the affected masticatory elevator muscles, thermotherapy (moist heat), traction of the TMJs, and coordination exercises
Peroz[17] (2001), Germany; Cohort	N = 221 Female: 163 Male: 58 Age: 35 (18–81) y Diagnosis: TMD Group 1: TMD without ear symptoms; n = 134; age: 35.7 ± 13.6 y Group 2: TMD with otalgia; n = 80; age: 40.5 ± 15 y Group 3: TMD with tinnitus; n = 8; inclusive one patient with tinnitus and otalgia; age: 46 ± 13 y	Individual conservative treatment comprising self-inspection to avoid parafunction, heat therapy, splint therapy, relaxation exercises, mouth-opening exercises, and counseling
Sobhy et al[18] (2004), Egypt; Cohort	N = 30 Female: 25 Male: 5 Age: 24.3 (11–40) y Diagnosis: TMD and otalgia or tinnitus Group A: myofascial pain dysfunction syndrome and otalgia or tinnitus Group B: disc displacement with reduction and otalgia or tinnitus	Group A: counseling, analgesics, nonsteroidal anti-inflammatory agents, muscle relaxants, physiotherapy, and soft occlusal splints (night guard) Group B: as above, but with hard acrylic occlusal splints
Ström et al[22] (2013), Sweden; Cohort	N = 45 Female: 21; age: 49 ± 12 y Male: 24; age: 47 ± 12 y Diagnosis: long-standing tinnitus with jaw muscle tenderness	Splint therapy and acupuncture
Suvinen et al[23] (1997), Australia; Cohort	N = 42 Female: 39 Male: 3 Age: 44.8 (± 17.0) y Diagnosis: TMD	Counseling and standard interocclusal appliance therapy
Wright and Bifano[19] (1997), USA; Cohort	N = 93 Female: NR Male: NR Age: 31 (18–67) y Diagnosis: TMD and ringing or buzzing in their ears of head	Individual conservative TMD therapy comprising self-care instructions, splint therapy, jaw-stretching exercises, behavioral psychologic therapy, stretching exercises, posture training and/or physical therapy modalities, pharmaceutical therapy (n = 18), and individual psychologic consultations
Wright et al[20] (2000), USA; Cohort	N = 15 Female: 7 Male: 8 Age: 57.6 (43–74) y Diagnosis: Tinnitus or dizziness and TMD or otalgia	Mandibular dental orthotic, standard TMD self-care instructions, and additional TMD therapy (relaxation, biofeedback, physical therapy, counseling, cognitive therapy, medications, etc)

TMD = temporomandibular disorders; NR = not reported; VAS = visual analog scale; THI = Tinnitus Handicap Inventory; TMJ = temporomandibular joint; GPE = global perceived effect; THQ = Tinnitus Handicap Questionnaire.

