applied sciences

MDPI

Review

Correlation between Temporomandibular Disorders and Tinnitus and Possible Treatment Strategies: Comprehensive Review

Angelo Michele Inchingolo [1,†], Alessio Danilo Inchingolo [1,†], Vito Settanni [1], Nicole De Leonardis [1], Merigrazia Campanelli [1], Grazia Garofoli [1], Stefania Benagiano [1], Giuseppina Malcangi [1], Elio Minetti [2], Andrea Palermo [3], Francesco Inchingolo [1,*], Gianna Dipalma [1,*,‡] and Assunta Patano [1,‡]

[1] Department of Interdisciplinary Medicine, University of Bari "Aldo Moro", 70124 Bari, Italy; angeloinchingolo@gmail.com (A.M.I.); ad.inchingolo@libero.it (A.D.I.); v.settanni@libero.it (V.S.); nicoledeleonardis@outlook.it (N.D.L.); merigrazia.92@hotmail.it (M.C.); graziagarofoli.g@libero.it (G.G.); stefania.studiobenagiano@gmail.com (S.B.); giuseppinamalcangi@libero.it (G.M.); assuntapatano@gmail.com (A.P.)

[2] Department of Biomedical, Surgical, Dental Science, University of Milan, 20161 Milan, Italy; elio.minetti@gmail.com

[3] College of Medicine and Dentistry, Birmingham B4 6BN, UK; andrea.palermo2004@libero.it

* Correspondence: francesco.inchingolo@uniba.it (F.I.); giannadipalma@tiscali.it (G.D.); Tel.: +39-3312111104 (F.I.); +39-3396989939 (G.D.)

† These authors contributed equally to this work as first authors.

‡ These authors contributed equally to this work as last author.

Abstract: This study intends to investigate the relationship between otologic symptoms, in particular, tinnitus, and temporomandibular disorders (TMD). The literature studies during the previous 20 years had focused on the treatment and alleviation of the otologic symptoms and were limited to randomized clinical trials, case reports, and prospective studies. The following Boolean keywords, (tinnitus) AND (temporomandibular disorders OR temporomandibular therapy), were used in the databases of PubMed, Scopus, and Web of Science between 2003 and 9 May 2023 with an English language restriction. Results: The computerized search turned up 693 articles in total, and after eliminating duplicates, reviewing them, and determining their eligibility, 20 papers were included. Conclusion: The connections between temporomandibular TMD and tinnitus are numerous and intricate. It is unclear whether TMD could be the source of tinnitus or only its symptoms. Tinnitus may not always occur in persons with TMD, indicating that additional causes may potentially be involved in its occurrence. The precise mechanisms behind the link between TMD and tinnitus need to be clarified by additional study.

Keywords: tinnitus; craniomandibular disorders; craniomandibular disorders treatments; temporomandibular disorders; temporomandibular joint

Citation: Inchingolo, A.M.; Inchingolo, A.D.; Settanni, V.; De Leonardis, N.; Campanelli, M.; Garofoli, G.; Benagiano, S.; Malcangi, G.; Minetti, E.; Palermo, A.; et al. Correlation between Temporomandibular Disorders and Tinnitus and Possible Treatment Strategies: Comprehensive Review. *Appl. Sci.* **2023**, *13*, 8997. https://doi.org/10.3390/app13158997

Academic Editor: Rocco Franco

Received: 19 July 2023
Revised: 31 July 2023
Accepted: 4 August 2023
Published: 5 August 2023

1. Introduction

The joint connecting the temporal bone and the mandible is known as the temporomandibular joint (TMJ), and it consists of two components separated by an articular disc [1]. The TMJ plays a fundamental role in facilitating various jaw movements, including propulsion, lateral motion, and opening and closing of the mouth [1]. Temporomandibular disorders (TMD) represent a group of musculoskeletal conditions that affect the masticatory muscles, the temporomandibular joint, and related structures [1]. These disorders manifest through symptoms such as pain in the temporomandibular joint area or nearby, audible joint noises during mandibular movements, alterations in mandibular kinematics (such as deviations in opening, closing, laterality, and protrusion), and other related

issues [1]. Tinnitus, a condition characterized by the perception of sound without an external source, and TMD are two complex medical issues that can interact in significant ways. Tinnitus, also known as "ringing in the ears," represents a subjective symptom, while temporomandibular disorders involve the complex musculoskeletal system of the jaw and surrounding structures [2].

In a study on the relationship between TMD otological symptoms, the data indicate that the prevalence of otologic symptoms (tinnitus, labyrinthitis, dizziness, loss of balance, and deafness) is 87% [3,4]. Tinnitus is the most common symptom and it is associated with 25–65% of TMD cases according to the scientific literature ~~[5–11]~~. Tinnitus can sometimes be associated with somatic issues, even in the absence of hearing loss. This condition is known as "somatic tinnitus" (ST) or somatosensory tinnitus [7,12,13]. Among the common causes of ST are TMJ and head and neck diseases [7,12,14–18]. In cases of ST, the patient experiences altered somatosensory input from the temporomandibular joint or cervical spine [19]. Some studies have explored the connections between the cochlear nuclei (CN) and the somatosensory system in the cervical or temporomandibular region, providing a physiological basis for ST [20–22]. Afferent fibers from the dorsal root ganglia or trigeminal ganglion convey cervical somatosensory or temporomandibular information to the brain and central auditory system. ST may be suspected when at least one of the following is present in the patient's medical history: (a) history of head or neck trauma; (b) tinnitus associated with dental, jaw, or cervical spine manipulation; (c) recurrent pain episodes in the head, neck, or shoulder girdle; (d) temporal coincidence of the appearance or increase of both pain and tinnitus; (e) tinnitus worsening during inadequate postures while resting, walking, working, or sleeping; and (f) intense bruxism episodes during the day or night [23].

Simons et al. additionally suggested that tight myofascial trigger point bands in the deep masseter and lateral pterygoid muscles might be linked to middle ear injury [24].

Other authors claimed that the existence of this somatic modulation, as demonstrated by voluntary movements or particular resistance tests, is a key factor in the diagnosis of ST, if not the key factor [15,25]. The best way to identify ST is unclear because there are no established guidelines for clinical evaluation [19].

TMDs can cause various symptoms related to the ears and auditory system due to the anatomical proximity of the TMJ to these structures [26,27]. Sensations of closed ears and referred pain can be attributed to the malfunctioning of the Eustachian tube and tensor muscles [28,29]. Additionally, both the tensor muscles of the tympanic and palatine veil are innervated by the trigeminal; therefore, deep pain affecting the structures of this nerve can cause otological symptoms due to the brain stimulation [30–36].

It is unclear and still up for debate if craniomandibular problems and auditory symptoms relate to one another [37–39]. Some research indicates a decrease in otologic symptoms after receiving TMD treatments [8,37,40–46], while other studies do not support this association [47].

The aim of this study is to conduct a scoping review of the literature about the correlation between tinnitus and temporomandibular problems.

2. Materials and Methods

2.1. Protocol and Registration

This scoping review was conducted according to the standards of Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) [48].

