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# The association of TMJ sounds with different dental and skeletal measurements along with headache and pain using DC/TMD

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DISSERTATION

# THE ASSOCIATION OF TMJ SOUNDS WITH DIFFERENT DENTAL AND SKELETAL MEASUREMENTS ALONG WITH HEADACHE AND PAIN USING DC/TMD

by

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## DEDICATION

I would like to dedicate this work to my parents who dedicated their time, prayer, and all possible support means to me and provided the best possible environment for me to pursuit my education journey. To my sisters and brothers who supported me through my ups and down through my 5 years in Boston. To my friends who were always by my side to answer for anything I needed. My gratitude to all I have mentioned, it would not be possible with each and every one of you.

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The Association of TMJ Sounds with Different Dental and Skeletal measurements Along with Headache and Pain Using DC/TMD

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ABSTRACT

**Purpose:** It has been suggested in some studies that certain malocclusion features are related to Temporomandibular Joint (TMJ) clicking, which is a prevalent sign of Temporomandibular Disorders (TMD's). This study aimed to evaluate different dental and skeletal malocclusion parameters and their relation to TMJ sounds. Also, to examine TMJ sounds with the presence of headache and TMJ pain using Diagnostic Criteria for Temporomandibular Disorders.

**Materials & Methods:** A sample of 460 subjects seeking orthodontic treatment were evaluated using DC/TMD. Dental measures were recorded based on the initial records along with the clinical examination of the DC/TMD. Skeletal measurements were recorded after lateral cephalometric radiographs were traced. All measurements were confirmed before collection by one examiner using all the initial records.

**Results:** The sample was comprised of 283 females and 177 males. Clicking prevalence among the sample was 13%, of which 70% were females. Hispanic and Other group were significantly associated with opening and closing TMJ click. Class III dental was highly significant with TMJ click (OR: 0.35). Females who had headache had higher odds of having headache compared to males. Headache was significantly associated with all TMJ click variables (Open click

[OR:10], lateral click [OR:10], self-reported click [OR:4.7]). Moreover, TMJ pain was significant with open click (OR:7.6), lateral click (OR:14.4), and self-reported click (OR:7.7). African-American group had 0.28 odds of having TMJ pain compared to Hispanics and Other. Finally, Males have 0.29 odds of having TMJ pain compared to females.

**Conclusion:** In conclusion TMJ click upon opening and closing, lateral excursion, and self-reported click is highly associated with headache and chronic headache in general with a prevalence higher in females. Pain was highly associated with TMJ click of all sorts, with a higher prevalence in females and the Hispanic and other group. Finally, TMJ click was found more in the Hispanic and other group and class III dental occlusion subjects.

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## LIST OF ABBREVIATIONS

BU ..... Boston University

CI..... Confidence Interval

CITI..... Collaborative Institutional Training Initiative

DC/TMD ..... Diagnostic Criteria for Temporomandibular Disorders

HIPAA ..... Health Insurance Portability and Accountability Act

ICC ..... Intraclass Correlation Coefficient

ID ..... Internal Derangement

IRB ..... Institutional Review Board

MD ..... Mean Difference

NHIS ..... National Health Interview Survey

OA ..... Osteoarthritis

OR ..... Odds Ratio

P ..... P-value

RDC/TMD ..... Reserach Criteria for Temporomandibular Disorders

SD ..... Standard Deviation

TMD ..... Temporomandibular Disorder

TMJ ..... Temporomandibular Joint

# LITERATURE REVIEW

# INTRODUCTION

## Definition of Temporomandibular Disorders (TMDs)

Temporomandibular Disorders (TMD's) is a term used to describe a multifactorial condition. The definition of the term has been a matter of debate among many authors, while its classification has been discussed to have different aspects, and it is still an ongoing debate with no consensus. [1] The current approach is that TMD is defined as a collection of other conditions affecting either the muscles of mastication, the temporomandibular joints (TMJ), or both. [2] Mcneill [3] added another factor to these common conditions, which is the disturbance in the stomatognathic system, such as limitation of mandibular movement along with pain and clicking sounds increased during mastication. Moreover, ringing sounds in ears associated with pain in the head and neck region are considered classic signs and symptoms.

The term TMD and its five-category classification suggested by Bell received the widest acceptance among the field and later approved by the American Dental Association at that time. [4] [5] Moreover, Schiffman et al, in 2014 found a more detailed classification with major four categorize then it divides into branches from each. The four main categorize are, Temporomandibular joint disorders, masticatory muscles disorders, Headache, and associated structures, in each of those major categorize are different types of disorders and they are as follow. First temporomandibular joint disorder: 1-Joint pain, 2-Joint disorder,

3-Joint disease, 4-Fractures, 5-Congenital/developmental disorders. Second masticatory muscles disorder:1-Muscles pain, 2-Contractures, 3-Hypertrophy, 4-Neoplasm, 5-Movement disorder, 6-Masticatory muscle pain attributed to systemic/central pain disorder. Third headache: Headache attributed to TMD. Fourth and last, associated structures: Coronoid hyperplasia. More detailed classification are shown in table (1). [6] This classification presented by Schiffman et al, is more detailed and had a broader spectrum to understand the disorder better.

## Etiology

TMD etiology has been a matter of debate exactly as its term over the years, some of this debate is based on actual science and some based on base experience and editorial opinions. It is believed that TMD etiology is multifactorial, but in reality it is still unclear. Some linked that the presentation of a functional somatic syndrome frequently meet other criteria for other syndromes and it shouldn't be looked at uniquely. [7] In essence, load-bearing joint remodeling is natural adaptation process essential in function and stress distribution. This phenomenon takes place early on, but when the capacity of this natural process has been exceeded, it turns into osteoarthritis. [8,9] Some studies tried to gather information regarding osteoarthritis and internal derangement, and noticed that etiology is

still unknown, whether ID takes place prior to OA or if they develop simultaneously in the presence of a causing factor. Although clear causality is still undiscovered, a known correlation is known between development of osteoarthritis and disc displacement of the temporomandibular joint. Therefore, until causality is proven, all possible causes must be covered in the management. [10] As mentioned earlier, temporomandibular disorders are multifactorial with not only the bone of the joint is involved but soft tissue too, including TMJ disc and the muscles around the joint. So, etiology is hard to investigate if the underlying cause was looked at solely.

## Diagnostic Criteria for Temporomandibular Disorders (DC/TMD)

Dworkin and LeResche proposed a diagnostic protocol called Research Criteria for Temporomandibular Disorders (RDC/TMD); the purpose was to provide standardized criteria for clinical research and epidemiological studies, using the available knowledge on temporomandibular joint disorders. RDC/TMD was comprised of 2 sections; Axis I: Clinical part of temporomandibular disorder, Axis II: disabilities with pain, and the patient's psychological profile. [11]

Axis-I was believed to be reliable and valid, but after testing, the instrument

recorded ≥ 0.70 in sensitivity and ≥ 0.95 in specificity, which was below the target. Then, this encouraged the development of the RDC/TMD Axis II, which demonstrated to be valid and reliable. Two international consensus workshops were held to finalize Axis I and Axis II instruments.

Finally, a new tool was proposed in 2014 by Schiffman et al., [6] known as Diagnostic Criteria for Temporomandibular Disorder (DC/TMD), which demonstrated to be both valid and reliable with a more comprehensive view, using a simpler and shorter screening instrument. This criteria proved to be suitable for both clinical and research settings. DC/TMD is an instrument that can detect TMD's with a range from simple to complex conditions. Axis I protocol a valid screening tool for the detection of pain related TMD, and a valid diagnostic diffrentation tool for the most common TMDs (sensitivity ≥ 0.86, specificity ≥ 0.98).[6]

## Prevalence

In 2001, the National Health Interview Survey (NHIS) was conveyed to compared self-reported TMD-type pain among different age groups, gender, and ethnicity. Caucasians and African Americans were looked at, Isong et al., [12] analyzed the data, and found out the following results; Prevalence over females was 6.8%, while males scored 1.8% with an overall prevalence among both groups was 4.6%. Prevalence was higher in Caucasian women at younger ages up to 55 years, then it decreases. However, African American women had a much lower prevalence at young ages, which increased after 55-64 years of age. The same pattern of racial difference was found among males. They concluded that age seems to have more of an influencing role in females over males.

Marina Fernandes de Sena et al., [13], in a systematic review done the year of 2013, reported the prevalence of signs and symptoms of TMD among children to be from 16% to 68%. Nevertheless, the investigator demonstrated the functional muscle signs and symptoms only with no regard for intra-articular disk disorders. However, in 2016, a systematic review reported the prevalence of intra-articular joint disorder clinical signs and symptoms was 16%. Joint crepitation with click 14%, while demonstrating 10% for TMJ clicking to be the most common sign, and 2.3% was for the jaw locking. [14]

Prevalence of the disease recorded in the studies varied significantly, ranging from 6% to 93% based on patient self-reports and a range of 0% to 93% based on clinical examination. This suggests that there must be an explanation of the way of conducting questionnaires and examinations because it is unlikely to have such discrepancies in a

population. [12] Also, it suggests the need for an established questionnaire and examination protocol to be followed, more studies are needed to verify those percentages using diagnostic criteria of the above mentioned.

## Headache

Headache is a complicated condition or disorder that is a significant issue for many people. It can originate due to different etiologies and through different pathways. Cranial structure problems, such as intercranial pressure and brain tumors, can be the source of certain types of headache. These types of headache poses a serious problem and should be identified and referred for proper medical attention. They are usually accompanied by systemic symptoms (e.g. muscle weakness, numbness, paresthesia, and seizure). When those symptoms arise an immediate action should be taken to refer the patient to the appropriate specialist.[15,16]

Headache prevalence varies based on the type, the more common headache disorders are as follow, Chronic migraine headache present with a prevalence from 1% - 4% of the population.[17,18] Also, for tension-type headache the prevalence is 2.2%.[19] For more of an

international base population, a systematic review done to document headache prevalence and disability worldwide found that, the prevalence of adults with an active headache is 46% for headache in general, 42% for tension-type headache, 11% for migraine, and 3% for chronic daily headache.[20] Headache has been associated with TMD in several studies.[21-23] Furthermore, it can be either primary headache, or secondary headache.[24,25]

**Purpose of the Study:**

This study aims to evaluate the association between TMJ sounds with dental and skeletal measurements, examine the association between TMJ sounds with headache and TMJ pain.

**Objectives:**

i- Evaluation of TMJ sounds and dental/skeletal measurements.

ii- Association between TMJ sounds and the presence of headache and pain.