Frequency and duration of intervention	Tinnitus severity outcome	Follow-up	Results
6 mo for a minimum of 8 h to a maximum of 15 h per d	VAS-severity THI	Posttreatment	VAS-severity: Significant decrease in all groups between pre- and posttreatment (group 1: –22.92%; *P* = .002; group 2: –25.54%; *P* < .001; group 3: –47.97%; *P* = .001) THI: Significant decrease in all groups between pre- and posttreatment (group 1: –25.33%; *P* = .005; group 2: –38.58%; *P* < .001; group 3: –65.38%; *P* = .001)
Not specified	THI VAS-change (no change from baseline, improvement, complete remission, impairment)	3–5 mo after initiation of dental functional therapy	THI: NR VAS: 8% reported complete remission, 36% improvement, 56% no change In patients with acute tinnitus (n = 8), 7 reported improvement, 1 complete remission; 14 of the 17 patients with chronic tinnitus reported no change. Improvement of total remission was reported by 8 of 16 patients who received physiotherapy, but only by 3 of 9 participants without physiotherapy.
Mean therapy duration: 7 (± 5) mo Mean therapy frequency: 4 consultations (minimum 1, maximum 16)	GPE	1 y	GPE: 1 year after therapy, 1 patient reported less tinnitus noises, no change in tinnitus in the other 7 patients
Not specified	THQ	After treatment	THQ: Significant decrease of the scores after therapy, which means improvement of tinnitus (20% incidence of tinnitus in this study)
Splint therapy: 6 mo; acupuncture was given 5 to 6 consecutive sessions	VAS-severity	1 y	VAS: Significant decrease in subjective tinnitus after 1 year. One-third of the patients (15) reported a reduction of 50% or more on their tinnitus evaluation on the VAS scale. All but 6 of the 45 patients reported reduction of their tinnitus.
Not specified	GPE	6 mo	GPE: Improvement in terms of ringing in the ears was greater in the rapid responding group.* *Subjects were divided into rapid and slow responders according to whether their subjective degree of improvement on a VAS scale (TMD pain) at 6 mo following standard simple conservative management was above or equal to/below 50%, respectively.
Not specified	GPE	Posttreatment	GPE: 56%, 30%, and 14% reported their tinnitus had been resolved, significantly improved, and minimal or no change, respectively.
3 mo	GPE, THQ	Posttreatment, 6-mo follow-up	GPE: Of the 14 patients who reported tinnitus, 6, 3, and 5 reported resolution, significant to moderate improvement, and minimal to no change, respectively. THQ: No trends for the overall THQ score or any of its three factors being associated with patients' tinnitus improvement. In patients with at least moderate improvement in their tinnitus, the THQ score decreased from 46.3 to 20.4.

Table 2 Summary of the (Randomized) Controlled Trials

Study characteristics	Population characteristics	Intervention and control	Frequency and duration of intervention
Bösel et al[16] (2008), Germany; CT with cross-over design	N = 59 Female: 28 Male: 31 Age: 49 (12–69) y Diagnosis: chronic tinnitus and at least 1 TMD symptom present	Cross-over ofsplint therapy and self-therapy (heat treatment, massage of the jaw muscles, and self-monitoring to reduce unconscious muscular tension) vs control	6 wk splint therapy 6 wk self-therapy
Erlandsson et al[14] (1991), Sweden; RCT with cross-over design	N = 32 Female: 14 Male: 18 Age: 50 (24–65) y Diagnosis: severe tinnitus and self-reported TMD or headaches	SGT comprising: occlusal splints, occlusal adjustments, and exercise therapy vs BFT comprising: biofeedback training, progressive relaxation, and counseling	Not specified
Tullberg and Ernberg[15] (2006), Sweden; RCT	Patients (P): n = 73 Control (C): n = 50 Female: 39 P, 27 C Male: 34 P, 23 C Age: P = 48 ± 12 y, C = 47 ± 14 y Diagnosis: patients suffering from combination of tinnitus and TMD, controls suffering from tinnitus	Splints, occlusal adjustments, jaw exercises, and laser therapy vs waiting list	1 to 6 sessions

TMD = temporomandibular disorders; VAS = visual analog scale; CT = controlled trial; NRS = numeric rating scale; GPE = global perceived effect; SGT = stomatognathic treatment; BFT = biofeedback therapy; TQ = Tinnitus Questionnaire.

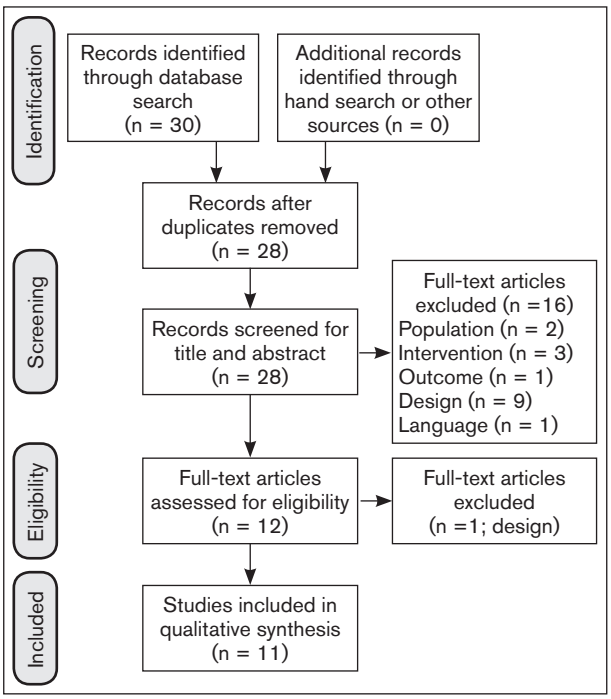

Fig 1 Flowchart of study selection process.