2.2. Search Processing

A search on PubMed, Scopus, and Web of Science was performed (Table 1) to find papers that matched the topic of the relationship between tinnitus and TMD, dating from 1 January 2003 to 9 May 2023. The search strategy used the Boolean keywords: (tinnitus

OR acuphen* OR acufen*) AND ("temporo mandibular disorder" OR "temporomandibular joint").

Table 1. Database search indicators.

Articles screening strategy	KEYWORDS: A: tinnitus; B: acuphen*; C: acufen*; D: temporo mandibular disorder; E: temporomandibular joint
	Boolean Indicators: (A OR B OR C) AND (D OR E)
	Timespan: from 1 January 2003 to 9 May 2023
	Electronic databases: PubMed; Scopus; WOS

2.3. Inclusion Criteria

The following inclusion criteria were considered: (1) studies that investigated the relationship between tinnitus and temporomandibular disorder, (2) randomized clinical trials, retrospective and observational studies, (3) English language, (4) full text available.

Papers that did not match the above criteria were excluded.

The review was conducted using the PCC criteria:

- Population: adults, male and female, with tinnitus and TMD,
- Concept: correlation between tinnitus and TMD,
- Context: public health care.

2.4. Exclusion Criteria

The exclusion criteria were as follows: (1) animal studies; (2) in vitro studies; (3) off-topic; (4) reviews, letters, or comments to editors; (5) no English language.

2.5. Data Processing

Five reviewers (N.D.L., G.G., V.S., M.C., and S.B.) independently consulted the databases to collect the studies and rated their quality based on selection criteria. The selected articles were downloaded into Zotero (version 6.0.15). Any divergence between the reviewers was settled by a discussion with a senior reviewer (F.I.).

3. Results

3.1. Study Selection and Characteristics

The electronic database search identified a total of 693 articles (Scopus N = 355, PubMed N = 191, Web of Science N = 147), and no articles were included through the hand search.

After the deletion of duplicates, 376 studies were screened by evaluating the title and abstract, focusing on the association between tinnitus and TMD.

There were 323 articles that did not meet the inclusion criteria (316 off topic, 33 review, four not in English) and two reports not retrieved, leading to 21 records being selected. After an eligibility check, one record was eliminated and 20 records were selected for qualitative analysis. The selection process and the summary of selected records were shown in Figure 1 and Table 2, respectively.

Among the included studies, eight papers examined the correlation between tinnitus and TMD, suggesting a causal role of TMDs in the onset and maintenance of tinnitus [1,14,15,49–53].

One study investigated the relationship between tinnitus and subtypes of TMD in patients with TMD. Patients with TMD might have a higher incidence of tinnitus when they present with PTF (type 1) [54].

Another study, on the other hand, indicated a higher incidence of tinnitus among patients with TMD, potentially related to a reduction in glenoid fossa depth [55].

Four studies have evaluated the treatment effect of temporomandibular joint disorders when tinnitus is found, showing improvement after therapy [3,56–58].

Several authors have highlighted the psychological implications of TMDs and tinnitus, evaluating the incidence of stress on the onset of these pathologies and the impact on treatment. In addition, the incidence of depression in these patients has been discussed [50–53,59–62].

Two studies explored gender differences in the onset of TMD [52,61]. Female patients with TMD had a higher incidence of risk than male patients with TMD [52].

One paper described two cases of TMJ herniation that had tinnitus as an initial symptom and were treated differently [63].

Finally, a paper in 2020 described a rare case of tinnitus induced by chewing [64].

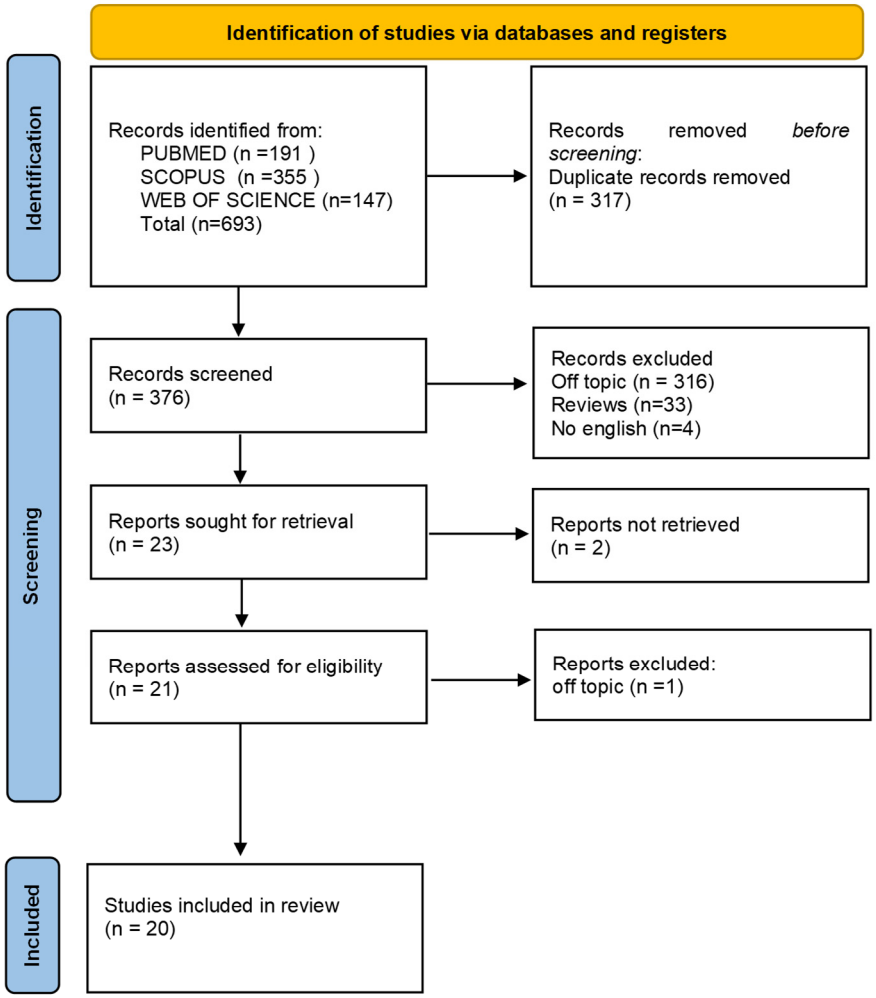

Figure 1. Literature search Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram and database search indicators.

Table 2. Descriptive summary of item selection.

