Temporomandibular Disorder Pain After Whiplash Trauma: A Systematic Review

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Aims: *To assess, by systematic review of the literature,* (1) *the prevalence and incidence of temporomandibular disorder (TMD) pain after whiplash trauma, and* (2) *whether treatment modalities commonly used for TMD are equally effective in patients with solely TMD pain and those with TMD/whiplash-associated disorders (WAD) pain.* ***Methods:*** *A systematic literature search of the PubMed, Cochrane Library, and Bandolier databases was conducted from January 1966 through October 2012. The systematic search identified 125 articles. After an initial screening of abstracts, 45 articles were reviewed in full text. Two investigators evaluated the methodological quality of each identified study.* ***Results:*** *Eight studies on prevalence/incidence of TMD pain in WAD and four studies on interventions in TMD pain and WAD met the inclusion criteria. The reported median prevalence of TMD pain after whiplash trauma was 23% (range 2.4% to 52%) and the incidence ranged from 4% to 34%. For healthy controls, the reported median prevalence was 3% (range 2.5% to 8%) and the incidence ranged from 4.7% to 7%. For patients with a combination of TMD pain and WAD, treatment modalities conventionally used for TMD, such as jaw exercises and occlusal splints, had less of an effect (median improvement rate of 48%, range 13% to 68%) compared to TMD patients without a whiplash injury (75%, range 51% to 91%).* ***Conclusion:*** *There is some evidence that prevalence and incidence of TMD pain is increased after whiplash trauma. The poorer treatment outcome suggests that TMD pain after whiplash trauma has a different pathophysiology compared to TMD pain localized to the facial region.* J OROFAC PAIN 2013;27:217–226. doi: 10.11607/jop.1027

Key words: jaw, neck, systematic review, temporomandibular disorders, whiplash injuries

Patients with temporomandibular disorders (TMD) typically report jaw pain, pain on jaw movements, and impaired jaw mobility.[1] The etiology of TMD is considered to be multifactorial, but it is recognized that indirect trauma caused by whiplash trauma can be a contributing factor. The term whiplash trauma describes a translatory trauma to the neck followed by hyperextension-flexion trauma to the neck. The incidence in Sweden is about 1 to 3.2 per 1,000 inhabitants, mostly from traffic injuries but also from other traumas such as falls.[2] Common signs and symptoms after whiplash injury are neck pain, impaired neck movements, and headaches.[3,4] Although most individuals recover from an acute whiplash injury, a substantial number of patients, about

one in three individuals, will develop long-lasting problems termed whiplash-associated disorders (WAD).[5] The symptoms following whiplash trauma are heterogeneous and relate both to mechanical injuries to the neck, pain sensitization, and psychological and social factors.[6] In addition to persisting neck pain, neck stiffness, and headaches, common symptoms are dizziness, sleep problems, cognitive problems, and a generally reduced quality of life.[4] Patients also report problems with daily jaw activities as well as pain and discomfort during eating and chewing, which can further affect daily life and social activities.[7]

Although several studies have reported TMD pain in patients with WAD,[8–10] conflicting data on the prevalence and incidence have been reported.[11,12] Thus, although the prevalence and incidence of TMD pain in the general population is well documented, there currently seems to be a gap in knowledge about the prevalence and incidence of TMD pain in patients with WAD. Prevalence is a measure of the total number of cases with a disease in the population at a specific time. The term incidence is related to onset of disease and explains the rate at which new cases occur in a population, which allows for cause and effect analyses. Furthermore, it is unclear whether the treatment modalities normally advocated for patients with TMD pain are effective in patients with a combination of TMD pain and whiplash injury. Studies in animals and humans show a close biomechanical and anatomical relationship between the jaw and neck regions, and suggest a functional linkage between the jaw-face and craniocervical sensorimotor systems.[13] As jaw function relies on linked motor control of the jaw and neck motor systems, pain and dysfunction in the neck may impair jaw function. In chronic WAD, an association has been shown between pain and dysfunction of the neck and disturbed jaw motor function. The findings include reduced amplitude for both mandibular and head-neck movements, disturbed coordination of jaw and head-neck movements,[14,15] and reduced endurance during chewing.[16] Several studies have demonstrated shared symptoms of neck pain and TMD. Thus, in studies of TMD patients, neck pain is common,[17–20] and in studies of neck pain patients, TMD is common.[21,22]

Therefore, the aims of the present study were to assess, by systematic review of the literature, *(1)* the prevalence and incidence of TMD pain after whiplash trauma, and *(2)* whether treatment modalities commonly used for TMD are equally effective in patients with solely TMD pain and those with TMD/WAD pain.

Materials and Methods

Inclusion and Exclusion Criteria

Clinical studies in adult patients (> 18 years) with TMD pain and whiplash injury were included. Studies were included for assessment of prevalence or incidence if they reported TMD pain in a whiplash population. Intervention studies in patients with TMD and whiplash were included if TMD pain or global improvement according to IMMPACT[23] were reported. Articles were excluded if no separate outcome measure of TMD pain or global rating could be identified. Epidemiologic studies were excluded if they were not based on a whiplash population or if data from the same cohort had been reported in another article (dual publication).

Literature Search

The search strategy was designed to identify studies that focussed on *(1)* prevalence and incidence of TMD pain in a whiplash population and *(2)* management of TMD pain in WAD.