**Hypothesis:**

H0: There is no association between dental/skeletal measurements and TMJ sounds.

H0: There is no association between TMJ sounds and the presence of headache.

H0: There is no association between TMJ sounds and the presence of TMJ pain.

## MATERIALS AND METHODS

This retrospective study was conducted at Boston University Department of Orthodontics. The sample size was calculated using the formula n=Z^2*P(1-P)/d^2.[26] The assumed prevalence of 33%, with 5% precision gave a total sample size of 340 individuals. However, This was the minimum and in this study we have screened 460 subjects following previous studies done in this field.

Participants went under inclusion and exclusion criteria. Subjects fell in an age range between 7 to 50 years of age. Races included in the study were Caucasians, African-American, Hispanic and other (Asian, middle eastern, Indian). We decided to call it that, because Hispanics were the majority in this group and the other ethnicity numbers were not enough to have them as a separate group.

In the Orthodontic department at Boston University a clinical protocol was implemented by one of the faculty who specializes in TMJ, Diagnostic Criteria for Temporomandibular Disorder (DC/TMD) became a standard practice and was included as one of the legal records taken at the initial visit for patients. So, the clinical protocol for the initial visit for taking pretreatment records included DC/TMD (Symptom questionnaire and clinical exam chart), and regular orthodontic records (Photographs, dental cast, and lateral Cephalometric and Panoramic X-rays). In addition, to insure that the department was able to use the data collected by the residents valid for research use calibration was needed.

At the beginning of the orthodontic program, all new residents are calibrated for the use of this protocol. Calibration is conducted as a presentation of how to conduct the examination based on the protocol described by Schiffman et al.[6] Then, hands-on training is carried out by one instructor, residents are paired to do the exam on each other. Every class has eight residents, so each resident would perform seven exams, then two weeks later, they are asked to perform the same exam on their partners again to ensure intra-examiner reliability. The instructor (golden standard) conducts the exam on all of the residents to ensure inter/intra-examiner reliability.

The examination includes using a sterilizable metal ruler for the millimetric measurements, a pediatric stethoscope to detect crepitation sounds, and a digital finger caliber to calibrate finger pressure for palpation.

All data for each class is inserted into an excel sheet and sent to the Biostatistician to calculate Kappa coefficient. Kappa coefficient is calculated to be >0.6; if not, then further training sessions were conducted.

DC/TMD's symptom questionnaire and clinical exam chart data was collected retrospectively from the Salud system, and then it was coded and inserted in an excel sheet. Data from the DC/TMD tool were extracted individually, so each piece of information was analyzed too, rather than analyzing the outcome of the tool by itself.

Patient's demographics was extracted from Salud as well and coded for confidentiality and HIPAA compliance. Then, patient's orthodontic photographs viewed through Dolphin software® , re-checking overjet and overbite measurements given by the DC/TMD tool was done through measurements from cephalometric tracing. Finally, accessing

Cephalometric X-rays using Dolphin * software to extract cephalometric tracing numbers to translate it into skeletal measurement outcomes. Retracing was done for all cephalometric X-rays by one investigator to ensure reliable measurements across the sample.

IRB was approved by Boston University's Institutional Review Board and their guidelines were followed throughout the study. Data was classified according to the variables of interest and then was inserted into SAS 9.4.

**Inclusion criteria include:**

- Patients who receive any comprehensive orthodontic treatment at BU.
- Patients who have completed both Symptoms Questionnaire and the clinical examination chart.
- Patients between 7 and 50 years of age.
- Patients with full medical records and demographics.
- A patient who've been examined after the calibration sessions.

**Exclusion criteria will be as follows:**

- Any patient with Craniofacial deformity.
- Any patient who failed to be examined by DC/TMD tool.
- Any patient whom been diagnosed with a systemic disease involving the joints (e.g., Rheumatoid arthritis).

## Variables of Interest

**Diagnostic Variables:**

- Dental Malocclusion Classification (Class I, Class II, Class III).
- Skeletal Discrepancy Classification (Class I, Class II, Class III).
- Vertical Discrepancy (Normal overbite, Open bite, Deep bite).
- Mandibular angulation (Normodivergent, Hyperdivergent, Hypodivergent).

**Demographic Variables:**

- Age – Continuous
- Races – Categorical (Caucasian, African-American, Hispanic and other [Asia, Middle eastern, Indian]).
- Gender: Categorical ( Male, Female)

**Cephalometric Variables:**

- ANB (A point – Nasion – B point)
- FMA (Frankfort Horizontal – Mandibular plane)
- SNA (Sella – Nasion – A point)
- SNB (Sella – Nasion – B point)
- U1-NA (Upper incisor – Nasion A point line) measurement in mm.
- U1-SN (Upper incisor – Sella Nasion line) Angle measurement.

- L1 -NB (Lower incisor – Nasion B point line) measurement in mm.
- IMPA ( Lower incisor – Mandibular plane) Angle measurement.
- Occlusal plane-SN ( Occlusal plane – Sella nasion line)
- Llip-E plane ( Lower lip – Esthetic line) measurement in mm.
- Ulip-E plane (Upper lip – Esthetic line) measurement in mm.
- OJ – Overjet.
- OB- Overbite.

**DC/TMD Variables:**

- Joint clicking upon opening and closing.
- Joint crepitus upon opening and closing.
- Joint clicking upon lateral excursion movement. (Right lateral, left lateral, and protrusive)
- Joint crepitus upon lateral excursion movement. (Right lateral, left lateral, and protrusive)
- Joint pain.
- Headache upon clinical examination.
- Self-reported headache period in years.
- Self-reported clicking of the joint.

**Statistical Analysis:**

Descriptive/univariate analysis (Mean ±SD, and proportion), bivariate analysis (Chi-square, T-test, and ANOVA with multiple comparisons), Logistic regression model was used to analyze the data and establish correlations. Statistical significance will be set at the 0.05 level. SAS 9.4 * will be used for all previously stated statistical analyses.

**Reliability:**

Calibration was done as explained earlier and Kappa coefficient and intraclass correlation coefficient (ICC) scores were calculated.

- Inter-examiner reliability score :
  - The least Kappa score = 0.6
  - The lest ICC score = 0.8
- Intra-examiner reliability score :
  - The least ICC score = 0.92

**Approval and Training:**

This study was approved by the Institutional Review Board (IRB number H-40893). All necessary human subject trainings were completed through the Collaborative Institutional Training Initiative (CITI).

**TABLES**

**Table (1)**

Taxonomic Classification for Temporomandibular Disorders

**I. TEMPOROMANDIBULAR JOINT DISORDERS 1. Joint pain**
A. Arthralgia
B. Arthritis
**2. Joint disorders** A. Disc disorders
1. Disc displacement with reduction
2. Disc displacement with reduction with intermittent locking 3. Disc displacement without reduction with limited opening
4. Disc displacement without reduction without limited opening
B. Other hypomobility disorders 1. Adhesions / adherence
2. Ankylosis a. Fibrous
b. Osseous
C. Hypermobility disorders
1. Dislocations a. Sublaxation b. Luxation
**3. Joint diseases**
A. Degenerative joint disease 1. Osteoarthrosis
2. Osteoarthritis
B. Systemic arthritides
C. Condylysis/idiopathic condylar resorption D. Osteochondritis dissecans
E. Ostronecrosis
F. Neoplasm
G. Synovial chondromatosis
**4. Fractures**
**5. Congenital/developmental disorders**
A. Aplasia
B. Hypoplasia C. Hyperplasia
**II. MASTICATORY MUSCLE DISORDERS 1. Muscle pain**
A. Myalgia
1. Local myalgia
2. Myofascial pain
3. Myofascial pain with referral
B. Tendonitis
C. Myositis
D. Spasm

2. **Contracture**
3. **Hypertrophy**
4. **Neoplasm**
5. **Movement disorders**

**A. Orofacial dyskinesia**

**B. Oromandibular dystonia**

**6. Masticatory muscle pain attributed to systemic/central pain disorders**

A. Fibromyalgia/ widespread pain

**III. HEADACHE**
**1. Headache attributed to TMD**
**IV. ASSOCIATED STRUCTURES 1. Coronoid hyperplasia**

This table was quoted from Schiffman et al. [6]

**Variable means**

**Table (2)**

| VARIABLE | MEANS (SD) |
|---|---|
| **Age** | 25.4 (13.8) |
| **Wits** | 2.1 (0.7) |
| **ANB** | 1.8 (0.6) |
| **FMA** | 1.6 (0.8) |
| **GOGNSN** | 1.6 (0.7) |
| **SNA** | 83.3 (4.6) |
| **SNB** | 79.9 (4.6) |
| **SN_GOGN** | 31.5 (6.7) |
| **gonial_angle** | 117 (7.5) |
| **U1_NA** | 6 (3.8) |
| **U1_SN** | 108 (9.9) |
| **L1_NB** | 7.3 (3.8) |
| **IMPA** | 95.8 (9.3) |
| **U1_L1** | 121.6 (14.5) |
| **occpln_SN** | 15.1 (5.6) |
| **Llip_E** | 1.4 (4.2) |
| **Ulip_E** | -1.1 (3.8) |
| **SN_Me** | 69.2 (13.4) |
| **Oj** | 2.8 (2.7) |
| **Ob** | 2.6 (2.7) |
| **Midline** | -0.02 (1.8) |

| | |
|---|---|
| **Maxopening_Nopain** | 46.7 (6) |
| **Maxopening_pain** | 47.7 (5.8) |
| **Maxopening_assissted** | 50.7 (5.8) |
| **Right_lateral** | 8.9 (2.4) |
| **Left_lateral** | 9 (2.4) |
| **Protrusive** | 7.7 (1.7) |
| **Headache_period_years** | 0.3 (2.2) |
| **Headache_Period_motnhs** | 0.05 (0.6) |

**Results Distribution**
**Table (3)**

| Variables | No. | Percentage |
|---|---|---|
| **Male** | 177 | 38.48% |
| **Female** | 283 | 61.52% |
| **Caucasian** | 104 | 22.61% |
| **African-American** | 175 | 38.04% |
| **Hispanic and Other** | 181 | 39.35% |
| **Class I** | 238 | 51.74% |
| **Class II** | 153 | 33.26% |
| **Class III** | 69 | 15% |
| **Headache** | 28 | 6.09% |
| **Open/close click** | 60 | 13.04% |
| **Open/close crepitus** | 9 | 1.96% |
| **Lateral excursion click** | 27 | 5.87% |
| **Lateral excursion crepitus** | 7 | 1.52% |
| **Self-reported click** | 51 | 11.09% |

