# An Artificial Intelligence Tool for the Diagnosis of Facial Pain

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**BACKGROUND AND OBJECTIVES:** Differentiation between temporomandibular disorders (TMDs) and trigeminal neuralgia (TN) as causes of orofacial pain is very important because the nature of these disorders and their treatments are vastly different. TMDs are usually treated with a rehabilitative approach, although dental correction or even surgery may be necessary in rare cases where the origin of the pain appears to be related to oral or temporomandibular joint pathology. By contrast, TN is largely treated with anticonvulsant medications, trigeminal nerve surgery, or trigeminal ablative procedures. TMDs are several orders of magnitude more common than TN, which may result in misdiagnosis and mistreatment if the proper diagnosis is not made initially.

**METHODS:** We completed a study of 101 patients with either TMD or TN using supervised machine learning. A predictive model was developed using the 2 inputs of a questionnaire and directed physical examination.

**RESULTS:** The network was trained to achieve the corresponding correct output, which was based on orofacial physical examination and expert diagnosis of each subject.

**CONCLUSION:** The analysis of this network indicated that TMDs and TN can be reliably differentiated using a standardized questionnaire and physical examination with approximately 90% accuracy.

**KEY WORDS:** Orofacial pain, Temporomandibular disorders, Temporomandibular joint, Trigeminal neuralgia, Trigeminal nerve, Questionnaire, Machine learning

Orofacial pain is challenging for both patients and clinicians. If therapy is effective, accurate diagnosis is essential. Our work confronts what we believe is diagnostic confusion over a common cause of orofacial pain, temporomandibular disorders (TMDs), and the rarer neurological problem of trigeminal neuralgia (TN). Both syndromes can cause severe disabling pain.

TMDs are a heterogeneous group of musculoskeletal and neuromuscular conditions involving the temporomandibular joint (TMJ) complex and the surrounding musculature and osseous components. They also often occur with one or more chronic overlapping pain conditions such as migraine, low back pain, or fibromyalgia.[1]

**ABBREVIATIONS: AI,** artificial intelligence; **ML,** machine learning; **PHN,** postherpetic neuralgia; **STN,** symptomatic trigeminal neuralgia; **SVM,** Support Vector Machine; **TDP,** trigeminal deafferentation pain; **TMDs,** temporomandibular disorders; **TMJ,** temporomandibular joint; **TN,** trigeminal neuralgia; **TN1,** trigeminal neuralgia type 1; **TNP,** trigeminal neuropathic pain.

TMDs have been recognized as a public health problem affecting approximately 5% to 12% of the population,[2] with some estimates running as high as 50% of the population.[3] TMD is the second most common musculoskeletal condition (after chronic low back pain) resulting in pain and disability.[4] It has been estimated that the annual TMD management cost in the United States, excluding imaging, has doubled in the past decade to $4 billion.[4]

TMDs have an extensive differential diagnosis, as many conditions mimic these disorders. Therefore, clinicians must be vigilant when obtaining a thorough medical history. Common symptoms include headache, bruxism, pain in the TMJ, cervicalgia, joint sounds, and otalgia. Common signs include tenderness upon palpation of the masticatory muscles at the angle of the mandible and cervical muscles. Imaging, such as cone beam computed tomography or MRI, is indicated when the diagnosis is doubtful or if conservative treatments have failed.[5]

With advancing age, there appears to be an increasing prevalence of TMJ degeneration, suggesting that in individuals older than 65 years, the majority of patients with TMD have the degenerative joint disorder form of the disease.[6] TMD can be

difficult to diagnose because both myogenic and arthrogenic types can be present at the same time.[1] TMD comorbidities include headaches, fibromyalgia, and psychological disorders (anxiety and depression).[7,8]

Neuropathic pain appears to be an important aspect of certain TMD disorders; however, in these cases, the pathophysiology of the pain is related to overt or suspected nerve injury.[9,10] TMD remains a controversial, if not somewhat confusing, diagnosis, although attempts have been made to rationalize the classification of these disorders.[4]

TN is a much rarer problem, with a prevalence of approximately 0.03% to 0.3% of the population.[11,12] Its incidence tends to increase with age, with the condition being more common in individuals older than 50 years. TN affects women more frequently than men for reasons that have not been completely explained.[13] In individuals with multiple sclerosis, the incidence of TN is substantially higher, with estimates ranging from 2.4% to 3.8%.[14] TN may be caused by vascular conflict of the trigeminal nerve as it passes from the trigeminal ganglion through the ambient cistern to the brainstem[15] or rarely from a tumor, aneurysm, or vascular malformation with compression of the nerve. TN often occurs in the complete absence of neurovascular or other apparent pathological contact.[16,17]