The search encompassed all articles that were indexed in PubMed, the Cochrane Library, and Bandolier; published in English, Swedish, or German; and published between January 1, 1966, and October 31, 2012. The search terms used for PubMed were: "Whiplash injuries" [MeSH] or "Whiplash Associated Disorders" or "Whiplash" AND "Temporomandibular joint disorder" [MeSH] or "Craniomandibular disorders" or "Temporomandibular disorders" or "Temporomandibular joint dysfunction" or "Jaw pain" or "Facial pain." For the Cochrane Library and Bandolier database, the search strategy included the terms "Whiplash" AND "Craniomandibular disorders" or "TMJ" or "TMD." References in original articles and review articles were handsearched to identify additional studies.

Procedures

Two of the authors (BH, TL) independently read all titles and abstracts that were found in multiple searches to identify potentially eligible articles for inclusion. All potentially eligible studies were then retrieved, and full-text articles were reviewed to determine if they met the inclusion criteria. Disagreement was resolved by discussion among the investigators. Authors were not contacted for missing information. The reviewers were experienced orofacial pain researchers.

The data extracted from the epidemiologic studies were: study design, study sample, number of subjects (age and sex), outcome measure, prevalence/

incidence of TMD pain, quality score, and author's conclusions. The data extracted from the intervention studies were: study design, study sample, number of subjects (age and sex), dropouts, type of intervention, outcome measures, results, quality score, and author's conclusions.

Quality Assessment

Both investigators independently evaluated the methodological quality of each identified study. They used a scoring system modified from Macfarlane et al[24] that utilized a standardized checklist with 21 items to assess the quality of each study. The criteria were scored as *yes*, *no*, or *unable to determine*. Only criteria scored as yes gave a score, added up to give a total quality score for the paper; the results were presented as percentages of total attainable score. All articles were discussed to verify the appraisal process until consensus was reached. Disagreements on individual item scores were resolved in independent arbitration.

After the independent assessments of the individual items, which rendered the total quality scores, the inter-reliability of the two authors was calculated with kappa statistics.

Results

The systematic search of three databases identified a total of 125 articles (Fig 1). The two reviewers independently screened abstracts according to the inclusion criteria.

After the initial screening of abstracts, 45 articles were reviewed in full text. Of these, a total of 33 articles were excluded[12,25–56] (Table 1). Eight studies[8–10,57–61] on the prevalence and incidence of TMD pain in whiplash (Table 2), and four intervention studies [48,62–64] on the effect of treatment in patients with TMD pain and whiplash (Table 3) met the inclusion criteria.

The median quality score for included studies on prevalence/incidence was 60% (range 40% to 81%) and for studies on interventions 55% (range 40% to 65%). There was a good agreement in the scoring of the individual items (used to calculate the total quality score), carried out by the two investigators (kappa: 0.84).

The reported median prevalence of TMD pain after whiplash trauma was 23% (range 2.4% to 52%) and the incidence ranged from 4% to 34% (median 10%). For healthy controls, the reported median prevalence was 3% (range 2.5% to 8%) and the incidence ranged from 4.7% to 7% (median 6%).

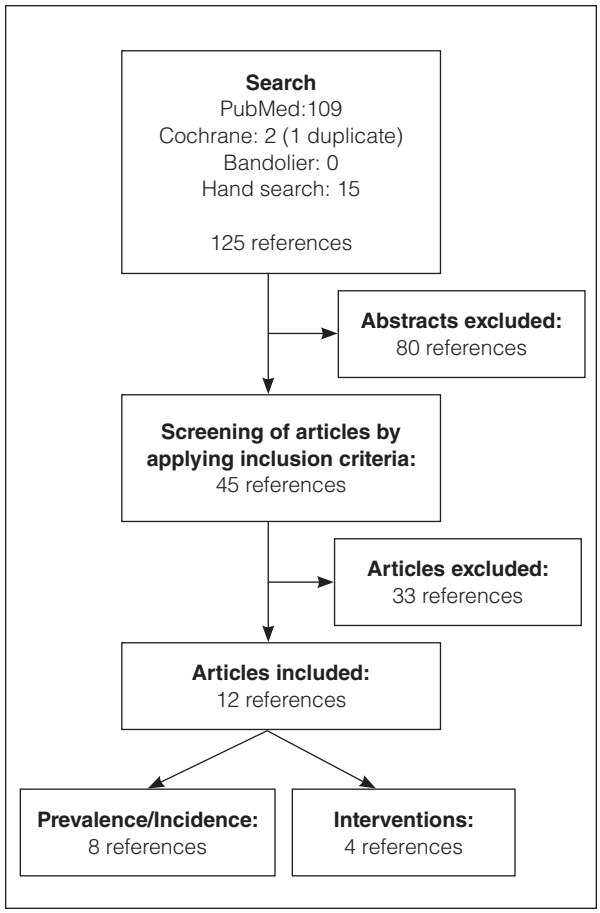

Fig 1 Flow diagram of search result and references included and excluded in the systematic review.