Authors	Type of Study	Study Design	Conclusion
Sobhy et al., 2004 [56]	A case-control study	Fifteen patients with dysfunctional myofascial pain syndrome and ear symptoms make up group (A). Fifteen patients in group (B) with disc dislocation, click, otalgia, or tinnitus. Occlusal splints, muscle relaxants, and anti-inflammatory	Before starting treatment, all of the patients in group (A) experienced otalgia. Ten patients were pain-free following therapy, five of whom saw a significant reduction in pain from severe to mild. Eight patients in group (B) no longer had pain,

		medications were used to alleviate jerks when opening or closing the mouth as well as otalgia or tinnitus.	and seven saw a reduction in pain from severe to mild.
Webster et al., 2011 [57]	A prospective cohort study	The patients' age, gender, and tinnitus characteristics—the location of the symptom and the duration of time—were examined and an audiometric assessment was performed. Tinnitus intensity was assessed by a digital analogue scale before and after TMD treatment.	There was a significant decrease in tinnitus recognition by patients undergoing treatment for temporomandibular dysfunction.
Vielsmeier et al., 2011 [49]	A case-control study	In this study, the investigators compared 61 tinnitus patients without subjective complaints to a group of 30 patients with TMJ and tinnitus. With relation to demographic and clinical parameters, 61 patients with tinnitus but no subjective complaints were studied for mandibular joint dysfunction.	Patients with tinnitus who also had TMD had better hearing and tended to be female. In the sample that was looked at, 28% of the patients had TMD, while 72% did not.
Hilgenberg et al., 2012 [51]	An observational study	By assigning a score ranging from 0 to 100, the Mann–Whitney test was performed to examine the correlation between the severity of otological symptoms, the level of depression, and tinnitus.	In the tinnitus group, 40% of patients had severe depression, 30% had moderate depression, and 58% had typical levels of the illness. High tinnitus severity levels were substantially correlated with pain intensity.
Vielsmeier et al., 2012 [14]	A retrospective study	The demographic, tinnitus, and audiological traits of 1204 tinnitus patients from the Tinnitus Research Initiative (TRI) Database with and without subjective TMJ symptoms were collected and compared using questionnaires and numerical ratings.	In tinnitus patients with TMD, traditional risk factors for tinnitus such as older age and male gender are less important. Tinnitus with TMD represents a subgroup of tinnitus that is most frequently masked by somatic maneuvers and music or sound stimulation
Akhter et al., 2013 [50]	A randomized clinic trial	Students with TMD symptoms were divided into seven groups: clicking only, TMJ pain only, difficulty opening the mouth only, clicking and pain, clicking and difficulty opening the mouth, difficulty opening the mouth and pain, and combination of three symptoms. The participants in the control group did not have any TMD symptoms.	TMD symptoms were shown to be substantially linked to auditory symptoms and headache.
Fernandes et al., 2013 [60]	A cross-sectional, clinically based study	The Temporomandibular Disorders Research Diagnostic Criteria TMD was classified using Axis I, while self-reported tinnitus and	Painful temporomandibular problems, severe depression, and self-reported tinnitus are all strongly linked.

		depression levels were scored using Axis II.	
Ward et al., 2015 [15]	A prospective cohort study	A questionnaire with a series of questions was used to gather information about somatic tinnitus, and a score from 0 to 100 was assigned based on how severe it was.	In the questionnaire, 108 out of the 671 individuals claimed they could control their tinnitus using somatic exercises. Therefore, 16.1% of the population had tinnitus.
Lee et al., 2016 [52]	A retrospective population-based cohort study	Patients with TMJ disorder suffered from hearing loss, and degenerative and vascular ear disorders were compared with the control patients.	Higher age, hearing loss, and male gender have all been identified as risk factors for tinnitus. Female TMD patients had a greater risk incidence than male TMD patients.
Çakur et al., 2016 [54]	A comparative study	CBCT pictures were examined based on PTF subtype diagnosis.	PTF (type 1) might be associated with an increased incidence of tinnitus in patients with TMD.
Kusdra et al., 2018 [1]	A retrospective study	A number of 485 medical records and data (gender, age, and otologic symptoms) were collected and analyzed.	A high prevalence of otological symptoms (in particular tinnitus) was found in TMD patients.
Lim, et al., 2019 [63]	A clinical case	The authors describe two cases of TMJ herniation through IF that presented with tinnitus and received different treatments.	In the case of surgery, the bone can be obliterated using tragal cartilage or the patient can be observed closely on an outpatient basis.
Edvall et al., 2019 [62]	An observational study	The online survey consisted of a combination of standardized questionnaires.	Stress and the patients' psychophysical state is an important risk factor in the increase of TMD—tinnitus.
Choi et al., 2020 [64]	A clinical case	Case of a 75-year-old patient who complained of chewing-induced popping tinnitus on the left side and echoendoscope examination revealed that the left tympanic membrane was protruding outwards due to due to the clenching of the teeth.	Mastitication-induced tinnitus is one of the probable signs of spontaneous ejection of TMJ tissue into the middle ear through a prolonged tympanic hole. Clenching the patient's teeth causes outward bulging of the TMJ, which is accompanied with clicking tinnitus.
Van der Wal et al., 2022 [3]	A randomized clinical trial	A total of 80 patients with TMD were enrolled from a tinnitus clinic. Patients were randomly assigned to either the physical therapy with occlusal splints group or the control group.	A treatment of TMD pain that allows for a reduction in tinnitus severity in patients with somatic tinnitus attributed to the TMJ.
Lavinsky et al., 2020 [53]	A comparative study	A number of 53 adult patients with bilateral or unilateral TMD participated in the study, 30 of whom had tinnitus and 23 of whom did not.	The most frequent finding in both groups (24 individuals with tinnitus versus 15 without) was displacement of the articular disc.
Van der Wal et al., 2020 [61]	A retrospective study	Treatments used: HD-tDCS over 3 weeks' time in six sessions, psychological therapies were	Males improved in the TRT +CBT group.

		provided with a TRT +CBT combination and a maximum of 18 sessions of orofacial therapy in 9 weeks.	Females improved in the HD-tDCS (p = 0.0009) and orofacial therapy group.
Plaza-Manzano et al., 2021 [58]	Randomized clinic trial	A secondary analysis of a clinical study was performed in 61 subjects with TMD-related tinnitus to determine the efficacy of incorporating cervico-mandibular manual treatment into exercise coupled with an education program.	In people with TMD-related tinnitus who received physical treatment, baseline tinnitus severity, and localized pressure pain threshold (PPT) over the temporalis muscle were predictive of clinical results.
Koparal et al., 2022 [55]	An observational study	TC was used to assess 82 patients with temporomandibular disorders (TMD) (40 patients without tinnitus and 42 patients with tinnitus).	The study revealed that decreased glenoid fossa depth may be associated with a higher incidence of tinnitus in TMD patients.
Kong et al., 2022 [59]	A cross-sectional study	Participants were divided into four groups: those with no TMD and no tinnitus, those with TMD but no tinnitus, those with TMD but no tinnitus, and those with both TMD and tinnitus.	TMD and tinnitus both have a significant influence on HRQoL in the Korean population.

4. Discussion

Some studies have investigated the correlation between TMD and tinnitus by evaluating whether treatment of TMD could benefit otological symptoms.