Results

Study Selection

After the initial search, 28 unique articles were retrieved from the four databases. After selection, based on title and abstract, the full texts of 12 articles were screened, and 11 articles were included in the systematic review. In total, 17 articles were discarded: 2 due to the described population, 3 because of the described intervention, 1 because of the outcome measures, 10 due to the design of the study, and 1 because of the language. Details of the selection process are shown in Fig 1.

Study Characteristics

Of the 11 articles selected for this review, 2 were RCTs, 1 was a controlled trial, and 8 were cohort studies. The treatment of the patients consisted of occlusal dental splints, occlusal dental adjustments, physical therapy, biofeedback therapy, relaxation exercises, counseling, pharmacotherapy, acupuncture, laser therapy, and psychologic therapy. The duration of the interventions ranged from one session to 7 months, although duration and frequency of the interventions were often not specified.

The reported primary tinnitus outcome measures were visual analog scale (VAS) for tinnitus severity (VAS-severity), VAS for change in tinnitus (VAS-change), VAS for tinnitus intensity (VAS-intensity), Tinnitus Questionnaire (TQ), Tinnitus Handicap Inventory (THI), Tinnitus Handicap Questionnaire (THQ), numeric rating scale (NRS) for tinnitus severity (NRS-severity), global perceived effect (GPE), and a custom-made questionnaire.

Risk of Bias and Level of Evidence

The results of the risk of bias assessment are presented in Figs 2 and 3.

Generally, a high risk of bias was present in the included studies. The main methodologic limitations of the studies were related to the lack of statistical analyses between groups and before vs after treatment,

Tinnitus severity outcome	Follow-up	Results
TQ	After first 6 wk of treatment (splint therapy or self-therapy) Posttreatment (12 wk)	TQ: No significant difference between pre- and posttreatment scores in patients with light to moderate tinnitus (TQ: 0–46). Significant decrease in pre- to posttreatment scores in patients with severe to very severe tinnitus (TQ: 47–84). This difference was statistically significant in comparison with the control group.
VAS-intensity (0–100) NRS-severity (1–9)	Posttreatment 6-mo follow-up	VAS-intensity: Significant decrease after SGT or BFT (n = 31). No significant changes after SGT or BFT alone (n = 13 or 18). NRS-severity: No significant changes.
GPE Custom-made questionnaire	Posttreatment (GPE) and 2–3 y follow-up (questionnaire)	GPE: 73% reported improvement, 27% reported no change. Questionnaire: Significantly decreased tinnitus severity. Significantly more improvement in the patients than in the control group.

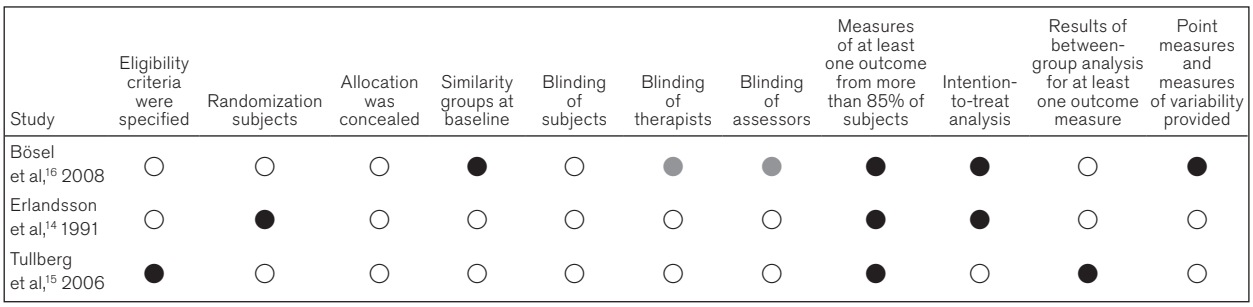

Fig 2 Risk of bias assessment for (randomized) controlled trials according to the PEDro Scale. Black = yes; white = no; gray = not mentioned.

