Prognosis of conservative treatment in individuals with temporomandibular disorders and tinnitus: a systematic review

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Summary

Introduction: There are reports in the literature of improved tinnitus after treatment for temporomandibular disorders (TMDs), however there's the lack of standardization of these interventions. The aim was analyzed the results of conservative treatment in individuals with TMDs in terms of tinnitus. The target outcome of the studies was subjective perception of improvement in tinnitus before and after conservative treatment.

Methods: A systematic review was performed, according to Cochrane's recommendations, registered on Prospero (CRD42017063832). In the universe of 1052 titles, 211 abstracts were read and 10 full articles were selected and divided into groups: group 1 - Individuals with TMD/tinnitus treated with a myorelaxant splint and group 2 - Individuals with TMD/tinnitus treated with a myorelaxant splint and associated therapies such as: physiotherapy, acupuncture among others.

Results: The two groups showed promising results in terms of tinnitus improvement and remission, with a statistically significant different in group 2, which exhibited a higher percentage of improvement or remission, suggesting that the combination of a myorelaxant splint and other conservative therapies is the best approach.

Conclusion: TMD treatment showed good results for improvement in tinnitus, particularly in those who complained of muscle pain.

Level of evidence: II a.

KEY WORDS: tinnitus, temporomandibular joint syndrome, conservative treatment.

Introduction

The temporomandibular joint (TMJ) is situated anteriorly to the external acoustic meatus (ear canal) between the head of the mandible and the mandibular fossa (squamous and tympanic parts of the temporal bone). It contains an articular disk covered by a fibrous capsule and interposed anteriorly into the lateral pterygoid muscle and posteriorly into the fat pad. The muscles of mastication are responsible for movement in this joint^{1,2}.

The anatomical relationship between the TMJ and the ear begins with embryonic development of the first pharyngeal arch, and the innervation of some structures by the trigeminal nerve can generate pain throughout the facial region³.

Anatomical dysfunctions of the TMJ are defined as temporomandibular disorders (TMD), which affect the TMJ, masticatory and facial muscles, spreading to the stomatognathic and auditory systems. Its etiology is multidimensional and involves neurobiological, biomechanical, neuromuscular and biopsychosocial factors. An assessment of the anatomical and mechanical characteristics associated with the TMJ can serve as the basis for understanding an individual's clinical condition^{3,4}.

The main incapacitating symptoms are muscle and/or joint pain, restricted or deviated joint movement, joint noises, headaches, neck pain, earache and tinnitus^{1,5}.

Tinnitus is the term for hearing sounds in the inner ear that are not from an external source and can be mild, characterized by occasional ringing of varying intensities, or severe, in the form of constant loud noise that is untreatable⁶.

Considered one of the greatest medical mysteries, it is suggested that the somatosensory stimuli that induce tinnitus are closely linked to anomalous cross-modal plasticity of somatosensory-auditory interactions, whereby the somatic modulations of tinnitus are the result of abnormal auditory neural interactions and the distortion of normal synaptic activity in the central nervous system, that is, information on muscle contractions is carried by the somatosensory system and, on reaching the cuneiform nucleus, can influence tinnitus through its projection on the auditory

pathway due to hyperactivity in the cochlear nucleus. In particular, stimulation of specific ipsilateral cranial nerves (branches of the trigeminal nerve) modulates hyperactivity in the dorsal cochlear nucleus (DCN), which explains how ipsilateral tinnitus can be modulated by moving the head and neck⁷.

There is a number of TMD conservative treatment options. From the use of myorelaxant splint isolately or associated to other therapies such as physiotherapy, acupuncture, lasertherapy, and cognitive-behavioral therapy, to the injection of hyaluronic acid in patients with inflammatory-degenerative TMJ disease related to cervical spine disorders^{8,9}.

The interaction between tinnitus and TMD is a longstanding and complex issue; tinnitus is known to be more prevalent among those suffering from TMD when compared to the general population and conservative treatment of the symptoms of muscle significantly improves tinnitus¹⁰.

Thus, the aim of this systematic literature review is to assess the results of conservative treatment in individuals with temporomandibular disorders in terms of improving tinnitus.

Materials and methods

This research was ethically conducted according to international standards as described in Padulo et al.¹¹.

The systematic review was performed to answer the following question: does conservative treatment in individuals suffering from temporomandibular disorders improve tinnitus?

Based on this question, the review was carried out in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement¹². A protocol was published in the PROSPERO database (<http://www.crd.york.ac.uk/PROSPERO>) under CRD42017063832.

