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Literature review

The relationship of whiplash injury and temporomandibular disorders: a narrative literature review☆

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Abstract

Objective: The purpose of this article is to offer a narrative review and discuss the possible relationship between temporomandibular disorders (TMDs) and whiplash injuries.

Methods: Databases from 1966 to present were searched including PubMed; Manual, Alternative, and Natural Therapy Index System; and Cumulative Index for Nursing and Allied Health Literature. Search terms used included *whiplash injury*, *temporomandibular disorders* and *craniomandibular disorders*. Inclusion criteria consisted of studies on orofacial pain of a musculoskeletal origin addressing the following topics: posttraumatic temporomandibular disorder (pTMD) incidence and prevalence, mechanism of injury, clinical findings and characteristics, prognosis (including psychologic factors). Excluded were studies of orofacial pain from nontraumatic origin, as well as nonmusculoskeletal causes including neurologic, vascular, neoplastic, or infectious disease.

Results: Thirty-two studies describing the effects of whiplash on TMD were reviewed based on inclusion/exclusion criteria. The best evidence from prospective studies indicates a low to moderate incidence and prevalence. Only 3 studies addressed mechanism of injury theories. Most studies focusing on clinical findings and characteristics suggest significant differences when comparing pTMD to idiopathic/nontraumatic patients. Regarding prognosis, most studies suggest a significant difference when comparing pTMD to idiopathic/nontraumatic TMD patients, with pTMD having a poorer prognosis.

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Conclusions: There is conflicting evidence regarding the effects of whiplash on the development of TMD. Furthermore, because of lack of homogeneity in the study populations and lack of standardization of data collection procedures and outcomes measured, this review cannot conclusively resolve the controversies that exist concerning this relationship. This review of the literature is provided to clarify the issues and to provide useful clinical information for health care providers managing TMD such as doctors of chiropractic, physical therapists, dentists, and medical doctors.

Introduction

Substantial controversy exists regarding the incidence, prevalence, proposed mechanism of injury, clinical characteristics, and prognosis of temporomandibular disorders (TMDs) due to whiplash. A study concluded that the incidence of temporomandibular joint (TMJ) pain and clicking after whiplash injury was extremely low and that patients who did not have clicking on resolution of their initial pain dysfunction subsequently did not develop this problem.[1] Some authors have suggested that chronic posttraumatic temporomandibular disorder (pTMD) from whiplash is a cultural phenomenon unique to North America.[2] Other authors have proposed opposite conclusions, as in the study by Pullinger and Seligman[3] where it was observed that up to 79% of the patients being treated at a university-based specialty clinic for anterior dislocation of the temporomandibular meniscus considered the onset of this problem to have surfaced after a vehicular collision. The following terms and descriptions are provided to gain a greater understanding of the nature of this problem.

Whiplash description

A whiplash injury best describes a rapid whipping motion of a flexible object in 2 simultaneous directions. This motion, when occurring during a car crash, mostly involves motion of the head and neck in extension and flexion in relation to the torso but can involve lateral motions as well. It can be stated that "whiplash" is an oversimplification of the complex forces that occur. These forces occur when there is a rapid head acceleration that is sometimes 2 to 3 times greater than the vehicle and results in injury to the internal structures of the neck. Previous studies have described these as tensile, compressive, shear, and torque forces.[4-6] The 1995 Quebec Task Force adopted the following definition of whiplash. *Whiplash* is an acceleration-deceleration mechanism of energy transfer to the neck. It may result from rear-end or side-impact motor vehicle collisions, but can also occur during diving or other mishaps. The impact may result in bony or soft-tissue injuries (eg, whiplash injury), which in turn may lead to a variety of clinical manifestations (eg, whiplash-associated disorders [WAD]).[7]

TMD description

Dworkin et al[8] described TMD as a cluster of disorders characterized by pain in the preauricular area, the TMJ, and/or the muscles of mastication; limitations or deviations in mandibular range of motion; and noises in the TMJ during mandibular function. McNeill et al[9] considered TMD as a subclassification of musculoskeletal and rheumatologic disorders. Although sometimes viewed as one syndrome of the masticatory system, the current view is that TMDs are a cluster of related disorders with many common features. The most common initial symptom is pain that is aggravated by chewing or other jaw functions. Other symptoms include jaw ache, earache, headache, and facial pain. In addition to complaints of pain, patients with these disorders frequently have limited jaw movement, and joint sounds described as clicking, popping, grating, or crepitus. Pain or dysfunction caused by nonmusculoskeletal causes (such as neurologic, vascular, neoplastic, or infectious disease) in the orofacial region is not considered a primary TMD even though myofascial pain may be present. Temporomandibular disorders due to whiplash can be described as a group of signs and symptoms related to the TMJ and the muscles of mastication in patients who have received a traumatic cervical extension-flexion (extrinsic) injury, but who have not had direct physical injury to their jaw.

In epidemiologic studies[8,10] of TMD focusing on signs and symptoms, TMD-related pain was reported by 12.1% of the general population. Temporomandibular disorder pain in a sample population studied

occurred at about the same prevalence as abdominal pain and chest pain, but was less common than back pain and headache. As in other studies, an increased rate of TMD pain among females was found, at an approximately 4:1 ratio. In a survey of 897 French-speaking adults from Quebec by Goulet et al,[11] idiopathic/nontraumatic TMD (iTMD) symptoms were self-reported in 30% of the general population, with 5% reporting frequent and moderate to severe episodes (clinically significant iTMD). This information on iTMD is important to note when comparing the prevalence of pTMD.

The objective of this article is to report on the possible relationship between TMDs and whiplash injuries. This article discusses the controversies that currently exist and summarizes relevant literature regarding the incidence, prevalence, proposed mechanism(s) of injury, and clinical diagnostic and prognostic characteristics in whiplash/TMD patients. This article also provides useful clinical information for those providing care for these patients and identifies areas for future research.