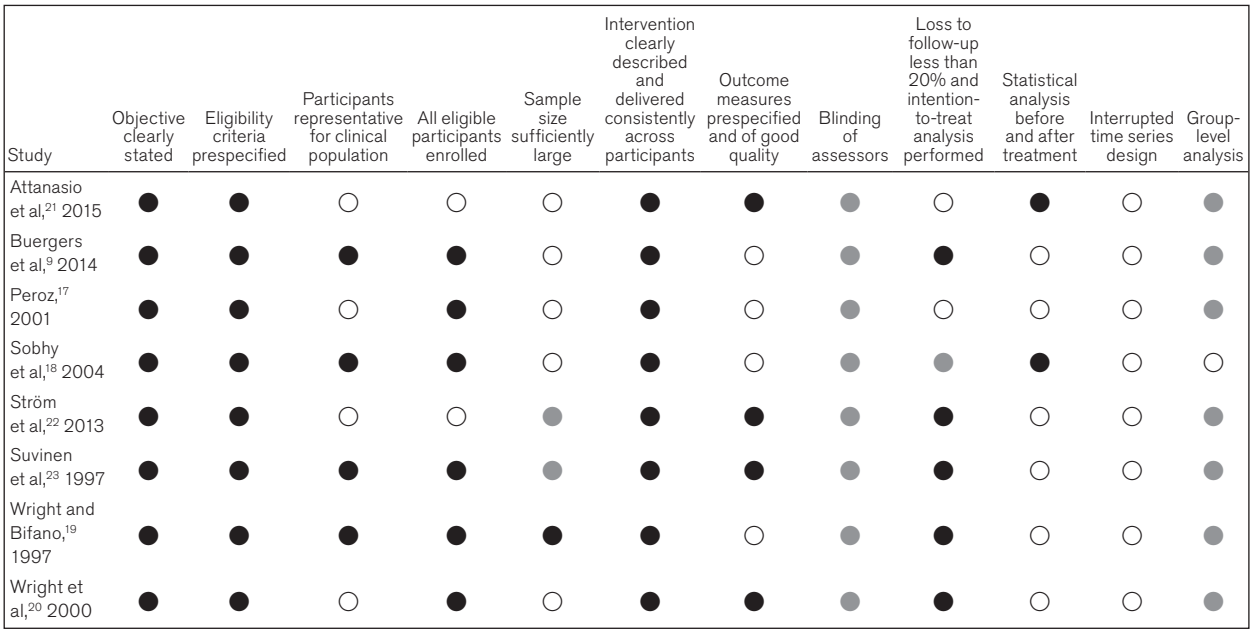

Fig 3 Risk of bias assessment for cohort studies using the quality assessment tool for before-after studies with no control group. Black = yes; white = no; gray = other (cannot determine, not applicable, not reported).

Table 3 GRADE Evidence for (Randomized) Controlled Trials

Outcome	No. of participants	Quality of the evidence
Tinnitus improvement measured using a variety of scales	214 (3 studies)	Low (due to serious risk of bias)[a]

[a]Details in Fig 2.

Table 4 GRADE Evidence Rating for Cohort Studies

GRADE domain	Judgment	Concerns
Risk of bias	See risk of bias assessment, Fig 2	Very serious limitations, downgrade 2 levels
Inconsistent results	All studies show consistent decrease of tinnitus symptoms	No serious limitations, no downgrade
Indirectness of evidence	There is direct evidence for tinnitus improvement	No serious limitations, no downgrade
Imprecision	The group of 214 included patients is sufficiently large to show a decrease in tinnitus symptoms with 80% power, as calculated in a sample size calculation	No serious limitations, no downgrade
Publication bias	There are no signs of publication bias	No serious limitations, no downgrade

incomplete presentation of the data, and selective reporting. Furthermore, the lack of information concerning blinding of the subjects, therapists, and investigators caused a high risk of bias. Consequently, the level of evidence of this systematic review is low according to the GRADE system (Tables 3 and 4).

