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The Role of Magnetic Resonance Imaging of the Temporomandibular Joint to Investigate Tinnitus in Adults with Temporomandibular Joint Disorder: A Comparative Study

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Abstract

Introduction The prevalence of tinnitus is higher in individuals with temporomandibular joint disorder (TMD) than in the general population. Magnetic resonance imaging (MRI) of the temporomandibular joint (TMJ) is the method of choice for investigation, and it has been hypothesized that specific MRI findings might be observed in TMD with comorbid tinnitus.

Objective To comparatively describe MRI findings in patients with TMD with and without tinnitus, identifying the most common TMJ alterations and determining whether a correlation exists between severity of TMD and tinnitus.

Methods A cross-sectional study of 53 adult patients with bilateral or unilateral TMD (30 with and 23 without tinnitus). The association between tinnitus and morphological aspects of TMD (changes in condylar morphology, articular eminence morphology, and disc morphology), disc displacement (with/without reduction), condylar translation, and intra-articular effusion was analyzed on MRI images.

Results The mean patient age was 46.12 ± 16.1 years. Disc displacement was the most common finding in both groups (24 patients with tinnitus versus 15 without; $p = 0.043$). Only the frequency of disc displacement with reduction was significantly different between groups.

Conclusion Additional imaging techniques should be explored to detect specific aspects of the relationship between tinnitus and TMD.

Keywords
- magnetic resonance imaging
- temporomandibular joint
- temporomandibular joint disorders
- tinnitus

Introduction

The temporomandibular joint (TMJ), which is among the most complex joints in the human body,[1] is routinely exposed to considerable loads, as indicated by animal, in vitro, and mathematical models.[2] With time, such exposure, alone or associated with underlying disorders, is thought to generate physiological and pathological changes,[3] which may lead to temporomandibular joint dysfunction (TMD) of varying complexity and magnitude.[4–7] The most common symptoms reported by patients with TMD include pain, deviations or restrictions in the range of motion, presence of clicking,

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crackling, or popping sounds,[8] and otologic symptoms such as tinnitus,[9] defined as a phantom sound in the absence of an external source.[10]

The prevalence of tinnitus is higher in individuals with TMD than in the general population.[5] Neither TMD nor tinnitus are life-threatening, but both can cause great distress.[3,10,11] Although the pathogenesis of the relationship between TMD and tinnitus is poorly understood, a common etiological mechanism has been suggested.[12] Therefore, the investigation of findings peculiar to TMD patients with tinnitus may be useful to clarify the link between these two entities, and may shed light on the mechanisms involved in the onset of TMD and tinnitus.

Magnetic resonance imaging (MRI) of the TMJ is the method of choice for investigation of TMD.[13] It has been hypothesized that specific MRI findings might be observed in TMD with comorbid tinnitus.[14] Thus, the aim of the present study was to comparatively describe MRI findings in patients with TMD with and without tinnitus, identifying the most common TMJ alterations and determining whether a correlation exists between the severity of TMD and tinnitus.

Methods

The project was approved by our local institutional review board. All procedures were in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

This cross-sectional comparative study analyzed chart data and imaging findings. All investigators signed a data use agreement that ensured anonymity.

The inclusion criteria were age $>$ 17 years and diagnosis of TMD,[15,16] based on clinical symptoms including pain, clicking or crackling sounds, and mandibular opening with deviation. The exclusion criteria were objective tinnitus; tinnitus with a diagnosed etiology; Ménière disease; noise-induced hearing loss, ear surgery, or infections; and abuse of ototoxic medications or substances (furosemide, aspirin) or stimulants. Individuals with certain systemic diseases (diabetes, hypothyroidism) were also excluded.