Methods

Databases from 1966 to present were searched including PubMed; Manual, Alternative, and Natural Therapy Index System; and Cumulative Index for Nursing and Allied Health Literature. Search terms used included *whiplash injury*, *temporomandibular disorders*, and *craniomandibular disorders*. Inclusion criteria included studies on orofacial pain of a musculoskeletal origin addressing the following topics: pTMD incidence and prevalence, mechanism of injury, clinical findings and characteristics, and prognosis, including psychologic factors. Excluded were studies of orofacial pain from nontraumatic origin, as well as nonmusculoskeletal causes including neurologic, vascular, neoplastic, or infectious disease. Quality scoring was not used for several reasons. Because of the complexities of the topic, the studies needed to be varied in research design, for example, case-controls for causation issues and randomized controlled trials or cohorts for prognosis issues. In addition to the variety of research designs, other problems when comparing studies included differences in populations studied, outcomes used, and data collected. General comments on quality and limitations of the studies reviewed are provided where appropriate. Studies listed in the tables are categorized into those that tend to dispute or show a weak relationship and those that support a relationship of whiplash and TMD. In addition, studies are listed in chronological order beginning with the most current publications.

In addressing the topic of whiplash and TMDs, we focused on finding the best evidence regarding 4 issues, as follows: (1) What are the incidence and prevalence of pTMD compared with iTMD? (2) What are the mechanism(s) of injury, both direct and indirect? (3) How do the clinical findings or characteristics in iTMD compare to those in pTMD populations? (4) What are the differences in prognosis in iTMD and pTMD populations?

Results

There were a total of 1483 articles captured from the regions searched. Thirty of these articles were initially included for review based on the above inclusion/exclusion criteria. In addition, 2 articles recommended by peer review process were included, for a total of 32 articles reviewed.

Incidence and prevalence

Eight prospective and 8 retrospective studies were identified that attempted to assess the incidence or prevalence of pTMD. Some of these studies have provided data on clinical characteristics and prognosis; and therefore, they are also included in those sections of this article. Table 1 lists studies on incidence or prevalence, including design, methods, and results. These findings are categorized into 2 groups for comparison purposes and are listed in reverse chronological order. The first 8 studies, including 4 prospective (Visscher et al,[12] Kasch et al,[13] Bergman et al,[14] Heise et al[1]) and 4 retrospective studies (Carroll et al,[15] Ferrari et al,[2] Deboever et al,[16] Probert et al[17]), indicate a low incidence or prevalence. A second group of 8 studies, including 4 prospective studies (Sale et al,[18] Haggman et al,[19] Garcia and Arrington,[20] Kronn[21]) and 4 retrospective studies (Klobas et al,[22] Pullinger and Seligman[3], Pullinger and Monteiro,[23] Weinberg and Lapoints[24]), indicate a moderate to high incidence or prevalence.

Mechanism of TMJ injury in whiplash trauma

Table 2 lists studies on mechanism of injury, including design, methods, and results. Two prospective

Table 1 Incidence or prevalence of whiplash injury and TMD

Author (Year) and Type of Study	Protocol/Groups Studied	Intervention/Outcomes	Duration and Rate of Follow-Up	Results
Low incidence or prevalence of whiplash injury and TMD				
Carroll et al (2007)[15] retrospective study	7462 Individuals filing collision-related personal injury claims were assessed. Two distinct groups were addressed: those with WAD and those without WAD.	A retrospective analysis of the records extracted from Saskatchewan claim forms dated 1994-1995.	NA	14.9% (n = 1158) of the total study population reported TMD symptoms. TMD was more prevalent in the WAD group (15.8%) vs the group without WAD (4.7%).
Visscher et al (2005)[12] prospective study	65 Patients were distributed into 3 groups: no neck pain (n = 31), neck pain (n = 11), and WAD pain (n = 23).	Standardized oral history and physical examination of the masticatory and cervical regions were performed.	NA	WAD group had TMD pain (17%) ($P < .028$) more than the other 2 groups (0.0%).
Kasch et al (2002)[13] Prospective Study	19 Acute MVA whiplash individuals and 20 age- and sex-matched controls without previous head or neck trauma were assessed for incidence of TMD.	Examination protocol included: Visual Analog $Scale_{0\text{-}100}$, McGill Pain Scale, Pain Detection Threshold, neurologic examination, and a clinical TMD examination; all were performed within 4 wk and 6 mo postinjury.	Up to 6 mo after initial evaluation.	1 Subject (5%) from each group reported incidence of jaw pain at the initial evaluation. Visual Analog Scale scores tended to be higher for the WAD group (0.0-29.5) vs the control group (0.0-6.7) after 6 mo.
Ferrari et al (1999)[2] retrospective study	Compared the prevalence of TMD in 210 whiplash victims in Lithuania with age- and sex-matched controls.	Controlled historical cohort design	Initial survey occurred an average of 27 mo after the accident.	Only 2.4% of the accident victims (4/165) reported jaw pain for 1 d or more per month, and 0.6% had daily jaw pain. Both groups had low prevalence of jaw sounds, pain in or near the ear, jaw locking, tinnitus, and facial pain.
Bergman et al (1998)[14] prospective study	Incidence of TMD was assessed in 60 patients with symptoms in the neck after rear-end traffic collisions who underwent MRI of the TMJ 3-14 d after collision and were compared with 53 healthy volunteers.	A prospective analysis of the subjects was conducted via MRI. TMJ changes such as disk displacement and joint effusion and also the incidence of bleeding or edema in the soft tissues surrounding the joint in the acute phase after a well-defined whiplash trauma were used to compare the whiplash group with the control group.	MRIs were taken 3-14 d after the collision.	32 Patients (53%) and 24 controls (45%) had a displaced TMJ disk in 1 or both joints ($P = .39$). No statistically significant differences were found between the 60 patients and 53 volunteers regarding frequency, stage, grade, or direction of TMJ disk displacement or joint effusion.
DeBoever and Keersmaekers (1996)[16] retrospective study	400 Consecutive TMD patients were divided into 2 groups. Group 1 (n = 98, 24.5%) related history and symptoms to trauma to the head or cervical region, mainly whiplash accidents. Group 2 (n = 302, 75.5%) with no history of trauma.	Interview and clinical examination. Therapy was similar in both groups and consisted of conservative treatment.	Up to 1 y after initial evaluation.	Maximal mouth opening was less than 20 mm in 14.3% of patients with a history of trauma and in 4.1% of controls ($P < .01$).