Search strategy

The strategies were aimed at achieving a comprehensive search, including descriptors (DECs and MESH) and free text (FT), based on the four elements of the PICO framework (patient, intervention, comparison, outcome) present in the title, namely (tinnitus OR ringing in the ears OR ear buzzing) AND (temporomandibular disorders OR temporomandibular joint OR temporomandibular dysfunction OR craniomandibular dysfunction) AND (conservative therapy OR treatment).

The searches were conducted between February and May 2017 and were revised in June of the same year. The following databases were searched: Pubmed, ScienceDirect, SCOPUS, Web of Science, Scientific Electronic Library On-line (SciELO) and Latin American and Caribbean Health Sciences Literature (LILACS), in addition to the grey literature: Open-Grey.eu, DissOnline, with no language or date restrictions. There was no manual search of the articles included to prevent the risk of bias¹³.

Eligibility criteria

Inclusion criteria were clinical trials (randomized or not) or observational studies that evaluated improvement in tinnitus among individuals with temporomandibular disorders after conservative treatment by comparing data before and after intervention. Exclusion criteria were studies repeated on different databases and articles whose subjects exhibited other auditory pathologies, such as bilateral hearing loss, vertigo, ear pain, dizziness, ear fullness, Meniere's disease, as well as nonauditory conditions such as cervical spine and hormonal disorders.

Data extraction

The articles were initially selected based on the previously defined search strategies and in accordance with the eligibility criteria. The resulting titles and abstracts were evaluated independently by two researchers who were not blind to the relevant Authors or journals. Any differences were resolved by discussion. The entire text of the potentially eligible articles was obtained and analyzed in full.

The target outcome of the studies was subjective perception of improvement in tinnitus before and after conservative treatment of TMD.

The data from the articles were analyzed and the Authors were contacted to obtain additional information. In addition to information on the outcomes, the Authors' names, title, year of publication, country, pathology, intervention, number of sessions and groups studied were also extracted. A standard data extraction form was created based on the model adopted by Cochrane¹³.

Assessing risk of bias

Risk of bias was assessed in line with the recommendations of the Cochrane handbook and Newcastle-Ottawa scale¹⁴, adapted for observational studies and illustrated in Table I. The quality of the studies was evaluated independently by two researchers and differences were resolved by consensus. The maximum score possible was ten and the items assessed on the scale were: 1. representativeness of the sample; 2. sample size; 3. non-respondents; 4. ascertainment of exposure (risk factor); 5. comparability, to determine whether the subjects in different outcome groups are comparable based on the study design or analysis and controlling confounding factors; 6. assessment of the outcomes and 7. statistical test.

Data analysis

The studies assessed tinnitus before and after treatment through subjective questionnaires that resulted in varied data collection; some used the visual analogue scale (VAS) or Tinnitus Handicap Inventory, while others did not quantitatively explain the scores, making it impossible to perform a meta-analysis in this systematic literature review.

However, in order to compare tinnitus remission or improvement for the different TMD treatments, the

Table I. Risk of bias of articles included.

Scores/Authors	Felício et al., 1999	Felício et al., 2006	Webster et al., 2011	Uemoto et al., 2012	Strom et al., 2013	Attanasio et al., 2015	Wright, Bifano, 1997	Tullberg, Ernberg, 2006	Wright, 2007	Buergers et al., 2014
Selection										
1	b) *	b) *	b) *	b) *	b) *	b) *	b) *	b) *	c) -	c) -
2	b) -	b) -	b) -	b) -	b) -	b) -	b) -	b) -	b) -	b) -
3	b) -	b) -	b) -	b) -	c) -	c) -	c) -	a) *	b) -	c) -
4	c) -	b) *	a) **	c) -	b) *	a) **	b) *	c) -	c) -	a) **
Comparability										
1	a) *	a) *	a) *	a) *	a) *	a) *	a) *	a) *	a) *	a) *
	b) -	b) *	b) *	b) -	b) -	b) *	b) *	b) *	b) *	b) *
Results										
1	c) *	b) **	c) *	c) *	c) *	c) *	c) *	b) **	c) *	c) *
2	b) -	a) *	a) *	b) -	a) *	a) *	a) *	a) *	a) *	b) -
Total	**	*****	*****	**	*****	*****	*****	*****	****	*****

data were separated into two groups (group 1 - Individuals with TMD / tinnitus treated with a myorelaxant splint and group 2 - Individuals with TMD/tinnitus treated with a myorelaxant splint and associated therapies) and the categorical variables were analyzed using the chi-squared test. The results were considered significant for p-values <0.05 and calculations were performed using SPSS software, version 21.