Four studies investigated treatment effect in patients with combined TMD pain and neck pain after whiplash trauma, showing a median improvement rate of 48% (range 13% to 68%) compared to 75% (range 51% to 91%) for TMD patients without whiplash injury. One study showed no effect from jaw exercises.[62] A treatment regimen using a combination of occlusal splints, medication, and physiotherapy was used in one study, which reported a lower global improvement for patients under litigation compared to those not under litigation (68% vs 91%).[48] A lower global improvement with similar treatment regimes was found in another study of patients with TMD pain after whiplash compared to TMD patients without a history of trauma (48% vs 75%).[64] The final study, with similar treatments (counseling, occlusal splints, and muscle exercises), showed a 13% pain reduction in the neck-injured group compared to 51% pain reduction in the TMD group without a history of neck trauma.[63]

Table 1 Articles Excluded from the Study (n = 33)

Article	Reasons for exclusion
Sale et al[25]	Dual publication[10]
Kim et al[26]	Not whiplash population, no data on TMD pain
Severinsson et al[12]	No data on TMD pain
Hulse and Losert-Bruggner[27]	No data on TMD pain
Grushka et al[28]	Not whiplash population, no data on TMD pain
Ferrari et al[29]	Dual publication[8]
Abd-Ul-Salam et al[30]	Not whiplash population, no data on TMD pain
Kasch et al[31]	No data on TMD pain
Kasch et al[32]	No data on TMD pain
Friedman and Weisberg[33]	Not whiplash population
Kolbinson et al[34]	Not whiplash population, no data on TMD pain
Bergman et al[35]	No data on TMD pain
Kolbinson et al[36]	Not whiplash population
Kolbinson et al[37]	Not whiplash population, no data on TMD pain
Kolbinson et al[38]	Not whiplash population
Khan et al[39]	No data on TMD pain, whiplash diagnosis unclear
Greco et al[40]	Patient group not defined whiplash
Garcia and Arrington[41]	Not whiplash population, no data on TMD pain
Burgess et al[42]	Not whiplash population
Goldberg et al[43]	Not whiplash population, no data on TMD pain
De Boever and Keersmaekers[44]	Not whiplash population, no data on TMD pain
Seligman and Pullinger[45]	Not whiplash population
Steigerwald et al[46]	No data on TMD pain, diagnosis unclear
Probert et al[47]	Data on TMD pain unclear, diagnosis unclear, risk for selection bias due to inclusion criteria
Burgess and Dworkin[48]	Not whiplash population, no data on TMD pain
Braun et al[49]	No data on TMD pain
Pressman et al[50]	Not whiplash population, no data on TMD pain
Uppgaard[51]	Not whiplash population, no data on TMD pain
Burgess[52]	Not whiplash population
Pullinger and Seligman[53]	Not whiplash population
Pullinger and Monteiro[54]	Not whiplash population
Weinberg and Lapointe[55]	Not whiplash population
Brooke and Stenn[56]	Not whiplash population, diagnosis unclear

Table 2 Articles Reporting Prevalence/Incidence of TMD Pain (n = 8)

Article	Study design	Study sample	Number of subjects (% females), age
Sale and Isberg[10]	Prospective case-control	WAD I-III Controls	59 (63%), 33 y 53 (58%), 36 y
Carroll et al[8]	Cohort prospective	Whiplash claimants Controls	7,452 (60%), 37 y 636
Visscher et al[61]	Case-control	Chronic WAD II Chronic neck pain Controls	25 15 25 Total: 65 (55%),40 y
Klobas et al[9]	Case-control	Chronic WAD II-III Controls	54 (60%), 37 y 66 (61%), 38 y
Ferrari et al[57]	Case-control	Whiplash Controls	165 (16%), 39 y 180 (13%), 39 y
Magnusson[60]	Case series	Chronic WAD	38 (66%), 33 y
Kronn[59]	Case-control	Whiplash Controls	40 (35%), 32 y 40 (35%), 33 y
Heise et al[58]	Case series	Whiplash	155 (62%), 38 y

*P values, odds ratio (OR), relative risk (RR), and confidence interval (CI) in bold for differences between whiplash groups and control groups.
Prev = prevalence; Inc = incidence; TMJ = temporomandibular joint.

Discussion

This systematic review has shown that there is evidence that the prevalence and incidence of TMD pain are higher in patients with WAD compared to control groups. In addition, data suggest a less favorable treatment outcome for this patient group compared to TMD pain patients without a history of neck injury.

There are variations in the terminology to describe pain in the jaw-face region following whip-

Outcome measure	Prevalence/ Incidence*	Quality score	Authors' conclusion	Comments
TMJ pain	Inc = 34% Inc = 7% **P = .009, OR 6.6 (95% CI 1.6–27.2)**	81%	1/3 is at risk for developing late TMJ pain after whiplash trauma	Questionnaire not validated. Outcome measure unclear; interview procedure unclear.
Reduced/ painful jaw movement	Prev = 17.4% Inc = 15.8% Inc = 4.7% **RR 3.36 (95% CI 2.36-4.78)**	67%	Reduced/painful jaw movement more common in WAD. Incidence associated with age < 50 y, female sex, dysphagia, and more intense neck pain	Whiplash diagnosis unclear. Controls were claimants without whiplash. Outcome measure unclear. At follow-up of those with jaw pain (44% response rate): 78% had recovered from jaw pain during first year.
TMD pain	Prev = 52% Prev = 27% Prev = 8% **P = .003**	60%	Prevalence of widespread pain and psychological distress in chronic WAD suggest that the TMD pain in these patients is part of a more widespread chronic pain disorder	WAD group only grade II. Age and sex distribution not given for the separate groups. Unclear how control group was recruited and how representative it is.
Pain on jaw movements	Prev = 30.2% Prev = 3.0% **P < .001**	70%	Higher prevalence of TMD in chronic WAD than in controls; this indicates that trauma to the neck also affects temporomandibular function	Inclusion and exclusion criteria unclear. Outcome measures unclear.
Jaw pain	Prev = 2.4% Prev = 3.3% **P = .86**	60%	Unlike in many Western societies, Lithuanian accident victims do not appear to report chronic symptoms of TMD despite their acute whiplash injuries	Questionnaire sent on average 27 months after accident (from police records). Methodological weaknesses, outcome measures not reliable. Skewed sex distribution.
TMJ pain and tenderness	Prev = 28.9%	45%	Many symptoms in late whiplash syndrome conform with the criteria of other specific diagnoses	Large group excluded (n = 64), outcome measure unclear. Diagnosis unclear. No control group.
TMJ pain	Prev = 30% Prev = 2.5% **P < .001**	45%	More TMJ dysfunction and demand for treatment after whiplash; findings suggest the benefit of examining the jaw in whiplash injured patients	Control group consists of patients with unclear diagnosis. Diagnosis and definition outcome measure unsure. Methodological weaknesses.
TMJ and masticatory muscle pain	Prev = 14% Inc = 4%	40%	Incidence of TMJ pain following whiplash injury is extremely low	Diagnoses and definition of outcome measure is unclear. Results unclear. No control group.