Table 1 (*continued*)

Author (Year) and Type of Study	Protocol/Groups Studied	Intervention/Outcomes	Duration and Rate of Follow-Up	Results
Probert et al (1994)[17] retrospective study	28 Subjects with TMD were identified from a total of 20 673 subjects who were involved in a road traffic accidents and claimed health care services	A retrospective analysis of the records from the Transport Accident Commission of Victoria, Australia, in the year 1987.	Subjects not lost to follow-up because all claims for treatment were made to the Transport Accident Commission, regardless of clinician involved.	0.4% of subjects with mandibular fractures and 0.5% of subjects with whiplash injuries presented for treatment of an associated TMD. Females more common, with a ratio of 5:2.
Heise et al (1992)[1] prospective study	155 Patients who had sustained whiplash injuries and reported to emergency trauma center. 63 with radiographic evidence of trauma (group 1) and 92 without (group 2) were studied for incidence of TMD.	Initial examination included evaluation of tenderness, crepitus, and clicking/popping. Muscles of mastication and neck were examined for tenderness. Contact by phone at 1 mo and 1 y follow-up	Initial examination, 1-mo follow-up (group 1 = 81% and group 2 = 85%), and 1-y follow-up (group 1 = 70% and group 2 = 65%)	8 Patients in group 1 (12.7%) had masticatory muscle and TMJ pain. 14 Patients in group 2 (15.2%) had masticatory muscle and TMJ pain. Combined ~14%. At 1-y follow-up, no new reports of symptoms.
Moderate to high incidence or prevalence of whiplash injury and TMD				
Sale and Isberg[18] (2007) prospective study	60 Consecutive patients involved in rear-end automobile collisions. 53 Control subjects matched by age and sex.	After the accident, subjects were examined by an orthopedic surgeon who graded the patients' neck symptoms and trauma-related symptoms on the WAD scale. The subjects also received MRI imaging and answered a 38-item questionnaire that was followed up by an interview with an examiner to ensure the accuracy of the questionnaire answers.	1-y follow-up questionnaire	Subjects with asymptomatic TMJs at the inceptive examination developed joint symptoms significantly more often during the follow-up period than the asymptomatic control group. Of the asymptomatic collision group, 34% developed TMJ symptoms vs 7% for the control group.
Klobas et al (2004)[22] retrospective study	120 Subjects were divided into 2 groups. Group 1 (n = 54) consisted of individuals with chronic WAD and clinical signs and symptoms of TMD. The control, group 2 (n = 66), consisted of individuals undergoing routine dental checkup.	A 2-part standardized evaluation comprised: an anamnestic questionnaire and a clinical examination.	NA	89% of individuals in the WAD group had severe TMD symptoms, whereas only 18% of subjects from the control group experienced similar intensity levels. TMD signs were more prevalent in those subjects with WAD.
Haggman-Henrikson et al (2004)[19] Prospective Study	50 Patients with WAD, 50 patients with pTMD and 50 healthy subjects	Endurance was evaluated during unilateral chewing of gum for 5 min when participants reported fatigue and pain.	NA	All the healthy subjects were able to complete the task, whereas 25% of pTMD and most WAD patients discontinued the task. Most WAD patients also reported fatigue and pain.

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Table 1 (*continued*)

Author (Year) and Type of Study	Protocol/Groups Studied	Intervention/Outcomes	Duration and Rate of Follow-Up	Results
Garcia and Arrington (1996)[20] Prospective Study	The relationship between cervical whiplash and TMJ injuries was documented with MRI in 87 consecutive MVA cervical whiplash patients who presented with TMJ symptoms and had sustained no direct trauma to the face, head, or mandible and had no TMJ complaints before the MVA.	TMJs were evaluated for internal derangement, effusion, and inflammation using T1- and T2-weighted images. Documentation of pTMD symptoms and relationship with MRI findings.	NA	Disk displacement with reduction, 118/164 (72%); disk displacement without reduction, 25/164 (15%); effusion, 113/164 (69%); inflammation or edema, 84/164 (51%); total TMJ abnormalities, 156/164.
Kronn (1993)[21] prospective study	40 Consecutive whiplash patients (pTMD) compared with 40 matched control patients.	Evaluation of joint sounds, mandibular opening, and overall presence of symptoms.	Initial evaluation with no additional follow-up.	TMJ pain in 30% of whiplash subjects vs 2.5% controls ($P = .001$), limitation of mouth opening 37.5% vs 7.5% ($P < .01$), and same percentages in muscle masticatory muscle tenderness ($P < .01$) were found.
Pullinger and Seligman (1991)[3] retrospective study	Prevalence of trauma history was studied among 6 diagnostic subgroups of 230 patients with TMD from a private practice setting and compared with controls (61 asymptomatic students, 161 symptomatic students, and 150 general dental patients).	Controlled historical design. Trauma history was obtained through personal interview.	NA	Except for subluxation diagnostic group, trauma typified TMD groups: 63% disk displacement with reduction, 79% disk displacement without reduction, 44% osteoarthritis with history of derangement, 53% primary OA, and 54% myalgia only. Significant difference (<.001) when compared with controls (13%-18%).
Pullinger and Monteiro (1988)[23] retrospective study	Differences in prevalence of head or neck trauma (whiplash), orthodontic treatment and molar oral surgery procedures were compared among 152 patients with TMD. 331 Students constituted the comparison population. Setting was a university-based specialty clinic.	Controlled historical design. Trauma history was obtained through questionnaires.	NA	The TMD patients reported a history of moderate or severe trauma significantly more than asymptomatic comparison group ($P < .001$). A history of trauma was also significantly more frequent in symptomatic comparison group. The prevalence of trauma in the TMD group was 30.4%.
Weinberg and Lapoints (1987)[24] retrospective study	28 Patients with postwhiplash TMD. No experience of TMD before accident.	Symptoms and examination findings were noted. 25 Subjects received arthroscopic surgery	Initial evaluation at an average of 126 d after whiplash.	Internal derangements were seen in 22 of 25 (88%) patients who consented to arthrographic investigation. Confirmed in the 10 patients who elected to have surgery.