Results

Of the 1052 titles, 211 abstracts were considered relevant based on searches of the aforementioned databases and 21 articles were selected to be read in full. Of these, 11 were excluded for not meeting the eligibility criteria (Tab. II).

Thus, 10 complete articles were included in the qualitative analysis. The flow diagram illustrating the search and selection process is shown in Figure 1.

The articles were divided into two groups as a function of the TMD treatments applied: group 1 - Individuals with TMD/tinnitus treated with a myorelaxant splint (Michigan splint) and group 2 - Individuals with TMD/tinnitus treated with a myorelaxant splint (Michigan splint) and associated therapies, such as: physiotherapy, acupuncture, biofeedback therapy, and cognitive behavioral therapy; however, no studies were found that compared the different treatments at the same time. The details of each study in

groups 1 and 2 are displayed in Tables III and IV, respectively.

Group 1. Subjects with TMD / tinnitus treated with a myorelaxant splint (Michigan splint)

In a study by Felício et al.¹⁵, auditory symptoms were observed in individuals suffering from temporomandibular disorders. Of the 58 participants, women predominated (86.21%), aged between 30 and 50 years. Twenty-eight subjects exhibited no tinnitus and of the 36 who reported it prior to treatment onset, 27 showed a significant improvement after using a splint for two months. The subjects characterized tinnitus as “short high pitched whistle” often accompanied by tingling, an important element in differentiating between tinnitus and other auditory pathologies. Improvements in the auditory symptoms were observed as a function of the occlusal splint, that is, the treatment favored symptom remission, once again demonstrating the relationship between the symptoms and TMDs.

Felício et al.¹⁶ tested a protocol to quantify the frequency and severity of TMD symptoms according to the perception of patients, in two stages. In the first part of stage 1 participants answered questions on the presence of auditory signs and the most prevalent symptoms, such as pain in the muscles of mastication and/or TMJ during jaw movements and on palpation of the structures. In part two the subjects indicated the severity of TMD-related signs and symptoms,

Table II. Complete articles excluded from the review.

Author/year	Title	Localization	Reason
Sletten et al., 2015	The effect of specially designed and managed occlusal devices on patient symptoms and pain: a cohort study	USA	Does not assess tinnitus
Felício et al., 2008	Otologic symptoms of temporomandibular disorder and effect of orofacial myofunctional therapy	Brazil	Therapy differed from the chosen methodology - myofunctional
Bjorne, 2007	Assessment of temporomandibular and cervical spine disorders in tinnitus patients	Switzerland	Treatment differed from the chosen methodology - lidocaine
Sobhi et al., 2004	Evaluation of aural manifestations in temporomandibular joint dysfunction	Egypt	Therapies were compared as opposed to symptoms. Soft and hard splint.
Copper et al., 1991	Electromyography of masticatory muscles in craniomandibular disorders.	USA	Electromyography and does not assess tinnitus
Bush, 1987	Tinnitus and otalgia in temporomandibular disorders	USA	Questionnaire study that does not specify the treatment
Williamson, 1990	The Interrelationship of internal derangements of the temporomandibular joint, headache, vertigo, and tinnitus: a survey of 25 patients	USA	Double splint therapy and does not evaluate tinnitus
Rubinstein et al., 1990	Prevalence of signs and symptoms of craniomandibular disorders in tinnitus patients	Switzerland	Prevalence study
Rubinstein and Carlsson, 1987	Effects of stomatognathic treatment on tinnitus: a retrospective study	Switzerland	Treatment is not specified Retrospective study
Erlandsson, Rubistein and Carlsson, 1990	Tinnitus: evaluation of biofeedback and stomatognathic treatment	Sweden	Compares therapies at different times
Parker and Chole, 1995	Tinnitus, vertigo and temporomandibular disorders	USA	Treatment not specified

including tinnitus, using a visual analogue scale (VAS).

In stage 2, involving treatment with an occlusal splint made from thermopolymerizable acrylic resin (n=42), 34 subjects reported the presence of tinnitus characterized by a brief high-pitched sound similar to a whistle. After 50 days of use, participants once again completed a VAS-type questionnaire and the results showed improvement in 26 subjects, whereas 16 reported more severe tinnitus. It was concluded that, despite the positive outcome of tinnitus remission, participants whose treatment was not successful reported more severe tinnitus. This was attributed the improvement in painful TMD symptoms, which switched subjects' focus from pain to tinnitus.