Synthesis of the Results

For each individual study, a summary of the characteristics of the study group, type of intervention, and main results are presented in Tables 1 and 2. Table 1 presents the results of the cohort studies, and Table 2 presents the results of the RCTs and controlled trial.

Two RCTs[14,15] and one controlled trial[16] investigated the effect of TMD treatment on tinnitus severity or intensity. These studies showed a positive effect of the combination of splint therapy and exercise treatment on VAS-severity,[15,16] VAS-intensity,[14] and GPE.[15] One study[16] specified that the treatment effect was only present in patients with severe to very severe tinnitus (TQ score: 47 to 84 points), while the others found an effect in the overall study group.

Additionally, the results of eight cohort studies were considered. Five of these[9,17–20] investigated the effect of a combination of physical therapy modalities and dental care (oral appliances or occlusal adjustments). No unambiguous conclusions can be drawn from these studies. Improvement in tinnitus severity using GPE was shown in 14% to 86% of the treated patients.[17,20] Improvement in VAS-change was reported in 44% of the patients in one study.[9] No significant decrease in THQ score was found.[18,20]

The remaining three cohort studies[21–23] used oral appliances without physical therapy modalities. One study combined the oral appliances with acupuncture[22] and one with counseling.[23] The application of oral appliances alone resulted in a significant decrease in VAS-severity (23% to 48%) and THI (25% to 65%).[21] In combination with acupuncture, application of oral appliances showed at least a 50% decrease in VAS-severity in 33% of the patients.[22] Combination with counseling showed that patients whose TMD improved faster indicated a larger improvement on GPE.[23]

Differences in outcome measures, unmatched group characteristics, and the absence of a consistent TMD therapy made it impossible to perform either a descriptive analysis or quantitative meta-analysis in this systematic review.

Discussion

This systematic review aimed to investigate whether TMD treatment can positively influence tinnitus complaints.

Overall, positive effects of conservative TMD treatment on tinnitus complaints were found. Several TMD treatment modalities have been described, but the combination of splint therapy and exercise treatment is the most investigated treatment for TMD-related tinnitus complaints. This treatment approach showed a positive effect on tinnitus intensity and GPE in two RCTs and a positive effect on tinnitus severity in patients with severe to very severe tinnitus in one controlled trial. Additionally, five cohort studies investigated a similar treatment approach, showing positive effects on tinnitus complaints in three studies but little effect in the other two. However, it must be noted that improvement in tinnitus complaints can also be caused by the natural course of the tinnitus.

The effect of oral appliances alone or in combination with acupuncture or counseling are currently not investigated thoroughly enough to be conclusive.

The multifactorial etiology of TMD cannot be ignored, especially when analyzing a patient population with tinnitus. Studies have demonstrated that TMD patients show increased somatization, stress, anxiety, and depression relative to healthy individuals.[24,25] These symptoms are also often associated with tinnitus itself, and psychologically based treatments such as tinnitus retraining therapy (TRT) or cognitive behavioral therapy (CBT) are currently recommended as best evidence–based treatment in the general tinnitus population.[26] Therefore, specific multimodal therapies incorporating behavioral and educational approaches, which seem to offer more benefit than a single-treatment program, should be advised in patients with TMD-related tinnitus.[27]

Patients should be educated regarding the possible causes of TMD, and it is important that they understand their own central role in its management.[28–31] Although patient education is an essential part in the treatment of TMD, four studies did not implement counseling in their treatment program. Occlusal adjustments were included in two studies, but this is an irreversible treatment that should be looked upon with extreme caution,[32] since evidence for the role of such occlusal adjustments in the management or prevention of TMD is lacking.[33–35]

Additionally, when studying TMD treatment, only those subjects that require the treatment should be included. In the study from Attanasio et al,[22] for instance, patients without TMD, with a predisposition to TMD, and with TMD were included. All these patients were treated with neuromuscular occlusal dental splints, an older treatment modality to reduce masticatory muscle tension and to protect teeth from bruxism and clenching.[36,37] In 10 patients, however, no TMD complaints were present, and thus they did not require this treatment. Since splint therapy is not likely to change the tinnitus severity in these patients, the effect of the treatment in patients with tinnitus and TMD will be underestimated in this study.