Table 2 Causation—mechanism(s) of injury

Author (Year) and Type of Study	Protocol/Groups Studied	Intervention/ Outcomes	Duration and Rate of Follow-Up	Results
Disputes the correlation between whiplash injury and TMD				
White et al (2005)[25] prospective study	Tests on 10 cadavers were reviewed to measure the relative translation between upper and lower incisors during a low-speed, rear-end impact.	High speed radiographic images were used to measure incisor translation at various seat-back angles and body postures.	N/A	Relative protrusion, retrusion, and mouth opening were computed from the 7 tests meeting inclusion criteria and compared with normal physiologic limits during daily activities such as mastication. It was concluded that low-speed, rear-end automobile collisions do not appear to create the motion required to initiate injury to the TMJ.
Howard et al (1995)[26] prospective study	4 Live human subjects participated as vehicle occupants in a series of 10 vehicle-to-vehicle low-velocity impact tests.	Accelerometer sensor and high-speed cinematography data were obtained from live human test subjects in motor vehicles–staged low-velocity rear-end collisions.	NA	Force magnitudes generated at the TMJ during low-speed collisions constitute a minor fraction of the forces experienced at the joint during normal physiologic function.
Supports the correlation between whiplash injury and TMD				
Burgress et al (1996)[27] retrospective study	219 Consecutive pTMD patients examined by author in an oral medicine clinic.	Self-reports and medical examinations including: questionnaire detailing impact characteristics and body position and posture.	Initial evaluation with no additional follow-up.	Significant interaction between vehicle damage and maximum jaw opening. Speed >40 mph and greater pain, looking right or left at impact, and more pain and masticatory muscles tender to palpation than was looking forward. Jaw opening or closing or restraint use did not reveal significant differences in terms of TMJ variables.

studies[25,26] focusing on low-impact rear-end collisions dispute a direct mechanism of injury theory, whereas 1 retrospective study[27] identifying crash characteristics of pTMD patients provides some support of whiplash-induced TMD. Overall, the mechanisms of injury remain poorly understood.

Comparison of clinical characteristics in iTMD and pTMD patients

Table 3 list studies on clinical findings and characteristics, including design, methods, and results. Twelve studies[19-21,24,28-35] were identified (4 prospective and 8 retrospective studies) that focused on clinical findings and characteristics. Most the studies lend support to the correlation of whiplash and TMD, with some providing a comparison of pTMD to iTMD patients demonstrating significant differences.

Comparing prognosis in iTMD and pTMD patients

Table 4 list 7 studies[16,22,36-40] comparing prognosis in iTMD and pTMD patients, including design, methods, and results. Five studies suggest a significant difference when comparing pTMD to iTMD patients, with pTMD having a poorer prognosis. It should be noted that, of these 5 studies, 3 prospective studies and 1 literature review included psychologic factors, whereas 1 prospective study did not. Two other studies did not show a significant difference, including 1 prospective investigation and 1 retrospective study.

Table 3 Comparing clinical characteristics in pTMD and iTMD populations

Author (Year) and Type of Study	Protocol/Groups Studied	Intervention/Outcomes	Duration and Rate of Follow-Up	Results
Lends support to the correlation between whiplash injury and TMD				
Haggman-Henrikson et al (2004)[19] prospective	50 Patients with WAD, 50 patients with pTMD, and 50 healthy subjects	Endurance was evaluated during unilateral chewing of gum for 5 min when participants reported fatigue and pain.	NA	All the healthy subjects were able to complete the task, whereas 25% of pTMD and most WAD patients discontinued the task. Most WAD patients also reported fatigue and pain.
Haggman-Henrikson et al (2002)[28] prospective	12 Subjects were studied for incidence of pain and dysfunction in the jaw and neck regions that had developed after neck trauma. The traumas consisted of MVA and falls that resulted in WAD class II-III. These subjects were compared with a control group.	Movements in the mandible and head were monitored in 3 dimensions while performing 3 standardized motor tasks.	Duration between trauma and examination was 1-9 y for females and 2-4 y for males.	Compared with the healthy subjects, the WAD group showed smaller magnitude and altered coordination pattern of mandibular and head movements. The authors conclude that neck trauma can derange integrated jaw and neck behavior, and underline the functional coupling between jaw and head-neck motor systems.
Abd-Ul-Salam et al (2002)[29] retrospective study	30 Patients with refractory TMJ symptoms who had cervical flexion-extension injury.	Clinical data and operative reports of patients with a diagnosis of TMJ whiplash injury from 1997-2002 were reviewed.	NA	A wide range of arthroscopic findings, ranging from chondromalacia to moderate or severe synovitis and adhesions was observed, as well as combinations of these abnormalities.
Friedman and Weisberg (2000)[30] retrospective study	Investigation of whiplash as a causative factor for TMD. The records of 300 patients with pTMD preceded by a motor vehicle accident were examined retrospectively.	TMD evaluations involved active range of motion, palpation, application of resistive forces to opening and closing of jaw. Cervical spine was also evaluated with range of motion, and muscle and joint palpation; and several canned tests were included to rule out inconsistent analysis.	NA	The most common presenting symptoms, in order, were jaw pain, neck pain, posttraumatic headache, jaw fatigue, and severe TMJ clicking. The most common TMD findings were masseter trigger points, closing jaw muscle hyperactivity, TMJ synovitis, opening jaw muscle hyperactivity, and advanced TMJ disk derangement.
Kolbinson and Epstein (1997)[31] retrospective study	30 Previously treated patients with TMD after MVA.	A retrospective pilot study to investigate persistence of TMD after MVA and effects of litigation.	NA	Jaw, head, and neck pain, and jaw dysfunction persisted in most patients regardless of litigation status
Goldberg et al (1996)[32] retrospective study	1st phase, 14 patients with pTMD compared with 13 patients with iTMD. 2nd phase, 5 pTMD compared with 6 nontrauma (iTMD) patients.	1st phase–reaction time tests, neuropsychologic assessment, and clinical examination with examiner blinded to groups.	Initial with no additional follow-up	Clinical examination: pTMD group had greater reaction to muscle palpation. Reaction time tests were significantly slower for pTMD group.