Webster et al.¹⁰ studied the effect of TMD treatment on perceived tinnitus. Forty-two patients were examined by the same specialists and 15 (average age 37.7 years) who met the inclusion criteria were diagnosed with TMD and tinnitus, of whom 86.7% were

women. They were treated by continuous use of a Michigan splint for 5 months and tinnitus severity was assessed by VAS before and after treatment. There was a significant reduction in tinnitus severity ($p < 0.001$) in 11 patients and 4 (26.66%) reported their tinnitus had disappeared, which was explained by their younger age, with minimum exposure to noise and few audiometric changes.

Uemoto et al.¹⁷ assessed the impact of treatment with a thermoplastic acrylic resin splint on the frequency of ear disorders, including tinnitus, in patients with TMD. Of the 19 who completed 2 to 6-month-long treatment, there was a decline in the prevalence of tinnitus from 14 to 6 individuals (68.5%) and a slight improvement in its intensity in the others, indicating that the myorelaxant splint is a conservative and reversible therapy capable of improving TMD-related ear symptoms.

Strom et al.¹⁸ assessed the effect of treatment with an intraoral splint for six months on tinnitus in 45 pa-

Figure 1. Flowchart of search and selection of articles.

tients (24 men and 21 women) with an average age of 48 years and long-term tinnitus (6.5 years), recorded on a VAS. Twenty patients exhibited a reduction in TMD symptoms and improved tinnitus and were released from treatment. The remainder 25 began the second stage of the study and were submitted to 5 to 6 thirty-minute acupuncture sessions with 3 manual stimulations, combined with the splint. The 45 participants were reassessed one year after treatment and subjective tinnitus had declined from 78 to 52 according to the VAS. This reduction was observed in both the splint group and splint plus acupuncture group, demonstrating that many patients with tinnitus and muscle pain can benefit from treatment with an intra-oral splint and acupuncture.

In another study, Attanasio et al.¹⁹ found a correlation

between tinnitus and TMDs in 86 subjects of both sexes, aged between 18 and 60 years. The final sample in the study was composed of 55 individuals. Those with tinnitus were evaluated for TMDs and classified into three groups: group 1 - No TMDs, group 2 - Predisposed to TMDs and group 3 - With TMDs. All participants completed a VAS and Tinnitus Handicap Inventory (THI) before and after treatment under the supervision of the same researcher. They were treated with a neuromuscular occlusal splint for six months and then asked again about the severity of their symptoms using the same VAS and questionnaire (THI). Group 1 (n=10) displayed a significant decrease in scores on the THI (25.33%) and VAS (22.92%). Declines in group 2 (n=30) and 3 (n=15) were 38.58% and 65.38% on the THI and 25.54%

Table III. Characteristics of the studies included. Intervention: occlusal splint.

Author/Year	Title	Place	N	Methodology	Treatment	Results	Conclusion
Felício et al., 1999	Ear symptoms in temporomandibular disorders before and after occlusal treatment	Brazil	58 subjects with TMD: 28 without and 36 with tinnitus	Questionnaire Ear, nose and throat examinations	Occlusal splint for 2 months	Of the 36 participants with tinnitus, 27 improved	Significant improvement in tinnitus
Felício et al., 2006	A preliminary protocol for multi-professional centers for the determination of signs and symptoms of temporomandibular disorders	Brazil	42 subjects with TMD: 8 without and 34 with tinnitus	Visual analogue scale for TMD symptoms and severe tinnitus	Occlusal splint (worn for a total of 50 days: continuous use for 15 days and only at night for the remainder)	Of the 42 participants with TMD, 16 reported tinnitus even after using the splint and 26 did not	Increase in perceived tinnitus even after improvement in TMD symptoms.
Webster et al., 2011	Evaluating the effect of the temporomandibular disorder treatment over tinnitus	Brazil	15 subjects with TMD and tinnitus	Visual analogue scale for TMD symptoms and severe tinnitus Bilateral otoscopy, anterior rhinoscopy and oral examination	Michigan splint for 5 months, continuous use	Of the 15 participants, tinnitus disappeared in 4 and a significant reduction was observed in the remainder (11)	There was a significant decline in perceived tinnitus in those submitted to TMD treatment