**Frequency for Gender Distribution**
**(Table 4)**

| Variables | Male | Female | P-value |
|---|---|---|---|
| **Opening click present** | 10.17% | 14.84% | 0.1 |
| **Opening crepitus present** | 1.69% | 2.12% | 1 |
| **Lateral Excursions click present** | 3.39% | 7.4% | 0.1 |
| **Lateral Excursions crepitus present** | 1.13% | 1.77% | 0.7 |
| **Self-reported click present** | 8.47% | 12.72% | 0.1 |
| **Pain Present** | 2.82% | 9.54% | 0.007* |
| **Headache Present** | 2.82% | 8.13% | 0.02* |

**Frequency for Race Distribution**
**(Table 5)**

| Variables | Caucasian | African American | Hispanic and other | P-value |
|---|---|---|---|---|
| **Opening click present** | 11.54% | 5.14% | 21.55% | < .0001* |
| **Opening crepitus present** | 2.88% | 2.29% | 1.1% | 0.5 |
| **Lateral excursions click present** | 9.62% | 1.71% | 7.73% | 0.009* |
| **Lateral excursions crepitus present** | 0.96% | 1.71% | 1.66% | 0.8 |
| **Self-reported click present** | 13.46% | 4.57% | 16.02% | 0.001* |
| **Pain present** | 8.65% | 2.29% | 10.5% | 0.007* |
| **Headache Present** | 5.77% | 1.71% | 10.5% | 0.002* |

**Frequency for Dental Classification Distribution**
**(Table 6)**

| Variables | Class I | Class II | Class III | P-value |
|---|---|---|---|---|
| **Opening click present** | 10.08% | 13.07% | 23.19% | 0.02* |
| **Opening crepitus present** | 1.26% | 3.27% | 1.45% | 0.4 |
| **Lateral excursions click present** | 5.04% | 6.54% | 7.25% | 0.6 |
| **Lateral excursions crepitus present** | 0.84% | 1.96% | 2.90% | 0.2 |
| **Self-reported click present** | 7.14% | 11.11% | 24.64% | 0.0007* |
| **Pain present** | 3.36% | 8.50% | 15.94% | 0.001* |
| **Headache present** | 3.36% | 9.15% | 8.70% | 0.03* |

**Frequency table for subjects presented with headache and TMJ clicking (Table 7)**

| Variables | Headache | P-value |
|---|---|---|
| **Opening click present**<br><br>**Opening click absent** | 60.7%<br><br>39.2% | <.0001 |
| **Lateral Excursions click present**<br><br>**Lateral Excursions click absent** | 46%<br><br>53% | <.0001 |
| **Self-reported click present**<br><br>**Self-reported click absent** | 39.2%<br><br>60.7% | <.0001 |

**Bivariate Test of Opening/Closing Click and Presented Measurements (Table 8)**

| Variables | Open Click absent Mean (SD) | Open Click Present Mean (SD) | Mean difference (SD) | P-value |
|---|---|---|---|---|
| **Age** | 25.2 (13.9) | 27 (12.6) | -1.8 (13.8) | 0.3 |
| **ANB°** | 3.5 (3.4) | 2.1 (4.3) | 1.4 (3.5) | 0.003* |
| **FMA°** | 24.8 (5.9) | 25 (7.3) | -0.2 (6.1) | 0.7 |
| **SNA°** | 83.4 (4.6) | 82.2 (4.8) | 1.2 (4.6) | 0.059* |
| **SNB°** | 79.9 (4.5) | 80.1 (5.2) | -0.1 (4.6) | 0.7 |
| **U1-NA – mm** | 6.01 (3.7) | 6.4 (4.6) | -0.4 (3.8) | 0.3 |
| **U1-SN°** | 108 (9.6) | 108 (11.6) | -0.08 (9.96) | 0.9 |
| **L1-NB – mm** | 7.5 (3.8) | 6.4 (3.5) | 1.08 (3.7) | 0.039* |
| **IMPA°** | 96.24 (9.2) | 93.4 (9.7) | 2.78 (9.2) | 0.03* |
| **Occlusal plane – SN°** | 15.2 (5.4) | 14.49 (5.6) | 0.72 (5.6) | 0.3 |
| **L.Lip-E – mm** | 1.68 (4.2) | 0.11 (3.8) | 1.5 (4.2) | 0.007* |
| **U.Lip-E – mm** | -0.9 (3.8) | -2.9 (3.5) | 1.9 (3.7) | 0.0002* |
| **Overjet – mm** | 2.9 (2.6) | 2.5 (3.4) | 0.37 (2.7) | 0.3 |
| **Overbite – mm** | 2.69 (2.7) | 2.08 (2.78) | 0.61 (2.78) | 0.1 |
| **Midline – mm** | 0.02 (1.7) | -0.33 (2.06) | 0.35 (1.83) | 0.1 |
| **Headache period (Year)** | 0.18 (1.5) | 1.6 (4.8) | -1.4 (2.2) | <0.0001* |

**Bivariate test of opening/closing crepitus and presented measurements (Table 9)**

| Variables | Open crepitus absent Mean (SD) | Open crepitus Present Mean (SD) | Mean difference (SD) | P-value |
|---|---|---|---|---|
| **Age** | 25.5 (13.8) | 20.5 (7.5) | 4.9 (13.8) | 0.2 |
| **ANB°** | 3.3 (3.5) | 3.7 (3.7) | -0.37 (3.5) | 0.7 |
| **FMA°** | 24.7 (6.1) | 28 (8.1) | -3.2 (6.1) | 0.1 |
| **SNA°** | 83.3 (4.6) | 80.3 (4.8) | 3 (4.6) | 0.056* |
| **SNB°** | 80 (4.6) | 76.6 (4) | 3.3 (4.6) | 0.03* |
| **U1-NA – mm** | 6 (3.8) | 7.6 (5.9) | -1.5 (3.8) | 0.2 |
| **U1-SN°** | 108 (9.8) | 108.5 (13.2) | -0.4 (9.9) | 0.8 |
| **L1-NB – mm** | 7.3 (3.8) | 7.8 (4) | -0.5 (3.8) | 0.6 |
| **IMPA°** | 95.8 (9.3) | 97.2 (7) | -1.3 (9.3) | 0.6 |
| **Occlusal plane – SN°** | 15 (5.5) | 18.8 (10.5) | -3.7 (5.6) | 0.049* |
| **L.Lip-E – mm** | 1.4 (4.2) | 2 (5.3) | -0.5 (4.2) | 0.7 |
| **U.Lip-E – mm** | -1.2 (3.8) | 0.5 (3.9) | -1.7 (3.8) | 0.1 |
| **Overjet – mm** | 2.8 (2.7) | 4.7 (4) | -1.9 (2.7) | 0.03 * |
| **Overbite – mm** | 2.6 (2.7) | 2.1 (2.4) | 0.5 (2.7) | 0.5 |
| **Midline – mm** | -0.01 (1.8) | -0.5 (2.1) | 0.5 (1.8) | 0.3 |
| **Headache period (Year)** | 0.3 (2.2 | 0.4 (1.3) | -0.07 (2.2) | 0.9 |

**Bivariate Test of Lateral Excursion Click and Presented Measurements (Table 10)**

| Variables | Lateral excursion Click Absent Mean (SD) | Lateral excursion Click Present Mean (SD) | Mean difference (SD) | P-value |
|---|---|---|---|---|
| **Age** | 25.1 (13.7) | 29.5 (14) | -4.3 (13.7) | 0.1 |
| **ANB°** | 3.3 (3.5) | 2.8 (3.4) | 0.51 (3.5) | 0.4 |
| **FMA°** | 24.9 (5.9) | 23.9 (8.9) | 0.93 (6.1) | 0.4 |
| **SNA°** | 83.3 (4.6) | 82.2 (4.8) | 1.1 (4.6) | 0.2 |
| **SNB°** | 90 (4.6) | 79.4 (5.7) | 0.5 (4.6) | 0.5 |
| **U1-NA – mm** | 6.1 (3.8) | 5.2 (3.8) | 0.9 (3.8) | 0.2 |
| **U1-SN°** | 108.3 (9.8) | 105.4 (11.5) | 2.8 (9.9) | 0.1 |
| **L1-NB – mm** | 7.5 (3.7) | 4.9 (3.2) | 2.5 (3.7) | 0.0005* |
| **IMPA°** | 96.1 (9.3) | 92.3 (7.6) | 3.7 (9.2) | 0.04* |
| **Occlusal plane – SN°** | 15.1 (5.4) | 14.3 (9) | 0.8 (5.6) | 0.4 |
| **L.Lip-E – mm** | 1.6 (4.2) | -0.7 (4.1) | 2.4 (4.2) | 0.004* |
| **U.Lip-E – mm** | -1 (3.8) | -2.9 (3.5) | 1.8 (3.8) | 0.01 |
| **Overjet – mm** | 2.8 (2.7) | 3.7 (3.6) | -0.8 (2.7) | 0.1 |
| **Overbite – mm** | 2.5 (2.7) | 3.2 (2.9) | -0.6 (2.7) | 0.2 |
| **Midline – mm** | 0.004 (1.8) | -0.4 (2.2) | 0.4 (1.8) | 0.2 |
| **Headache period (Year)** | 0.1 (1.4) | 3.4 (6.7) | -3.2 (2.1) | < .0001* |

**Bivariate Test of Lateral Excursion Crepitus and Presented Measurements (Table 11)**

| Variables | Lateral excursion Crepitus Absent Mean (SD) | Lateral excursion Crepitus Present Mean (SD) | Mean difference (SD) | P-value |
|---|---|---|---|---|
| **Age** | 25.4 (13.8) | 24.4 (12.9) | 1 (13.8) | 0.8 |
| **ANB°** | 3.3 (3.5) | 4.05 (2.1) | -0.72 (3.5) | 0.5 |
| **FMA°** | 24.7 (6) | 31.9 (9.8) | -7.2 (6.1) | 0.002* |
| **SNA°** | 83.3 (4.6) | 80.1 (5.7) | 3.2 (4.6) | 0.06 |
| **SNB°** | 80 (4.6) | 76 (4) | 4 (4.6) | 0.02* |
| **U1-NA – mm** | 6 (3.8) | 6.1 (6.3) | -0.06 (3.8) | 0.9 |
| **U1-SN°** | 108.2 (9.9) | 103.8 (11.1) | 4.3 (9.9) | 0.2 |
| **L1-NB – mm** | 7.3 (3.8) | 7.5 (1.9) | -0.1 (3.8) | 0.9 |
| **IMPA°** | 95.9 (9.3) | 94.1 (5) | 1.7 (9.3) | 0.6 |
| **Occlusal plane – SN°** | 15 (5.5) | 22.4 (9) | -7.4 (5.6) | 0.0006 * |
| **L.Lip-E – mm** | 1.4 (4.2) | 1.6 (5.5) | -0.1 (4.2) | 0.9 |
| **U.Lip-E – mm** | -1.1 (3.8) | -1 (3.9) | -0.1 (3.8) | 0.9 |
| **Overjet – mm** | 2.8 (2.7) | 4 (4) | -1.1 (2.7) | 0.2 |
| **Overbite – mm** | 2.6 (2.7) | 0.8 (3.6) | 1.7 (2.7) | 0.09 |
| **Midline – mm** | -0.01 (1.8) | -0.2 (2.4) | 0.2 (1.8) | 0.7 |
| **Headache period (Year)** | 0.3 (2.2) | 0.8 (1.5) | -0.4 (2.2) | 0.5 |