Table 3 (*continued*)

Author (Year) and Type of Study	Protocol/Groups Studied	Intervention/Outcomes	Duration and Rate of Follow-Up	Results
Seligman and Pullinger (1996)[33] retrospective study	Populations of 52 females with iTMD and pTMD.	Multiple stepwise logistic regression analysis of trauma history and 16 other cofactors.	NA	Non-MVA trauma was defining feature of TMJ intracapsular disorders, and MVA trauma explained a small but significant percentage of myofascial pain patients.
Steigerwald et al (1996)[34] retrospective study	Symptoms of 43 patients with whiplash-induced TMD who underwent arthroscopic surgery were compared with those of other TMD populations.	Patients were polled regarding symptoms before and 24 h after arthroscopic surgery.	NA	Whiplash-induced TMDs differ from insidious-onset TMDs by prevalence of neck pain and intensity of neck pain with concurrence of shoulder pain, headache, and jaw pain.
Garcia and Arrington (1996)[20] prospective study	The relationship between cervical whiplash and TMJ injuries was documented with MRI in 87 consecutive MVA cervical whiplash patients who presented with TMJ symptoms and had sustained no direct trauma to the face, head, or mandible and had no TMJ complaints before the MVA.	TMJs were evaluated for internal derangement, effusion, and inflammation using T1- and T2-weighted images. Documentation of pTMD symptoms and relationship with MRI findings.	NA	Disk displacement with reduction, 118/164 (72%); disk displacement without reduction, 25/164 (15%); effusion, 113/164 (69%); inflammation or edema, 84/164 (51%); total TMJ abnormalities, 156/164 (95%).
Kronn (1993)[21] prospective study	40 Consecutive whiplash patients (pTMD) compared with 40 matched control patients with iTMD.	Evaluation of joint sounds, mandibular opening, and overall presence of symptoms.	Initial evaluation with no additional follow-up.	TMJ pain in 30% of whiplash subjects vs 2.5% nontraumatic ($P = .001$), limitation of mouth opening 37.5% vs 7.5% ($P < .01$), and same percentages in masticatory muscle tenderness ($P < .01$) were found.
Braun et al (1992)[35] retrospective study	25 Post–cervical trauma patients referred to physical therapy clinic and 25 asymptomatic age- and sex-matched volunteers. Litigating patients, n = 13; nonlitigating patients, n = 12.	Patients were evaluated with cervical and TMJ symptom questionnaires.	Initial evaluation at 2 d to 10 wk after trauma. No additional follow-up.	Cervical trauma group had significantly more pain with jaw function, limited jaw mobility, and evidence of mild-to-moderate intracapsular dysfunction. Litigating patients showed no significant difference in all 3 indices.
Weinberg and Lapoints (1987)[24] retrospective study	28 Patients with postwhiplash TMD. No experience of TMD before accident.	Symptoms and examination findings were noted. 25 Subjects received arthroscopic surgery.	Initial evaluation at an average of 126 d after whiplash.	Internal derangements were seen in 22 of 25 (88%) patients who consented to arthrographic investigation. Confirmed in the 10 patients who elected to have surgery.

Table 4 Comparing prognosis in pTMD and iTMD populations

Author (Year) and Type of Study	Protocol/Groups Studied	Intervention/Outcomes	Duration and Rate of Follow-Up	Results
Disputes the correlation between whiplash injury and TMD				
Klobas et al (2006)[22] Prospective	94 Patients with whiplash-related conditions were accepted for functional evaluation and rehabilitation. Of those patients, 55 were diagnosed with TMD and chronic WAD in accordance with the inclusion criteria.	The group was divided into a jaw exercise group who performed specific therapeutic jaw exercises and a control group.	3-wk and 6-mo follow-ups.	Except for an increase of maximum active mouth-opening capacity in the control group, there were no inter- or intragroup differences in symptoms and signs of TMD, at the 3-wk and 6-mo follow-ups.
DeBoever and Keersmaekers (1996)[16] retrospective study	400 Consecutive TMD patients were divided into two groups. Group 1 (n = 98, 24.5%): related history and symptoms to trauma to the head or cervical region, mainly whiplash accidents. Group 2 (n = 302, 75.5%): with no history of trauma.	Interview and clinical examination. The Helkimo index was calculated. Therapy was similar in both groups and consisted of conservative treatment.	Up to 1 y after initial evaluation.	They indicate that the prognosis for this condition was favorable using conservative treatment procedures. No significant difference between pTMD and iTMD at 1-y follow-up.
Supports the correlation between whiplash injury and TMD				
Krogstad et al (1998)[36] prospective treatment outcome study	N = 32 with 16 whiplash patients with TMD and 16 nontrauma patients with TMD.	Treatment consisted of counseling, exercise, and stabilization splint. Treatment outcome was assessed by changes in self-reported headache frequency, number of tender muscles to palpation, and visual analog scale.	Initial evaluation and outcome measured after therapy.	The pTMD group had higher measures of somatic complaints and psychologic distress and did not respond as well to therapy compared with the nontrauma group.
Greco et al (1997)[37] prospective treatment outcome study	N = 361. Compared presenting problems and response to treatment in 103 pTMD patients and 258 iTMD patients.	Treatment consisted of intraoral appliance, biofeedback, and stress management. Outcome measures included clinical changes, oral parafunctional habits, global evaluation or improvement, and use of pain medications at follow-up.	6-mo follow-up/ 65%	A small but significant proportion of pretreatment variability (8.7%) could be accounted for by onset (trauma vs nontrauma). Both groups show positive outcomes with treatment with higher use of pain medications in the pTMD group.
Kolbinson et al (1996)[38] retrospective study (literature review)	Narrative literature review concerning the relationships between MVA, TMD, whiplash, headache, neck pain, and litigation. Total of 87 studies reviewed, with 9 addressing TMD.	Various	NA	The review showed that patients with pTMD tended to respond less well to treatment than did iTMD patients. Biological and psychologic factors may contribute. Litigating patients and nonlitigating patients were not dramatically different in traits such as pain and return to work. Chronic pain frequently continues after litigation.

