# Neuropsychologic Deficits and Clinical Features of Posttraumatic Temporomandibular Disorders

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*Previous studies have shown that characteristics of posttraumatic temporomandibular disorders (pTMD) differ considerably from those of nontraumatic or idiopathic temporomandibular disorders (iTMD). Both the rate of recovery and the amount of treatment required appear to be different for both groups. In this blinded study, 14 patients with iTMD and 13 patients with pTMD were examined. Patients submitted to a variety of reaction-time tests and neuropsychologic assessments to test their ability to cope with simple and more complex tasks with and without a variety of cognitive interferences. Clinical examination was used to assess signs of TMD. Eleven of the subjects (six iTMD, five pTMD) consented to a second phase of the investigation, whereby the patients were studied with single-photon emission computerized tomography (SPECT) using $^{99m}$Tc-hexamethylpropyleneamineoxime (HMPAO). For simple and complex reaction-time tests, the pTMD group was significantly slower than the iTMD group ($P < .05$ to $P < .001$). Other neuropsychologic assessment tools such as the Consonant Trigram Test and the California Verbal Learning Test indicated that pTMD patients were more affected by both proactive and retroactive interferences and were more likely to perseverate on a single thought. In clinical examination, pTMD patients demonstrated greater reaction to muscle palpation than did iTMD patients ($P < .05$). The SPECT results suggested that there were mild differences between the two populations, and further studies are required to confirm this finding. The results lend support to the concept that there are differences between pTMD and iTMD populations. It is suggested that although patients with pTMD may have some similarities to those with iTMD, the former population may benefit from being handled somewhat differently and should be assessed and treated using a more broad, multidisciplinary treatment paradigm. These results must be confirmed in studies of larger populations.*

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Chronic orofacial pain constitutes one of the most perplexing problems facing medical and dental practitioners today, and the costs to society have been estimated to be in the hundreds of millions of dollars.[1] There is evidence that temporomandibular disorders (TMD) comprises a large portion of orofacial pain conditions, and thus it is essential that TMD be understood more clearly.[2] In this regard, the study of a disease process may be facilitated when there is more than one presentation of that disease; with this in mind, it might be possible to delineate differences

between two similar yet distinct entities, thereby gaining further insight into the overall disorder. Previous investigations have focused on two important presentations of the TMD:

1. Those initially arising following a motor vehicle accident (MVA) related to an acceleration/deceleration injury (eg, cervical whiplash) (ie, posttraumatic TMD [pTMD])
2. Those that seem to arise spontaneously (ie, idiopathic TMD [iTMD])

These previous studies indicated that patients suffering from pTMD were refractory to treatment and suffered from a higher degree of symptoms suggestive of affective disorder (ie, no diagnosis of affective disorder had been made) in comparison to patients with iTMD.[3,4] This may provide some explanation as to why patients suffering from pTMD often require additional and varied treatment[5–7] and appear to be more refractory to therapy than those with iTMD.[4] Alternatively, the musculoligamentous signs or symptoms of pTMD may be more profound than those observed for iTMD.

Notably, symptoms of affective disorder include sleep disturbance, decreased energy level, mood swings, and problems with cognitive functions such as memory and concentration.[4,8] However, these symptoms are not solely indicative of affective disorder and can also be identified with a variety of conditions including depressive illness, postconcussion syndrome (with or without demonstrable brain damage), posttraumatic stress disorder, or some combination thereof.[9]

Because the prevalence of overt symptoms suggestive of an affective disorder in patients with pTMD is high (60%), and since these patients often respond poorly to standard treatment, it is possible that the affective disorder may have a negative impact on treatment outcome.[4] Thus, it is suggested that it might be beneficial if affective disorders in patients with pTMD (or iTMD) were characterized more precisely and if its suspected presence were confirmed by the use of appropriate testing procedures.

In view of the above, this study was undertaken to investigate if iTMD and pTMD are different on the basis of clinical, psychologic, and neuropsychologic parameters. Moreover, because there is evidence that some neuropsychologic deficits may be associated with microorganic brain damage,[10] $^{99m}$technetium-labeled hexamethylpropyleneamineoxime single-photon emission computerized tomography ($^{99m}$Tc-HMPAO SPECT) was used to assess brain abnormalities in the two populations.

## Materials and Methods

### Inclusion Criteria

Participants for this study were selected from those referred for treatment of TMD at the Craniofacial Pain Unit, Mount Sinai Hospital, Toronto, or the Facial Pain Clinic, University of Toronto, Faculty of Dentistry. The inclusion criteria for this study consisted of patients with the following:

1. Primary complaint of facial pain related to suspected TMD, with symptoms present for at least 6 months. The diagnosis of TMD was based on signs and symptoms observed on evaluation (HT and DM) and conforming to criteria outlined elsewhere.[11–13] These may include tenderness to palpation of the muscles of mastication and/or the temporomandibular joint (TMJ), and/or limitation in normal mandibular movement.
2. Patients aged 18 to 65 years.
3. Women only, to ensure greater homogeneity within the population groups.
4. Presence/absence of an MVA (causing a cervical whiplash-type injury) as the proposed predisposing factor leading to the presentation of TMD symptoms, and confirmation that there was no history of pre-existing TMD in the posttraumatic population.

### Exclusion Criteria

Subjects were excluded from consideration within the study population if any of the following criteria were present:

1. Presence of osteoarthritis, osteoarthrosis.[13]
2. Presence of a previously diagnosed psychiatric disorder (ie, depression).
3. Presence of abnormal neurologic examination (AG and MS).
4. Patients with any type of metabolic, neoplastic, or vascular disorder (including migraine headache).
5. Patients currently on any type of medication or receiving treatment for the facial pain complaint (ie, tricyclic antidepressant, benzodiazepine, morphine derivatives).

Regarding criteria specifically directed at subjects who had been in MVAs, subjects were excluded if:

1. The subject suffered loss of consciousness as a result of the MVA.
2. The subject had symptoms of facial pain that predated the MVA.