Between 2009 and 2016, adult patients of both genders, with bilateral or unilateral TMD, were selected for the study. Patients with tinnitus and a clinical history of TMD were referred by their otologist to the investigator (a dentist specializing in TMD and orofacial pain) after other otologic comorbidities had been ruled out. Patients with TMD who did not have tinnitus were either referrals from otologists or other specialists or were walk-ins to our service. All patients in both groups underwent a clinical and dental assessment and MRI evaluation of the TMJ.

TMJ Evaluation

Temporomandibular joint evaluation was performed by the same examiner (DLB) in all patients. Mandibular range of motion was measured as described by Emshoff et al.[15] Briefly, maximum opening (measured in mm from the central maxillary incisor to the opposing mandibular incisor) and lateral excursions (relative to the maxillary midline, with the teeth slightly separated) were evaluated. The TMJ was auscultated with a stethoscope to detect unilateral or bilateral clicks during three openings and three lateral and protrusive movements.

Disc displacement with reduction was identified in the presence of a click in the TMJ during vertical mandibular motion and lateral or protrusive excursions and normal closing with or without clicking, reproducible on two of three occasions. Disc displacement without reduction was defined as a history of sudden reduction in mandibular opening, maximum unassisted mandibular opening 35 mm, and mandibular opening with assistance increased by 3 mm or less over maximum unassisted opening.

Otologic Evaluation

Patients reporting tinnitus underwent a full ear, nose and throat (ENT) investigation, including pure tone audiometry, to identify the underlying etiology (ear or systemic disorder). If a retrocochlear disorder was suspected, an evoked potential audiometry was performed. If a systemic cause was suspected, a laboratory workup was performed (metabolic, hormonal, renal function, and autoimmune panels).

MRI

Bilateral parasagittal and coronal T1- and T2-weighted MRIs of the TMJ, as well as cinematic images, were obtained using an HDXT GE 1,5 Tesla (GE Healthcare, Barueri, SP, Brazil) with open and closed mouth. Magnetic resonance imaging findings of condylar morphology, articular eminence morphology, and disc morphology, disc displacement with or without reduction, condylar excursion, and intra-articular effusion were described by an independent radiologist.

TMD Severity Score

The association between tinnitus and morphological aspects (changes in condylar morphology, articular eminence morphology, and disc morphology), disc displacement (with or without reduction), condylar translation, and intra-articular effusion was analyzed in MRIs of the TMJ. The selection of these criteria was based on the work of Ahmad et al.[17]

A TMD severity score was created for comparison between the groups with or without tinnitus. Each of the six criteria (changes in condylar morphology, articular eminence morphology, and disc morphology, disc displacement, translation, and intra-articular effusion) received a score of zero (absent), 1 (unilateral), or 2 (bilateral). The sum of the scores (minimum zero, maximum 12) indicated the severity of TMD. The mean TMD scores obtained for patients with tinnitus was then compared with the mean score obtained for patients without tinnitus.

Statistical Analysis

The sample size was calculated as 44 patients ($n = 22$/group), considering $\alpha = 5\%$ and a statistical power of 90% to detect a difference of one standard deviation (SD) in TMD severity score between groups, with one SD assumed to correspond to 2 score points.

Data were expressed as frequency of altered MRI findings. The TMD severity score was expressed as mean and SD. The Student *t*-test for independent samples was used to compare group means. The Fisher exact test was used to investigate association between categorical variables. Significance was established at $p < 0.05$.

Results

Fifty-three patients were enrolled in the present study. Of these, 30 had tinnitus (study group) and 23 did not have tinnitus (control group). The mean age was 46.12 years (standard deviation, 16.1 years). Thirty-three patients were women (63.5%). ►**Table 1** shows a comparison of age and gender between groups; there were no statistically significant differences.

As shown in ►**Table 2**, disc displacement with reduction was the most common MRI finding in both groups. A statistically significant difference was observed only for the frequency of disc displacement with reduction, which was significantly higher in patients with tinnitus.

►**Fig. 1** shows a representative MRI of disc displacement with reduction in a participant from the tinnitus group.

As shown in ►**Table 3**, no between-group difference in TMD severity score was observed.