TN consists of episodes of severe pain that occur suddenly and are described as sharp, shooting, or electric shock–like. Attacks can last from a few seconds to several minutes and may occur in quick succession. The location of the pain is invariably in the trigeminal sensory distribution of the mandibular, maxillary, and ophthalmic cutaneous divisions of facial sensation. Pain may be triggered by light touch, chewing, speaking, brushing teeth, or even a breeze. The frequency of attacks varies; while some individuals may experience multiple episodes in a day, others may have weeks or months without pain, sometimes referred to as a pain-free interval.

TN has been defined by the International Headache Society, although their International Classification of Headache Disorders (ICHD-3) classification scheme[18] parses the disorder into classical TN, purely paroxysmal (13.1.1.1.1), classical TN with concomitant continuous pain (13.1.1.1.2), secondary TN attributed to multiple sclerosis (13.1.1.2.1), TN attributed to a space-occupying lesion (13.1.1.2.2), and TN attributed to other causes (13.1.1.2.3). Of note, classical TN (13.1.1.1.1) also requires the "demonstration on MRI or during surgery of neurovascular compression (not simply contact), with morphological changes in the trigeminal nerve root." Idiopathic TN can be purely paroxysmal (13.1.1.3.1) or associated with concomitant continuous pain (13.1.1.3.2). Thus, this classification system combined clinical syndromes with imaging findings. On a *purely clinical basis*, 13.1.1.1.1 and 13.1.1.3.1 are identical, as are 13.1.1.1.2 and 13.1.1.3.2.

The goal of this study was to create a machine learning (ML)–or artificial intelligence (AI)–based diagnostic decision support system for first-stage clinical evaluation and diagnosis of patients with TN or TMDs. The goal was not only to train a diagnostic algorithm, but also to assess the significance of features in model training and understand clinically important predictors.

# METHODS

## Ethical Compliance

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

The subjects were recruited from the neurosurgery outpatient clinic. After obtaining informed consent, each patient was interviewed and examined by 2 experts: a neurosurgeon experienced in the diagnosis of TN (KJB) and a dentist specifically trained and experienced in the diagnosis of TMD syndromes (SB). All subjects completed our Facial Pain Questionnaire (Table 1). Each subject was assigned a clinical diagnosis by these 2 experts based solely on their histories and physical examinations, and in every case, *either* a diagnosis of TMD or TN was the result.

No subjects were admitted to the study whose diagnosis was (1) symptomatic trigeminal neuralgia (STN) secondary to multiple sclerosis, (2) other secondary causes of TN, such as tumors or vascular lesions, (3) trigeminal neuropathic pain (TNP) related to unintentional nerve injury, (4) trigeminal deafferentation pain (TDP) related to intentional nerve injury, or (5) postherpetic trigeminal neuralgia (PHN).[19] These diagnoses have a clear historical basis and do not present a diagnostic dilemma, since they can be made by history or questionnaires with high sensitivity and specificity, as previously reported.[20,21]

All subjects had an orofacial physical examination consisting of the presence or absence of the following 5 features: Examination field 1 (E1) mandibular midline shift during maximum interincisal opening, (E2) tenderness to lateral and intra-auricular palpation of the TMJ, (E3) painful "clicking" or "popping" of the TMJ on opening/closing, (E4) tenderness to palpation of the muscles of mastication, and (E5) pain on molar bite-down. Each of these examination features was treated as a separate variable (Table 2).

To analyze the questionnaire and examination data, 3 supervised ML algorithms, Random Forest Classifier, Logistic Regression, and Support Vector Machine (SVM), were chosen based on the interpretability and capability of evaluating feature importance. Each algorithm was trained on 3 feature subsets: (1) full feature set (51 features), (2) physical examination features only, and (3) 2 survey questions specified by the principal investigator. Hyperparameter optimization was performed using a grid search, and model performance was evaluated through 5-fold cross-validation. The mean weighted F1 score was used as the primary metric to assess accuracy. All data analyses, model training, and visualization were conducted using Python 3.7 with the sklearn, PANDAS, matplotlib, and Seaborn libraries.

Three supervised classification algorithms were evaluated: Random Forest, Logistic Regression, and SVM. For Random Forest, hyperparameter optimization was performed using GridSearchCV with 5-fold stratified cross-validation. The grid search explored n_estimators values from 50 to 400 and max_depth values of None, 10, and 20. The optimal configuration was n_estimators = 100 and max_depth = None, and these parameters were used in the final model.