Another study[15] included tinnitus patients without TMD in the control group and concluded that the patient group improved significantly more in comparison to the control group. Comparability of the study and control groups regarding type of tinnitus is, however, essential, since no improvement in tinnitus complaints can be expected after TMD intervention when the tinnitus is not related to TMD.

The risk of bias in the included studies was high due to several limitations. First, there is lack of homogeneity in the studied population. In four of the included studies, the presence or absence of tinnitus was evaluated by simply asking the patients to report tinnitus symptoms, without performing otologic or audiometric assessment.[9,17,19,23] Therefore, limited information about the tinnitus characteristics was present. Moreover, without performing an ENT examination, it is not possible to confirm the presence of somatic tinnitus because tinnitus and TMD can also occur without causal relation.[8] Additionally, the multifactorial aspects of TMD signs and symptoms should be considered. Some studies only included patients with myofascial TMD pain, while others included patients with different TMD etiologies. Moreover, in some studies, the criteria to confirm the presence of TMD were not clearly stated, and different TMD classification methods were used. The Helkimo Index was used in two studies, while six studies evaluated the TMJ complaints using the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD). The RDC/TMD was the internationally accepted classification system for TMD at the moment of publication of the studies,[38] but as of 2014, the updated version of the RDC/TMD is the most appropriate tool.[39] Due to the lack of homogeneity in both tinnitus and TMD evaluation, generalization of the conclusions is not possible. Furthermore, many different tinnitus outcome measures are used in the included studies. This hampers the comparability of the results. An international standard for outcome measurements in clinical trials of tinnitus is required to enable meta-analysis, as was also ascertained by Hall et al.[40] An international standard is being developed, but to date, no consensus has been reached.

Second, a high risk of bias was present due to a lack of statistical analyses between groups and before vs after treatment; lack of randomization; and lack of blinding of subjects, therapists, and/or assessors, as well as to the incomplete presentation of the data and selective reporting.

A second limitation of the studies included in this review is the lack of evaluation of Axis II findings and the duration of the TMD symptoms. Since the duration of TMD symptoms and psychosocial influences will largely influence the outcome of the TMD therapy, these items should be taken into account in every study investigating the effect of TMD treatment. Moreover, when psychosocial influences are present or TMD symptoms persist, other treatment modalities should be considered, including more psychology-based treatments.

Future research should focus on investigating the effect of the current best evidence–based TMD treatment, including the treatment of coexisting increased somatization, stress, anxiety, and depression. A combination of psychology-based tinnitus treatments, such as TRT or CBT, and TMD treatment can be a good way to include the treatment of psychosocial influences on both TMD and

tinnitus. This type of treatment should be evaluated using high-quality RCTs in large populations of patients with TMD-related tinnitus and using outcome measures with good psychometric properties, such as the Tinnitus Functional Index[41] or the Tinnitus Questionnaire.[42]

Conclusions

There is low-quality evidence for a positive effect of conservative TMD treatment on tinnitus complaints. The combination of splint therapy and exercise treatment is currently the best investigated treatment approach, showing a decrease in tinnitus severity and intensity. Despite the low level of evidence and the methodologic issues in the included studies, it is noteworthy that all included studies showed positive treatment effects.

Acknowledgments

The first and second authors are supported by a research grant from The Research Foundation—Flanders (FWO) (T001916N). The authors report no conflicts of interest.