### Study Population

From all new patients interviewed from June 1992 to January 1994 (approximately 1,500 patients), 27 patients were found to meet the above criteria and agree to participate in the study. The iTMD population consisted of 14 participants (mean age 29.9 ± 8.8 years, range 18 to 52), while the pTMD population had 13 participants (mean age 38.6 ± 9.5 years, range 28 to 54). Although the pTMD group was older than the iTMD population, significant differences in neuropsychologic test results (specifically, reaction-time tests) are not observed in groups younger than 60 years of age.[14] Within the pTMD population, 85% had completed high school; 93% of the iTMD population had done the same. The duration of symptoms varied in the pTMD group, from 13 to 82 months. The iTMD population presented with chronic complaints lasting a minimum of 9 months. Therefore, both populations may be considered chronic pain populations.[15]

### Blinding

In all cases, the role of the MVA as a probable precipitating factor of the patient's TMD was not disclosed to the examiner (MG), and the patients were told not to divulge any information regarding history of an MVA or lack of any. The blinded examiner did not ask any questions that might have induced the patient to give such information, and all data were analyzed in a coded fashion. If a patient would have indicated to the examiner that she was or was not involved in an MVA, the subject would have been excluded from the study. None of the patients were excluded from the study for such a reason.

### Neuropsychologic Tests

It has been reported that general screening tests using asymptomatic populations as comparisons can be used to gauge a patient's actual performance against an expected performance. Yet, no one set of tests holds an advantage over any other test under all circumstances.[16] Therefore, the tests chosen for this study were based on the authors' experience in the treatment of posttraumatic patient populations, and, as indicated above, all subjects entered into this study were given a battery of neuropsychologic tests as described below.

**Simple and Complex Multiple-Choice Reaction-Time Tests.** Individuals who have suffered from a head injury (mild or otherwise) may develop difficulties with information processing as based on increased reaction times to specific signals.[17] These deficiencies can be exaggerated when the required response to a given signal is complicated by a more complex signal.[14,17,18] Therefore, computer-based reaction-time tests that have been utilized previously for patients with mild traumatic brain injury were administered to both study populations. Reaction to a simple stimulus (simple reaction-time test [SRT]) was recorded in both the iTMD and pTMD study groups. Task complexity was increased by providing the subjects with a variety of shapes defined as either *target* or *nontarget* stimuli (easy multiple-choice reaction-time test [EMCRT]). Color and internal structure were also added to increase the complexity of the task further (complex multiple-choice reaction-time test [CMCRT]). Earlier investigations have also suggested that subjects with information processing difficulties may tend to fatigue more readily when performing such tests.[17] This was addressed by adding a second SRT at the end of the entire testing process. The majority of subjects consented to performing all facets of reaction-time testing, (10 of 13 pTMD and 13 of 14 iTMD subjects). Those that did not consent still agreed to participate in other aspects of this investigation.

**California Verbal Learning Test.** A primary deficit in encoding verbal information, as well as transferring the information to short- and long-term memory, has been observed in the head-injured population.[19] The California Verbal Learning Test (CVLT)[20] is a 16-item, four-category shopping list that can be used to test a subject's immediate recall (memory). It is designed to provide data on how learning tasks are performed, as well as the strategies used by the individual to achieve these goals. Therefore, variables such as semantic clustering, perseveration, intrusions, and interference to short-term and long-term recall were tested.[21]

**Peterson-Peterson Consonant Trigram Test.** Because there may be alterations in various aspects of memory in head-injured patients, subjects were also given the Peterson-Peterson Consonant Trigram Test, which evaluated memory under interference.[22] The subjects were asked to repeat three consonants presented after being challenged with a continuous mathematical subtraction problem for 3, 9, or 18 seconds. The total number of correct consonants repeated were scored, regardless of their order.

**Symptom Checklist–90 Revised.** To investigate the nature of psychological disturbance or distress, the Symptom Checklist–90 Revised (SCL-90R) test

was administered. This is a 90-item, self-report symptom inventory developed by Derogatis and Cleary,[23] and it identifies the presence of psychologic symptoms experienced by subjects during the 7 days prior to administration of the test. Each question is rated on a five-point scale of distress (eg, 0 = no distress, 4 = extreme distress) and includes nine primary symptom scales (somatization, obsessive-compulsive, interpersonal sensitivity, depression, anxiety, hostility, phobic-anxiety, paranoid ideation, psychoticism) and three global indexes (general severity index, positive symptom distress index, and positive symptom total). Scores are expressed in terms of a *t* score, with a mean of 50. Because there is evidence that virtually all patients with chronic pain will have high scores with the SCL-90R,[24] it was thought that in its usual form, this test might not add much useful information with respect to differentiation between the iTMD and pTMD patients, since both are chronic pain populations. Therefore, a revised form of this instrument focusing on the head-injured population was utilized as well.[25]

To compare the results of this study with previous data[4] regarding affective symptoms associated with chronic pain in a pTMD population, the depression scale of the SCL-90R was used to determine the prevalence of clinically significant depression. The SCL-90R depression scale has been shown to have a sensitivity of 67% and a specificity of 72% in a heterogeneous population survey.[26] Comparisons were based on both the raw scores of the depression questions and the number of patients in each population suffering from frank depression on the basis of derived scores (ie, prevalence).

### Clinical Examination

To determine whether there might be differences in the musculoligamentous components and other clinical aspects of iTMD and pTMD in addition to the putative neuropsychologic differences, subjects entering this investigation underwent complete extraoral and intraoral clinical examinations. The extraoral examination included palpation of the masseter, temporalis, and sternocleidomastoid muscles, as well as palpation and auscultation of the TMJ itself by one examiner (MG). Intraoral examination included a complete dental examination to rule out pain from dentoalveolar etiology. In addition, the medial pterygoid muscle, the lateral pterygoid muscle (or region), and the insertion of the temporalis muscle at the coronoid process were palpated. All scores assigned were based on the patients' responses when the sites were palpated (ie, evoked pain reaction). A scale of 0 to III was developed (0 meaning no pain response). A grade I pain response was considered a mild observance that discomfort was present in that the patient had to be asked whether pain was felt. A grade of II was assigned when changes in facial expression connoting a pain reaction (or verbal pain reaction) were produced (ie, the patient did not have to be asked). A grade of III was scored when definite avoidance to palpation was observed or when normal palpation force was abated before the patient reacted too violently. For analytical purposes, scores were concatenated into two groups: grade 0-I was considered as a negative pain reaction score; and grade II-III was considered as a positive pain reaction score.