lash trauma and WAD. Thus, at the present time, a universally accepted term is not available. This is highlighted by the fact that in the present review, different terms were used for the outcome measures in the included studies, for example TMJ pain, jaw pain, and TMD pain. The terminology chosen for the present review was TMD pain, although this term could be viewed as being too limiting to describe the condition in focus.

Prevalence and Incidence of TMD Pain

The reported median prevalence and incidence of TMD pain were 23% and 10%, respectively, which provide some evidence that prevalence and incidence of TMD pain increase in WAD.

Generally, there were large differences in study populations, and some indications that TMD pain after a whiplash trauma may develop over time

Table 3 Intervention Studies (n = 4)

Article	Study design	Study sample	Number of subjects (% females), age	Drop-out	Type of intervention	Outcome measures
Klobas et al[62]	RCT	WAD II-III Tx group	55: 25 (72%), 38 y	20%	Jaw exercises + whiplash rehabilitation program	Pain on jaw movement
		Controls	30 (70%), 36 y	10%	Whiplash rehabilitation program only	
Burgess and Dworkin[48]	Treatment outcome study	TMD + whiplash	100 (80%), 33 y	N/A	Information, counselling, occlusal splint, medication physiotherapy, biofeedback, etc.	Pain intensity, SCL-90-R, global improvement, jaw opening
Romanelli et al[64]	Case-control	TMD + whiplash	52	N/A	Occlusal splint, medication, physiotherapy, massage, chiropractic, etc	Pain intensity, SCL-90-R, global improvement
		TMD	52	N/A		
Krogstad et al[63]	Case-control	TMD + whiplash	16 (75%), 42 y	N/A	Info, counseling, muscle exercises, occlusal splint	Pain intensity, SCL-90-R, STAI, muscle tenderness
		TMD	16 (75%), 42 y	N/A		

*P values (in bold) for differences between TMD + whiplash groups and TMD only groups.
RCT = randomized controlled trial; N/A = not applicable; SCL-90-R = Symptom Checklist-90 Revised; STAI = State-Trait Anxiety Inventory; Tx = treatment.

rather than being part of an acute syndrome. One of the included studies in acute whiplash patients[58] reported a very low incidence of TMD pain following acute whiplash injury, whereas five of the studies based on chronic WAD patient groups reported TMD pain in 30% to 50% of patients,[9,10,59–61] compared to less than 10% for the control groups.

In contrast, one study[57] reported a prevalence of jaw pain in both the "whiplash population" and the control group that was lower than the prevalence reported in the general population.[24,65] One explanation for this might be a participant selection bias for the study in question. The patient group, predominately men, was recruited based on police reports rather than a whiplash diagnosis,[57] and the design, methodology, and conclusions from this study have been criticized.[5] Most studies on TMD have reported a higher prevalence than incidence, whereas for the healthy control groups in the present review, the reported incidence was higher than the prevalence. This may be due to the fact that the studies reporting on incidence had a higher proportion of female subjects, which is in line with a higher incidence of TMD pain for women in the general population,[65] and with women being more at risk for developing pain following whiplash trauma.[66]

Generally for the reports included in this systematic review, studies did not use screening questions with a proven reliability and validity for the diagnosis of TMD. In 1992, new guidelines with the aim to improve the diagnosis of TMD, Research Diagnostic Criteria for TMD (RDC/TMD),[1] were introduced. This protocol is now widely used by clinicians and researchers, and the guidelines are being revised to increase the diagnostic accuracy in line with the STARD (Standards for Reporting of Diagnostic Accuracy) statement.[67]

Interventions

The few interventional studies found in this review indicated a limited treatment effect in patients with combined TMD pain and WAD. These results are in line with findings that the effectiveness of occlusal splints is dependent on whether or not the TMD pain is associated with widespread pain. Thus, a better treatment effect has been reported in patients with TMD pain localized to the facial region, compared to patients with facial and widespread pain.[68] Taken together, the limited effect from the treatment modalities conventionally used for TMD[69] supports the notion that TMD pain after whiplash trauma has a different pathophysiology compared to localized TMD pain.