References

1. Eggermont JJ, Roberts LE. The neuroscience of tinnitus. Trends Neurosci 2004;27:676–682.
2. Baguley D, McFerran D, Hall D. Tinnitus. Lancet 2013;382:1600–1607.
3. Gilles A, Van Hal G, De Ridder D, Wouters K, Van de Heyning P. Epidemiology of noise-induced tinnitus and the attitudes and beliefs towards noise and hearing protection in adolescents. PLoS One 2013;8:e70297.
4. Axelsson A, Ringdahl A. Tinnitus—A study of its prevalence and characteristics. Br J Audiol 1989;23:53–62.
5. Teachey WS, Wijtmans EH, Cardarelli F, Levine RA. Tinnitus of myofascial origin. Int Tinnitus J 2012;17:70–73.
6. Saldanha AD, Hilgenberg PB, Pinto LM, Conti PC. Are temporomandibular disorders and tinnitus associated? Cranio 2012;30:166–171.
7. Abel MD, Levine RA. Muscle contractions and auditory perception in tinnitus patients and nonclinical subjects. Cranio 2004;22:181–191.
8. Michiels S, De Hertogh W, Truijen S, Van de Heyning P. Cervical spine dysfunctions in patients with chronic subjective tinnitus. Otol Neurotol 2015;36:741–745.
9. Buergers R, Kleinjung T, Behr M, Vielsmeier V. Is there a link between tinnitus and temporomandibular disorders? J Prosthet Dent 2014;111:222–227.
10. Pfaller K, Arvidsson J. Central distribution of trigeminal and upper cervical primary afferents in the rat studied by anterograde transport of horseradish peroxidase conjugated to wheat germ agglutinin. J Comp Neurol 1988;268:91–108.
11. Zhan X, Pongstaporn T, Ryugo DK. Projections of the second cervical dorsal root ganglion to the cochlear nucleus in rats. J Comp Neurol 2006;496:335–348.
12. Shore S, Zhou J, Koehler S. Neural mechanisms underlying somatic tinnitus. Prog Brain Res 2007;166:107–123.
13. Wright EF, Bifano SL. The relationship between tinnitus and temporomandibular disorder (TMD) therapy. Int Tinnitus J 1997;3:55–61.
14. Erlandsson SI, Rubinstein B, Carlsson SG. Tinnitus: Evaluation of biofeedback and stomatognathic treatment. Br J Audiol 1991;25:151–161.
15. Tullberg M, Ernberg M. Long-term effect on tinnitus by treatment of temporomandibular disorders: A two-year follow-up by questionnaire. Acta Odontol Scand 2006;64:89–96.
16. Bösel C, Mazurek B, Haupt H, Peroz I. Chronic tinnitus and craniomandibular disorders. Effectiveness of functional therapy on perceived tinnitus distress [in German]. HNO 2008;56:707–713.
17. Peroz I. Otalgia and tinnitus in patients with craniomandibular dysfunctions [in German]. HNO 2001;49:713–718.
18. Sobhy OA, Koutb AR, Abdel-Baki FA, Ali TM, El Raffa IZ, Khater AH. Evaluation of aural manifestations in tempo-ro-mandibular joint dysfunction. Clin Otolaryngol Allied Sci 2004;29:382–385.
19. Wright EF, Bifano SL. Tinnitus improvement through TMD therapy. J Am Dent Assoc 1997;128:1424–1432.
20. Wright EF, Syms CA 3rd, Bifano SL. Tinnitus, dizziness, and nonotologic otalgia improvement through temporomandibular disorder therapy. Mil Med 2000;165:733–736.
21. Attanasio G, Leonardi A, Arangio P, et al. Tinnitus in patients with temporo-mandibular joint disorder: Proposal for a new treatment protocol. J Craniomaxillofac Surg 2015;43:724–727.
22. Ström D, Behrenth E, Ekman K, Johansson A, Unell L, Carlsson GE. Management of tinnitus and jaw-muscle tenderness using an intraoral appliance and acupuncture. Swed Dent J 2013;37:105–110.
23. Suvinen TI, Hanes KR, Reade PC. Outcome of therapy in the conservative management of temporomandibular pain dysfunction disorder. J Oral Rehabil 1997;24:718–724.
24. Pankhurst CL. Controversies in the aetiology of temporomandibular disorders. Part 1. Temporomandibular disorders: All in the mind? Prim Dent Care.1997;4:25–30.
25. McKinney MW, Londeen TF, Turner SP, Levitt SR. Chronic TM disorder and non-TM disorder pain: A comparison of behavioral and psychological characteristics. Cranio 1990;8:40–46.
26. Makar SK, Mukundan G, Gore G. Treatment of tinnitus: A scoping review. Int Tinnitus J 2017;21:144–156.
27. Türp JC, Jokstad A, Motschall E, Schindler HJ, Windecker-Gétaz I, Ettlin DA. Is there a superiority of multimodal as opposed to simple therapy in patients with temporomandibular disorders? A qualitative systematic review of the literature. Clin Oral Implants Res 2007;18(suppl 3):s138–s150.
28. Durham J, Aggarwal V, Davies SJ, et al. Temporomandibular disorders (TMDs): An update and management guidance for primary care from the UK Specialist Interest Group in Orofacial Pain and TMDs (USOT). Royal College of Surgeons of England: Royal College of Surgeons of England, 2015.
29. Greene CS. Managing patients with temporomandibular disorders: A new "standard of care". Am J Orthod Dentofacial Orthop 2010;138:3–4.
30. Durham J, Wassell RW. Recent advancements in temporomandibular disorders (TMDs). Rev Pain 2011;5:18–25.
31. Dworkin SF, Huggins KH, Wilson L, et al. A randomized clinical trial using research diagnostic criteria for temporomandibular disorders-axis II to target clinic cases for a tailored self-care TMD treatment program. J Orofac Pain 2002;16:48–63.
32. Ghurye S, McMillan R. Pain-related temporomandibular disorder—Current perspectives and evidence-based management. Dent Update 2015;42:533–536, 539–542, 545–546.