All cross-validation and train-test splitting procedures used stratification by diagnosis to preserve class distribution within each fold and prevent bias from imbalanced sampling. A separate hold-out test set comprising 20% of the data was reserved before training and hyperparameter tuning. Final model evaluation, including reported F1 scores and classification metrics, was performed exclusively on this unseen test set to assess generalization performance.

| **TABLE 1. Oregon Health and Science University Facial Pain Questionnaire** |
|---|
| **Facial pain questionnaire** |
| 1. Do you have facial pain? |
| ☐ YES ☐ NO |
| 2. Do you remember exactly where you were the moment your facial pain started? |
| ☐ YES ☐ NO |
| 3. When you have pain, is it predominantly in your face (ie, forehead, eye, cheek, nose, upper/lower jaw, teeth, lips, etc.)? |
| ☐ YES ☐ NO |
| 4. Do you have pain on just one side of your face? |
| ☐ YES ☐ NO |
| 5. When you have pain, is it predominantly deep in your ear? |
| ☐ YES ☐ NO |
| 6. When you have pain, is it predominantly in the back of your throat or tongue, near the area of your tonsil? |
| ☐ YES ☐ NO |
| 7. Is your pain either entirely or mostly brief (seconds to minutes) and unpredictable sensations (electrical, shocking, stabbing, shooting)? |
| ☐ YES ☐ NO |
| 8. Do you have any constant background facial pain (eg, aching, burning, throbbing, stinging)? |
| ☐ YES ☐ NO |
| 9. Do you have constant background facial pain (aching, burning, throbbing, stinging) for more than half of your waking hours? |
| ☐ YES ☐ NO |
| 10. Do you have constant facial numbness? |
| ☐ YES ☐ NO |
| 11. Can your pain start by something touching your face (for example, by eating, washing your face, shaving, brushing teeth, wind)? |
| ☐ YES ☐ NO |
| 12. Since your pain began, have you ever experienced periods of weeks, months, or years, when you were pain-free? (This would not include periods after any pain-relieving surgery or while you were on medications for your pain) |
| ☐ YES ☐ NO |
| 13. Have you ever taken Tegretol (carbamazepine), Neurontin (gabapentin), Lioresal (baclofen), Trileptal (oxcarbazepine), Topamax (topiramate), Zonegran (zonisamide), or any other anticonvulsant medication for your pain? |
| ☐ YES ☐ NO |
| 14. Did you experience any major reduction in your facial pain (partial or complete) from taking any of the medications listed in Question 13, or any anticonvulsant medication? |
| ☐ YES ☐ NO |
| 15. Have you ever had trigeminal nerve surgery for your pain (eg, neurectomy, RF rhizotomy/gangliolysis, glycerol injection, balloon compression, rhizotomy, MVD, gamma knife)? |
| ☐ YES ☐ NO |
| 16. Have you experienced any major reduction in facial pain (partial or complete) from trigeminal nerve surgery (eg, neurectomy, RF rhizotomy/gangliolysis, glycerol injection, balloon compression, rhizotomy, MVD, gamma knife)? |
| ☐ YES ☐ NO |

| **TABLE 1. Continued.** |
|---|
| **Facial pain questionnaire** |
| 17. Did your pain start only after trigeminal nerve surgery (neurectomy, RF rhizotomy/gangliolysis, glycerol injection, balloon compression, rhizotomy, MVD, gamma knife)? (If this is a recurrence of your original pain after a successful trigeminal nerve surgery, answer "no") |
| ☐ YES ☐ NO |
| 18. Did your pain start after facial zoster or "shingles" rash (Herpes zoster—not be confused with "fever blisters" around the mouth)? |
| ☐ YES ☐ NO |
| 19. Do you have multiple sclerosis? |
| ☐ YES ☐ NO |
| 20. Did your pain start after facial injury? |
| ☐ YES ☐ NO |
| 21. Did your pain start only after facial surgery (oral surgery, ear, nose, throat surgery, plastic surgery)? |
| ☐ YES ☐ NO |
| 22. When you place your index finger right in front of your ears on both sides at once and feel your jaw open and close; is this where you predominantly feel pain? |
| ☐ YES ☐ NO |
| 23. Do you have pain, stiffness, or fatigue in your jaw from chewing, talking, or at dental visits? |
| ☐ YES ☐ NO |
| 24. Does your jaw ever get stuck, catch, lock, or go out? |
| ☐ YES ☐ NO |
| 25. Does your jaw make sounds (clicking, popping, grating) or has it at any time in the past? |
| ☐ YES ☐ NO |
| 26. Are you aware or do you suspect that you grind your teeth? |
| ☐ YES ☐ NO |
| 27. Does your bite feel strained or uncomfortable? |
| ☐ YES ☐ NO |
| 28. Have you noticed a recent change in your bite? |
| ☐ YES ☐ NO |
| 29. Do you habitually chew or accidentally bite your lips, cheeks or tongue? |
| ☐ YES ☐ NO |
| 30. Do you always have pain on just 1 side? |
| ☐ YES ☐ NO |
| 31. Do you have pain most of the time? |
| ☐ YES ☐ NO |
| 32. Have you been told that you had TMJ problems in the past? |
| ☐ YES ☐ NO |
| 33. Have you been told that you grind your teeth at night when you are sleeping, or has your dentist told you that you did? |
| ☐ YES ☐ NO |