Different explanatory models for the etiology of TMD pain after whiplash trauma have been suggested. An early model advocated that acceleration-deceleration of the head-neck induced overstretching or compression of the temporomandibular joint

Results*	Quality score	Authors' conclusion	Comments
No difference before/after treatment, or between groups	65%	Therapeutic jaw exercises did not reduce signs and symptoms of TMD in chronic WAD	Everyone had a rehabilitation program, including physical therapy.
Reduction of pain intensity about 60%; litigating subjects rated their overall improvement as significantly less (68% vs 91%)	45%	Litigation may affect pretreatment presentation and posttreatment status	No control group, unclear diagnosis, treatment outcomes unclear.
Reported improvement: 48% for TMD + whiplash, vs 75% for TMD ***P* < .001**	40%	Whiplash group had poorer outcome to therapy, which implied different pathophysiology	Age/sex of subjects not given. Unclear outcome measure and results, varying treatment.
Pain reduction in TMD + whiplash group 13% vs 51% in TMD group ***P* = .003**	65%	Conservative TMD treatment had a better effect for the TMD only group	Small sample. WAD group recruited from newspaper ad. Outcome measure unclear.

(TMJ), causing a "mandibular whiplash".[55] This concept was later refuted,[70] and instead an indirect mechanism was suggested.[71] Current research favor a neurobiological basis, indirectly supported by prospective studies showing that, although no structural damage to the TMJ was found after whiplash trauma, about a third of individuals developed TMJ pain after neck injury.[10] Furthermore, there is support, both in experimental[72–74] and clinical[75] studies, of overlapping spread and referral of muscle pain between the cervical and trigeminal regions. Recordings from single neurons in experimental animal settings have also shown convergence between trigeminal and cervical afferent inputs into the caudal part of the trigeminal sensory nucleus complex.[76–78] TMD pain in this patient group has been suggested to be part of a widespread pain syndrome.[61] Taken together, this suggests that the process of central sensitization and associated increased pain sensitivity may play a role in development of TMD pain after whiplash trauma.

Patients with pain after neck trauma may present a mixture of pain generators from both joints, ligaments, muscles, and nerves in the head and neck region that can affect the jaw system in different ways. In addition, this patient group presents with a range of other symptoms such as vertigo, and disturbances in memory, concentration, and sleep.[4,79,80] It has been reported that bruxism is associated with sleep disturbances such as obstructive sleep apnea, snoring, and leg movements (restless leg syndrome)[81]; one study reported that in 86% of cases, bruxism episodes were associated with an arousal response.[82] Thus, in WAD patients with sleep disturbances, a secondary effect on the jaw system may be caused by an increased load on the masticatory system from nighttime grinding. This is in line with the finding from the present review that some improvement in this patient group was seen with occlusal splint therapy.

This review used a scoring system modified from Macfarlane et al[24] that includes 21 items to evaluate study quality. The median scores for the epidemiologic and intervention studies were 60% and 55%, respectively. When this scoring system was used to evaluate epidemiologic studies of orofacial pain,[24] a median quality score of 70% was reported.

A notable finding was the considerable variation in the primary studies in study populations, methodology, and choice of outcome measures. There were also inconsistencies in the definition of the main outcome measure, TMD pain. Many of the primary studies were carried out before the introduction of the RDC/TMD criteria[1] for the diagnosis of TMD, and the IMMPACT recommendations for more patient-reported outcomes.[23] The intervention studies generally, due to study designs, only provided low-grade evidence. Hence, only one randomized controlled trial[62] was found in the literature search.

All these limitations taken together made it difficult to draw firm conclusions. More well-designed studies are needed that use the RDC/TMD criteria and IMMPACT guidelines when appropriate, and there is also a need for interventional studies, adhering to the CONSORT (Consolidated Standards of Reporting Trials) statement.[83,84]

There is a strong functional linkage between the jaw and craniocervical motor systems,[13] and an association has been shown between neck pain and dysfunction and deranged jaw function in chronic WAD.[85] The findings include disturbed jaw-neck motor function[14,15,86] as well as frequent jaw-face pain.[87] These findings may reflect spread of pain related to close sensorimotor linkage between the jaw and neck, as well as to lowered sensory and pain thresholds due to central sensitization. Taken together, these results have implications both for evaluating the pathophysiology of jaw-face pain in WAD, and for assessment and rehabilitation of these patients. Routine investigation of neck-injured patients should include the jaw-face region, which could provide a more individualized rehabilitation regimen. A multidisciplinary rehabilitation program including dentists should be advocated in patients with posttraumatic neck pain.

Conclusions

This review suggests that the prevalence and incidence of TMD pain are increased after whiplash trauma. The intervention studies indicated limited treatment effect in patients with combined TMD pain and neck pain after whiplash trauma. This poorer treatment outcome suggests that TMD pain after whiplash trauma has a different pathophysiology compared to localized TMD pain, and may be due to spread of pain and dysfunction between the neck and jaw regions, or be part of a regional or generalized pain syndrome caused by sensitization mechanisms. Since WAD is a heterogenous diagnosis, further studies on the relationship between TMD and WAD/posttraumatic neck pain should be designed to look for comorbidity between different possible pain generators, eg, facett-joints, global neck muscles, stabilizing, deep neck muscles, jaw muscles and joints, as well as the coordination of their functions. Furthermore, sensitization, psychological, and social factors have to be considered. There is a need for well-designed prospective studies to determine the incidence and possible risk indicators of TMD pain after whiplash trauma in order to provide better insights into the possible pathophysiological and cognitive mechanisms involved.