4.1. Association between TMD and Tinnitus

Vielsmeier et al. (2011) investigated the association between TMD and tinnitus by comparing patients with tinnitus and proven TMJ dysfunction to people with tinnitus but no subjective symptoms of TMJ dysfunction [49]. The results showed that tinnitus patients with TMJ disorder had better hearing function, were younger, experienced tinnitus at a younger age, and were more frequently female. Additionally, their perceived tinnitus loudness was lower, and more of them could modulate their tinnitus by moving their jaw or neck. This suggests that TMJ dysfunction might play a causal role in the generation and persistence of tinnitus. Therefore, the treatment of TMJ disorder could be a promising strategy for addressing tinnitus from a causal perspective [49].

In another piece of research conducted by the same authors, individuals with tinnitus and TMD were more likely to be female (with TMD: 54%; without: 33%), significantly younger, and with an earlier onset of tinnitus than those without TMD [49]. In addition, patients with tinnitus and TMD were more often able to mask tinnitus with sounds or music (with TMJ disorder: 85%; without: 74%) and could more often modulate tinnitus with somatic maneuvers (with TMJ disorder: 48%; without: 30%) [14].

Kusdra et al. (2018) investigated the prevalence of ear-related symptoms in patients with temporomandibular disorders (TMD) [1]. The researchers examined medical records of 485 patients at a specialized center and found that 87% of TMD cases reported otological symptoms, including tinnitus and ear fullness. The study provided evidence supporting the connection between TMD and otological symptoms, despite the symptoms not being directly caused by the ear [1]. A different study by Ward et al. investigated somatic tinnitus, which involves modulating tinnitus through somatic maneuvers, and showed a higher proportion of individuals with pulsatile tinnitus (not related to the heartbeat), under the age of 40, experiencing variations in tinnitus loudness, and having temporomandibular joint (TMJ) disorder [15].

Based on the data obtained from the studies examined, the prevalence of tinnitus among TMD patients is estimated to be 37.4% [15,49,53,55].

4.2. Factors Influencing TMD and Tinnitus Association

Some authors identified specific factors influencing the TMD and tinnitus association. Çakur et al. (2016) suggested that a certain type of TMD (PTF type 1) might be associated with an increased incidence of tinnitus. The authors employed a tac cone beam (CBCT) to assess the relationship between PTF subtype and tinnitus in TMD patients [54]. The study of Kijak et al. aimed to investigate the relationship between the displacement of the condyle in the temporomandibular joint (TMJ), the structure and position of the petrotympanic fissure (PTF), and comorbid tinnitus in patients with temporomandibular joint and muscle disorder (TMD) [65]. The researchers enrolled 331 TMD patients (268 women and 63 men), with an average age of approximately 40 years for women and 38 years for men. They used imaging studies of the facial part of the skull to analyze the TMJ and PTF configurations; around 10% of the TMD patients reported having tinnitus [65].

Lavinsky et al. (2020), using magnetic resonance imaging, found that patients with TMJ dysfunction and tinnitus presented a displacement of the joint disc with greater reduction than those with TMD but without tinnitus [53]. Furthermore, in the study of Jin Woo Choi et al. in 2020, the authors described a rare condition of chewing-induced tinnitus that occurs because of a defect in the normal ossification of the tympanic portion of the temporal bone that creates a communication pathway between the external auditory canal and the infratemporal fossa [64]. Instead, Koparal et al. aimed to use computed tomography (CT) to evaluate glenoid fossa depth and the horizontal angle of the ramus mandible in patients with TMD with tinnitus and without tinnitus to determine the association between TMD and tinnitus [55]. It was found that the glenoid fossa depth was decreased in patients with TMD and tinnitus compared to those with TMD only. This suggests a possible link between TMD and tinnitus due to the close anatomical relationship between the temporomandibular joint and the ear. Further research is needed to explore this association in more detail [55]. Another factor considered is the tympanic foramen or foramen of Huschke (FH), which is closed during the first five years of life [66]. The persistence of this defect can cause spontaneous herniation of the retrodiscal tissue of the TMJ in the middle ear with consequent mandibular clicking and tinnitus enlargement of the tympanic foramen, which can increase with age, resulting in tinnitus and hearing loss, as assessed by Lim et al. [63]. Assessment by high-resolution TBCT of the external auditory canal may be useful for diagnosis. Treatment in these cases requires surgery to correct the defect, which can be obliterated using tragus cartilage [67].

4.3. Study on Socio-Economic Factors and Psychological Variables

The study by Edvall et al. explored socio-economic factors, phenotypic characteristics, and psychological variables in tinnitus patients with or without TMJ complaints [62]. TMJ issues were more common in severe tinnitus cases, indicating a strong link. Subjects with TMJ complaints, mainly females, often attributed stress as the cause of their tinnitus. They experienced more severe tinnitus symptoms, poorer psychological well-being, and lower quality of life. This author uses TSCHQ (tinnitus sample case history questionnaire) [62]. They also reported difficulty tolerating sounds, headaches, vertigo, dizziness, and neck pain. These individuals often had pulsating or tonal tinnitus and somatic modulation, which worsened with loud sounds and stress. Stress was suggested to contribute to the co-occurrence and development of severe tinnitus, emphasizing dental care and stress management in comprehensive treatment [62]. In 2013, Fernandes et al., in their study, already demonstrated a strong link between tinnitus self-report, chronic severe TMD, and severe depression. The RDC/TMD questionnaire (research diagnostic criteria for temporomandibular disorders) was the test used [60]. These authors agree with Kong et al. (2022), who investigated the relationships between TMD, tinnitus, and quality of life in adults (nineteen years or older) using a nationally representative sample [59]. Participants were

assigned to four groups: those with no TMD and no tinnitus, those with TMD but no tinnitus, those with TMD but no tinnitus, and those with TMD and tinnitus. The TMD and tinnitus group referred to the major number of concerns in the normal activity, pain/discomfort, and anxiety/depression aspects [59]. Clinicians should comprehend the idea that tinnitus is a complicated, multidimensional developmental process encompassing numerous physical, psychosocial, and environmental components to avoid using overly simplified techniques when diagnosing and treating tinnitus patients [59,60]. Another study by Akhter et al. (2013) aimed to explore the connections between aural symptoms, headache, and depression with temporomandibular disorder (TMD) symptoms through a survey involving university students [50]. Finally, they reported that clicking-only TMD symptoms were linked to otalgia and depression and suggested the importance of considering a functional assessment of the stomatognathic system in individuals experiencing unexplained aural symptoms and headache [50]. Hilgenberg et al. (2012) investigated the prevalence of temporomandibular disorders (TMD) and otologic symptoms in individuals with and without tinnitus while also examining the impact of depression levels comparing a tinnitus group with a control group [51]. The study revealed that 85% of tinnitus patients showed signs of TMD, compared to 55% in the control group, and found a positive association between tinnitus severity, higher depression levels, and TMD [51].