In addition to TMJ and muscle palpation, a measure of the maximum interincisal opening for each patient was determined in millimeters, and the data were divided into two groups (less than 35 mm, and greater than or equal to 35 mm). Joint translation was assessed by manual or bidigital palpation.[27]

### Brain SPECT Scanning

Subtle changes in blood flow to various parts of the brain are detectable with the aid of $^{99m}$Tc-HMPAO SPECT and have been observed in individuals with mild traumatic brain injury.[10] Although the pTMD population in the present study did not have any overt signs of brain injury, their potential similarity to a brain-injured population indicated that it might be interesting to compare this parameter between the iTMD and pTMD patients. An intravenous injection of a small amount of radioactive tracer $^{99m}$Tc-HMPAO in a 5-mL saline solution was administered after 500 mg of sodium perchlorate had been given orally. Central perfusion of the radiotracer was assessed within 5 minutes of injection with the use of a rotating (360-degree) gamma detector for a 20-minute period.[28] Six iTMD and five pTMD subjects participated in this test comparison. The others refused to take part in this aspect of the study for various reasons.

### Statistical Analysis

Although the psychologic tests used may be appropriate for assessment of psychologic distress or frank neuropsychologic deficit, another goal of this study was to determine whether such tests could be used to differentiate between iTMD and

pTMD patient populations. To accomplish this, cut-off scores were assigned for each test (see Results). The cut-off scores were developed in a post hoc manner following preliminary analysis of data, indicating the likely points above or below that the respective groups (ie, iTMD or pTMD) might fall. In this way, it would be possible in some cases to further differentiate between the two populations. The statistical differences in the mean scores for each test group were determined with Student's *t* test (eg, reaction-time tests, SCL-90R, Consonant Trigram Test, Verbal Learning Tests). Fisher's Exact test was used to examine two-by-two comparisons in tests for SPECT scans, in evoked pain, and in tests where the cut-off scores were applied. Statistical significance was assigned at the $P < .05$ level.

## Results

Test outcomes for the two TMD populations were considerably different from one another as outlined below and could be used to differentiate between patients with iTMD and those with pTMD.

### Neuropsychologic Tests

**Simple and Complex Multiple-Choice Reaction-Time Tests.** Reactions to simple stimuli were significantly slower (35% to 45%) in the pTMD population than in the iTMD population when tests were performed either at the outset or at the end of the testing process (*t* test, $P < .05$ for test 1, and $P < .001$ for test 2) (Fig 1). This finding was replicated as tasks became more complex or more choices were required of the subjects. Both EMCRT and CMCRT data indicated that the reaction times for both target and nontarget stimuli were higher in the pTMD group (*t* test, $P < .005$ for both tests) (Figs 2 and 3). There was no statistically significant difference in error commission by the pTMD group as compared to the iTMD patients (Table 1).

Notably, reaction times obtained in the first and second tests of the iTMD group were virtually unchanged. However, in the pTMD group, reaction times increased (*t* test, $P < .05$) in the second test as compared to the first test, which might suggest fatigue.

When cut-off scores of 500 milliseconds (EMCRT) and 600 milliseconds (CMCRT) were used, group differentiation was also noted. Eight pTMD subjects and two iTMD subjects had EMCRT scores of greater than 500 milliseconds; two pTMD subjects and 11 iTMD subjects had EMCRT scores less than or equal to 500 milliseconds (Fisher's Exact test, $P < .01$). Nine pTMD subjects and two iTMD subjects had CMCRT scores of greater than 600 milliseconds; one pTMD subject and 11 iTMD subjects had CMCRT scores less than or equal to 600 milliseconds (Fisher's Exact test, $P < .001$).

**California Verbal Learning Test.** Comparison of iTMD and pTMD responses during the learning sessions (immediate recall) are illustrated in Fig 4. Immediate recall of the shopping list was significantly better (*t* test, $P < .05$) in the iTMD group. Information processing as demonstrated by clustering of similar items was similar in both groups, and there was no statistically significant difference in the level of intrusion of new words into the list. When interference posed by a different 16-item, four-group shopping list was given, there was no difference in recall ability (ie, better short-term memory). Similarly, after a 20-minute delay (long-

**Table 1** Results of Reaction-Time Test for pTMD and iTMD Patients (Mean Times in Milliseconds ± SE)

| Reaction time tests | pTMD (n = 10) | iTMD (n = 13) | Significance |
|---|---|---|---|
| First simple reaction-time test (SRT1) | 413.55 ± 29.61† | 304.13 ± 7.31* | $P < .05$ |
| Second simple reaction-time test (SRT2) | 470.92 ± 31.84† | 322.80 ± 10.1* | $P < .001$ |
| Easy multiple-choice reaction-time test (EMCRT) | | | |
| Target correct | 649.39 ± 48.98 | 486.48 ± 19.33 | $P < .05$ |
| Nontarget correct | 639.32 ± 51.04 | 456.98 ± 16.41 | $P < .05$ |
| No. of errors | 4.3 ± 0.86 | 4.2 ± 0.56 | NS |
| Complex multiple-choice reaction-time test (CMCRT) | | | |
| Target correct | 833.64 ± 50.41 | 608.88 ± 45.58 | $P < .05$ |
| Nontarget correct | 740.86 ± 51.55 | 529.86 ± 25.02 | $P < .05$ |
| No. of errors | 12.1 ± 2.02 | 7.1 ± 0.88 | NS |

*Comparison of SRT1 and SRT2 times indicates no statistically significant difference for the iTMD population.
†Comparison of SRT1 and SRT2 times indicates a statistically significant difference at $P < .05$ for pTMD population.