**Bivariate Test of Headache and Presented Measurements (Table 12)**

| Variables | Headache absent Mean (SD) | Headache Present Mean (SD) | Mean difference (SD) | P-value |
|---|---|---|---|---|
| **Age** | 25.1 (13.7) | 30.7 (13.4) | -5.6 (13.7) | 0.03* |
| **ANB°** | 3.3 (3.5) | 2.7 (4) | 0.6 (3.5) | 0.3 |
| **FMA°** | 24.9 (6) | 23.8 (7.7) | 1.03 (6.1) | 0.3 |
| **SNA°** | 83.3 (4.6) | 82.7 (5.3) | 0.58 (4.6) | 0.5 |
| **SNB°** | 79.9 (4.6) | 80 (5.6) | -0.02 (4.6) | 0.9 |
| **U1-NA – mm** | 6.1 (3.8) | 5.7 (4.4) | 0.35(3.8) | 0.6 |
| **U1-SN°** | 108.2 (9.9) | 106.8 (10.5) | 1.3 (9.9) | 0.4 |
| **L1-NB – mm** | 7.4 (3.8) | 5.7 (3.2) | 1.6 (3.7) | 0.02* |
| **IMPA°** | 96.02 (9.3) | 93.7 (9.5) | 2.2 (9.3) | 0.2 |
| **Occlusal plane – SN°** | 15.2 (5.6) | 13.7 (6.5) | 1.4 (5.6) | 0.1 |
| **L.Lip-E – mm** | 1.6 (4.1) | -0.6 (4.5) | 2.2 (4.2) | 0.007* |
| **U.Lip-E – mm** | -1 (3.7) | -2.8 (4.2) | 1.7 (3.8) | 0.01* |
| **Overjet – mm** | 2.8 (2.7) | 2.9 (3.5) | -0.1 (2.7) | 0.8 |
| **Overbite – mm** | 2.6 (2.7) | 2.3 (3.6) | 0.2 (2.7) | 0.6 |
| **Midline – mm** | -0.02 (1.8) | 0.03 (1.8) | -0.06 (1.8) | 0.8 |

**Bivariate Test of Self-Reported Click and Presented Measurements (Table 13)**

| Variables | Self-reported click absent Mean (SD) | Self-reported click Present Mean (SD) | Mean difference (SD) | P-value |
|---|---|---|---|---|
| **Age** | 25.4 (13.9) | 25.1 (12.4) | 0.3 (13.8) | 0.8 |
| **ANB°** | 3.5 (3.3) | 1.6 (4.7) | 1.9 (3.5) | 0.003* |
| **FMA°** | 24.7 (5.9) | 25.8 (7.3) | -1.1 (6.1) | 0.2 |
| **SNA°** | 83.5 (4.6) | 81.5 (4.8) | 1.9 (4.6) | 0.004* |
| **SNB°** | 79.9 (4.5) | 79.9 (5.5) | 0.04 (4.6) | 0.9 |
| **U1-NA – mm** | 5.9 (3.7) | 6.8 (4.8) | -0.8 (3.8) | 0.1 |
| **U1-SN°** | 108.1 (9.6) | 108 (12.3) | 0.1 (9.9) | 0.9 |
| **L1-NB – mm** | 7.4 (3.8) | 6.4 (3.5) | 1 (3.8) | 0.06 |
| **IMPA°** | 96.3 (9) | 92.2 (10.8) | 4 (9.2) | 0.003* |
| **Occlusal plane – SN°** | 15.1 (5.4) | 15 (7.5) | 0.04 (5.7) | 0.9 |
| **L.Lip-E – mm** | 1.6 (4.2) | 0.1 (3.9) | 1.5 (4.2) | 0.01* |
| **U.Lip-E – mm** | -0.9 (3.7) | -2.9 (3.8) | 1.9 (3.8) | 0.0006* |
| **Overjet – mm** | 2.9 (2.6) | 2 (3.2) | 0.9 (2.7) | 0.02* |
| **Overbite – mm** | 2.7 (2.7) | 1.6 (2.7) | 1.1 (2.7) | 0.006* |
| **Midline – mm** | -0.007 (1.7) | -0.13 (2.2) | 0.1 (1.8) | 0.6 |
| **Headache period (Year)** | 0.3 (2.1) | 0.6 (2.8) | -0.3 (2.2) | 0.2 |

**Bivariate Test of TMJ Pain and Presented Measurements (Table 14)**

| Variables | Pain absent Mean (SD) | Pain Present Mean (SD) | Mean difference (SD) | P-value |
|---|---|---|---|---|
| **Age** | 25 (13.7) | 30.5 (13.4) | -5.5 (13.7) | 0.02* |
| **ANB°** | 3.4 (3.5) | 1.7 (4.1) | 1.7 (3.5) | 0.008* |
| **FMA°** | 24.8 (6.1) | 24.7 (6.9) | 0.08 (6.1) | 0.9 |
| **SNA°** | 83.4 (4.6) | 81.3 (4.4) | 2.1 (4.6) | 0.01* |
| **SNB°** | 90 (4.5) | 79.5 (5.9) | 0.4 (4.6) | 0.6 |
| **U1-NA – mm** | 6 (3.8) | 5.8 (4.4) | 0.19 (3.8) | 0.7 |
| **U1-SN°** | 108.3 (9.8) | 105.2 (10.5) | 3 (9.9) | 0.09 |
| **L1-NB – mm** | 7.5 (3.8) | 5.3 (4.1) | 2.1 (3.7) | 0.001* |
| **IMPA°** | 96.2 (9.1) | 90.7 (10.5) | 5.5 (9.2) | 0.001* |
| **Occlusal plane – SN°** | 15 (5.5) | 15.5 (7.2) | -0.4 (5.6) | 0.6 |
| **L.Lip-E – mm** | 1.6 (4.1) | -1 (4.6) | 2.6 (4.1) | 0.0005* |
| **U.Lip-E – mm** | -1 (3.8) | -3.6 (3.5) | 2.6 (3.7) | 0.0002* |
| **Overjet – mm** | 2.8 (2.7) | 2.4 (2.7) | 0.4 (2.7) | 0.3 |
| **Overbite – mm** | 2.6 (2.7( | 2.2 (3) | 0.3 (2.7) | 0.4 |
| **Midline – mm** | -0.04 (1.8) | 0.3 (2) | -0.3 (1.8) | 0.2 |
| **Headache period (Year)** | 0.05 (0.5) | 4.6 (7.2) | -4.6 (1.9) | <.0001* |

**The Association Between Self-Reported Click and Included Measurements (Table 15)**

| Variable | OR | 95% CI | P-Value |
|---|---|---|---|
| **Age*** | 0.99 | 0.97—1.01 | 0.7 |
| **Gender†**<br>Male<br>Female (Ref) | 0.57 | 0.29 – 1.08 | 0.08 |
| **Race§**<br>**Caucasian**<br>**African** American<br>Other (Ref) | <br>0.81<br>0.24<br>--- | <br>0.4 – 1.6<br>0.10 – 0.54<br>--- | <br>0.1<br>0.001<br>--- |
| **DC¶**<br>**Class I**<br>**Class II**<br>**Class III (Ref)** | <br>0.22<br>0.30<br>--- | <br>0.10 – 0.49<br>0.14 – 0.67<br>--- | <br>0.006<br>0.1<br>--- |
| **ANB** | 0.88 | 0.81 – 0.95 | 0.002 |
| **FMA** | 1.03 | 0.99 – 1.09 | 0.1 |
| **SNA** | 0.93 | 0.86 – 1.00 | 0.04 |
| **SNB** | 1.01 | 0.95 – 1.08 | 0.6 |
| **U1 – NA** | 1.09 | 1.01 – 1.18 | 0.01 |
| **U1 – SN** | 1.01 | 0.98 – 1.04 | 0.4 |
| **L1 – NB** | 0.99 | 0.90 – 1.09 | 0.9 |
| **IMPA** | 0.96 | 0.93 – 0.99 | 0.03 |
| **Occlusal pl – SN** | 0.99 | 0.94 – 1.05 | 0.8 |
| **Llip – E** | 0.97 | 0.88 – 1.07 | 0.6 |
| **Ulip – E** | 0.90 | 0.81 – 0.99 | 0.04 |
| **Overjet** | 0.88 | 0.79 – 0.99 | 0.03 |
| **Overbite** | 0.85 | 0.76 – 0.94 | 0.003 |
| **Midline** | 0.95 | 0.81 – 1.11 | 0.53 |
| **Headache – Period – Year** | 1.01 | 0.92 – 1.12 | 0.72 |

*Controlling for Gender and race
†Controlling for age and race
§controlling for gender and age
¶controlling for age, gender, and race