**TABLE 1. Continued.**

| Facial pain questionnaire |
|---|
| 34. Can you sleep on your painful side? |
| ☐ YES ☐ NO |
| 35. Do you wear, or have you worn, a night guard? |
| ☐ YES ☐ NO |
| 36. If you have worn a night guard, did it help? (answer "no" if you have never worn a night guard) |
| ☐ YES ☐ NO |
| 37. Do you have pain with opening or closing your mouth? |
| ☐ YES ☐ NO |
| 38. Do you have pain with chewing hard or tough food? |
| ☐ YES ☐ NO |
| 39. Do you avoid chewing on your painful side? |
| ☐ YES ☐ NO |
| 40. Do you have pain with talking? |
| ☐ YES ☐ NO |
| 41. Do you have pain with yawning? |
| ☐ YES ☐ NO |
| 42. Does your pain include areas around or in your ear? |
| ☐ YES ☐ NO |
| 43. Does it hurt if you push on your temple or in the area just above or behind your ear on the painful side? |
| ☐ YES ☐ NO |
| 44. Does your pain increase during the day, and is it better in the morning when you wake up? |
| ☐ YES ☐ NO |
| 45. When you wake up in the morning, is your jaw stiff or tired? |
| ☐ YES ☐ NO |
| 46. Have you tried carbamazepine (Tegretol), oxcarbazepine (Trileptal), gabapentin (Neurontin), or pregabalin (Lyrica) for your pain? |
| ☐ YES ☐ NO |
| 47. If you have tried these medications, was most (>50%) of your pain relieved? (answer "no" if you have never tried these) |
| ☐ YES ☐ NO |

RF, random forest; MVD, microvascular decompression; TMJ, temporomandibular joint.

In this study, we considered only the *clinical* syndromes of patients with TN, which included the established ICHD-3 diagnoses of 13.1.1.1.1 and 13.1.1.3.1. These 2 ICHD-3 diagnostic groups were combined into one diagnosis and considered equivalent to a single diagnosis of trigeminal neuralgia type 1 (TN1), as previously characterized by our group.[19] The diagnosis of TN was made using the definitions specified in the ICHD-3 and TN1 paradigms. TMD was diagnosed using the diagnostic criteria/TMD criteria.[10]

## RESULTS

A total of 101 patients with either a TMD or TN diagnosis completed the questionnaire (Table 1) and orofacial examination (Table 2). 42 patients were diagnosed with TN, and 59 were diagnosed with TMD. These data were then used to develop 3 ML models with the outcome being "TMD" or "not TMD." "Not TMD" patients had a TN diagnosis by default.

**TABLE 2. Features of the Orofacial Examination**

| Field | Exam finding |
|---|---|
| E1 | Mandibular midline shift during maximum interincisal opening (deviation or deflection) |
| E2 | Tenderness to lateral and intra-auricular palpation of the TMJ |
| E3 | Painful "clicking" or "popping" of the TMJ on opening/closing |
| E4 | Tenderness to palpation of the muscles of mastication (temporalis, masseter) |
| E5 | Pain on molar bite-down on tongue blade indicating involvement of the lateral pterygoid muscle |

TMJ, temporomandibular joint.

The performance of the 3 ML models, Random Forest Classifier, Logistic Regression, and SVM, varied significantly (Table 3). The Random Forest Classifier and Logistic Regression achieved similar mean weighted F1 scores, with the Random Forest Classifier showing slightly better robustness and consistency across the cross-validation folds. Models trained on the full feature set consistently outperformed those trained on subsets such as physical examination features alone or the 2 selected survey questions.