Table 4 (*continued*)

Author (Year) and Type of Study	Protocol/Groups Studied	Intervention/Outcomes	Duration and Rate of Follow-Up	Results
Romanelli et al (1992)[39] retrospective study	N = 104. 52 Patients with MVA/TMD had no history of TMD before MVA; and 52 patients, age- and sex-matched, with TMD without MVA or other macrotrauma to the jaws or neck were used as controls.	Evaluation included history, clinical examination, diagnostic imaging as indicated. Interview to determine possible affective disorder. Therapy was conservative.	Treatment ranged from 3-5 y after MVA, with progress assessed at each visit.	The posttraumatic TMD patients required significantly more treatment than the control TMD patients. 60% of MVA/TMD patients had symptoms suggestive of affective disorder compared with only 14% of TMD patients.
Brooke and Stenn (1977)[40] prospective study	194 Patients with TMD. 20 Were reported to be postinjury TMD, and the remaining 174 comprised the noninjury group.	Treatment consisted of physical therapy, occlusal splints, and minor tranquilizers, as needed. Comparison of treatment outcomes for postinjury and noninjury TMD.	Treatment ranged from 16 to 44 mo after their first visit.	Smaller percentage of injury group became symptom free and required further treatment than noninjury group.

Discussion

Incidence and prevalence of TMD in whiplash populations

Eight prospective and 8 retrospective studies were identified that attempted to assess the incidence or prevalence of pTMD. Collectively, the incidence of TMD resulting from whiplash is variable. Further stratified studies with large patient populations are needed to standardize subjective findings and quantify objective outcomes. The best correlative evidence reviewed from controlled prospective studies indicates a range of low to moderate incidence (14%-37.5%) of TMD in whiplash populations. The wide range in results may be due to variations in the study populations, clinical features and outcomes targeted, and the type of data reported.

Limitations of studies are discussed to provide information on the weight of evidence that these studies provide. Most retrospective studies on the prevalence of whiplash injuries in TMD populations that were reviewed provide support for the correlation of whiplash injuries and TMD. However, there was a large range of prevalence from low to high. It should be noted that prevalence in itself does not prove etiology.[3] However, these studies may provide useful clinical information for the health care practitioner.

Notably, most studies showing a low correlation of TMD with WAD were conducted during the acute phases of whiplash injury. Conversely, most studies that supported an association between TMD and WAD were investigated once the whiplash symptoms reached a chronic phase (>6 months' duration). The potential correlation among the different phases of whiplash (acute or chronic) and the prevalence of TMD should be further investigated. Pullinger and Seligman[3] commented on this topic, suggesting possible reasons for the delayed onset of TMD symptoms. They noted that "jaw symptoms may initially be ignored in the presence of more serious injuries," and that "early disk displacement may go unreported because of the frequently painless nature of TMJ clicking." Furthermore, the high number of magnetic resonance imaging (MRI) findings in both iTMD and pTMD patients lends support to the statement of Pullinger and Seligman[3] that even seemingly minor events might elevate preexisting subclinical disorders into full symptomatic status.

A few studies need to be discussed because of their proposed strong conclusions. In a prospective study by Heise et al,[1] an investigation was designed to interview, examine, and follow up patients with a whiplash injury initially seen at an emergency trauma center and to report the incidence of TMJ pain and dysfunction initially and at 1-month and 1-year follow-ups. The authors concluded that the incidence of TMJ pain and clicking after whiplash injury was extremely low and that patients who did not have clicking on resolution of their initial pain dysfunction subsequently did not develop this problem. It should be noted that in this study the follow-up rate was statistically low and may not support its conclusions. More importantly, this

study was limited in it's failure to use a control group of nonwhiplash iTMD patients but rather divided pTMD groups by radiographic findings vs no radiographic findings. A second study performed very similarly to the study of Heise et al[1], but with an opposite conclusion, was conducted by Sale and Isberg[18] who performed a prospective study at a hospital in Sweden on 60 consecutive patients involved in rear-end car collisions. The subjects were examined by an orthopedic surgeon and graded on the Quebec WAD scale. The subjects then underwent an MRI and were given a 38-item questionnaire. If the patient reported any TMJ complaint on the questionnaire, an examiner was sent in to verify the accuracy of the complaints and identify it as a true TMJ complaint. A follow-up was performed approximately 1 year later, where both subjects and controls completed the self-questionnaire again. Of the rear-end collision subjects, 34% of the asymptomatic TMJ group developed TMJ symptoms within the 1 year compared with only 7% of the asymptomatic control group. The conclusion by the authors is that 1 in 3 people who are exposed to whiplash trauma is at risk of developing delayed TMJ pain and dysfunction during the year after the accident.