To be continued

Continue from Table III

2012	therapy for otological changes in patients with temporomandibular joint disorders		with TMD: 14 with tinnitus	Pain scale: 0 – No pain or discomfort 1 – Discomfort 2 – Presence of pain 3 – Presence of intense pain	a minimum of two and a maximum of six months	participants, 8 exhibited no tinnitus and 6 reported a reduction in its severity	prevalence of signs and symptoms of tinnitus
Strom et al., 2013	Management of tinnitus and jaw-muscle tenderness using an intra oral appliance and acupuncture	Switzerland	45 subjects with TMD and tinnitus	RDC/TMD Visual analogue scale to assess the presence and severity of tinnitus Audiological examination	Rigid acrylic resin Michigan-type splint for six months	Of the 45 participants, 20 reported their tinnitus had disappeared	Almost 50% of the subjects responded successfully to splint treatment in the form of tinnitus remission
Attanasio et al., 2015	Tinnitus in patients with temporomandibular joint disorder: proposal for a new treatment protocol	Italy	55 subjects with tinnitus: of which 15 exhibited TMD	Anamnesis, audiometric testing and ear, nose and throat examinations Visual analogue scale (VAS) Tinnitus Handicap Inventory (THI)	Occlusal splint for 6 months, worn at night for at least 8 hours and for a maximum of 15 hours a day	There was a statistically significant decline of 65.38% on the THI and 47.97% according to the VAS	Treatment for tinnitus was most effective in patients with TMD

Table IV. Characteristics of the studies included. Intervention: Occlusal splint and associated therapies.

Author/Year	Title	Place	N	Methodology	Treatment	Results	Conclusion
Wright and Bifano, 1997	Tinnitus improvement through TMD therapy	USA	93 individuals with TMD and tinnitus	RDC/TMD Tinnitus-related questionnaire Study period: 2 years	Splint 6 hours of behavioral therapy Stretching exercises Prescribed medication Individual psychological consultations	52 participants (56%) reported their tinnitus had cleared; 28 (30%) that it had significantly improved; and 13 (14%) related little or no improvement	Individuals with coexisting TMD and tinnitus were more likely to exhibit tinnitus remission or improvement following TMD treatment
Tullberg and Ernberg, 2006	Long-term effect on tinnitus by treatment of temporomandibular disorders: a two-year follow-up by questionnaire	Sweden	73 subjects with TMD and tinnitus	Questionnaire, clinical examination Before and two years after treatment	Individual treatment plan: jaw relaxation: occlusal splint; minimal occlusal adjustment; isotonic and isometric exercises; 1 to 6 sessions of laser therapy	73% of subjects reported an improvement in tinnitus and 27% showed no change	Signs and symptoms of TMD were common in subjects suffering from tinnitus and TMD treatment exhibited a long-term beneficial effect on tinnitus, particularly in those with the mild form

To be continued

Continue from Table IV

Wright, 2007	Otologic symptom improvement through TMD therapy	USA	132 subjects with TMD and tinnitus	RDC/TMD Clinical and ear examinations	Splint therapy and cognitive behavioral therapy with physiotherapy, stretching, psychological treatment and prescribed medication	72 (55%) participants reported tinnitus remission and 37 (28%) a significant improvement	83% showed improved or resolved tinnitus
Buergers et al., 2014	Is there a link between tinnitus and temporomandibular disorders?	Germany	25 individuals with TMD and tinnitus	Functional analysis of TMJ RDC/TMD THI	Michigan splint + physiotherapy (massage of the jaw muscles, heat treatment, stretching TMJs and coordinated exercises) for 3-5 months	There was complete tinnitus remission in 2 subjects; perceived improvement in 9; and no change in 14	The results showed a significant correlation between tinnitus and TMD, suggesting that functional dental treatment can have a positive effect on tinnitus associated with TMD

and 47.97% on the VAS, respectively. In group 3, two of the 15 patients were completely cured. There was a general improvement in quality of life, which was more pronounced in group 3, and in almost all cases the perceived severity of tinnitus decreased. Only two patients in group 2 showed no change in tinnitus, but their answers to the questionnaires demonstrated better acceptance of the condition. Tinnitus did not worsen in any of the participants and the treatment was most effective in patients with TMD (group 3). The Authors concluded that when the most common causes of tinnitus are excluded, such as ear disorders and neurological diseases, the functionality of the TMJ should be assessed in order to treat its pathology and improve or resolve tinnitus.

Group 2. Subjects with TMD/tinnitus treated with a myorelaxant splint (Michigan splint) and associated therapies

Wright and Bifano²⁰ studied 93 patients aged between 18 and 67 years (mean age 31 years) suffering from TMD and tinnitus. The subjects were examined by the same specialists, according to research diagnostic criteria for temporomandibular disorders (RDC/TMD) and a questionnaire for tinnitus. The conservative treatment selected was the use of a splint, instructions for self-care (avoid chewing gum and hard foods), six hours of behavioral therapy with psychologists, stretching exercises and postural training by a physiotherapist, prescribed medication such as nonsteroidal anti-inflammatories and tricyclic antidepressants, and individual sessions with a psychologist. Of the 93 patients: 52 (56%) reported their tinnitus had cleared; 28 (30%) that it had significantly improved; and 13 (14%) related little or no improvement. The Authors attributed these results to the fact that the patients were young, with short-term and typically unilateral tinnitus that began at approximately the same time as the symptoms of TMD, worsened along with these symptoms and seemed to be stress-related, in addition to the fact that they had normal hearing with no hearing loss. As such, patients with coexisting TMD and tinnitus were more likely to exhibit tinnitus remission or improvement following TMD treatment.