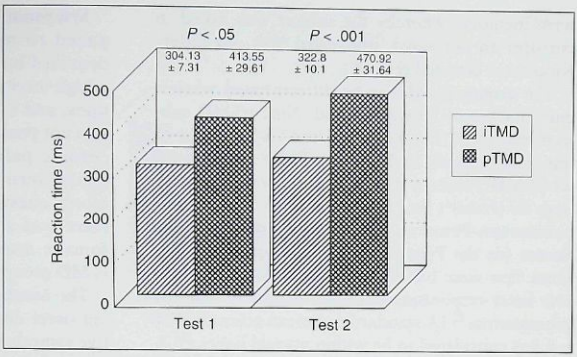


Fig 1 Reaction time to simple stimulus in milliseconds ± SE of 13 iTMD (control) subjects and 10 pTMD (MVA) subjects. Statistical significance determined by Student's *t* test.

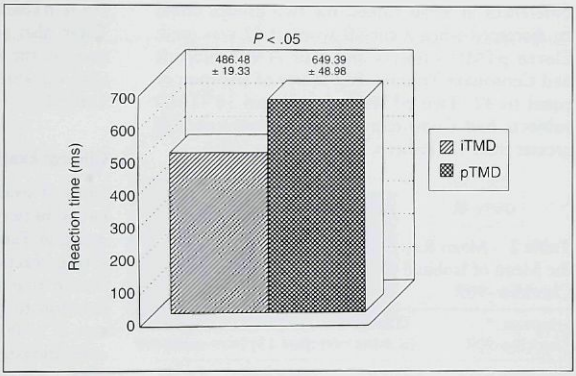


Fig 2 Reaction time to easy multiple-choice reaction-time stimulus (target stimuli only) in milliseconds ± SE of 13 iTMD (control) subjects and 10 pTMD (MVA) subjects. Statistical significance determined by Student's *t* test.

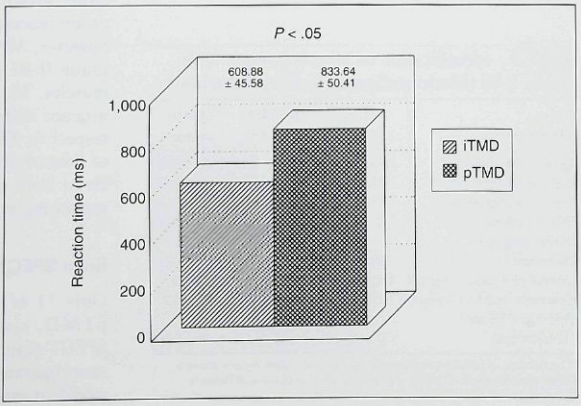


Fig 3 Reaction time to complex multiple-choice reaction-time stimulus (target stimuli only) in milliseconds ± SE of 13 iTMD (control) subjects and 10 pTMD (MVA) subjects. Statistical significance determined by Student's *t* test.

term memory) whereby the subject was asked to perform an unrelated, nonverbal task, no differences were detected (Fig 5).

The groups could also be differentiated when a cut-off score of 50 was utilized. Nine pTMD subjects and three iTMD subjects had CVLT scores of less than or equal to 50; four pTMD subjects and 11 iTMD subjects had CVLT scores of greater than 50 (Fisher's Exact test, $P < .05$).

**Peterson-Peterson Consonant Trigram Test.** Scores for the Peterson-Peterson Consonant Trigram Test were based on the total number of correct letter responses, regardless of initial order of presentation.[22] (A standardized mean score of 47.9 ± 4.9 is considered to be within normal limits.[29]) A mean score of 46.8 ± 2.04 was demonstrated in the iTMD group, while the pTMD group scored only 37.0 ± 1.25 ($P < .001$) (Fig 6). In addition to differences in mean values, the two groups could be discerned when a cut-off score of 42 was used. Eleven pTMD subjects and four iTMD subjects had Consonant Trigram Test scores of less than or equal to 42. Two pTMD subjects and 10 iTMD subjects had Consonant Trigram Test scores of greater than 42 (Fisher's Exact test, $P < .05$).

**Table 2** Mean Raw Scores ± Standard Errors of the Mean of Isolated Questions From Symptom Checklist–90R

| Symptom Checklist–90R | iTMD (n = 14) | pTMD (n = 13) | Significance |
|---|---|---|---|
| Head injury score | 1.23 ± 0.17 | 2.02 ± 0.30 | $P < .05$ |
| Depression score | 1.38 ± 0.43 | 1.00 ± 0.24 | NS |

**Table 3** Identification of Muscle Groups With Grade II-III (Moderate/Severe) Pain on Palpation*

| Muscle site | iTMD (n = 14) | | pTMD (n = 13) | | Significance |
|---|---|---|---|---|---|
| TMJ pain (external) | 43% | (6) | 77% | (10) | $P = .078$ |
| Masseter (external) | 7% | (1) | 62% | (8) | $P = .004$ |
| Temporalis (external) | 14% | (2) | 54% | (7) | $P = .034$ |
| SCM (external) | 0 | | 38% | (5) | $P = .015$ |
| Medial pterygoid (internal) | 29% | (4) | 62% | (8) | $P = .091$ |
| Laterial pterygoid (internal) | 64% | (9) | 69% | (9) | $P = .56$ |
| Coronoid insertion (internal) | 57% | (8) | 62% | (8) | $P = .56$ |
| Opening < 35 mm (interincisal) | 0 | | 23% | (3) | $P = .098$ |

*The number of patients within each category is noted in parentheses. Differences between iTMD and pTMD were assessed with Fisher's Exact test, and significance was set at $P < .05$.

**Symptom Checklist–90 Revised.** When compared to normalized values that have been described by others,[23] it was evident that there was a high level of somatic symptoms in both populations, and in fact, on the basis of the SCL-90R, it was not possible to differentiate between these two chronic pain populations. However, when the revised version of the SCL-90R consisting of head-injury questions was used,[25] it was evident that there was a significantly higher (64%, $P < .05$) somatic response in the pTMD group versus the iTMD group (Table 2).

The number of subjects in each group manifesting overt depression (as distinguished from affective symptoms alone[4]) was determined. The prevalence of depression in the pTMD population was 10% higher than that in the iTMD population, but this difference was not statistically significant (54% pTMD versus 43% iTMD, $t$ test, $P > .05$). There also were no statistically significant differences in the raw scores associated with the depression questions (1.38 versus 1.00, $P > .05$) (see Table 2).