Discussion

The present study set out to analyze the existence of specific MRI findings in patients with TMD and tinnitus that could differentiate them from patients with TMD without tinnitus. A few studies so far have analyzed characteristic imaging features of tinnitus,[14,18] but none has focused specifically on the association of TMD and tinnitus.

Upon analysis of MRI findings in patients with tinnitus and those without, we observed that disc displacement with reduction was significantly more frequent in patients with tinnitus. Historical studies, such as that by Myrhaug,[19] suggest that tinnitus originates from a temporomandibular dysfunction of muscular origin, which might cause secondary hypertonia of the tensor tympani and tensor veli palatini, thus triggering aural symptoms. The sensory-motor theory, in turn, postulates that tinnitus may be modulated by muscle contractions, such as those that occur on palpation of myofascial trigger points. On the other hand, a classic study[20] reported the existence of a ligament (the discomalleolar ligament) that attaches to the malleus, crosses the petrotympanic fissure, and then attaches to the posteromedial aspect of the articular disc and capsule. Thus, excursion of the disc and condyle during mandibular motion could impart mobility to the malleus and alter tension in the tympanic membrane,[3] which could explain the otologic symptoms, among them tinnitus, experienced by patients with disc displacement. Indeed, the landmark studies of Block,[21] Ren and Isberg,[22] and Paparo et al[23] correlated disc displacement with tinnitus, corroborating the findings of our investigation. Costen,[24] Coleman,[25] and Komori et al[26] found no relationship between disc displacement without reduction and tinnitus, but did find a correlation in disc displacement with reduction; these findings are consistent with our results. It bears stressing that comparison of prior findings to those of the present study is hindered by the fact that previous studies neither performed objective MRI investigation nor used comparative designs. It should also be noted that a causal relationship between tinnitus and TMD or MRI findings is still hypothetical and has not yet been established in the literature.

The severity scale proposed in the present study can also contribute to further research in the field (i.e., MRI-based

Table 1 Distribution of age and gender in the overall sample and in the groups with and without tinnitus

Variable	Overall	Tinnitus ($n = 30$)	No tinnitus ($n = 23$)	*p*
Age (years), mean ± SD	46.1 ± 16.1	48.9 ± 15.6	42.6 ± 16.4	0.172[a]
Women, n (%)	33 (63.5)	16 (55.2)	17 (73.9)	0.247[b]

[a]Student *t*-test.
[b]Fisher exact test.

Table 2 Frequency of magnetic resonance imaging findings in patients with temporomandibular joint disorder with and without tinnitus

Variable	Tinnitus ($n = 30$)	No tinnitus ($n = 23$)	*p*[a]
Condylar morphology			0.719
Unilateral	3 (10.0)	3 (13.0)	
Bilateral	8 (26.7)	8 (34.8)	
Articular eminence morphology			0.111
Unilateral	1 (3.3)	1 (4.3)	
Bilateral	–	3 (13.0)	
Disc morphology			0.325
Unilateral	1 (3.3)	2 (8.7)	
Bilateral	14 (46.7)	14 (60.9)	
Disc displacement with reduction			**0.043**
Unilateral	–	3 (13.0)	
Bilateral	24 (80.0)	12 (52.2)	
Intra-articular effusion			0.522
Unilateral	2 (6.7)	3 (13.0)	
Bilateral	1 (3.3)	2 (8.7)	
Condylar translation			0.095
Unilateral	9 (30.0)	14 (60.9)	
Bilateral	10 (33.3)	4 (17.4)	

All variables expressed as means and standard deviations.
Bold indicates statistical significance.
[a]Fisher exact test for comparison between total (unilateral + bilateral) values.