The Random Forest Classifier was selected as the final algorithm after a comprehensive evaluation of the model performance and characteristics (Best F1 Weighted test data score: 0.953 [95% CI: 0.855-1.000], Receiver Operator Characteristic-Area Under the Curve (ROC-AUC) test data score: 0.952 [95% CI: 0.837-1.000]). The Random Forest Classifier was preferred over Logistic Regression because of its inherent advantages, including robustness to outliers, effective handling of imbalanced data sets, and capacity to model complex, nonlinear feature interactions. These attributes indicate that the Random Forest classifier is the most suitable algorithm for distinguishing between TMD and TN diagnoses. Table 3 summarizes the mean F1 cross-validation scores of the 3 models (Random Forest, Logistic Regression, and SVM) across 3 different scenarios: all features, orofacial physical examination, and questionnaire only (questions 3 and 5). Figure 1 depicts the receiver operating characteristic curves for the (a) Random Forest (b) Linear Regression, and (c) SVM models.

Figure 2 depicts the decrease in mean model accuracy if those examination (E#) or questionnaire features (Q#) were *eliminated* from the model. Only the top 8 features are shown in this figure, and Table 4 lists the data from which this figure was developed.

**TABLE 3. The Performance of the Three Models (Random Forest, Logistic Regression, and SVM) Across Three Different Scenarios: All Features, Orofacial Physical Examination, and Questionnaire Only (Questions 3 and 5)**

| | Scenario | Model | Best F1 weighted training score | Mean F1 weighted cross-validation score | Best F1 weighted test data score |
|---|---|---|---|---|---|
| 0 | Full features | Random Forest | 0.915565 | 0.892036 | 0.812169 |
| 1 | | Logistic Regression | 0.892036 | 0.892036 | 0.859104 |
| 2 | | SVM | 0.889910 | 0.889910 | 0.859104 |
| 3 | Physical screening examination | Random Forest | 0.842498 | 0.891271 | 0.952829 |
| 4 | | Logistic Regression | 0.867498 | 0.892036 | 0.952829 |
| 5 | | SVM | 0.855376 | 0.889910 | 0.952829 |
| 6 | Questionnaire (Q3 and Q5 only) | Random Forest | 0.842498 | 0.892036 | 0.952829 |
| 7 | | Logistic Regression | 0.867498 | 0.892036 | 0.952829 |
| 8 | | SVM | 0.855376 | 0.889910 | 0.952820 |

SVM, Support Vector Machine.
The metrics reported are Best Weighted Training Score: The best F1 training score achieved through training (from GridSearchCV); Mean F1 Cross Validation Score: The mean F1 score from 5-fold cross-validation; and Best F1 Weighted Test Data Score: The score on the test data using the best model.