### Clinical Examination

Clinical examination demonstrated some differences between iTMD and pTMD patients. As noted in Table 3, using the criteria of moderate to severe reaction to palpation (grade II-III), it was shown that more pTMD patients had a positive reaction to palpation of the external masseter ($t$ test, $P = .004$), temporalis ($P = .034$), and sternocleidomastoid muscles (SCM) ($P = .015$) than did iTMD patients. There were no statistically significant differences in positive pain reactions produced on palpation of the internal muscles in either group. None of the patients in the iTMD group reacted to palpation of the cervical muscles; however, 38% of pTMD individuals demonstrated grade II-III pain reaction on palpation of these muscles. Moreover, there was no statistically significant difference between the two groups with respect to TMJ palpation reaction. The prevalence of limited opening (ie, less than 35 mm) was similar in both groups as was the prevalence of signs suggesting symptomatic internal derangement.

### Brain SPECT Scanning

Only 11 of the 27 participants in the study (five pTMD, six iTMD) agreed to undergo brain SPECT scanning. Using previously described diagnostic parameters for normal and abnormal perfusion,[30] it was possible to correctly identify four of

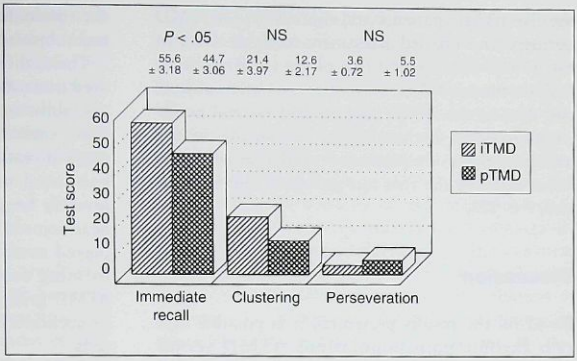


Fig 4 California Verbal Learning Test demonstrating mean raw scores ± SE for immediate recall in learning phase. Clustering and perseveration demonstrated. Statistical significance determined by Student's *t* test.

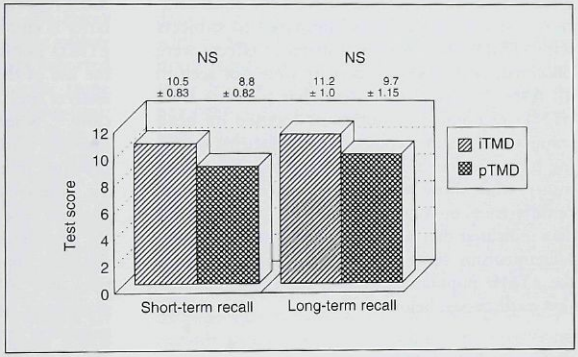


Fig 5 California Verbal Learning Test demonstrating mean raw scores ± SE for short-term recall and long-term recall testing. No statistically significant difference was demonstrated between control (iTMD) and MVA (pTMD) populations (Student's *t* test).

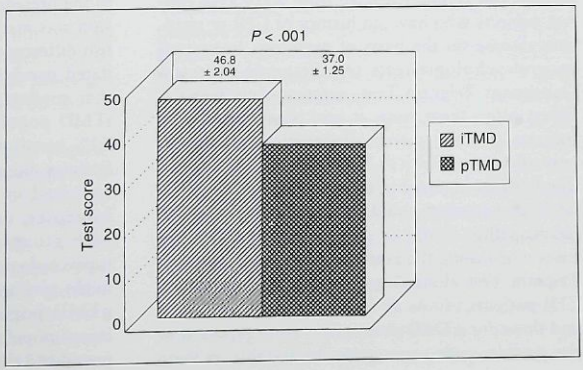


Fig 6 Consonant Trigram Test raw score results for memory with interference. Values are mean raw scores ± SE for control (iTMD) and MVA (pTMD) groups. Statistical significance determined by Student's *t* test.

the five pTMD patients and four of the six iTMD patients with blinded assessment methods. Four of the pTMD subjects and two of the iTMD subjects had perfusion deficit; one of the pTMD subjects and four of the iTMD subjects had normal perfusion. However, the number of participants in this aspect of the study precluded validation of differences between the two test groups (Fisher's Exact test, $P = .18$).

## Discussion

Based on the results presented, it is possible that two chronic pain populations (iTMD versus pTMD) might be differentiated from one another on the basis of data generated from the various neuropsychologic and clinical evaluations. In this study, those suffering from pTMD performed less efficiently in the spectrum of tests for concentration and reaction time as compared to subjects with iTMD. Only marginal memory effects were observed, since memory deficits were not seen in all tests. It was also evident that patients with pTMD responded to questions focused on head trauma in a manner comparable to patients suffering from previously identified mild traumatic head injury, while those with iTMD did not. In addition to differences on a neuropsychologic level, the data also indicated that some of the underlying musculoligamentous signs may be more pronounced in the pTMD population than in the iTMD population as discussed below.

### Neuropsychologic Tests

Previous studies in fully recovered patients with prior closed head injury (CHI) indicated that these patients can be differentiated from a group of control subjects who have no history of CHI or pertinent disease on the basis of responses to various neuropsychologic tests (eg, Peterson-Peterson Consonant Trigram Test, reaction-time tests).[29] When using these tests, it was possible to place patients into the correct diagnostic category (ie, control versus CHI) at least 85% of the time.[29] The findings reported in the present study are similar in that patients could be identified correctly as having either iTMD or pTMD in about 78% of cases when using the Peterson-Peterson Consonant Trigram Test alone. Interestingly, test scores for CHI patients (40.4) as reported in the literature and those for pTMD patients (37.0) as reported in the present study were quite comparable as were the results for iTMD (47.9) and the normal control subjects (46.8) reported by Stuss et al.[29]

The California Verbal Learning Test has been used extensively in testing of cognitive and memory abilities in patients with a variety of conditions, including Huntington's chorea and Parkinson's disease.[31] It has also been employed as a validated means to assess verbal learning in severely head-injured adults.[19] In learning trials, head-injured persons recalled fewer list items, displayed more intrusions, and had less success performing semantic clustering. In our tests, the pTMD group was also less able to recall list items as accurately as the iTMD subjects in two of six tests.