4.4. Tinnitus Treatment

In 2020, Van der Wal et al. discovered significant gender differences in the treatment results of numerous tinnitus care approaches [61]. Women in this study population have demonstrated a better response to treatment after receiving successive HDtDCS (high-definition transcranial direct current stimulation) sessions. HD-tDCS is a unique non-invasive brain stimulation technology based on the idea that mild intensity electric currents applied to locations of the scalp generate underlying cerebral activity [61]. These findings are consistent with those of Frank et al. (2012), who found greater benefits from frontal tDCS in women [68]. Chun-Feng Lee et al. (2016) conducted retrospective cohort research in 2016 on patients aged 20 years and older who had recently been diagnosed with TMJ dysfunction [52]. The authors suggested that TMD may increase the risk of tinnitus, but they found age, sex, and comorbidities of hearing loss, noise impacts on the inner ear, and degenerative and vascular ear illnesses as demographic characteristics and comorbidities that may be related to tinnitus [52]. The incidence of tinnitus was greater in the TMJ disease cohort than in the control patient, and female TMD patients have a higher risk incidence than male TMD patients [52]. Sobhy et al. (2004) conducted a case-control study aiming to assess the aural manifestations in patients with TMD and the effect of TMD treatment on tinnitus. Thirty patients were divided into two groups: Group (A) with myofascial pain dysfunction syndrome, and Group (B) with disc displacement with reduction. In conclusion, this study highlights the importance of evaluating aural manifestations in TMD patients. The results suggest that conservative treatment of TMD can effectively alleviate ear symptoms and improve the overall condition in these patients. In fact, the incidence of ear symptoms (otalgia and tinnitus) significantly decreased after therapy in both groups [56]. The same results were obtained by Webster et al. (2011), who found a significant decrease in tinnitus symptoms after treating temporomandibular dysfunction [57]. The researchers conducted a prospective cohort study involving individuals with TMD and tinnitus, and after dental treatment for TMD, there was a significant decrease in the intensity of tinnitus. Notably, tinnitus completely disappeared in four (26.6%) patients [57]. Van der Wal et al. (2020) conducted a randomized clinical trial, demonstrating that treating TMD pain reduced tinnitus severity in patients with somatic tinnitus attributed to the temporomandibular joint. The same results were obtained by Webster et al. (2011), who found a significant decrease in tinnitus recognition after treating temporomandibular dysfunction. The researchers conducted a prospective cohort study involving individuals with TMD and tinnitus, and after dental treatment for TMD, there was a significant decrease in the intensity of tinnitus. Notably, tinnitus completely disappeared in

four (26.6%) patients [57]. In 2020, Plaza-Manzano et al. evaluated the impact of physical, clinical, psychological, and psychophysical factors on treatment results following the use of cervico-mandibular manual therapy, education, and exercise in patients with TMD and tinnitus [58]. The study highlighted the importance of baseline tinnitus severity and localized PPT over the temporalis muscle as significant factors in predicting treatment outcomes for individuals with TMD-related tinnitus undergoing physical therapy. Other predictors, such as sex and quality of life, also played a role but were less influential in the treatment outcomes [58].

5. Conclusions

In conclusion, there are numerous and complex relationships between TMD and tinnitus. Even while some writers have questioned whether an issue with the TMJ is the actual cause of tinnitus or just one of its symptoms, research shows that there is a strong correlation between the two illnesses. This study reveals that not all patients with TMD will develop tinnitus, indicating that other factors may also contribute. Tinnitus is known to be associated with advanced age, male gender, and hearing loss.

Numerous alternative processes have been used to explain the connection between tinnitus and TMD. Tinnitus can be caused by the trigeminal nerve, which innervates the TMJ, modulating the activity of the central auditory pathway. Tinnitus development may also be influenced by structural anomalies, such as a shallower glenoid fossa or flaws in the ossification of the temporal bone. Additionally, there is evidence that stress and bruxism may share a same ethology with tinnitus and TMD.

Physical therapy, manual therapy, exercise, education, and surgical intervention are some of the different treatment modalities for TMJ-related tinnitus. Studies have demonstrated that a multidisciplinary strategy that incorporates several medicines can enhance clinical results. With some encouraging results, repetitive transcranial magnetic stimulation (rTMS) has also been researched as a potential treatment option for tinnitus.

According to data in the literature, occlusal splints do not contribute to the improvement of tinnitus symptoms.

Tinnitus has an impact on patients' quality of life, so a multidisciplinary treatment approach is necessary. A thorough approach to diagnosis and treatment is essential because both illnesses have been linked to significant levels of depression. Tinnitus is a complex condition and treating it effectively and enhancing patients' wellbeing requires an understanding of how it interacts with TMD.

To create more specialized and individualized treatment modalities, additional study is required to clarify the precise mechanisms behind the association between TMD and tinnitus. Large-scale, national-level investigations that take the influence on quality of life into consideration are especially necessary. To effectively serve patients with TMD and tinnitus and ultimately improve their quality of life, healthcare providers must increase our understanding of this complex link.

Author Contributions: Conceptualization, A.M.I., G.M., and V.S.; methodology, E.M., N.D.L.; software, M.C. and A.P. (Andrea Palermo); validation, G.G., S.B., and A.D.I.; formal analysis, E.M.; investigation, N.D.L., V.S., G.G., and G.D.; resources, F.I.; data curation, A.M.I., and A.P. (Assunta Patano); writing—original draft preparation, A.M.I., A.D.I., and A.P. (Assunta Patano); writing—review and editing, G.M.; visualization, G.G., S.B., V.S.; supervision, N.D.L.; project administration, M.C., F.I., G.D., and A.P. (Assunta Patano); funding acquisition, A.P. (Andrea Palermo), F.I., G.D., A.M.I. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

CN	Cochlear nucleus
FH	Foramen of Huschke
MRI	Magnetic Resonance Imaging
TBCT	Tetrahedron Beam Computed Tomography
TC	Computed Tomography
TMD	Temporomandibular Disorders
TMJ	Temporomandibular Joint
PTF	Petrotympanic Fissure
HD tDCS	High-Definition Transcranial Direct Current Stimulation