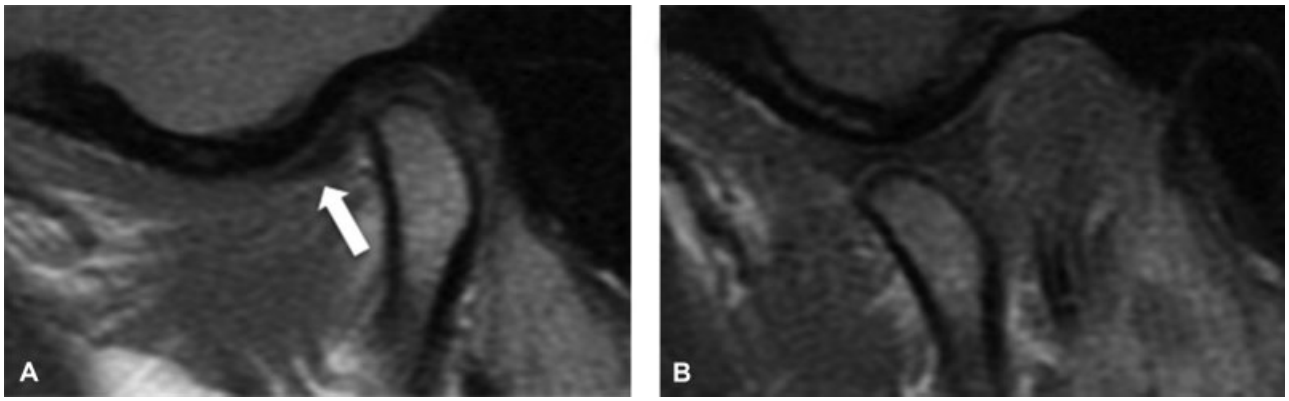

Fig. 1 Parasagittal T1-weighted magnetic resonance imaging of the temporomandibular joint (A, closed mouth; B, open mouth) showing anterior disc displacement (arrow) with reduction.

Table 3 Temporomandibular severity score (mean ± SD) in patients with and without tinnitus

TMD severity score		p^a
Tinnitus ($n = 30$)	No tinnitus ($n = 23$)	
5.27 ± 2.05	5.78 ± 2.00	0.363

Abbreviations: SD, standard deviation; TMD, temporomandibular joint disorder.
[a]Student *t*-test for independent samples.

investigation of the relationship between TMD and tinnitus). The mean scores obtained in the groups with and without tinnitus were not significantly different. However, this finding may simply reflect that MRI is unable to discriminate between individuals with tinnitus and those without, which suggests that other imaging criteria, or perhaps even another imaging modality, should be explored for study of the relationship between TMD and tinnitus. Moreover, the fact that nearly all patients with tinnitus and TMD exhibited bilateral disc displacement with reduction (80% versus 52% in patients without tinnitus) suggests that this specific abnormality warrants further exploration in future studies with larger samples.

One positive aspect of this study was the homogeneity of gender and age distribution between the groups with and without tinnitus. Another strength was the absence of referral bias, as all patients had been referred to us by otologists after excluding individuals with tinnitus of known etiology. Thus, inclusion in the present study was restricted to patients with clinical symptoms of TMD in whom other comorbidities had been ruled out.

Limitations of this study include the sample size, which, though adequate for the proposed objective, did not allow statistical comparison of subgroups. This may have prevented us from capturing the full dimension of the correlation between severity and prevalence of TMD and tinnitus. Also, a causal relationship between tinnitus and TMD was not established in the present study. However, the present results can serve as a basis for larger prospective studies to shed further light on the relationship between TMD and tinnitus. In addition, further studies are needed on the effect of disc repair on tinnitus, an aspect which was not explored in the present study.

Conclusion

The present study shows that MRI may not be sufficiently sensitive to detect specific aspects of the relationship between tinnitus and TMD. However, the identification of differences in the prevalence of disc displacement with reduction between individuals with and without tinnitus may provide an important contribution to treatment of these patients, and suggests there is further room to explore the relationship between tinnitus and TMD.

Conflict of Interest

The authors have no conflicts of interest to disclose.

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