Although comparisons made in the present study are not meant to imply that the pTMD population is suffering from closed head injury, taken together, the findings outlined here complement those reported for head-injured patients. This similarity is emphasized further by the finding that the pTMD population could be identified readily by the use of the SCL-90R that has been modified to analyze and identify head-injured patients specifically.[25] When comparing the presence of affective disorder observed in this population with that in previous investigations,[4] there were some intriguing differences. As reported previously in a retrospective analysis of pTMD and iTMD patients,[4] the prevalence of symptoms suggestive of affective disorder approached 60% in the pTMD population; only 14% of iTMD subjects possessed similar symptoms. It must be emphasized that although subjective symptoms suggestive of affective disorder, including sleep disturbances, energy level decreases, and feelings of depression, were assessed in the prior investigation, no actual medical diagnoses of depression were ever made either. Indeed, in the present study, no actual diagnosis of depression was made. However, it was possible to establish differences between populations based on validated psychometric tests, and these data showed that similar proportions of both the pTMD and iTMD populations suffered from depression (ie, 54% versus 43%, respectively, see Results). These findings might be more fitting with what would be expected in most chronic pain populations.[32] Moreover, depression was equally distributed in both groups, and yet performance on the neuropsychologic tests was significantly different. This might give more credence to the concept that the pTMD population is similar to the mild head-injury population. In relation to this, it might be postulated that since both populations had equiva-

lent levels of depression, the demonstrated neuropsychologic deficits in the pTMD population are probably not the result of depression alone, but perhaps of other processes (central nervous system injury?). In other words, if the neuropsychologic deficits were the result of depression alone, similar deficits would have been expected in both groups; this was clearly not the case.

### Reaction-Time Tests

Impaired information processing as a result of a variety of ailments including head injury has been demonstrated with various types of reaction-time testing.[16,17,29] Webster and Scott,[16] Stuss et al,[17] and Stuss and coworkers[29] showed that reaction times for performance of simple tasks triggered by particular visual stimuli were increased in the head-injured group as compared to the control group. The results reported in the present study are parallel to the data presented in the latter investigation. Although there were some rather strong similarities between the findings reported here and those of others,[17,18] there were some interesting differences. For example, unlike findings reported by Hugenholtz et al[18] and Stuss et al,[17] patients in the pTMD group of our study demonstrated fatigue in that they were unable to complete a second SRT with the same facility as their first SRT. This did not occur in the iTMD group, and as indicated above, was not demonstrated in the previously studied head-injured populations. Thus, the fatigue factor, or some other as yet unidentified factor, may have some impact on concentration and information processing, which might explain the prevalence of fatigue in the pTMD population. Importantly, the mean ages of the two populations were different ($P < .05$), which could have had an impact on the outcome of the neuropsychologic measures used here. However, test deficits because of aging do not seem to be apparent until 60 years of age.[17] Since none of the patients were of this age, little effect should be noted; nonetheless, some caution should be used in interpretation of these data.

In this investigation, two chronic pain populations were compared, but the question arises as to whether and how these populations would compare to an asymptomatic control group of subjects. Although this was not done in our study, it is possible to compare our findings with data presented in earlier investigations because virtually identical software was used.[16] It appears that reaction times for asymptomatic control individuals are substantially lower than those of both the pTMD and iTMD populations studied here. This warrants further investigation but could suggest that in the presence of chronic pain, or other such factors not studied in these populations, there are measurable alterations in responses in reaction-time tests. Regardless of this, the further superimposition of trauma may confer an even greater impact on reaction times. These findings seem to emphasize the concept that the selection of an appropriate control group is essential, and that comparison of three groups (an asymptomatic group and two comparable differentially diagnosed disease groups that differ only with respect to trauma history) is necessary to validate the hypotheses suggested by this study. Nonetheless, the use of the two disease subgroups used here still seems to be valid.

### Brain Injury and pTMD

Because the psychologic and neuropsychologic data suggest some similarities between subjects with pTMD and individuals with mild traumatic brain injury, it would be appropriate to define some features of brain injury and concussion. It has been suggested that the terms *minor brain injury* and *concussion* may be used interchangeably.[33] In this regard, *concussion* has been defined as "an acceleration/deceleration injury to the head almost always associated with a period of amnesia, followed by a characteristic group of symptoms including most but not necessarily all of the following such as headache, poor memory, and vertigo."[33] Although a related loss of consciousness is an important defining feature, its absence does not exclude such a diagnosis.[33] Notably, the later-stage symptoms of concussion include irritability, anxiety, depression, poor memory, poor concentration, insomnia, and fatigue, which are, as described earlier, quite prevalent in the pTMD population. Thus, although patients with a documented loss of consciousness were excluded from this investigation, it is conceivable that they may be similar to patients with concussion-related disorders,[34] given the marked preponderance of the aforementioned symptoms as well as the test results reported in the present study. Although it cannot be concluded unequivocally that the pTMD population has indeed suffered a mild brain injury, or concussion for that matter, the potential similarities between this population and the mild traumatic brain injury population should be studied further.

The concept that underlying affective dysfunction may play a role in TMD is not new. Indeed, it is thought that chronic TMD may have both anatomic and psychogenic components.[35] In this

regard, others have indicated that depressive illnesses are an integral aspect of any chronic pain experience, including TMD, and must be addressed to obtain an optimum treatment result.[36] Importantly, it can be suggested that the iTMD patients in this study are suffering from chronic pain (longer than 6 months), and yet the prevalence of neuropsychologic deficit, unlike that observed in patients with pTMD, was low. This is interesting in light of recent evidence indicating that the presence of chronic pain predisposes to depression, while there seems to be a similar predilection for individuals with depression to develop pain.[37] Another parameter that might influence or be related to symptom reports and chronicity is level of education; however, the small sample size precluded elucidation of such a relationship.