References

1. Kusdra, P.M.; Stechman-Neto, J.; de Leão, B.L.C.; Martins, P.F.A.; de Lacerda, A.B.M.; Zeigelboim, B.S. Relationship between Otological Symptoms and TMD. *Int. Tinnitus J.* **2018**, *22*, 30–34. https://doi.org/10.5935/0946-5448.20180005.
2. Baguley, D.; McFerran, D.; Hall, D. Tinnitus. *Lancet* **2013**, *382*, 1600–1607. https://doi.org/10.1016/S0140-6736(13)60142-7.
3. van der Wal, A.; Michiels, S.; Van de Heyning, P.; Gilles, A.; Jacquemin, L.; Van Rompaey, V.; Braem, M.; Visscher, C.M.; Topsakal, V.; Truijen, S.; et al. Reduction of Somatic Tinnitus Severity Is Mediated by Improvement of Temporomandibular Disorders. *Otol. Neurotol.* **2022**, *43*, e309–e315. https://doi.org/10.1097/MAO.0000000000003446.
4. Kuttila, S.; Kuttila, M.; Bell, Y.L.; Alanen, P.; Jouko, S. Aural Symptoms and Signs of Temporomandibular Disorder in Association with Treatment Need and Visits to a Physician. *Laryngoscope* **1999**, *109*, 1669.
5. Silveira, A.M.; Feltrin, P.P.; Zanetti, R.V.; Mautoni, M.C. Prevalence of Patients Harboring Temporomandibular Disorders in an Otorhinolaryngology Departament. *Braz. J. Otorhinolaryngol.* **2007**, *73*, 528–532. https://doi.org/10.1016/S1808-8694(15)30105-1.
6. Mummolo, S.; Nota, A.; Marchetti, E.; Padricelli, G.; Marzo, G. The 3D Tele Motion Tracking for the Orthodontic Facial Analysis. *Biomed. Res. Int.* **2016**, *2016*, 4932136. https://doi.org/10.1155/2016/4932136.
7. Wu, C.; Stefanescu, R.A.; Martel, D.T.; Shore, S.E. Tinnitus: Maladaptive Auditory-Somatosensory Plasticity. *Hear Res.* **2016**, *334*, 20–29. https://doi.org/10.1016/j.heares.2015.06.005.
8. Williamson, E.H. Interrelationship of Internal Derangements of the Temporomandibular Joint, Headache, Vertigo, and Tinnitus: A Survey of 25 Patients. *Cranio* **1990**, *8*, 301–306. https://doi.org/10.1080/08869634.1990.11678328.
9. Parker, W.S.; Chole, R.A. Tinnitus, Vertigo, and Temporomandibular Disorders. *Am. J. Orthod. Dentofacial. Orthop.* **1995**, *107*, 153–158. https://doi.org/10.1016/s0889-5406(95)70130-3.
10. Vernon, J.; Griest, S.; Press, L. Attributes of Tinnitus That May Predict Temporomandibular Joint Dysfunction. *Cranio* **1992**, *10*, 282–287; discussion 287–288. https://doi.org/10.1080/08869634.1992.11677924.
11. Pasini, M.; Giuca, M.R.; Ligori, S.; Mummolo, S.; Fiasca, F.; Marzo, G.; Quinzi, V. Association between Anatomical Variations and Maxillary Canine Impaction: A Retrospective Study in Orthodontics. *Appl. Sci.* **2020**, *10*, 5638. https://doi.org/10.3390/app10165638.
12. Ralli, M.; Greco, A.; Turchetta, R.; Altissimi, G.; de Vincentiis, M.; Cianfrone, G. Somatosensory Tinnitus: Current Evidence and Future Perspectives. *J. Int. Med. Res.* **2017**, *45*, 933–947. https://doi.org/10.1177/0300060517707673.
13. Shore, S.; Zhou, J.; Koehler, S. Neural Mechanisms Underlying Somatic Tinnitus. *Prog. Brain Res.* **2007**, *166*, 107–123. https://doi.org/10.1016/S0079-6123(07)66010-5.
14. Vielsmeier, V.; Strutz, J.; Kleinjung, T.; Schecklmann, M.; Kreuzer, P.M.; Landgrebe, M.; Langguth, B. Temporomandibular Joint Disorder Complaints in Tinnitus: Further Hints for a Putative Tinnitus Subtype. *PLoS ONE* **2012**, *7*, e38887. https://doi.org/10.1371/journal.pone.0038887.
15. Ward, J.; Vella, C.; Hoare, D.J.; Hall, D.A. Subtyping Somatic Tinnitus: A Cross-Sectional UK Cohort Study of Demographic, Clinical and Audiological Characteristics. *PLoS ONE* **2015**, *10*, e0126254. https://doi.org/10.1371/journal.pone.0126254.
16. Bhatt, J.; Ghavami, Y.; Lin, H.W.; Djalilian, H. Cervical Spine Dysfunctions in Patients with Chronic Subjective Tinnitus. *Otol. Neurotol.* **2015**, *36*, 1459–1460. https://doi.org/10.1097/MAO.0000000000000827.
17. Ralli, M.; Altissimi, G.; Turchetta, R.; Mazzei, F.; Salviati, M.; Cianfrone, F.; Orlando, M.P.; Testugini, V.; Cianfrone, G. Somatosensory Tinnitus: Correlation between Cranio-Cervico-Mandibular Disorder History and Somatic Modulation. *Audiol. Neurootol.* **2016**, *21*, 372–382. https://doi.org/10.1159/000452472.
18. Levine, R.A.; Abel, M.; Cheng, H. CNS Somatosensory-Auditory Interactions Elicit or Modulate Tinnitus. *Exp. Brain Res.* **2003**, *153*, 643–648. https://doi.org/10.1007/s00221-003-1747-3.
19. Michiels, S.; Ganz Sanchez, T.; Oron, Y.; Gilles, A.; Haider, H.F.; Erlandsson, S.; Bechter, K.; Vielsmeier, V.; Biesinger, E.; Nam, E.-C.; et al. Diagnostic Criteria for Somatosensory Tinnitus: A Delphi Process and Face-to-Face Meeting to Establish Consensus. *Trends Hear.* **2018**, *22*, 2331216518796403. https://doi.org/10.1177/2331216518796403.
20. Lanting, C.P.; de Kleine, E.; Eppinga, R.N.; van Dijk, P. Neural Correlates of Human Somatosensory Integration in Tinnitus. *Hear. Res.* **2010**, *267*, 78–88. https://doi.org/10.1016/j.heares.2010.04.006.