Ferrari et al[2] performed a survey study (controlled historical cohort design), in which 2.4% of the accident victims (4/165) reported jaw pain for 1 day or more per month and 0.6% had daily jaw pain. The authors concluded that despite acute whiplash injuries, Lithuanian accident victims did not appear to report the chronic symptoms of TMD. The authors have suggested that chronic pTMD and whiplash are a cultural phenomenon unique to North America. However, one other non–North American–based study based in Sweden by Klobas et al[22] refutes this idea, which identified a correlation between TMD and WAD. Another consideration is that perhaps the cultural phenomenon is unique to Lithuania and may reflect underreporting by patients due to a lack of cultural awareness regarding the management of this condition. In addition, it is hard to refute the large number of objective MRI findings of TMJ abnormalities in North American studies.

One should be cautious of the outcomes displayed by some studies that supported or disputed the relationship between TMD and WAD based solely on questionnaires, without clinical contact, detailed clinical histories, or follow-up to document objective findings. Special attention should be placed on MRI during the objective/clinical investigation. Future studies focusing on etiology and incidence, incorporating the use of MRI, would be advantageous because of the important objective findings that it represents.

Mechanism of TMJ injury in whiplash trauma

Historically, there have been 2 proposed theories describing the mechanism of injury resulting in TMD: the direct injury theory and the indirect injury theory. The direct injury theory describes a sequential extension-flexion of the neck accompanied by simultaneous jaw movement resulting in shear stress and compressive forces to the retrodiskal tissues.[24,41] Wakeley[41] described an anteromedial displacement of the articular disk as a result of direct trauma to the TMJ during cervical hyperextension. He speculated that the pull of the lateral pterygoid muscle in combination with the force of trauma causes a stretching of the posterior attachment of the disk. He felt that this was particularly significant if the trauma occurred when the mouth was open and the attachment was already stretched.

In an indirect theory by Lader,[42] he suggested that whiplash-induced myospasm leads to abnormal jaw posturing and parafunctional activity that results in eventual dyscoordination and internal derangement. Other indirect mechanisms may include postinjury stress, cervical postural changes, and postural imbalance.[43-47] These may be important considerations when evaluating and managing TMD.

Only 3 of the studies reviewed herein addressed a direct mechanism of injury. Two prospective studies[25,26] dispute the direct theory, whereas 1 retrospective study[27] identifying crash characteristics of pTMD patients provided some support of whiplash-induced TMD.

In a study by Howard et al,[26] forces generated at the TMJ during a low-velocity, rear-end collision were measured using live human test subjects. The study concluded that forces generated at the TMJ constitute a minor fraction of the forces experienced at the joint during normal physiologic function. A study conducted by White et al[25] reviewed 38 tests in which high-speed radiographs were used to examine the effect of low-impact, rear-end collisions on cadavers. The initial studies were conducted to examine cadaveric cervical spine kinematics, but the authors of this study used the data and images to measure the position of the upper and lower incisors and compare them to the normal physiologic range in daily activities such as mastication. The conclusion by the authors is that low-speed, rear-end impact collisions did not produce motion that would be beyond the physiologic TMJ motion. The authors do acknowledge that there are several severe limitations of this study. One of the limitations was that they could only use 7 tests from the previous studies because of their inclusion criteria. The study also only analyzed the relative motion between the mandible and

maxilla and not at the TMJ directly. In one retrospective study, Burgress et al[27] examined 219 consecutive patients presenting to an oral medicine clinic. Results indicated a significant interaction between vehicular damage and maximum jaw opening on clinical examination. According to the McGill Pain Questionnaire, looking right or left at impact was linked to significantly more pain and mean number of masticatory muscles tenderness to palpation than was looking forward. Impact speed of 40 mph or higher was associated with significantly greater pain.

There is limited evidence that either supports or disputes the proposed theoretical mechanisms of injury of TMD due to whiplash, and they remain poorly understood. The limited existing evidence was focused only on a direct mechanism of injury for internal derangement and TM pain, and did not address other WADs that may progress to TMD. These may include myospasm in cervical and orofacial musculature, altered forward head posture, altered occlusion, and/or posttraumatic stress disorder.

Comparison of clinical characteristics in iTMD and pTMD patients

There is moderate evidence from 12 studies that supports the occurrence of TMD after whiplash, based on a significant difference in clinical characteristics between iTMD and pTMD populations. These significant characteristic differences are highlighted in the articles by Kronn[21] and Friedman and Weisberg.[30] Kronn found that, when compared with iTMD patients, pTMD patients were more likely to have TMJ pain, limitation of mouth opening, and masticatory muscle tenderness. These findings were reinforced by the study of Friedman and Weisberg[30] that found that, along with jaw pain, fatigue, and TMJ clicking, neck pain was also an associated finding with TMD pain after whiplash. Steigerwald et al[34] determined that an increased intensity of neck pain, with concurrent headache and shoulder pain, was present in pTMD as opposed to iTMD. For clinicians, these findings are important because the severity of symptoms and the presentation of iTMD and pTMD are different. Whiplash/TMD patients may require additional treatment, and the duration of their recovery period may be longer. Magnetic resonance imaging studies have also been conducted to examine the TMJ after motor vehicle accidents. The study of Garcia and Arrington[20] found that disk displacement may occur with and without reduction, effusion, and inflammation or edema. The drawback with many of these studies is that there was no control group to compare these findings relative to the general population. Bergman et al[14] compared a pTMD group to a control group of the normal population. The study found that there were no statistically significant differences between the pTMD group and the normal population. This does not mean that there is no joint injury during whiplash, but clinicians should be aware of the prevalence of abnormal TMJ in the normal population and treat accordingly. It is proposed that, with underlying subclinical TMJ problems, the injury can push the TMJ apparatus beyond its adaptive capabilities, resulting in pTMD.[16]

It should be noted that several of the studies demonstrated the same clinical characteristics. Similar significant findings in these studies include an increased incidence of limited jaw mobility/limitation in mouth opening, masticatory muscle tenderness, and a high incidence of internal derangement. One study found a lesser incidence of internal derangement in pTMD patients based on a significant decrease in intracapsular symptoms. Identifying clinical characteristics in pTMD patients may be useful for those providing treatment of these individuals. "The present findings concerning a significantly higher presence of cardinal signs and symptoms of TMJ dysfunction, together with a relatively high demand for treatment, warrant further study and, from a clinical point of view, are valid arguments for the routine examination of the TMJ and masticatory system in all patients with a cervical whiplash injury."[21]