### Clinical Examination

Clinical pain measures have been shown to vary from study to study.[38–40] Therefore, it is difficult to make direct comparisons of results between the various investigations. In our study, signs of tenderness to palpation of the TMJ and muscles of mastication on the basis of evoked reaction were more severe in the pTMD group as compared to those in the iTMD group. This is consistent with previous reports that suggested that pTMD patients may suffer from more severe symptoms than iTMD patients (assuming signs can be correlated to symptoms).[3,4] On the other hand, pTMD patients may simply exaggerate their responses more than iTMD patients. Others have shown that within a pTMD population, characteristics of pain (some sites in the head and neck region) and range of mandibular opening can vary, based on the type of trauma occurring.[38]

Positive palpation reactions in the external masseter, temporalis, and sternocleidomastoid muscles as shown in the pTMD group may further serve to differentiate iTMD and pTMD patients. The increased prevalence of cervical muscle involvement should not be surprising given that the nature of the injury in pTMD patients was an inclusion criterion for this group.[38] Thus, it is not possible to evaluate a cause-effect relationship in this study. Importantly, the mechanisms underlying any increased prevalence of muscle involvement in pTMD patients are not known. Although the concept of mandibular whiplash has been put forth in the past, this idea has not been widely accepted. Furthermore, inasmuch as the incidence of pTMD is apparently very low,[40] it does not seem likely that direct hyperextension/flexion injury to the facial muscles would have occurred. Similarly, the lack of difference in joint signs between the groups in the present study would also mitigate against a mandibular whiplash phenomenon.

### SPECT Scanning

In recent years, SPECT imaging has been used for a multitude of purposes, including central nervous system dopamine receptor imaging, studies on aging and dementia, and localization of central tumors, to name a few.[41–44] It has also been suggested that SPECT scanning can detect subtle changes in blood flow to various parts of the brain, which might occur as a result of traumatic brain injury. Insofar as the pTMD population seems to possess many features that also typify the head-injury population, it was hypothesized that perfusion deficits might be observed in the pTMD population, but not in the control iTMD population. These brain perfusion changes may be related to pathologic alterations and possibly related further to conditions such as depression, for example.[45] Such essentially anatomic alterations are so subtle that they cannot be detected by either computerized tomography or magnetic resonance imaging.[10] Importantly, perfusion deficits are not specific for traumatic brain injury alone. Central nervous system dysfunction from any etiology can coincide with a perfusion deficit.[10] The present study does suggest that more pTMD patients may have perfusion deficits than do iTMD patients, which lends support to the neuropsychologic test findings. In this regard, the identification of some pTMD patients and some iTMD patients by the use of SPECT scanning was possible. In addition, this aspect of the study suggests that some iTMD patients also have central nervous system dysfunction (ie, perfusion deficit), which has been shown by others to be secondary to long-term pain or depression.[10] These findings, if confirmed, could have major implications for understanding this component of the patient with posttraumatic pain, but it is also obvious that much more study is required to elucidate the underlying pathophysiology, if it exists at all. In any event, SPECT data must be considered preliminary at this point, and these mild differences cannot be considered clinically significant yet.

### Litigation

Previous studies have indicated that the prospect of litigation as a result of an MVA may produce a prolongation of symptoms that may not be ob-

served otherwise.[39,46] However, there are also studies that show that litigation may not have the impact traditionally assigned to it from a number of perspectives. First, litigation may provide a release of emotional stress for a given patient, thereby alleviating one factor thought to play a role in aggravation of chronic pain.[47] Second, it has been demonstrated that chronic pain patients do not simply improve when litigation has ended.[33,48] Third, although it may be possible for "unscrupulous" or "malingering" patients to misrepresent their symptoms (and even reactions to muscle palpation) to the investigators, it does not seem probable that such individuals could have altered their responses to the neuropsychologic and reaction-time tests, since, at the very least, they would not have known a priori how they were expected to perform on those tests. Finally, the Province of Ontario, from which all patients were derived, recently passed a "no-fault" insurance system for the province, effectively eliminating litigation (except for very severe cases) and disallowing large settlements for motor vehicle accident victims. Because virtually all of the pTMD patients were derived from the post-no fault era, this fact alone would seem to be inconsistent with the notion that the chronicity or characteristics of the pTMD (MVA) group are related to legal proceedings. Nonetheless, the potential impact of litigation or other secondary gain issues cannot be dismissed lightly and could indeed have a profound effect on the various parameters studied here.

### Sample Size

Sample size calculations for this study were based on results previously obtained.[4] It was shown that 60% of pTMD patients and only 14% of iTMD patients had evidence for affective disorder. Therefore, based on these figures, as well as a study power of 0.8, the sample size calculation[49] indicated a need of 25 patients per group. However, truly large differences between test populations can be identified readily even with small samples,[50] and in fact, large populations are required when only small or potentially minor differences are present. Nonetheless, it is essential that the data described here, although in large part significant, be confirmed with larger samples. Furthermore, asymptomatic control subjects and perhaps iTMD patients with refractory or more long-standing conditions should be included.

## Conclusions

The results reported in this investigation suggest a number of provocative findings. On the basis of a battery of neuropsychologic tests, measurable differences between iTMD and pTMD patients could be discerned, suggesting a higher prevalence of cognitive deficit in the pTMD group. In addition, the data show that the psychologic tests used in this investigation, and in particular the various reaction-time tests, can be used to differentiate between iTMD and pTMD patients. The clinical findings suggest that some musculoligamentous signs in pTMD patients are more severe than those observed in iTMD patients. Although it was not possible to demonstrate statistically significant differences between pTMD and iTMD patients on the basis of SPECT scanning, there were some intriguing trends that suggested underlying central nervous system changes in a subset of pTMD patients. Taken together, the data suggest that differences may exist between pTMD and iTMD patient populations. These important distinctions may explain, in part, why the clinical course and presentation of pTMD appears to be unique. Furthermore, these findings underscore the need for more controlled investigations of these two conditions. In regard to treatment, it is apparent that although some of the more routine treatment modalities used to manage TMD in general may be applicable to both iTMD and pTMD (ie, bite plane therapy), there may also be a need to treat iTMD and pTMD differently in many respects so as to include the central contributions as well as the musculoligamentous injuries. These findings notwithstanding, it must also be emphasized that similar study of patients with other posttraumatic musculoligamentous injuries (eg, cervical hyperextension/flexion without TMD) might also reveal the existence of cognitive impairment; these data do not clarify the relationship, if it exists at all, between cervical hyperextension/flexion injury[16] and TMD development. Thus, it is important to recognize that the presence of cognitive impairment in the population described herein does not constitute conclusive evidence of a causal link between the neuropsychologic deficit and other clinical characteristics of pTMD, but only co-morbidity. Rather, these findings should illustrate the need to approach assessment and treatment of posttraumatic pain more broadly, and not focus solely on either the musculoligamentous signs or neuropsychologic deficits alone.