Tullberg and Ernberg²¹ analyzed the presence of signs and symptoms of TMDs in patients with tinnitus and the long-term effect of TMD treatment on tinnitus. An individual treatment plan was proposed, consisting of information on the association between tinnitus and TMDs and the importance of self-care (relaxing the jaw, preventing contact between the teeth when not chewing and avoiding gum), an occlusal splint manufactured for patients with localized myalgia or TMJ pain and subjective morning stiffness in the masticatory muscles (68% of patients), minimal occlusal adjustment was carried out on teeth with premature contact when closing the mouth (81% of subjects), instruction on isotonic and isometric exercises (84%), and aluminum gallium arsenide laser therapy for those exhibiting tension on manual palpation (88%

of participants). The number of sessions varied from 1 to 6, with an average of 3.7. Of the 120 patients who began treatment, only 73 completed it, 73% of whom reported their tinnitus had improved and 27% that it remained unchanged. Two to three years after treatment, the 73 patients completed the same reassessment questionnaire by email and 43% confirmed the improvement in tinnitus; 39% reported no change and 17% that it had worsened. In the control group, 12% stated their tinnitus had improved compared to the previous two years, 32% that it had not changed and 56% that it was worse. It was concluded that the treatment for TMD alleviated tinnitus in the long-term and that the most beneficial effects were observed in patients with intermittent tinnitus. Moreover, those with tinnitus should consult a dentist when medical causes have been ruled out and dentists could also contribute by asking their patients about intermittent tinnitus and conducting a more detailed examination of the masticatory system.

Wright²² conducted an investigation to identify a clinically valid method to determine which ear symptoms are more likely to improve when TMD symptoms are resolved. The RDC/TMD questionnaire, clinical and ear examinations were applied and 132 participants confirmed the presence of tinnitus associated with TMD symptoms. They were treated conservatively with a splint and cognitive behavioral therapy consisting of physiotherapy, stretching, psychological treatment and prescribed medication. As a result, 55% (72) showed complete remission, 28% (37) a significant improvement and only 17% (23) no change or minimal improvement. The Authors also obtained results in terms of differential diagnosis for subjects with muscular TMDs, that is, pain in the masticatory muscles (resolved or significantly improved in 85% of participants), and for those with a TMD where the source of pain was in the TMJ itself (tinnitus remission or improvement in 79% of cases). It was concluded that a number of patients with a preexisting TMD and tinnitus perceived an improvement or complete remission of ear symptoms after conservative therapy for TMDs, which were more prevalent among 20 to 40 years old, while tinnitus predominated among older individuals.

Buergers et al.²³ conducted a clinical prospective study to assess the possible association between tinnitus and TMDs and investigate the effect of stomatognathic treatment on tinnitus-related anxiety. Twenty-five patients underwent functional analysis of the TMJ using RDC/TMD and answered the tinnitus questionnaire (THI). The chosen treatment was a Michigan or distraction splint, individual physiotherapy (massage of the jaw muscles, heat treatment, stretching TMJs and coordinated exercises) for 3-5 months. The results showed complete tinnitus remission in 2 patients, a perceived improvement in 9 and no change in 14. Of the 25 patients, 16 received physiotherapy, 8 of whom exhibited an improvement. The findings demonstrated a significant correlation between tinnitus and TMDs and the treatment out-

comes suggest that dental therapy may have a positive effect on TMD-related tinnitus.

Discussion

The quality of the articles included was analyzed according to the adapted Newcastle-Ottawa scale¹⁴. In the final assessment, 7 studies obtained percentages greater than or equal to 50% (7/10), with a maximum score of 70% (7/10); however, sample sizes in the studies were not calculated with a view to achieving the desired confidence interval and only 3 studies^{10,18,22} used a validated measurement tool for assessment. Convenience sampling was found to be very common in the scientific articles and is a worrisome fact. Moreover, it is important for studies to use validated instruments for data collection, such as RDC/TMD, THI, VAS and appropriate statistical tests, with a need for methodological adjustments to enable future comparisons, thereby raising the quality of systematic literature reviews, including those with meta-analyses.