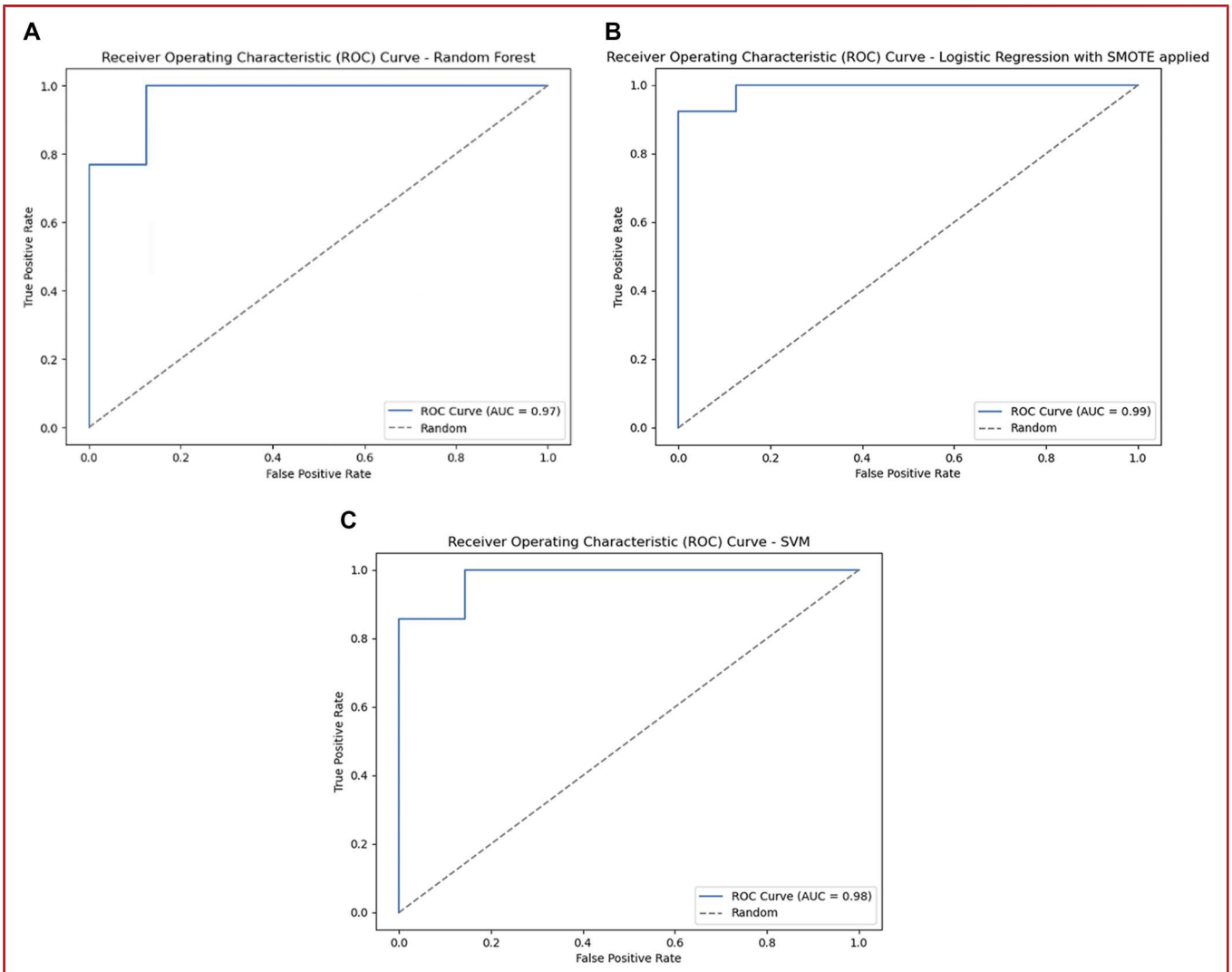


**FIGURE 1.** **A**, *ROC curves for Random Forest model.* **B**, *ROC curve for Linear Regression model.* **C**, *ROC curve for SVM model. AUC, area under the curve; ROC, receiver operating characteristic; SVM, Support Vector Machine.*

The top predictors of TMD, both derived from the orofacial examination, were tenderness to lateral and intra-auricular palpation of the TMJ and tenderness to palpation of the muscles of mastication (temporalis, masseter). From the questionnaire, the most important question was "Is your pain either entirely or mostly brief (seconds to minutes) and unpredictable sensations (electrical, shocking, stabbing, shooting)?"

## DISCUSSION

We previously reported the use of an artificial neural network for the diagnosis of facial pain.[20,21] The analysis of this network's ability to diagnose TN1 showed high sensitivity and specificity (0.924 and 0.878, respectively). The diagnosis of TN2 using this model was not clear (0.625 and 0.964, respectively). The diagnoses of TNP, TDP, STN, and postherpetic neuralgia (PHN) were also readily apparent in the earlier questionnaire (0.867-1.0 and 0.952-1.0, respectively). This comports with the fact that these diagnoses can be obtained from a simple history of the patient. Therefore, we chose not to include cases of TNP, TDP, STN, and PHN in the current analysis. Our previous work suggested that the challenge is separating TN from TMDs, given the roughly 3 orders of magnitude difference in the prevalence of these conditions, which may result in misdiagnosis by assigning some cases of TMD to TN.

Feature importance analysis from the Random Forest Classifier Identified "Is there tenderness on palpation of the TMJ, and if so,