**The Association Between Open/Close Click and Included Measurements (Table 16)**

| Variable | OR | 95% CI | P-Value |
|---|---|---|---|
| **Age*** | 1.01 | 0.99 – 1.03 | 0.3 |
| **Gender†**<br>Male<br>Female (Ref) | 0.6 | 0.3 – 1.1 | 0.09 |
| **Race§**<br>**Caucasian**<br>**African** American<br>Other (Ref) | <br>0.46<br>0.18<br>--- | <br>0.2 – 0.9<br>0.08 – 0.3<br>--- | <br>0.8<br>0.0008<br>--- |
| **DC¶**<br>**Class I**<br>**Class II**<br>**Class III (Ref)** | <br>0.35<br>0.38<br>--- | <br>0.17 – 0.7<br>0.17 – 0.8<br>--- | <br>0.059<br>0.1<br>--- |
| **ANB** | 0.91 | 0.84 – 0.98 | 0.02 |
| **FMA** | 1.01 | 0.96 – 1.06 | 0.5 |
| **SNA** | 0.96 | 0.90 – 1.03 | 0.3 |
| **SNB** | 1.02 | 0.96 – 1.09 | 0.3 |
| **U1 – NA** | 1.06 | 0.98 – 1.14 | 0.09 |
| **U1 – SN** | 1.01 | 0.98 – 1.04 | 0.3 |
| **L1 – NB** | 0.98 | 0.89 – 1.07 | 0.6 |
| **IMPA** | 0.98 | 0.95 – 1.01 | 0.1 |
| **Occlusal pl – SN** | 0.97 | 0.92 – 1.02 | 0.3 |
| **Llip – E** | 0.97 | 0.88 – 1.06 | 0.5 |
| **Ulip – E** | 0.90 | 0.82 – 0.99 | 0.03 |
| **Overjet** | 0.96 | 0.87 – 1.06 | 0.4 |
| **Overbite** | 0.92 | 0.83 – 1.02 | 0.1 |
| **Midline** | 0.88 | 0.76 – 1.02 | 0.1 |
| **Headache – Period – Year** | 1.12 | 1.02 – 1.23 | 0.01 |

*Controlling for Gender and race
†Controlling for age and race
§controlling for gender and age
¶controlling for age, gender, and race

**The Association Between Open/Close Crepitus and Included Measurements (Table 17)**

| Variable | OR | 95% CI | P-Value |
|---|---|---|---|
| **Age*** | 0.96 | 0.90 – 1.02 | 0.2 |
| **Gender†**<br>Male<br>Female (Ref) | 0.7 | 0.1 – 2.9 | 0.6 |
| **Race§**<br>**Caucasian**<br>**African** American<br>Other (Ref) | <br>2.8<br>2<br>--- | <br>0.4 – 17.1<br>0.3 – 11.6<br>--- | <br>0.3<br>0.7<br>--- |
| **DC¶**<br>**Class I**<br>**Class II**<br>**Class III (Ref)** | <br>0.93<br>2.6<br>--- | <br>0.09 – 9.2<br>0.2 – 23.4<br>--- | <br>0.4<br>0.1<br>--- |
| **ANB** | 1.02 | 0.8 – 1.2 | 0.7 |
| **FMA** | 1.09 | 0.98 – 1.2 | 0.1 |
| **SNA** | 0.8 | 0.7 – 1 | 0.054 |
| **SNB** | 0.8 | 0.7 – 0.9 | 0.04 |
| **U1 – NA** | 1.1 | 0.9 – 1.3 | 0.1 |
| **U1 – SN** | 1.004 | 0.9 – 1.07 | 0.9 |
| **L1 – NB** | 1.08 | 0.8 – 1.3 | 0.4 |
| **IMPA** | 1.02 | 0.9 1.1 | 0.6 |
| **Occlusal pl – SN** | 1.1 | 0.9 – 1.2 | 0.08 |
| **Llip – E** | 1.02 | 0.8 – 1.2 | 0.8 |
| **Ulip – E** | 1.1 | 0.9 – 1.4 | 0.1 |
| **Overjet** | 1.2 | 0.9 – 1.4 | 0.06 |
| **Overbite** | 0.9 | 0.7 – 1.1 | 0.4 |
| **Midline** | 0.8 | 0.5 – 1.2 | 0.3 |
| **Headache – Period – Year** | 1.07 | 0.81 – 1.41 | 0.6 |

*Controlling for Gender and race
†Controlling for age and race
§controlling for gender and age
¶controlling for age, gender, and race

**The Association Between Lateral Excursion Click and Included Measurements (Table 18)**

| Variable | OR | 95% CI | P-Value |
|---|---|---|---|
| **Age*** | 1.01 | 0.99 – 1.04 | 0.1 |
| **Gender†**<br>Male<br>Female (Ref) | 0.4 | 0.1 -1.07 | 0.07 |
| **Race§**<br>**Caucasian**<br>**African** American<br>Other (Ref) | <br>1.2<br>0.18<br>--- | <br>0.5 – 2.8<br>0.05 – 0.6<br>--- | <br>0.02<br>0.004<br>--- |
| **DC¶**<br>**Class I**<br>**Class II**<br>**Class III (Ref)** | <br>0.64<br>0.67<br>--- | <br>0.2 – 1.9<br>0.2 – 2.1<br>--- | <br>0.5<br>0.6<br>--- |
| **ANB** | 0.9 | 0.87 – 1.12 | 0.8 |
| **FMA** | 0.98 | 0.92 – 1.05 | 0.6 |
| **SNA** | 0.98 | 0.89 – 1.08 | 0.7 |
| **SNB** | 0.99 | 0.90 – 1.08 | 0.8 |
| **U1 – NA** | 0.9 | 0.8 – 1.1 | 0.7 |
| **U1 – SN** | 0.99 | 0.95 – 1.03 | 0.6 |
| **L1 – NB** | 0.8 | 0.7 – 0.9 | 0.02 |
| **IMPA** | 0.97 | 0.92 – 1.01 | 0.1 |
| **Occlusal pl – SN** | 0.97 | 0.90 – 1.04 | 0.4 |
| **Llip – E** | 0.9 | 0.8 – 1 | 0.4 |
| **Ulip – E** | 0.9 | 0.8 – 1.1 | 0.7 |
| **Overjet** | 1.16 | 1.00 – 1.33 | 0.03 |
| **Overbite** | 1.11 | 0.95 – 1.29 | 0.1 |
| **Midline** | 0.87 | 0.70 – 1.07 | 0.1 |
| **Headache – Period – Year** | 1.21 | 1.09 – 1.35 | 0.0003 |

*Controlling for Gender and race
†Controlling for age and race
§controlling for gender and age
¶controlling for age, gender, and race

**The Association Between Lateral Excursion Crepitus and Included Measurements (Table 19)**

| Variable | OR | 95% CI | P-Value |
|---|---|---|---|
| **Age*** | 0.99 | 0.93 – 1.05 | 0.8 |
| **Gender†**<br>Male<br>Female (Ref) | 0.6 | 0.1 – 3.3 | 0.5 |
| **Race§**<br>**Caucasian**<br>**African** American<br>Other (Ref) | <br>0.5<br>1.008<br>--- | <br>0.06 – 5.7<br>0.2 – 5<br>--- | <br>0.6<br>0.7<br>--- |
| **DC¶**<br>**Class I**<br>**Class II**<br>**Class III (Ref)** | <br>0.22<br>0.3<br>--- | <br>0.20– 0.41<br>0.1 – 0.6<br>--- | <br>0.006<br>0.17<br>--- |
| **ANB** | 1.05 | 0.84 – 1.3 | 0.6 |
| **FMA** | 1.19 | 1.06 – 1.3 | 0.003 |
| **SNA** | 0.8 | 0.7 – 1.001 | 0.051 |
| **SNB** | 0.7 | 0.6 – 0.9 | 0.02 |
| **U1 – NA** | 0.9 | 0.8 – 1.2 | 0.9 |
| **U1 – SN** | 0.9 | 0.8 – 1.02 | 0.2 |
| **L1 – NB** | 0.9 | 0.7 – 1.2 | 0.9 |
| **IMPA** | 0.9 | 0.8 – 1.05 | 0.5 |
| **Occlusal pl – SN** | 1.26 | 1.09 – 1.47 | 0.002 |
| **Llip – E** | 0.9 | 0.7 – 1.2 | 0.8 |
| **Ulip – E** | 0.9 | 0.7 – 1.2 | 0.8 |
| **Overjet** | 1.1 | 0.8 – 1.4 | 0.2 |
| **Overbite** | 0.8 | 0.6 - 1 | 0.1 |
| **Midline** | 0.9 | 0.6 – 1.3 | 0.7 |
| **Headache – Period – Year** | 1.05 | 0.8 – 1.3 | 0.6 |

*Controlling for Gender and race
†Controlling for age and race
§controlling for gender and age
¶controlling for age, gender, and race

**The Association Between Headache and Included Measurements (Table 20)**

| Variable | OR | 95% CI | P-Value |
|---|---|---|---|
| **Age*** | 1.02 | 1.00 – 1.05 | 0.052 |
| **Gender**† <br> Male <br> Female (Ref) | 0.3 | 0.1 – 0.8 | 0.02 |
| **Race**§ <br> **Caucasian** <br> **African** American <br> Other (Ref) | <br> 0.4 <br> 0.12 <br> --- | <br> 0.17 – 1.2 <br> 0.03 – 0.4 <br> --- | <br> 0.5 <br> 0.008 <br> --- |
| **DC**¶ <br> **Class I** <br> **Class II** <br> **Class III (Ref)** | <br> 0.3 <br> 0.7 <br> --- | <br> 0.1 – 1.05 <br> 0.2 – 2.2 <br> --- | <br> 0.03 <br> 0.4 <br> --- |
| **ANB** | 0.97 | 0.87 – 1.09 | 0.7 |
| **FMA** | 0.97 | 0.91 – 1.04 | 0.5 |
| **SNA** | 1.009 | 0.91 – 1.11 | 0.8 |
| **SNB** | 1.02 | 0.93 – 1.11 | 0.6 |
| **U1 – NA** | 1.01 | 0.91 – 1.13 | 0.7 |
| **U1 – SN** | 1.003 | 0.96 – 1.04 | 0.8 |
| **L1 – NB** | 0.92 | 0.81 – 1.05 | 0.2 |
| **IMPA** | 0.98 | 0.94 – 1.02 | 0.4 |
| **Occlusal pl – SN** | 0.94 | 0.87 – 1.02 | 0.1 |
| **Llip – E** | 0.93 | 0.82 – 1.06 | 0.3 |
| **Ulip – E** | 0.96 | 0.84 – 1.09 | 0.5 |
| **Overjet** | 1.05 | 0.91 – 1.21 | 0.4 |
| **Overbite** | 0.97 | 0.84 – 1.13 | 0.7 |
| **Midline** | 0.9 | 0.8 – 1.2 | 0.9 |

*Controlling for Gender and race
†Controlling for age and race
§controlling for gender and age
¶controlling for age, gender, and race