The studies were limited to patients who sought out specific services, characterizing the sample as unrepresentative of the average target population since variables such as ethnicity, sex and geographic location were not taken into account. Results in 8 studies^{10,15,17-20,22,23} were self-reported and in the remaining two^{16,21} were assessed by comparing patient records. Finally, almost all the studies used appropriate statistical tests, with the exception of three^{13,15,21} that did not clearly describe the statistical test applied.

In all the articles included, clinical dental examinations were performed by dental surgeons experienced in temporomandibular disorders (TMDs) and ear exams were carried out by ear, nose and throat specialists. Although the questionnaire by the American Academy of Orofacial Pain questionnaire on research diagnostic criteria for temporomandibular disorders (RDC/TMD) validated for Portuguese is the most recommended tool to standardize research methodologies in this area, only those by Strom et al.¹⁸, Wright and Bifano²⁰, Wright²² and Buergers et al.²³ applied it. With respect to perceived tinnitus in these patients, only Attanasio et al.¹⁹ and Buergers et al.²³ applied the Tinnitus Handicap Inventory (THI), while Felício et al.¹⁶, Webster et al.¹⁰, Strom et al.¹⁸ and Attanasio et al.¹⁹ used the VAS to record TMD and tinnitus symptoms, highlighting the lack of standardized methods in the studies analyzed.

In relation to sex, women predominated in studies by Felício et al.¹⁵, Wright²², Webster et al.¹⁰, and Uemoto et al.¹⁷, whereas of the 45 subjects assessed by Strom et al.¹⁸, only 21 were women. The remaining papers^{16,19,20,23} did not specify participants' sex. In regard to age, the average for participants was 30¹⁸, 31²⁰, 37.7¹⁰, 40 to 48^{17,18,21} and 54.1 years²³. Studies by Felício et al.¹⁵, Felício et al.¹⁶, Uemoto et al.¹⁷, Webster et al.¹⁰, Attanasio et al.¹⁹, Strom et al.¹⁸ and

Wright²² followed similar inclusion and exclusion criteria.

With respect to the most prevalent symptoms of TMDs, the papers by Felício et al.¹⁵, Wright²², Webster et al.¹⁰, and Wright and Bifano²⁰ only specified auditory symptoms and not those related to facial muscles; Felício et al.¹⁶ highlighted muscle and joint pain as well as joint noises; Uemoto et al.¹⁷ diagnosed individuals with TMDs as those who exhibited at least 3 of the following symptoms: TMJ pain, headache, muscle pain, restricted jaw movements, abnormal static and dynamic occlusion, pain during chewing, open locked jaw, chewing difficulties, tooth wear, and limited mouth opening. Among parafunctional habits, bruxism (teeth grinding) was the most common (78.9%, 15 patients), similar to Tullberg and Ernberg²¹, who reported the presence of facial or jaw pain, headaches, jaw fatigue and jaw noises. Attanasio et al.¹⁹ used Wilkes staging classification and Strom et al.¹⁸ did not specify TMD symptoms, except for muscle sensitivity.

Time since tinnitus onset, unilateral or bilateral tinnitus and their characteristics may interfere in the result of the therapy applied. Unfortunately, the studies by Felício et al.¹⁵ and Felício et al.¹⁶ did not provide this information; Attanasio et al.¹⁹ reported a minimum time since chronic tinnitus onset of 12 months as the inclusion criterion; Wright²² an average of 42 months since tinnitus onset, that is, chronic tinnitus; Webster et al.¹⁰ mean tinnitus duration of 24 months, which was unilateral in 60% of cases; Uemoto et al.¹⁷ that unilateral tinnitus was most prevalent, on the right side; Strom et al.¹⁸ reported long-term tinnitus (6.5 years); Wright and Bifano²⁰ observed tinnitus duration of 4 months to 49 years, and Tullberg and Ernberg²¹ recorded average tinnitus duration of 7.5 years, with 63% of subjects exhibiting bilateral tinnitus and 36% associating tinnitus onset with periods of increased stress or stressful events such as exposure to loud noises.

All the studies used a myorelaxant splint on the upper arch. The material used may interfere in the proprioceptors of the stomatognathic system, possibly causing bruxism, which could trigger an increase in perceived tinnitus when the splint is made from flexible material. Since Michigan, occlusal and myorelaxant splints are rigid, the Authors used one of the aforementioned synonyms when describing them^{10, 15, 17, 18, 20, 21, 23} and only Felício et al.¹⁶ and Uemoto et al.¹⁷ mentioned the use of colorless thermopolymerizable resin.