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References

1. Dworkin S, LeResche L. Research diagnostic criteria for temporomandibular disorders: Review, criteria, examinations and specifications, critique. J Craniomand Disord 1992;6: 301–355.
2. Björnstig U, Hildingsson C, Toolanen G. Soft-tissue injury of the neck in a hospital based material. Scand J Soc Med 1990;18:263–267.
3. Spitzer W, Skovron M, Salmi L, et al. Scientific monograph of the Quebec task force on whiplash-associated disorders: Redefining "whiplash" and its management. Spine 1995; 20(8 suppl):1S–73S.
4. Sterner Y, Gerdle B. Acute and chronic whiplash disorders—A review. J Rehabil Med 2004;36:193–209.
5. Freeman M, Croft A, Rossignol A, Weaver D, Reiser M. A review and methodological critique of the literature refuting whiplash syndrome. Spine 1999;24:86–96.
6. Treleaven J. Dizziness, unsteadiness, visual disturbances, and postural control: Implications for the transition to chronic symptoms after a whiplash trauma. Spine (Phila Pa 1976) 2011;36:S211–217.
7. Grönqvist J, Häggman-Henrikson B, Eriksson PO. Impaired jaw function and eating difficulties in whiplash-associated disorders. Swed Dent J 2008;32:171–177.
8. Carroll LJ, Ferrari R, Cassidy JD. Reduced or painful jaw movements after collision-related injuiries: A population-based study. J Am Dent Assoc 2007;138:86–93.
9. Klobas L, Tegelberg A, Axelsson S. Symptoms and signs of temporomandibular disorders in individuals with chronic whiplash-associated disorders. Swed Dent J 2004;28:29–36.
10. Sale H, Isberg A. Delayed temporomandibular joint pain and dysfunction induced by whiplash trauma: A controlled prospective study. J Am Dent Assoc 2007;138:1084–1091.
11. Kasch H, Hjorth T, Svensson P, Nyhuus L, Jensen T. Temporomandibular disorders after whiplash injury: A controlled prospective study. J Orofac Pain 2002;16:118–128.
12. Severinsson Y, Bunketorp O, Wenneberg B. Jaw symptoms and signs and the connection to cranial cervical symptoms and post-traumatic stress during the first year after a whiplash trauma. Disabil Rehabil 2010;32:1987–1998.
13. Eriksson PO, Häggman-Henrikson B, Nordh E, Zafar H. Co-ordinated mandibular and head-neck movements during rhythmic jaw activities in man. J Dent Res 2000;79: 1378–1384.
14. Eriksson PO, Zafar H, Häggman-Henrikson B. Deranged jaw-neck motor control in whiplash-associated disorders. Eur J Oral Sci 2004;112:25–32.
15. Häggman-Henrikson B, Zafar H, Eriksson PO. Disturbed jaw behavior in whiplash-associated disorders during rhythmic jaw movements. J Dent Res 2002;81:747–751.
16. Häggman-Henrikson B, Österlund C, Eriksson PO. Endurance during chewing in whiplash-associated disorders and TMD. J Dent Res 2004;83:946–950.
17. Clark G, Green E, Dorman M, Flack V. Craniocervical dysfunction levels in a patient sample from a temporomandibular joint clinic. J Am Dent Assoc 1987;115:251–256.
18. De Wijer A, Steenks M, De Leeuw J, Bosman F, Helders P. Symptoms of the cervical spine in temporomandibular and cervical spine disorders. J Oral Rehabil 1996;23:742–750.