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## Resumen

Deficiencias Neurosicológicas y Características Clinicas del Desórden Temporomandibular Post-Traumático

Estudios previos han indicado claramente que las caracteristicas del desórden temporomandibular post-traumatico (DTMp) se diferencian considerablemente de aquellas encontradas en los desórdenes temporomandibulares no-traumaticos ó idiopáticos (DTMi). Tanto la proporción de pacientes recuperados, como la cantidad de tratamiento requerida aparentan ser diferentes para ambos grupos. En este estudio, 14 pacientes diagnosticados con DTMi y 13 pacientes diagnosticados con DTMp fueron examinados. Los pacientes han sido sometidos a una variedad de exámenes de reacción de tiempo asi como a una serie de evaluaciones neurosicológicas con el propósito de verificar sus habilidades para realizar tanto tareas simples como complejas con y sin una variedad de intervenciones cognitivas. Once pacientes (6 controles y 5 DTMp) consintieron participar en una segunda parte del estudio, en la cual fueron evaluados por medio de la tomografía computerizada (SPECT) utilizando $^{99m}$Tc-hexametilpropilenoaminoxim (HMPAO). Comparándo los resultados de los exámenes de tiempo de simple reacción se observó que fueron considerablemente más bajos en el grupo con DTMp (35%-45%) que el grupo con DTMi ($P <$ .05). Otros métodos de evaluación neurosicológica utilizados, tales como El Triagrama de Consonantes (Consonant Triagram) y El Aprendizaje Verbal California (California Verbal Learning) indicaron que los pacientes con DTMp fueron mucho más afectados por las interferencias pro- y retroactivas y tendieron a perseverar en un sólo pensamiento. Diferencias entre los subgrupos con DTMi y los con DTMp pudieron también ser demonstradas con el exámen clinico porque los pacientes con DTMp demonstraron ser más sensibles a la palpación de los musculos que los pacientes con DTMi. Con respecto a la perfusión cerebral, los resultados del SPECT sugieren diferencias menores entre las dos poblaciones. En conjunto los resultados apoyan el concépto de que existen diferencias entre las poblaciones diagnosticadas con DTMp y las diagnosticadas con DTMi. En base a los descubrimientos reportados aqui, sugerimos que aúnque los pacientes con DTMp pueden presentar ciertas similitudes con los pacientes con DTMi, los con DTMp deberían ser manipulados diferentemente asi como deberían ser diagnosticados y tratados utilizándo un tratamiento multidisciplinario más amplio. Estos resultados sin embargo deben ser confirmados por estudios efectuados sobre poblaciones más grandes.



## Zusammenfassung

Neuropsychologische Verluste und klinische Leistungen bei posttraumatischen Myoarthropathien

Vorausgegangene Studien haben gezeigt, dass sich die Merkmale von posttraumatischen Myoarthropathien (posttraumatic temporomandibular disorders [pTMD]) deutlich von denjenigen bei nichttraumatischen oder idiopathischen Myoarthropathien (iTMD) unterscheiden. Sowohl die Erholungsgeschwindigkeit als auch der Behandlungsaufwand scheint für beide Gruppen unterschiedlich. Bei dieser Blindstudie wurden 14 Patienten mit iTMD und 13 Patienten mit pTMD untersucht. Die Patienten wurden einigen Reaktionszeittests und neuropsychologischen Beurteilungen unterworfen, um die Fähigkeit zu prüfen, wie sie mit einfachen und komplexen Aufgaben mit und ohne kognitiven Interferenzen umgehen. Bei einem klinischen Untersuch wurden Zeichen von Myoarthropathien beurteilt. 12 der Patienten (6 iTMD, 5 pTMD) erklärten sich für eine zweite Untersuchung bereit, wobei die Patienten mit SPECT (single-photon emission computerized tomography) unter Verwendung von $^{99m}$Tc-Hexamethylpropylenaminoxim (HMPAO) untersucht wurden. Bei einfachen und komplexen Reaktionszeittests war die pTMD-Gruppe signifikant langsamer als die iTMD-Gruppe. Andere neuropsychologische Beurteilungsinstrumente wie der "Consonant Trigram Test" und der "California Verbal Learning Test" wiesen darauf hin, dass pTMD-Patienten mehr durch proaktive und retroaktive Interferenzen beeinträchtigt waren und eher auf einem bestimmten Gedanken beharrten. Unterschiede zwischen den iTMD- und den pTMD-Patienten konnten auch mit der klinischen Untersuchung gezeigt werden, indem die pTMD-Patienten bei der Muskelpalpation empfindlicher als die iTMD-Patienten waren. Bei der Hirnperfusion waren kleine Unterschiede zwischen den 2 Gruppen zu finden. Es sind weitere Studien notwendig, um dies zu bestätigen. Zusammengenommen unterstützen diese Resultate das Konzept, dass zwischen pTMD- und iTMD-Populationen Unterschiede vorliegen. Aufgrund der vorliegenden Resultate wird vorgeschlagen, dass trotz gewisser Gemeinsamkeiten zwischen pTMD- und iTMD-Populationen die erstere von einer etwas umfassenderen, multidisziplinären Beurteilung und Behandlung profitieren könnte. Diese Resultate müssten aber durch Studien bei grösseren Populationen bestätigt werden.