The time during which the splint was used varied. In the study by Felício et al.¹⁵, participants wore the splint for only two months, whereas those in the investigation conducted by Felício et al.¹⁶ wore it for 50 days, continuously for the first 15 days and only at night for the remainder of the time. Uemoto et al.¹⁷ recommended the splint be worn for a minimum of two and maximum of six months, namely 24h/day in the first 3 weeks, followed by 16 h for another three weeks, then 12 h for three weeks, and finally 8 h at

night until treatment completion. In the article by Webster et al.¹⁰, a splint was worn continuously for 5 months, Strom et al.¹⁸ and Attanasio et al.¹⁹ prescribed a period of six months, while Wright²² and Wright and Bifano²⁰ did not specify a time for splint therapy.

As for the differential diagnosis of muscular and joint TMD with resolution of tinnitus, only the study by /TMD in its methodology.

Among the inclusion criteria of the studies was the absence of hearing loss, and of the articles assessed, only Webster et al.¹⁰ included 5 patients with mild sensorineural hearing loss, which was also the only study that described visual analogue scores for tinnitus before and after treatment for TMDs.

A meta-analysis was not possible in this systematic literature review due to the subjectivity of the signs and symptoms of TMDs, including tinnitus, making accurate diagnosis difficult, in addition to the lack of standardized methodologies in the studies that assessed tinnitus remission, partial improvement or worsening, since some applied VAS, RDC/TMD or THI, but none applied all three at the same time nor did they quantitatively explain the validated questionnaire scores.

Thus, considering only the effect of the results of conservative TMD treatment on tinnitus in the two groups, the chi-squared test was applied as the only possible method, despite not being the most appropriate. Thus, a comparison of group 1, which obtained a mean of 65% total recovery or significant improvement, with group 2 (mean of 76%, Table V) generated a p-value of 0.015. This statistical result highlights the fact that, despite the promising result of conservative TMD treatment, a myorelaxant splint associated with other therapies is more efficient in tinnitus remission than treatment with a splint alone, reinforcing the effect of muscle contractures on the common structures of the auditory and stomatognathic systems.

Conclusion

Correlation between tinnitus and TMD poses a complex open problem; as tinnitus is more prevalent among those suffering from TMD compared to the general population, and conservative treatment of the symptoms of muscle has significant impact on tinnitus improvement.

Our objective is to assess the results of conservative treatment in individuals with temporomandibular disorders in terms of improving tinnitus. As such, TMD treatment showed promising results in the remission or improvement of even chronic tinnitus, particularly in individuals with hearing loss who exhibit TMDs associated with muscle pain.

The obtained statistical results highlight the fact that a myorelaxant splint associated with other therapies is more efficient in tinnitus remission than treatment with a splint alone, reinforcing the effect of muscle

Table V. Percentage improvement in tinnitus in both groups.

Group 1. Individuals with TMD/ tinnitus treated with a myorelaxant splint (Michigan splint)						Group 2. Subjects with TMD/ tinnitus treated with a myorelaxant splint (Michigan splint) and associated therapies					
Author/Year	N (%) with TMD/ Tinnitus	Results N (%) Significant Improvement	Results N (%) Absence	Results N(%) Permanence		Author/Year	N (%) with TMD/ Tinnitus	Results N (%) Significant improvement	Results N (%) Absence	Results N (%) Permanence	
Felício et al., 1999	36 (100%)	27 (75%)	-	9 (25%)		Wright and Bifano, 1997	93 (100%)	28 (30%)	52 (56%)	13 (14%)	
Felício et al., 2006	34 (100%)		18 (52,94%)	16 (47,05%)		Tullberg and Ernberg, 2006	73 (100%)	32 (43%)	12 (17%)	29 (39%)	
Webster et al., 2011	15 (100%)	11(73,34%)	4 (26,67%)			Wright, 2007	132 (100%)	37 (28%)	72 (55%)	23 (17%)	
Uemoto et al., 2012	14 (100%)	6 (42,86%)	8 (57,14%)			Buergers et al., 2014	25 (100%)	9 (36%)	2 (8%)	14 (56%)	
Strom et al., 2013	45 (100%)		20 (44,44%)	25 (55,56%)							
Attanasio et al., 2015	15 (100%)	10 (65,38%)		5 (34,62%)							
Total	159 (100%)	54 (33,96%)	50 (31,44%)	55 (34,60%)		Total	323 (100%)	106 (32,82%)	138 (42,72%)	79 (24,45%)	

contractures on the common structures of the auditory and stomatognathic systems.

Conflict of interest

The Authors have no financial or personal relationship with other people of organizations that could inappropriately influence this work.

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