33. 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;83:549–560.
34. Forssell H, Kalso E. Application of principles of evidence-based medicine to occlusal treatment for temporomandibular disorders: Are there lessons to be learned? J Orofac Pain 2004;18:9–22.
35. Koh H, Robinson PG. Occlusal adjustment for treating and preventing temporomandibular joint disorders. J Oral Rehabil 2004;31:287–292.
36. Ebrahim S, Montoya L, Busse JW, et al. The effectiveness of splint therapy in patients with temporomandibular disorders: A systematic review and meta-analysis. J Am Dent Assoc 2012;143:847–857.
37. Conti PC, dos Santos CN, Kogawa EM, de Castro Ferreira Conti AC, de Araujo Cdos R. The treatment of painful temporomandibular joint clicking with oral splints: A randomized clinical trial. J Am Dent Assoc 2006;137:1108–1114.
38. Dworkin SF, LeResche L. Research diagnostic criteria for temporomandibular disorders: Review, criteria, examinations and specifications, critique. J Craniomandib Disord 1992;6: 301–355.
39. Schiffman E, Ohrbach R, Truelove E, et al. Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) for clinical and research applications: Recommendations of the International RDC/TMD Consortium Network* and Orofacial Pain Special Interest Group. J Oral Facial Pain Headache 2014;28:6–27.
40. Hall DA, Haider H, Kikidis D, et al. Toward a global consensus on outcome measures for clinical trials in tinnitus: Report from the First International Meeting of the COMiT Initiative, November 14, 2014, Amsterdam, The Netherlands. Trends Hear 2015;19.
41. Meikle MB, Henry JA, Griest SE, et al. The tinnitus functional index: Development of a new clinical measure for chronic, intrusive tinnitus. Ear Hear 2012;33:153–176.
42. Zeman F, Koller M, Schecklmann M, Langguth B, Landgrebe M,TRI database study group. Tinnitus assessment by means of standardized self-report questionnaires: Psychometric properties of the Tinnitus Questionnaire (TQ), the Tinnitus Handicap Inventory (THI), and their short versions in an international and multi-lingual sample. Health Qual Life Outcomes 2012;10:128.