21. Shore, S.E. Plasticity of Somatosensory Inputs to the Cochlear Nucleus--Implications for Tinnitus. *Hear. Res.* **2011**, *281*, 38–46. https://doi.org/10.1016/j.heares.2011.05.001.
22. Zhan, X.; Pongstaporn, T.; Ryugo, D.K. Projections of the Second Cervical Dorsal Root Ganglion to the Cochlear Nucleus in Rats. *J. Comp. Neurol.* **2006**, *496*, 335–348. https://doi.org/10.1002/cne.20917.
23. Sanchez, T.G.; Rocha, C.B. Diagnosis and Management of Somatosensory Tinnitus: Review Article. *Clinics* **2011**, *66*, 1089–1094. https://doi.org/10.1590/S1807-59322011000600028.
24. Simons, D.G.; Travell, J.G.; Simons, L.S.; Travell, J.G. *Travell & Simons' Myofascial Pain and Dysfunction: The Trigger Point Manual*, 2nd ed.; Williams & Wilkins: Baltimore, MD, USA, 1999; ISBN 978-0-683-08363-7.
25. Biesinger, E.; Groth, A.; Höing, R.; Hölzl, M. Somatosensoric tinnitus. *HNO* **2015**, *63*, 266–271. https://doi.org/10.1007/s00106-014-2971-9.
26. Ciancaglini, R.; Loreti, P.; Radaelli, G. Ear, Nose, and Throat Symptoms in Patients with TMD: The Association of Symptoms According to Severity of Arthropathy. *J. Orofac. Pain* **1994**, *8*, 293–297.
27. Michelotti, A. Bell's Orofacial Pains: The Clinical Management of Orofacial Pain, 6th Edition (2005): Author: Jeffrey, P. Okeson Publisher: Quintessence Publishing Co. Ltd, New Malden, Surrey, UK Price: £47.00 ISBN: 0-86715-439-X. *Eur. J. Orthod.* **2005**, *27*, 532. https://doi.org/10.1093/ejo/cji087.
28. Gargiulo Isacco, C.; Ballini, A.; Paduanelli, G.; Nguyen, K.C.D.; Schiffman, M.; Aityan, S.K.; Tapparo, O.; Khoa, N.; Dipalma, G.; Inchingolo, F.; et al. A Systematic Review on Persistent Trigeminal Artery, in Searching for a Therapeutic Solution to Idiopathic and Unresponsive Trigeminal Nerve Inflammations and Migraines. *J. Biol. Regul. Homeost. Agents* **2019**, *33*, 155–169.
29. Quinzi, V.; Scibetta, E.T.; Marchetti, E.; Mummolo, S.; Giannì, A.B.; Romano, M.; Beltramini, G.; Marzo, G. Analyze My Face. *J. Biol. Regul. Homeost. Agents* **2018**, *32*, 149–158.
30. Malkin, D.P. The Role of TMJ Dysfunction in the Etiology of Middle Ear Disease. *Int. J. Orthod.* **1987**, *25*, 20–21.
31. Sicher, H.; Du Brul, E.L. *Anatomia Oral de Sicher e DuBrul*, 8 ed.; Artes Medicas: São Paulo, Brazil, 1991.
32. Brookes, G.B.; Maw, A.R.; Coleman, M.J. 'Costen's Syndrome'—Correlation or Coincidence: A Review of 45 Patients with Temporomandibular Joint Dysfunction, Otalgia and Other Aural Symptoms. *Clin. Otolaryngol. Allied Sci.* **1980**, *5*, 23–36. https://doi.org/10.1111/j.1365-2273.1980.tb01624.x.
33. Cox, K.W. Temporomandibular Disorder and New Aural Symptoms. *Arch. Otolaryngol. Head Neck Surg.* **2008**, *134*, 389–393. https://doi.org/10.1001/archotol.134.4.389.
34. Ramírez, L.M.; Ballesteros, L.; Sandoval, G. Tensor Tympani Muscle: Strange Chewing Muscle. *Med. Oral Patol. Oral Cir. Bucal* **2007**, *12*, 96–100.
35. Penkner, K.; Köle, W.; Kainz, J.; Schied, G.; Lorenzoni, M. The Function of Tensor Veli Palatini Muscles in Patients with Aural Symptoms and Temporomandibular Disorder. An EMG Study. *J. Oral Rehabil.* **2000**, *27*, 344–348. https://doi.org/10.1046/j.1365-2842.2000.00530.x.
36. Franz, B.; Anderson, C. The Potential Role of Joint Injury and Eustachian Tube Dysfunction in the Genesis of Secondary Ménière's Disease. *Int. Tinnitus J.* **2007**, *13*, 132–137.
37. Ren, Y.F.; Isberg, A. Tinnitus in Patients with Temporomandibular Joint Internal Derangement. *Cranio* **1995**, *13*, 75–80. https://doi.org/10.1080/08869634.1995.11678048.
38. Pekkan, G.; Aksoy, S.; HekImoglu, C.; Oghan, F. Comparative Audiometric Evaluation of Temporomandibular Disorder Patients with Otological Symptoms. *J. Cranio-Maxillofac. Surg.* **2010**, *38*, 231–234. https://doi.org/10.1016/j.jcms.2009.07.001.
39. Inchingolo, F.; Tatullo, M.; Marrelli, M.; Inchingolo, A.M.; Tarullo, A.; Inchingolo, A.D.; Dipalma, G.; Podo Brunetti, S.; Tarullo, A.; Cagiano, R. Combined Occlusal and Pharmacological Therapy in the Treatment of Temporo-Mandibular Disorders. *Eur. Rev. Med. Pharmacol. Sci.* **2011**, *15*, 1296–1300.
40. Bush, F.M. Tinnitus and Otalgia in Temporomandibular Disorders. *J. Prosthet. Dent.* **1987**, *58*, 495–498. https://doi.org/10.1016/0022-3913(87)90282-4.
41. Marasa, F.K.; Ham, B.D. Case Reports Involving the Treatment of Children with Chronic Otitis Media with Effusion via Craniomandibular Methods. *Cranio* **1988**, *6*, 256–270. https://doi.org/10.1080/08869634.1988.11678247.
42. Wright, E.F.; Bifano, S.L. Tinnitus Improvement through TMD Therapy. *J. Am. Dent. Assoc.* **1997**, *128*, 1424–1432. https://doi.org/10.14219/jada.archive.1997.0062.
43. Wright, E.F.; Syms, C.A.; Bifano, S.L. Tinnitus, Dizziness, and Nonotologic Otalgia Improvement through Temporomandibular Disorder Therapy. *Mil. Med.* **2000**, *165*, 733–736.
44. Gelb, H.; Gelb, M.L.; Wagner, M.L. The Relationship of Tinnitus to Craniocervical Mandibular Disorders. *Cranio* **1997**, *15*, 136–143. https://doi.org/10.1080/08869634.1997.11746004.
45. Steigerwald, D.P.; Verne, S.V.; Young, D. A Retrospective Evaluation of the Impact of Temporomandibular Joint Arthroscopy on the Symptoms of Headache, Neck Pain, Shoulder Pain, Dizziness, and Tinnitus. *Cranio* **1996**, *14*, 46–54. https://doi.org/10.1080/08869634.1996.11745949.
46. Björne, A. Assessment of Temporomandibular and Cervical Spine Disorders in Tinnitus Patients. *Prog. Brain Res.* **2007**, *166*, 215–219. https://doi.org/10.1016/S0079-6123(07)66019-1.