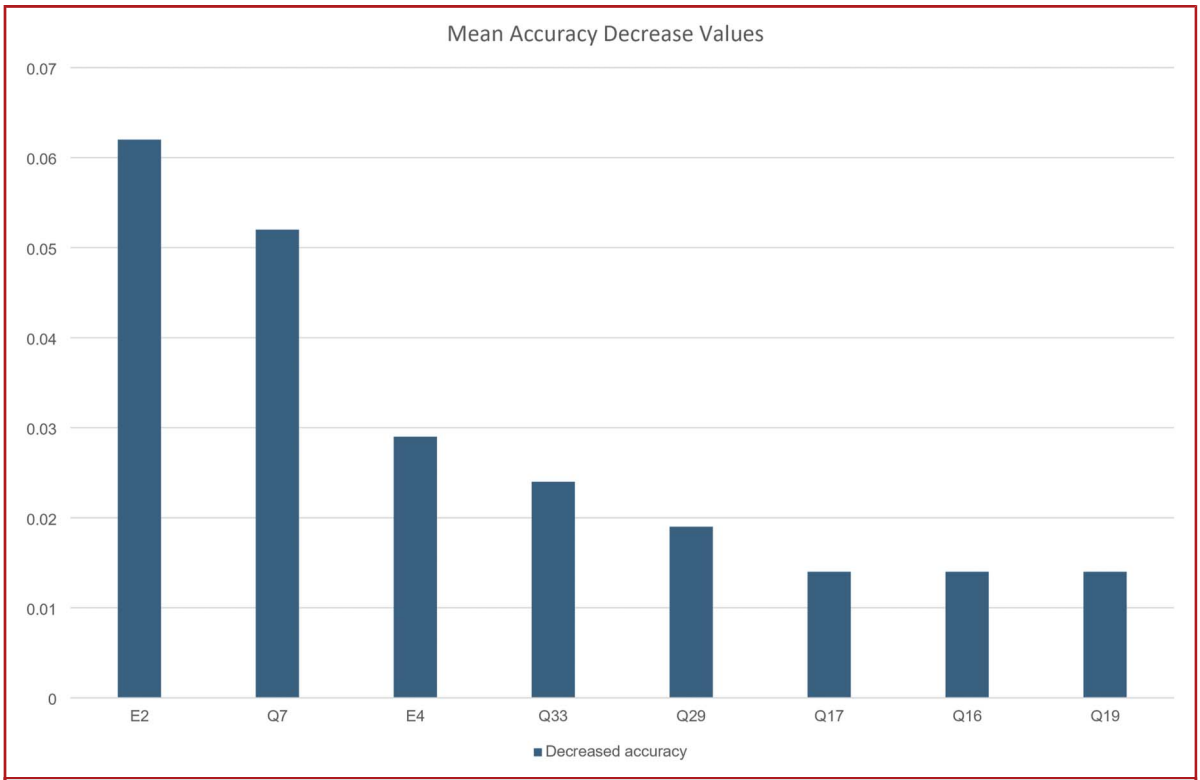


**FIGURE 2.** *Mean model accuracy decreases if an examination feature (E#) or questionnaire feature (Q#) was eliminated from the model. Only the top 8 features are listed.*

which side(s)", "Is your pain either entirely or mostly brief and unpredictable sensations?", "Is there pain or tenderness on palpation of the temporalis and masseter muscles?", "Are you aware or do you suspect that you grind your teeth?", "Do you habitually chew or accidentally bite your lips, cheeks or tongue?", "Did your pain start only after trigeminal nerve surgery?" "Have you experienced any major reduction in facial pain from trigeminal nerve surgery?", and "Do you have multiple sclerosis?" as the most predictive variables in order of importance, aligning with clinical expectations and offering interpretable insights into the diagnostic process (Figure 2, Table 4). These findings support the notion that brief pain and pain reduction from previous surgery are strong indicators for the diagnosis of TN. By contrast, pain on palpation of the mastication muscles and a history of bruxism point toward a TMD diagnosis.[22]

The subjects in this study diagnosed with TMD would qualify for the diagnosis of TN2.[18] This may indicate that many patients who would fit TN2 according to the Burchiel classification[19] are, in fact, TMD. This could also apply to patients who meet the criteria for "trigeminal neuralgia with concomitant continuous pain" according to the ICHD-3 classification. This hypothesis can be tested in future prospective studies.

In our study, 17/59 (28.8%) patients diagnosed with TMD responded "yes" to the question "Is your pain either *entirely or mostly* brief (seconds to minutes) and unpredictable sensations (electrical, shocking, stabbing, shooting)?" Given the overall prevalence of TMD in comparison with TN, that is, TMD is approximately 3 orders of magnitude more common, this would infer that the number of patients with TMD potentially *misdiagnosed* with TN would be, at least, more than 2 orders of magnitude greater than patients with bona fide TN. Other than this question, our study did not attempt to grade the relative incidence of any brief pain that patients with TMD might report. This is the focus of future research.