Prognosis in pTMD patients

A basic axiom of epidemiology is that the clinical importance of a disease cannot be fully understood without investigating its expression in general populations as well as persons seeking treatment.[48] Discussing prognosis of TMD/whiplash individuals provides another perspective of these types of patients. The most common method of studies in this area is the comparison of prognosis in iTMD and pTMD patients. A total of 7 studies compared the prognosis in iTMD and pTMD populations. Five studies (Krogstad et al,[36] Greco et al,[37] Kolbinson et al,[38] Romanelli et al,[39] Brooke et al[40]) suggested a significant difference in some but not all of the outcomes measured, with pTMD patients having a poorer prognosis than iTMD patients. It should be noted that most of these studies included psychologic factors. One study by Kolbinson et al[31] indicated that litigation was not a factor for determining prognosis

and that the patient's symptoms and findings persisted regardless of litigation status. Two studies (DeBoever and Keersmaekers,[16] Klobas et al[22]) did not show a significant difference between pTMD and iTMD patients. The prospective study by Klobas et al[22] focused on an exercise therapy as the only intervention for pTMD patients and found no difference between the jaw exercise group and the control group. In contrast, other studies included other therapeutic interventions such as moist heat and massage, nonsteroidal anti-inflammatory drugs, muscle relaxants, analgesics, intraoral appliances, antidepressant medication, trigger point injection, and biofeedback.

A narrative literature review by Kolbinson et al[38] concerning the relationships between motor vehicle accidents (MVA), TMD, whiplash, headache, neck pain, and litigation examined 87 studies including 9 addressing TMD. The review showed that patients with pTMD responded less well to treatment than did iTMD patients, and that both biological and psychologic factors may have contributed. In addition, this review focused on factors of litigation and found that litigating patients and nonlitigating patients were not dramatically different in traits such as pain and return to work. Chronic pain frequently continued after litigation. Another study by the same authors[31] found that jaw, head, and neck pain and jaw dysfunction persisted in most patients regardless of litigation status.

Brooke and Stenn[40] proposed a possible mechanism that may influence the different prognoses of pTMD and iTMD patients: "while recovery of the original tissue damaged may have already taken place, through a process of (maladaptive) learning, the patient develops oral habits which increase the likelihood of muscle fatigue and subsequent pain."

The functional clinical examination of TMD should comprise palpation of muscles, registration of joint sounds, and measurement of maximum jaw opening.[36] In many patients, the intensity of symptoms in the TMJ region and in masticatory muscles is less than symptoms of pain and dysfunction in the cervical region, and is thus easily overlooked. However, TMD symptoms may become more apparent after disappearance of the major complaints. Temporomandibular disorder symptoms should be treated immediately after trauma before they become chronic. Counseling and reassurance of the patient after trauma are very important and may help prevent the development of posttraumatic stress disorder. Health care providers evaluating and treating patients after trauma to the head or after whiplash accidents should be aware of the possible involvement of joints and jaw muscles. Evaluation of the function of the TMJ and masticatory apparatus is therefore highly recommended.[16]

Standardized research needs to be designed and conducted to include larger prospective controlled studies addressing the issues of: incidence, proposed mechanism(s) of injury, clinical characteristics, and prognosis in whiplash/TMD patients. Standardization of data collection procedures and outcomes used is needed to gain a greater understanding of this complex condition. An understanding of the possible mechanisms of this type of injury may lead to a better assessment and management of this condition.

Additional research questions may include the following: (1) Why do some whiplash individuals develop TMD and others do not? (2) What are the predisposing or precipitating factors involved? (3) What evidence describes other contributing or possible competing etiologies to whiplash/TMD? (4) Why is TMD more associated with chronic WAD than acute WAD? (5) Does time play a role in development in pTMD? (6) Does this correlate with some of the indirect mechanisms proposed earlier?

Prospective studies on whiplash populations should capture a comprehensive picture of important variables affecting TMD and provide a comparison with controls. These variables could be identified through the use of MRI, joint blocks/injections, standardized reliable and valid clinical tests, and appropriate outcomes measures. Other findings already correlated with whiplash and TMD in research studies, such as balance and postural abnormalities, shoulder-neck-headache, stress and psychosocial factors, parafunctional and adaptive habits, central mediated pain factors, and others, should be included as potential variables or descriptors to be defined in whiplash/TMD populations.[43-47]

Limitations

This article should be used within the context of a narrative literature review with its inherent limitations. A systematic literature review uses a strict methodology to answer a specific research question with specific outcomes, whereas a narrative review is better suited in addressing a broader range of questions and provides a summary of findings. Although this article used general inclusion/exclusion criteria, it lacked important criteria with flowchart demonstrating steps of exclusion based on identification of studies included with specific research designs such as randomized control trials/case-control studies/cohort studies and identification of studies with specific statistical approaches and sample

size. Other limitations include the lack of quality scoring and formal blinded appraisal of studies reviewed. Furthermore, it should be noted that the large variations in results may be due to variables that include the characteristics of the populations studied, clinical features or outcomes targeted, and the type of data reported. Along with other factors previously mentioned, this variation made comparison of the data difficult and therefore inconclusive.

Conclusions

There is conflicting evidence regarding the effects of whiplash on the development of TMD. The incidence of TMD resulting from whiplash varies from low to moderate, and the mechanisms of injury remain poorly understood. There is moderate evidence that supports the occurrence of TMD after whiplash based on significant differences in clinical characteristics and prognosis between iTMD and pTMD populations. Regarding prognosis, it appears that pTMD patients tend to respond less well to treatment than iTMD patients. Physical and psychologic factors may both contribute.

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