47. Loughner, B.A.; Larkin, L.H.; Mahan, P.E. Discomalleolar and Anterior Malleolar Ligaments: Possible Causes of Middle Ear Damage during Temporomandibular Joint Surgery. *Oral Surg. Oral Med. Oral Pathol.* **1989**, *68*, 14–22. https://doi.org/10.1016/0030-4220(89)90108-4.
48. Tricco, A.C.; Lillie, E.; Zarin, W.; O'Brien, K.K.; Colquhoun, H.; Levac, D.; Moher, D.; Peters, M.D.J.; Horsley, T.; Weeks, L.; et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann. Intern. Med.* **2018**, *169*, 467–473. https://doi.org/10.7326/M18-0850.
49. Vielsmeier, V.; Kleinjung, T.; Strutz, J.; Bürgers, R.; Kreuzer, P.M.; Langguth, B. Tinnitus with Temporomandibular Joint Disorders: A Specific Entity of Tinnitus Patients? *Otolaryngol. Head Neck Surg.* **2011**, *145*, 748–752. https://doi.org/10.1177/0194599811413376.
50. Akhter, R.; Morita, M.; Ekuni, D.; Hassan, N.M.M.; Furuta, M.; Yamanaka, R.; Matsuka, Y.; Wilson, D. Self-Reported Aural Symptoms, Headache and Temporomandibular Disorders in Japanese Young Adults. *BMC Musculoskelet Disord.* **2013**, *14*, 58. https://doi.org/10.1186/1471-2474-14-58.
51. Hilgenberg, P.B.; Saldanha, A.D.D.; Cunha, C.O.; Rubo, J.H.; Conti, P.C.R. Temporomandibular Disorders, Otologic Symptoms and Depression Levels in Tinnitus Patients. *J. Oral Rehabil.* **2012**, *39*, 239–244. https://doi.org/10.1111/j.1365-2842.2011.02266.x.
52. Lee, C.-F.; Lin, M.-C.; Lin, H.-T.; Lin, C.-L.; Wang, T.-C.; Kao, C.-H. Increased Risk of Tinnitus in Patients with Temporomandibular Disorder: A Retrospective Population-Based Cohort Study. *Eur. Arch. Otorhinolaryngol.* **2016**, *273*, 203–208. https://doi.org/10.1007/s00405-015-3491-2.
53. Lavinsky, D.; Lavinsky, J.; Setogutti, E.T.; Rehm, D.D.S.; Lavinsky, L. The Role of Magnetic Resonance Imaging of the Temporomandibular Joint to Investigate Tinnitus in Adults with Temporomandibular Joint Disorder: A Comparative Study. *Int. Arch. Otorhinolaryngol.* **2020**, *24*, e68–e72. https://doi.org/10.1055/s-0039-1688840.
54. Çakur, B.; Yaşa, Y. Correlation Between Tinnitus and Petrotympanic Fissure Status Among Patients with Temporomandibular Joint Dysfunction. *J. Oral Maxillofac. Surg.* **2016**, *74*, 47–52. https://doi.org/10.1016/j.joms.2015.07.020.
55. Koparal, M.; Sirik, M.; Yavuz, G.Y.; Ege, B. Evaluation of the Relationship between Temporomandibular Joint Disorders and Tinnitus with Computed Tomography. *J. Stomatol. Oral Maxillofac. Surg.* **2022**, *123*, e199–e205. https://doi.org/10.1016/j.jormas.2022.06.015.
56. Sobhy, O.A.; Koutb, A.R.; Abdel-Baki, F.A.; Ali, T.M.; El Raffa, I.Z.; Khater, A.H. Evaluation of Aural Manifestations in Tempоro-Mandibular Joint Dysfunction. *Clin. Otolaryngol. Allied Sci.* **2004**, *29*, 382–385. https://doi.org/10.1111/j.1365-2273.2004.00842.x.
57. Evaluating the Effect of the Temporomandibular Disorder Treatment over Tinnitus. Available online: https://arquivosdeorl.org.br/additional/acervo_eng.asp?id=786 (accessed on 30 May 2023).
58. Plaza-Manzano, G.; Delgado-de-la-Serna, P.; Díaz-Arribas, M.J.; Rodrigues-de-Souza, D.P.; Fernández-de-Las-Peñas, C.; Alburquerque-Sendín, F. Influence of Clinical, Physical, Psychological, and Psychophysical Variables on Treatment Outcomes in Somatic Tinnitus Associated with Temporomandibular Pain: Evidence from a Randomized Clinical Trial. *Pain Pract.* **2021**, *21*, 8–17. https://doi.org/10.1111/papr.12919.
59. Kong, G.-S.; Lee, S.-H.; Park, K.S.; Cho, J.-H.; Kim, K.-W.; Ha, I.-H. Association of Temporomandibular Disorders and Tinnitus with Health-Related Quality of Life: A Cross-Sectional Study Using the Fifth Korea National Health and Nutrition Examination Survey. *J. Oral Rehabil.* **2022**, *49*, 283–294. https://doi.org/10.1111/joor.13287.
60. Fernandes, G.; Gonçalves, D.A. de G.; de Siqueira, J.T.T. de; Camparis, C.M. Painful Temporomandibular Disorders, Self Reported Tinnitus, and Depression Are Highly Associated. *Arq. Neuropsiquiatr.* **2013**, *71*, 943–947. https://doi.org/10.1590/0004-282X20130191.
61. Van der Wal, A.; Luyten, T.; Cardon, E.; Jacquemin, L.; Vanderveken, O.M.; Topsakal, V.; Van de Heyning, P.; De Hertogh, W.; Van Looveren, N.; Van Rompaey, V.; et al. Sex Differences in the Response to Different Tinnitus Treatment. *Front. Neurosci.* **2020**, *14*, 422. https://doi.org/10.3389/fnins.2020.00422.
62. Edvall, N.K.; Gunan, E.; Genitsaridi, E.; Lazar, A.; Mehraei, G.; Billing, M.; Tullberg, M.; Bulla, J.; Whitton, J.; Canlon, B.; et al. Impact of Temporomandibular Joint Complaints on Tinnitus-Related Distress. *Front. Neurosci.* **2019**, *13*, 879. https://doi.org/10.3389/fnins.2019.00879.
63. Lim, K.H.; Jung, J.Y.; Rhee, J.; Choi, J. Temporomandibular Joint Herniation through the Foramen of Huschke with Clicking Tinnitus. *Eur. Ann. Otorhinolaryngol. Head Neck Dis.* **2019**, *136*, 497–499. https://doi.org/10.1016/j.anorl.2018.05.014.
64. Choi, J.W.; Nahm, H.; Shin, J.E.; Kim, C.-H. Temporomandibular Joint Herniation into the Middle Ear: A Rare Cause of Mastication-Induced Tinnitus. *Radiol. Case Rep.* **2020**, *15*, 125–127. https://doi.org/10.1016/j.radcr.2019.10.032.
65. Kijak, E.; Szczepek, A.J.; Margielewicz, J. Association between Anatomical Features of Petrotympanic Fissure and Tinnitus in Patients with Temporomandibular Joint Disorder Using CBCT Imaging: An Exploratory Study. *Pain Res. Manag.* **2020**, *2020*, e1202751. https://doi.org/10.1155/2020/1202751.
66. Mao, J.J.; Nah, H.-D. Growth and Development: Hereditary and Mechanical Modulations. *Am. J. Orthod. Dentofacial. Orthop.* **2004**, *125*, 676–689. https://doi.org/10.1016/j.ajodo.2003.08.024.

67. Heffez, L.; Anderson, D.; Mafee, M. Developmental Defects of the Tympanic Plate: Case Reports and Review of the Literature. *J. Oral Maxillofac. Surg.* **1989**, *47*, 1336–1340. https://doi.org/10.1016/0278-2391(89)90738-6.
68. Frank, E.; Schecklmann, M.; Landgrebe, M.; Burger, J.; Kreuzer, P.; Poeppl, T.B.; Kleinjung, T.; Hajak, G.; Langguth, B. Treatment of Chronic Tinnitus with Repeated Sessions of Prefrontal Transcranial Direct Current Stimulation: Outcomes from an Open-Label Pilot Study. *J. Neurol.* **2012**, *259*, 327–333. https://doi.org/10.1007/s00415-011-6189-4.