**The Association Between Pain and Included Measurements (Table 21)**

| Variable | OR | 95% CI | P-Value |
|---|---|---|---|
| **Age*** | 1.02 | 0.99 – 1.05 | 0.02 |
| **Gender†**<br>Male<br>Female (Ref) | 0.26 | 0.09 – 0.71 | 0.008 |
| **Race§**<br>**Caucasian**<br>**African** American<br>Other (Ref) | <br>0.7<br>0.1<br>--- | <br>0.3 – 1.8<br>0.05 – 0.5<br>--- | <br>0.1<br>0.004<br>--- |
| **DC¶**<br>**Class I**<br>**Class II**<br>**Class III (Ref)** | <br>0.1<br>0.3<br>--- | <br>0.05 – 0.4<br>0.1 – 0.8<br>--- | <br>0.002<br>0.6<br>--- |
| **ANB** | 0.88 | 0.80 – 0.98 | 0.02 |
| **FMA** | 1.007 | 0.94 – 1.07 | 0.8 |
| **SNA** | 0.91 | 0.83 – 1.001 | 0.051 |
| **SNB** | 0.99 | 0.91 – 1.08 | 0.9 |
| **U1 – NA** | 1.04 | 0.93 – 1.15 | 0.4 |
| **U1 – SN** | 0.98 | 0.94 – 1.02 | 0.4 |
| **L1 – NB** | 0.8 | 0.7 – 0.9 | 0.04 |
| **IMPA** | 0.94 | 0.90 – 0.98 | 0.005 |
| **Occlusal pl – SN** | 1.02 | 0.95 – 1.09 | 0.5 |
| **Llip – E** | 0.89 | 0.79 – 1.01 | 0.08 |
| **Ulip – E** | 0.8 | 0.7 – 0.9 | 0.03 |
| **Overjet** | 0.9 | 0.8 – 1.1 | 0.5 |
| **Overbite** | 0.9 | 0.8 – 1.1 | 0.5 |
| **Midline** | 1.09 | 0.9 – 1.3 | 0.3 |
| **Headache – Period – Year** | 2 | 1.4 – 2.9 | < .0001 |

*Controlling for Gender and race
†Controlling for age and race
§controlling for gender and age
¶controlling for age, gender, and race

**The Association Between Self-Reported Click and Included Measurements (Table 22)**

| Variable | OR | 95% CI | P-Value |
|---|---|---|---|
| **Age*** | 0.99 | 0.97—1.01 | 0.7 |
| **Gender**† <br> Male <br> Female (Ref) | 0.57 | 0.29 – 1.08 | 0.08 |
| **Race**§ <br> **Caucasian** <br> **African** American <br> Other (Ref) | <br> 0.81 <br> 0.24 <br> --- | <br> 0.4 – 1.6 <br> 0.10 – 0.54 <br> --- | <br> 0.1 <br> 0.001 <br> --- |
| **DC**¶ <br> **Class I** <br> **Class II** <br> **Class III (Ref)** | <br> 0.22 <br> 0.30 <br> --- | <br> 0.10 – 0.49 <br> 0.14 – 0.67 <br> --- | <br> 0.006 <br> 0.1 <br> --- |
| **ANB** | 0.88 | 0.81 – 0.95 | 0.002 |
| **FMA** | 1.03 | 0.99 – 1.09 | 0.1 |
| **SNA** | 0.93 | 0.86 – 1.00 | 0.04 |
| **SNB** | 1.01 | 0.95 – 1.08 | 0.6 |
| **U1 – NA** | 1.09 | 1.01 – 1.18 | 0.01 |
| **U1 – SN** | 1.01 | 0.98 – 1.04 | 0.4 |
| **L1 – NB** | 0.99 | 0.90 – 1.09 | 0.9 |
| **IMPA** | 0.96 | 0.93 – 0.99 | 0.03 |
| **Occlusal pl – SN** | 0.99 | 0.94 – 1.05 | 0.8 |
| **Llip – E** | 0.97 | 0.88 – 1.07 | 0.6 |
| **Ulip – E** | 0.90 | 0.81 – 0.99 | 0.04 |
| **Overjet** | 0.88 | 0.79 – 0.99 | 0.03 |
| **Overbite** | 0.85 | 0.76 – 0.94 | 0.003 |
| **Midline** | 0.95 | 0.81 – 1.11 | 0.53 |
| **Headache – Period – Year** | 1.01 | 0.92 – 1.12 | 0.72 |

*Controlling for Gender and race
†Controlling for age and race
§controlling for gender and age
¶controlling for age, gender, and race

**The Association Between Headache and TMJ Clicking (Table 23)**

| Variable | OR | 95% CI | P-Value |
|---|---|---|---|
| **Age*** | 1.02 | 0.9 – 1.05 | 0.09 |
| **Gender**[†]<br>Male<br>Female (Ref) | 0.3 | 0.1 – 1 | 0.05 |
| **Race**[§]<br>**Caucasian**<br>**African** American<br>Other (Ref) | 0.62<br>0.22<br>--- | 0.22 – 1.7<br>0.06 – 0.8<br>--- | 0.6<br>0.06<br>--- |
| **Opening/closing click** | 10 | 4.2 – 23.7 | <.0001 |
| **Lateral excursion click** | 20 | 7.4 – 54.5 | <.0001 |
| **Self-reported click** | 4.7 | 1.9 – 11.3 | 0.0005 |

[*]Controlling for Gender and race
[†]Controlling for age and race
[§]controlling for gender and age

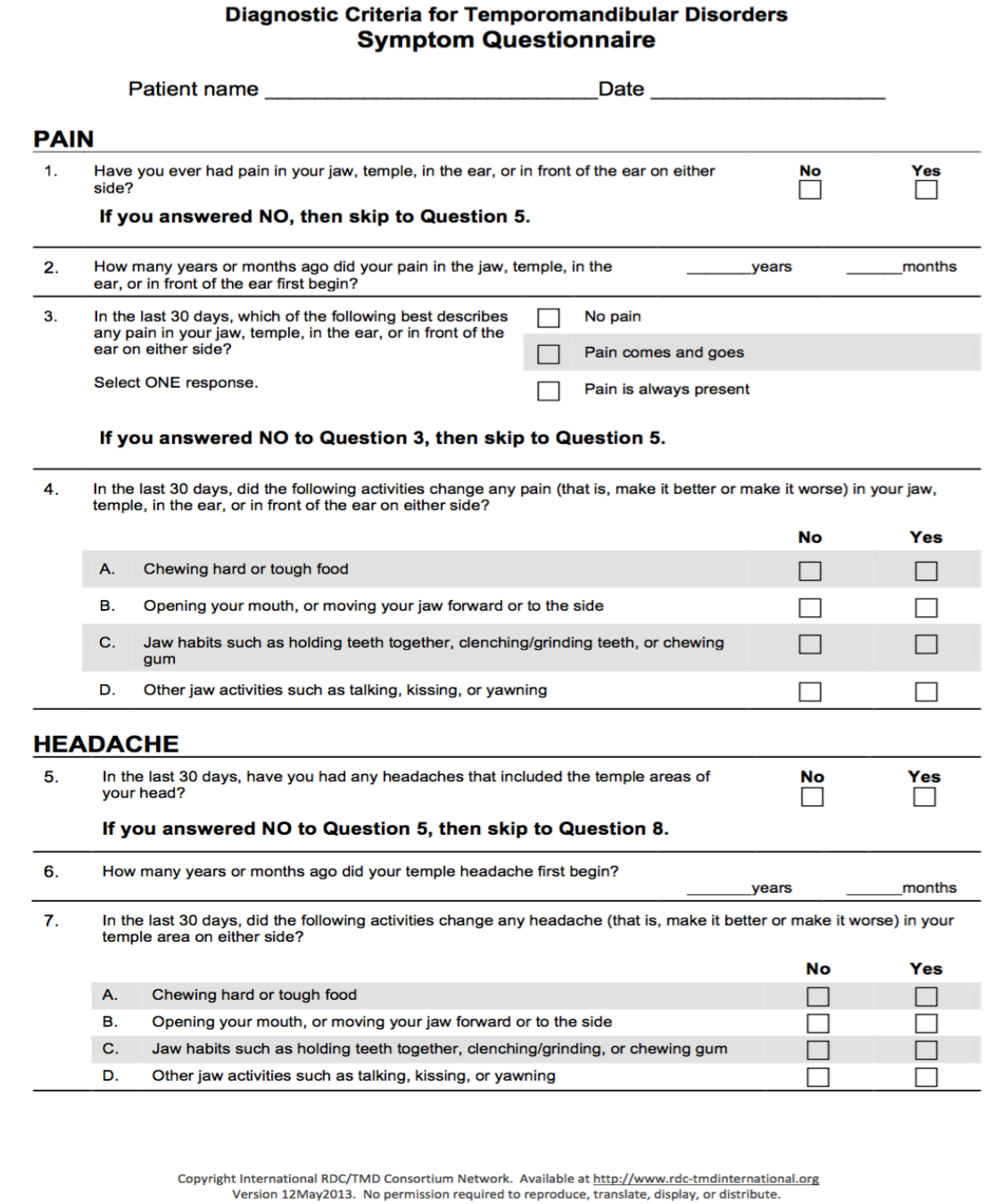
**The Association Between Pain and TMJ Clicking**
**(Table 24)**

| Variable | OR | 95% CI | P-Value |
|---|---|---|---|
| **Age*** | 1.02 | 0.9 – 1.05 | 0.09 |
| **Gender**[†]<br>Male<br>Female (Ref) | 0.29 | 0.1 – 0.8 | 0.01 |
| **Race**[§]<br>**Caucasian**<br>**African** American<br>Other (Ref) | <br>0.98<br>0.28<br>--- | <br>0.3 – 2.4<br>0.08 – 0.9<br>--- | <br>0.1<br>0.02<br>--- |
| **Opening/closing click** | 7.6 | 3.4 – 17.1 | <.0001 |
| **Lateral excursion click** | 14.4 | 5.6 – 36.9 | <.0001 |
| **Self-reported click** | 7.7 | 3.3 – 17.5 | <.0001 |

[*]Controlling for Gender and race
[†]Controlling for age and race
[§]controlling for gender and a

**LIST OF FIGURES**

**FIGURE (1)**



**Diagnostic Criteria for Temporomandibular Disorders**
**Symptom Questionnaire**

Patient name _____Date _____

## PAIN

1. Have you ever had pain in your jaw, temple, in the ear, or in front of the ear on either side? — No ☐ Yes ☐

**If you answered NO, then skip to Question 5.**

2. How many years or months ago did your pain in the jaw, temple, in the ear, or in front of the ear first begin? _____years _____months

3. In the last 30 days, which of the following best describes any pain in your jaw, temple, in the ear, or in front of the ear on either side?

Select ONE response.