One critical question that arises in any analysis such as the current work is the degree to which an imbalanced class distribution influences the performance of the model. To evaluate the generalizability of the model to real-world clinical settings—where TMD is substantially more prevalent than TN—we conducted additional experiments using synthetic data sets with a 10:1 TMD:TN class imbalance. Two models were trained: one using the original near-balanced training data with Synthetic Minority Oversampling Technique (SMOTE) applied, and one using a synthetically imbalanced training set in which the TN class was downsampled to one-tenth the size of the TMD class. Both models were evaluated on a similarly imbalanced 10:1 test set. The model trained on the imbalanced data set achieved a weighted F1 score of 0.696. By contrast, the model trained on the balanced

**TABLE 4. Feature Importance Ranked by Mean Decrease in Accuracy Using the Random Forest Classifier**

| | Mean accuracy decrease |
|---|---|
| Is there tenderness on palpation of the TMJ? (Exam question 2) | 0.062 |
| Is your pain either entirely or mostly brief (seconds to minutes) and unpredictable sensations? (Q7 on questionnaire) | 0.052 |
| Is there pain or tenderness on palpation of the temporalis and masseter muscles? (Exam question 4) | 0.029 |
| Are you aware or do you suspect that you grind your teeth? | 0.024 |
| Do you habitually chew or accidentally bite your lips, cheeks or tongue? | 0.019 |
| Did your pain start only after trigeminal nerve surgery? | 0.014 |
| Have you experienced any major reduction in facial pain from trigeminal nerve surgery? | 0.014 |
| Do you have multiple sclerosis? | 0.014 |
| Have you been told that you had TMJ problems in the past? | 0.01 |
| Do you have constant background facial pain for more than half of your waking hours? | 0.01 |
| Does your pain include areas around or in your ear? | 0.01 |
| Have you noticed a recent change in your bite? | 0.005 |
| Do you have constant background facial pain? | 0.005 |
| Do you have pain with chewing hard or tough food? | −0.01 |
| Age | −0.01 |
| Did you experience any major reduction in facial pain from taking anticonvulsant meds? | −0.014 |
| Have you experienced periods of weeks, months, or years when you were pain-free? | −0.024 |
| Do you have pain, stiffness, or fatigue in jaw from chewing, talking, or at dental visits? | −0.029 |
| Was most (>50%) of your pain relieved with medications? | −0.057 |

TMJ, temporomandibular joint.
Negative values indicate that removing the feature increased model accuracy on average, suggesting limited or adverse contribution to performance.

data set achieved a higher weighted F1 score of 0.874 when evaluated on the same imbalanced test set. This suggests that training on balanced data, as done in this study, can improve performance in imbalanced scenarios, likely by reducing false positives and improving recall for the minority (TN) class. Nevertheless, these findings highlight the importance of training distribution on model performance. Even when real-world deployment involves class imbalance, training on balanced data may support more robust feature learning across classes and enhance generalizability.

Our findings suggest that an AI-assisted diagnostic tool to distinguish TN from TMD is feasible, particularly when leveraging a combination of patient-reported data and clinical examination findings. The performance of the Random Forest classifier, particularly with the full feature set, highlights the value of integrating diverse data sources to improve diagnostic accuracy. The model's ability to pinpoint clinically relevant features, such as episodic and brief electrical pains favoring TN, and the presence of TMJ or muscle tenderness favoring TMD, provides a transparent framework that clinicians can interpret and incorporate into their decision-making process. However, the performance gap between the models trained on the full feature set and those trained on subsets underscores the importance of *comprehensive* data collection. Relying on a limited number of features may compromise the diagnostic precision and utility of the tool.

## Limitations

Although these results are encouraging, several challenges remain before such a tool can be implemented in general clinical practice. External validation of independent data sets is critical to ensure the generalizability of the model across different patient populations. In addition, although the interpretability of feature importance is a strength, it must be carefully balanced with clinical expertise to avoid overreliance on algorithmic outputs. Practical considerations, such as integration into clinical workflows, clinician trust, and addressing potential algorithmic bias, should also be addressed. This study lays the groundwork for future research on AI-assisted diagnostics for TN and TMD, with the potential to

enhance diagnostic accuracy and streamline patient care. These results must be tested and validated by other centers, particularly those that can combine the analyses of experts in both TN and TMD. Replication and validation of these results may allow us to add TMD to the list of diagnoses specified in our previous publications.[19,20]

## CONCLUSION

The analysis of this network indicated that TMDs and TN can be reliably differentiated using a standardized questionnaire and physical examination with approximately 90% accuracy. These tools may provide useful information for clinicians interested in this distinction.

### Data availability

All relevant data are within the paper and its Supporting Information files.

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