19. Visscher C, Lobbezoo F, de Boer W, van der Zaag J, Naeije M. Prevalence of cervical spinal pain in craniomandibular pain patients. Eur J Oral Sci 2001;109:76–80.
20. Wiesinger B, Malker H, Englund E, Wänman A. Back pain in relation to musculoskeletal disorders in the jaw-face: A matched case-control study. Pain 2007;131:311–319.
21. Ciancaglini R, Testa M, Radaelli G. Association of neck pain with symptoms of temporomandibular dysfunction in the general adult population. Scand J Rehabil Med 1999; 31:17–22.
22. De Wijer A, Steenks M, Bosman F, Helders P. Symptoms of the stomatognathic system in temporomandibular and cervical spine disorders. J Oral Rehabil 1996;23:733–741.
23. Turk DC, Dworkin RH, Burke LB, et al. Developing patient-reported outcome measures for pain clinical trials: IMMPACT recommendations. Pain 2006;125:208–215.
24. Macfarlane TV, Glenny AM, Worthington HV. Systematic review of population-based epidemiological studies of orofacial pain. J Dent 2001;29:451–467.
25. Sale H, Hedman L, Isberg A. Accuracy of patients' recall of temporomandibular joint pain and dysfunction after experiencing whiplash trauma: A prospective study. J Am Dent Assoc 2010;141:879–886.
26. Kim HI, Lee JY, Kim YK, Kho HS. Clinical and psychological characteristics of TMD patients with trauma history. Oral Dis 2010;16:188–192.
27. Hulse M, Losert-Bruggner B. Temporomandibular joint dysfunction. A consequence of whiplash-injury [in German]. HNO 2008;56:1114–1121.
28. Grushka M, Ching VW, Epstein JB, Gorsky M. Radiographic and clinical features of temporomandibular dysfunction in patients following indirect trauma: A retrospective study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:772–780.
29. Ferrari R, Russell AS, Carroll LJ, Cassidy JD. A re-examination of the whiplash associated disorders (WAD) as a systemic illness. Ann Rheum Dis 2005;64:1337–1342.
30. Abd-Ul-Salam H, Kryshtalskyj B, Weinberg S. Temporomandibular joint arthroscopic findings in patients with cervical flexion-extension injury (whiplash): A preliminary study of 30 patients. J Can Dent Assoc 2002;68:693–696.
31. Kasch H, Hjorth T, Svensson P, Nyhuus L, Jensen TS. Temporomandibular disorders after whiplash injury: A controlled, prospective study. J Orofac Pain 2002;16:118–128.
32. Kasch H, Stengaard-Pedersen K, Arendt-Nielsen L, Staehelin Jensen T. Pain thresholds and tenderness in neck and head following acute whiplash injury: A prospective study. Cephalalgia 2001;21:189–197.
33. Friedman MH, Weisberg J. The craniocervical connection: A retrospective analysis of 300 whiplash patients with cervical and temporomandibular disorders. Cranio 2000;18: 163–167.
34. Kolbinson DA, Epstein JB, Senthilselvan A, Burgess JA. Effect of impact and injury characteristics on post-motor vehicle accident temporomandibular disorders. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1998;85:665–673.
35. Bergman H, Andersson F, Isberg A. Incidence of temporomandibular joint changes after whiplash trauma: A prospective study using MR imaging. AJR Am J Roentgenol 1998; 171:1237–1243.
36. Kolbinson DA, Epstein JB, Senthilselvan A, Burgess JA. A comparison of TMD patients with or without prior motor vehicle accident involvement: Treatment and outcomes. J Orofac Pain 1997;11:337–345.
37. Kolbinson DA, Epstein JB, Senthilselvan A, Burgess JA. A comparison of TMD patients with or without prior motor vehicle accident involvement: Initial signs, symptoms, and diagnostic characteristics. J Orofac Pain 1997;11:206–214.
38. Kolbinson DA, Epstein JB, Burgess JA, Senthilselvan A. Temporomandibular disorders, headaches, and neck pain after motor vehicle accidents: A pilot investigation of persistence and litigation effects. J Prosthet Dent 1997;77:46–53.
39. Khan H, McCormack D, Burke J, McManus F. Incidental neck symptoms in high energy trauma victims. Ir Med J 1997;90:143.
40. Greco CM, Rudy TE, Turk DC, Herlich A, Zaki HH. Traumatic onset of temporomandibular disorders: Positive effects of a standardized conservative treatment program. Clin J Pain 1997;13:337–347.
41. Garcia RJ, Arrington J. The relationship between cervical whiplash and temporomandibular joint injuries: An MRI study. Cranio 1996;14:233–239.
42. Burgess JA, Kolbinson DA, Lee PT, Epstein JB. Motor vehicle accidents and TMDS: Assessing the relationship. J Am Dent Assoc 1996;127:1767–1772; quiz 1785.
43. Goldberg M, Mock D, Ichise M, et al. Neuropsychologic deficits and clinical features of posttraumatic temporomandibular disorders. J Orofac Pain 1996;10:126–140.
44. De Boever J, Keersmaekers K. Trauma in patients with temporomandibular disorders: Frequency and treatment outcome. J Oral Rehabil 1996;23:91–96.
45. Seligman DA, Pullinger AG. A multiple stepwise logistic regression analysis of trauma history and 16 other history and dental cofactors in females with temporomandibular disorders. J Orofac Pain 1996;10:351–361.
46. Steigerwald DP, Verne SV, 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.
47. Probert TC, Wiesenfeld D, Reade PC. Temporomandibular pain dysfunction disorder resulting from road traffic accidents—An Australian study. Int J Oral Maxillofac Surg 1994;23:338–341.
48. Burgess JA, Dworkin SF. Litigation and post-traumatic TMD: How patients report treatment outcome. J Am Dent Assoc 1993;124:105–110.
49. Braun B, DiGiovanna A, Schiffman E, Bonnema J, Fricton J. A cross-sectional study of temporomandibular joint dysfunction in post-cervical trauma patients. J Craniomandib Disord 1992;6:24–31.
50. Pressman BD, Shellock FG, Schames J, Schames M. MR imaging of temporomandibular joint abnormalities associated with cervical hyperextension/hyperflexion (whiplash) injuries. J Magn Reson Imaging 1992;2:569–574.
51. Uppgaard RO. Conservative and successful treatment of temporomandibular dysfunction in a private rural practice. Cranio 1992;10:235–240.
52. Burgess J. Symptom characteristics in TMD patients reporting blunt trauma and/or whiplash injury. J Craniomandib Disord 1991;5:251–257.
53. Pullinger AG, Seligman DA. Trauma history in diagnostic groups of temporomandibular disorders. Oral Surg Oral Med Oral Pathol 1991;71:529–534.
54. Pullinger AG, Monteiro AA. History factors associated with symptoms of temporomandibular disorders. J Oral Rehabil 1988;15:117–124.
55. Weinberg S, Lapointe H. Cervical extension-flexion injury (whiplash) and internal derangement of the temporomandibular joint. J Oral Maxillofac Surg 1987;45:653–656.