- ☐ No pain
- ☐ Pain comes and goes
- ☐ Pain is always present

**If you answered NO to Question 3, then skip to Question 5.**

4. In the last 30 days, did the following activities change any pain (that is, make it better or make it worse) in your jaw, temple, in the ear, or in front of the ear on either side?

| | | No | Yes |
|---|---|---|---|
| A. | Chewing hard or tough food | ☐ | ☐ |
| B. | Opening your mouth, or moving your jaw forward or to the side | ☐ | ☐ |
| C. | Jaw habits such as holding teeth together, clenching/grinding teeth, or chewing gum | ☐ | ☐ |
| D. | Other jaw activities such as talking, kissing, or yawning | ☐ | ☐ |

## HEADACHE

5. In the last 30 days, have you had any headaches that included the temple areas of your head? — No ☐ Yes ☐

**If you answered NO to Question 5, then skip to Question 8.**

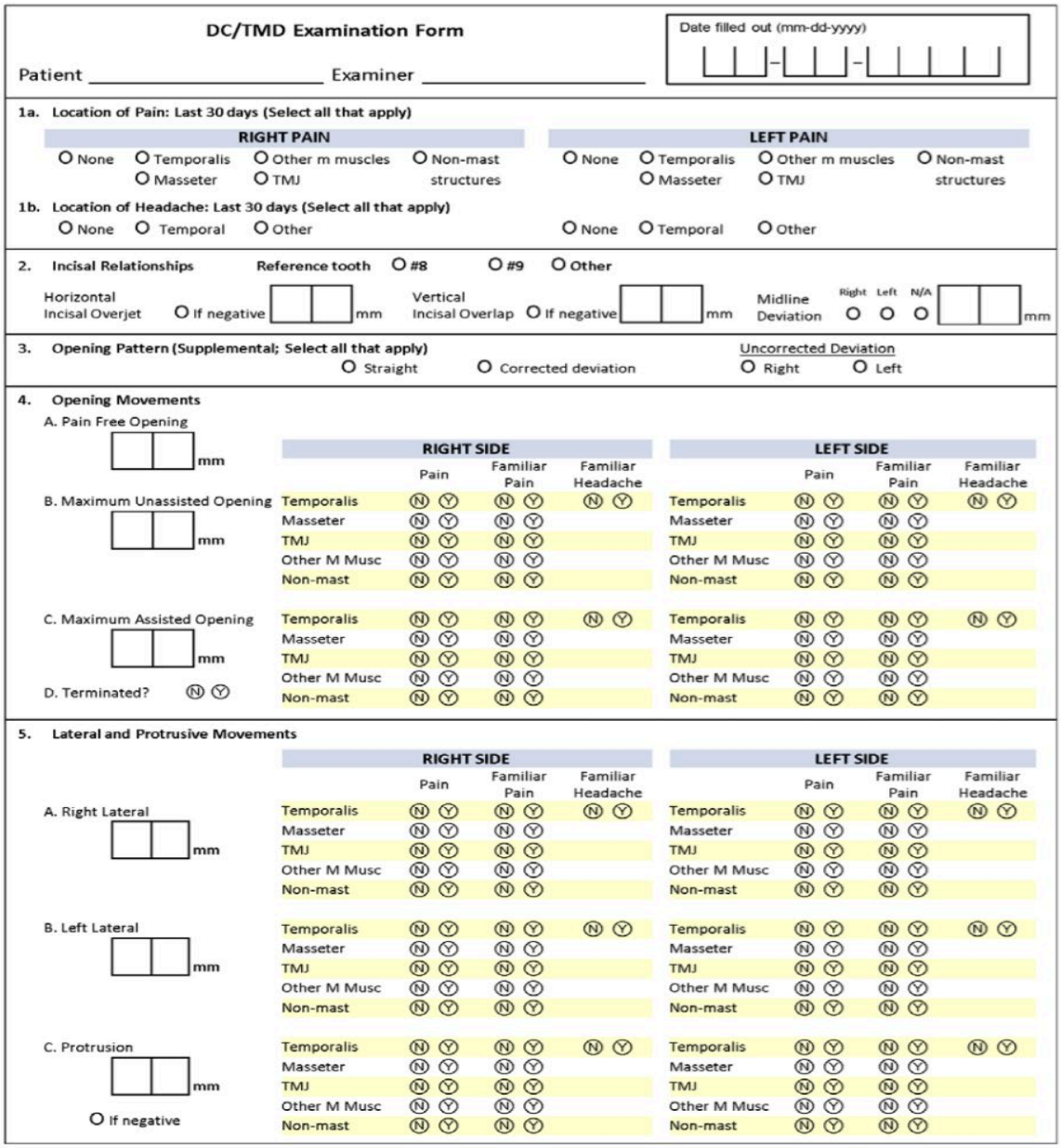
6. How many years or months ago did your temple headache first begin? _____years _____months

7. In the last 30 days, did the following activities change any headache (that is, make it better or make it worse) in your temple area on either side?

| | | No | Yes |
|---|---|---|---|
| A. | Chewing hard or tough food | ☐ | ☐ |
| B. | Opening your mouth, or moving your jaw forward or to the side | ☐ | ☐ |
| C. | Jaw habits such as holding teeth together, clenching/grinding, or chewing gum | ☐ | ☐ |
| D. | Other jaw activities such as talking, kissing, or yawning | ☐ | ☐ |

| JAW JOINT NOISES | | | | Office use | | |
|---|---|---|---|---|---|---|
| 8. | In the last 30 days, have you had any jaw joint noise(s) when you moved or used your jaw? | No ☐ | Yes ☐ | R ☐ | L ☐ | DNK ☐ |
| **CLOSED LOCKING OF THE JAW** | | | | | | |
| 9. | Have you ever had your jaw lock or catch, even for a moment, so that it would not open ALL THE WAY?<br>**If you answered NO to Question 9 then skip to Question 13.** | ☐ | ☐ | ☐ | ☐ | ☐ |
| 10. | Was your jaw lock or catch severe enough to limit your jaw opening and interfere with your ability to eat? | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11. | In the last 30 days, did your jaw lock so you could not open ALL THE WAY, even for a moment, and then unlock so you could open ALL THE WAY?<br>**If you answered NO to Question 11 then skip to Question 13.** | ☐ | ☐ | ☐ | ☐ | ☐ |
| 12. | Is your jaw currently locked or limited so that your jaw will not open ALL THE WAY? | ☐ | ☐ | ☐ | ☐ | ☐ |
| **OPEN LOCKING OF THE JAW** | | | | | | |
| 13. | In the last 30 days, when you opened your mouth wide, did your jaw lock or catch even for a moment such that you could not close it from this wide open position?<br>**If you answered NO to Question 13 then you are finished.** | ☐ | ☐ | ☐ | ☐ | ☐ |
| 14. | In the last 30 days, when you jaw locked or caught wide open, did you have to do something to get it to close including resting, moving, pushing, or maneuvering it? | ☐ | ☐ | ☐ | ☐ | ☐ |

**FIGURE (2)**



DC/TMD Examination Form

Date filled out (mm-dd-yyyy) ___-___-____

Patient _____ Examiner _____

**1a. Location of Pain: Last 30 days (Select all that apply)**

| RIGHT PAIN | | | | LEFT PAIN | | | |
|---|---|---|---|---|---|---|---|
| O None | O Temporalis | O Other m muscles | O Non-mast structures | O None | O Temporalis | O Other m muscles | O Non-mast structures |
| | O Masseter | O TMJ | | | O Masseter | O TMJ | |

**1b. Location of Headache: Last 30 days (Select all that apply)**

O None O Temporal O Other — O None O Temporal O Other

**2. Incisal Relationships** Reference tooth O #8 O #9 O Other

Horizontal Incisal Overjet O If negative ___ mm — Vertical Incisal Overlap O If negative ___ mm — Midline Deviation Right O Left O N/A O ___ mm

**3. Opening Pattern (Supplemental; Select all that apply)** O Straight O Corrected deviation — Uncorrected Deviation: O Right O Left

**4. Opening Movements**

A. Pain Free Opening ___ mm

B. Maximum Unassisted Opening ___ mm

C. Maximum Assisted Opening ___ mm

D. Terminated? (N) (Y)

| | RIGHT SIDE | | | | LEFT SIDE | | | |
|---|---|---|---|---|---|---|---|---|
| | | Pain | Familiar Pain | Familiar Headache | | Pain | Familiar Pain | Familiar Headache |
| B. Maximum Unassisted Opening | Temporalis | (N) (Y) | (N) (Y) | (N) (Y) | Temporalis | (N) (Y) | (N) (Y) | (N) (Y) |
| | Masseter | (N) (Y) | (N) (Y) | | Masseter | (N) (Y) | (N) (Y) | |
| | TMJ | (N) (Y) | (N) (Y) | | TMJ | (N) (Y) | (N) (Y) | |
| | Other M Musc | (N) (Y) | (N) (Y) | | Other M Musc | (N) (Y) | (N) (Y) | |
| | Non-mast | (N) (Y) | (N) (Y) | | Non-mast | (N) (Y) | (N) (Y) | |
| C. Maximum Assisted Opening | Temporalis | (N) (Y) | (N) (Y) | (N) (Y) | Temporalis | (N) (Y) | (N) (Y) | (N) (Y) |
| | Masseter | (N) (Y) | (N) (Y) | | Masseter | (N) (Y) | (N) (Y) | |
| | TMJ | (N) (Y) | (N) (Y) | | TMJ | (N) (Y) | (N) (Y) | |
| | Other M Musc | (N) (Y) | (N) (Y) | | Other M Musc | (N) (Y) | (N) (Y) | |
| | Non-mast | (N) (Y) | (N) (Y) | | Non-mast | (N) (Y) | (N) (Y) | |