56. Brooke R, Stenn P. Postinjury myofascial pain dysfunction: Its etiology and prognosis. Oral Surg Oral Med Oral Pathol 1978;45:846–850.
57. Ferrari R, Schrader H, Obelieniene D. Prevalence of temporomandibular disorders associated with whiplash injury in Lithuania. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1999;87:653–657.
58. Heise A, Laskin D, Gervin A. Incidence of temporomandibular joint symptoms following whiplash injury. J Oral Maxillofac Surg 1992;50:825–828.
59. Kronn E. The incidence of TMJ dysfunction in patients who have suffered a cervical whiplash injury following a traffic accident. J Orofac Pain 1993;7:209–213.
60. Magnusson T. Extracervical symptoms after whiplash trauma. Cephalalgia 1994;14:223–227.
61. Visscher C, Hofman N, Mes C, Lousberg R, Naeije M. Is temporomandibular pain in chronic whiplash-associated disorders part of a more widespread pain syndrome? Clin J Pain 2005;21:353–357.
62. Klobas L, Axelsson S, Tegelberg A. Effect of therapeutic jaw exercise on temporomandibular disorders in individuals with chronic whiplash-associated disorders. Acta Odontol Scand 2006;64:341–347.
63. Krogstad BS, Jokstad A, Dahl BL, Soboleva U. Somatic complaints, psychologic distress, and treatment outcome in two groups of TMD patients, one previously subjected to whiplash injury. J Orofac Pain 1998;12:136–144.
64. Romanelli G, Mock D, Tenenbaum H. Characteristics and response to treatment of posttraumatic temporomandibular disorder: A retrospective study. Clin J Pain 1992;8:6–17.
65. Drangsholt M. Temporomandibular pain. In: Crombie IK, Croft PR, Linton SJ, LeResche L, Von Korff M (eds). Epidemiology of Pain. Seattle, Washington: IASP Press, 1999: 203–233.
66. Walton DM, Pretty J, MacDermid JC, Teasell RW. Risk factors for persistent problems following whiplash injury: Results of a systematic review and meta-analysis. J Orthop Sports Phys Ther 2009;39:334–350.
67. Bossuyt PM, Reitsma JB, Bruns DE, et al. The STARD statement for reporting studies of diagnostic accuracy: Explanation and elaboration. Clin Chem 2003;49:7–18.
68. Raphael KG, Marbach JJ. Widespread pain and the effectiveness of oral splints in myofascial face pain. J Am Dent Assoc 2001;132:305–316.
69. List T, Axelsson S. Management of TMD: Evidence from systematic reviews and meta-analyses. J Oral Rehabil 2010;37: 430–451.
70. Howard RP, Bowles AP, Guzman HM, Krenrich SW. Head, neck, and mandible dynamics generated by 'whiplash'. Accid Anal Prev 1998;30:525–534.
71. Lader E. Cervical trauma as a factor in the development of TMJ dysfunction and facial pain. J Craniomandib Pract 1983;1:85–90.
72. Hellström F, Thunberg J, Bergenheim M, Sjölander P, Pedersen J, Johansson H. Elevated intramuscular concentration of bradykinin in jaw muscle increases the fusimotor drive to neck muscles in the cat. J Dent Res 2000;79:1815–1822.
73. Schmidt-Hansen PT, Svensson P, Jensen TS, Graven-Nielsen T, Bach FW. Patterns of experimentally induced pain in pericranial muscles. Cephalalgia 2006;26:568–577.
74. Svensson P, Wang K, Sessle B, Arendt-Nielsen L. Associations between pain and neuromuscular activity in the human jaw and neck muscles. Pain 2004;109:225–232.
75. Wiesinger B, Malker H, Englund E, Wanman A. Does a dose-response relation exist between spinal pain and temporomandibular disorders? BMC Musculoskelet Disord 2009;10:28.
76. Sessle BJ, Hu JW, Amano N, Zhong G. Convergence of cutaneous, tooth pulp, visceral, neck and muscle afferents onto nociceptive and non-nociceptive neurones in trigeminal subnucleus caudalis (medullary dorsal horn) and its implications for referred pain. Pain 1986;27:219–235.
77. Mørch CD, Hu JW, Arendt-Nielsen L, Sessle BJ. Convergence of cutaneous, musculoskeletal, dural and visceral afferents onto nociceptive neurons in the first cervical dorsal horn. Eur J Neurosci 2007;26:142–154.
78. Vernon H, Sun K, Zhang Y, Yu XM, Sessle BJ. Central sensitization induced in trigeminal and upper cervical dorsal horn neurons by noxious stimulation of deep cervical paraspinal tissues in rats with minimal surgical trauma. J Manipulative Physiol Ther 2009;32:506–514.
79. Guez M, Brännstrom R, Nyberg L, Toolanen G, Hildingsson C. Neuropsychological functioning and MMPI-2 profiles in chronic neck pain: A comparison of whiplash and non-traumatic groups. J Clin Exp Neuropsychol 2005;27:151–163.
80. Stålnacke BM. Relationship between symptoms and psychological factors five years after whiplash injury. J Rehabil Med 2009;41:353–359.
81. Ohayon MM, Li KK, Guilleminault C. Risk factors for sleep bruxism in the general population. Chest 2001;119:53–61.
82. Macaluso GM, Guerra P, Di Giovanni G, Boselli M, Parrino L, Terzano MG. Sleep bruxism is a disorder related to periodic arousals during sleep. J Dent Res 1998;77:565–573.
83. Goldsmith CH, Gross AR, MacDermid J, Santaguida PL, Miller J. What does the evidence tell us about design of future treatment trials for whiplash-associated disorders? Spine (Phila Pa 1976) 2011;36:S292–302.
84. Moher D, Schulz KF, Altman D. The CONSORT statement: Revised recommendations for improving the quality of reports of parallel-group randomized trials. JAMA 2001; 285:1987–1991.
85. Eriksson P-O, Häggman-Henrikson B, Hamayun Z. Jaw-neck dysfunction in whiplash-associated disorders. Arch Oral Biol 2007;52:404–408.
86. Zafar H, Nordh E, Eriksson P-O. Impaired positioning of the gape in whiplash-associated disorders. Swed Dent J 2006;30:9–15.
87. Häggman-Henrikson B, Gronqvist J, Eriksson PO. Frequent jaw-face pain in chronic whiplash-associated disorders. Swed Dent J 2011;35:123–131.