**5. Lateral and Protrusive Movements**

A. Right Lateral ___ mm

B. Left Lateral ___ mm

C. Protrusion ___ mm

O If negative

| | RIGHT SIDE | | | | LEFT SIDE | | | |
|---|---|---|---|---|---|---|---|---|
| | | Pain | Familiar Pain | Familiar Headache | | Pain | Familiar Pain | Familiar Headache |
| A. Right Lateral | Temporalis | (N) (Y) | (N) (Y) | (N) (Y) | Temporalis | (N) (Y) | (N) (Y) | (N) (Y) |
| | Masseter | (N) (Y) | (N) (Y) | | Masseter | (N) (Y) | (N) (Y) | |
| | TMJ | (N) (Y) | (N) (Y) | | TMJ | (N) (Y) | (N) (Y) | |
| | Other M Musc | (N) (Y) | (N) (Y) | | Other M Musc | (N) (Y) | (N) (Y) | |
| | Non-mast | (N) (Y) | (N) (Y) | | Non-mast | (N) (Y) | (N) (Y) | |
| B. Left Lateral | Temporalis | (N) (Y) | (N) (Y) | (N) (Y) | Temporalis | (N) (Y) | (N) (Y) | (N) (Y) |
| | Masseter | (N) (Y) | (N) (Y) | | Masseter | (N) (Y) | (N) (Y) | |
| | TMJ | (N) (Y) | (N) (Y) | | TMJ | (N) (Y) | (N) (Y) | |
| | Other M Musc | (N) (Y) | (N) (Y) | | Other M Musc | (N) (Y) | (N) (Y) | |
| | Non-mast | (N) (Y) | (N) (Y) | | Non-mast | (N) (Y) | (N) (Y) | |
| C. Protrusion | Temporalis | (N) (Y) | (N) (Y) | (N) (Y) | Temporalis | (N) (Y) | (N) (Y) | (N) (Y) |
| | Masseter | (N) (Y) | (N) (Y) | | Masseter | (N) (Y) | (N) (Y) | |
| | TMJ | (N) (Y) | (N) (Y) | | TMJ | (N) (Y) | (N) (Y) | |
| | Other M Musc | (N) (Y) | (N) (Y) | | Other M Musc | (N) (Y) | (N) (Y) | |
| | Non-mast | (N) (Y) | (N) (Y) | | Non-mast | (N) (Y) | (N) (Y) | |

**6. TMJ Noises During Open & Close Movements**

| RIGHT TMJ | Examiner | | Patient | Pain w/ Click | Familiar Pain |
|---|---|---|---|---|---|
| | Open | Close | | | |
| Click | N Y | N Y | N Y | N Y | N Y |
| Crepitus | N Y | N Y | N Y | | |

| LEFT TMJ | Examiner | | Patient | Pain w/ Click | Familiar Pain |
|---|---|---|---|---|---|
| | Open | Close | | | |
| Click | N Y | N Y | N Y | N Y | N Y |
| Crepitus | N Y | N Y | N Y | | |

**7. TMJ Noises During Lateral & Protrusive Movements**

| RIGHT TMJ | Examiner | Patient | Pain w/ Click | Familiar Pain |
|---|---|---|---|---|
| Click | N Y | N Y | N Y | N Y |
| Crepitus | N Y | N Y | | |

| LEFT TMJ | Examiner | Patient | Pain w/ Click | Familiar Pain |
|---|---|---|---|---|
| Click | N Y | N Y | N Y | N Y |
| Crepitus | N Y | N Y | | |

**8. Joint Locking**

| RIGHT TMJ | Locking | Reduction | |
|---|---|---|---|
| | | Patient | Examiner |
| While Opening | N Y | N Y | N Y |
| Wide Open Position | N Y | N Y | N Y |

| LEFT TMJ | Locking | Reduction | |
|---|---|---|---|
| | | Patient | Examiner |
| While Opening | N Y | N Y | N Y |
| Wide Open Position | N Y | N Y | N Y |

**9. Muscle & TMJ Pain with Palpation**

| RIGHT SIDE (1 kg) | Pain | Familiar Pain | Familiar Headache | Referred Pain |
|---|---|---|---|---|
| Temporalis(posterior) | N Y | N Y | N Y | N Y |
| Temporalis(middle) | N Y | N Y | N Y | N Y |
| Temporalis(anterior) | N Y | N Y | N Y | N Y |
| Masseter (origin) | N Y | N Y | | N Y |
| Masseter (body) | N Y | N Y | | N Y |
| Masseter (insertion) | N Y | N Y | | N Y |

| TMJ | Pain | Familiar Pain | Referred Pain |
|---|---|---|---|
| Lateral pole **(0.5 kg)** | N Y | N Y | N Y |
| Around lateral pole **(1 kg)** | N Y | N Y | N Y |

| LEFT SIDE (1 kg) | Pain | Familiar Pain | Familiar Headache | Referred Pain |
|---|---|---|---|---|
| Temporalis(posterior) | N Y | N Y | N Y | N Y |
| Temporalis(middle) | N Y | N Y | N Y | N Y |
| Temporalis(anterior) | N Y | N Y | N Y | N Y |
| Masseter (origin) | N Y | N Y | | N Y |
| Masseter (body) | N Y | N Y | | N Y |
| Masseter (insertion) | N Y | N Y | | N Y |

| | Pain | Familiar Pain | Referred Pain |
|---|---|---|---|
| Lateral pole **(0.5 kg)** | N Y | N Y | N Y |
| Around lateral pole **(1 kg)** | N Y | N Y | N Y |

**10. Supplemental Muscle Pain with Palpation**

| RIGHT SIDE (0.5 kg) | Pain | Familiar Pain | Referred Pain |
|---|---|---|---|
| Posterior mandibular region | N Y | N Y | N Y |
| Submandibular region | N Y | N Y | N Y |
| Lateral pterygoid area | N Y | N Y | N Y |
| Temporalistendon | N Y | N Y | N Y |

| LEFT SIDE (0.5 kg) | Pain | Familiar Pain | Referred Pain |
|---|---|---|---|
| Posterior mandibular region | N Y | N Y | N Y |
| Submandibular region | N Y | N Y | N Y |
| Lateral pterygoid area | N Y | N Y | N Y |
| Temporalistendon | N Y | N Y | N Y |

**11. Comments**

# RESULTS

## Results

In this study, we screened 460 subjects in table 2 shows the means of the variables of interest. Table 3 shows the distribution of the 460 subjects. The sample comprised of 283 females and 177 males, 104 Caucasian, 175 African-American, and 181 Hispanic and Others. Among dental classification distribution it consisted of 238 class I, 153 class II, 69 class III. Those who presented with headache were 28, open click 13.04% of the sample, and 11.09% for the self-reported click. While on table 4 shows the gender distribution among different TMJ sounds, headache, and the presence of pain (DC/TMD variables). It was observed that headache and pain presence were higher in females with 8.13%, and 9.54% respectively. In table 5, Same DC/TMD variables were tested against the distribution of races. Caucasians had more TMJ clicking upon right lateral, left lateral, and protrusive movement of the mandible with 9.62% than African-American and Hispanic and other groups. While with mandibular opening and closing movement clicking of the TMJ (21.55%) , Self-reported click (16.02%), presence of pain (10.5%), and headache (10.5%) upon clinical exam were higher in the Hispanic and other group. Finally, we tested the same variables as well with different dental classification (Table 6). Dental class III had higher percentages in clicking upon opening and closing of the mandible, self-reported click, and presence of pain of the TMJ with 23.19%, 24.6%, and 15.9% respectively than class II and I. Headache was present higher in class II (9.15%) & class III groups (8.70%) compared to class I.

**Dental and skeletal measurement with TMJ click upon opening and closing movement of the mandible**

In this study we tested opening and closing movement clicking (Open click) in subject with different dental and skeletal measurements, table 8 shows the t-test results. We found that retrusive maxilla is boarder line significant (MD=1.2, SD=4.6, P= 0.059) with open click according to SNA values. While retrusive (L1-NB) and upright (IMPA) lower incisor showed that it is associated significantly with open click (P=0.03) for both (MD=1.08, SD=3.7) and (MD=2.78, SD=9.2) respectively. Also, Protruded lower (L.Lip-E) and upper (U.lip-E) lips were significantly higher in subjects presented with open click upon clinical examination with P-values of (P=0.007) (MD=1.5, SD=4.2) and (0.0002) (MD=1.9, SD=3.7) respectively. Finally, subjects who reported headache period extending in years were higher in the open click group (P= <.0001, MD=-1.4, SD=2.2).

Table 16 shows the logistic regression model after adjusting for (Age, gender, race, and dental classification), the Hispanic and other group was significantly associated with open click after adjusting for covariates age and gender (OR, 0.18; 95% CI: 0.08–0.3). It remained significant for class III group after controlling for age, gender, and race (OR: 0.35; 95% CI: 0.17–0.7). Protruded upper lip was statistically significant in association with open click OR (0.9, 95% CI: 0.8–0.9). Finally, open click subjects have 1.12 odds of headache reported in years compared to non-click subjects ( 95% CI: 1—1.2).

**Dental and skeletal measurement with TMJ crepitus upon opening and closing movement of the mandible**

We tested opening and closing movement crepitus (Open crepitus) in subject with different dental and skeletal measurements, table 9 shows the t-test results. We found that retrusive maxilla is boarder line significant (*MD*=3, *SD*=4.6,*P*= 0.056) with open crepitus according to SNA values. While retrusive mandible was associated significantly with open crepitus (P=0.03, MD=76.6, SD=4). Also, steeper occlusal plane was associated with open crepitus in a border line significance P-value (0.049) (Md=-3.7, SD=5.6). Finally, subjects who had more overjet were higher in the open click group (P= 0.03, MD=-1.9, SD=2.7).

Table 17 shows the logistic regression model after adjusting for (Age, gender, race, and dental classification). The only significant relation was found on two variables. First, retrusive maxilla was boarder line associated with open crepitus (OR=0.8, 95% CI=0.7—1). Second, retrusive mandible according to SNB with an OR (0.8, 95% CI=0.7-0.9).

**Dental and skeletal measurement with TMJ click upon right lateral, left lateral, and protrusive movement of the mandible**

In this study we tested right lateral, left lateral, and protrusive movement clicking (lateral click) in subject with different dental and skeletal measurements, table 10 shows the t-test results. We found that retrusive (L1-NB) and upright (IMPA) lower incisor showed that it is associated significantly with lateral click (MD=2.5, SD=3.7, P=0.0005) and (MD=3.7, SD=9.2, P=0.04) respectively. Also, Protruded lower (L.Lip-E) was significantly higher in subjects presented with lateral click upon clinical examination with P-value of (P=0.004) (MD=2.4, SD=4.2). Finally, subjects who reported headache period extending in years were higher in the lateral click group (P= <.0001, MD=-3.2, SD=2.1).

Table 18 shows the logistic regression model after adjusting for (Age, gender, race, and dental classification), Caucasian group has 1.2 odds of having lateral click compared to Hispanic and other group. Also, African-American group has the odds of 0.18 of having lateral click compared to Hispanic and other group after adjusting for age and gender. Moreover, 1 millimeter increase in L1-NB has 0.8 odds of having lateral click ( 95% CI: 0.7—0.8). Also, 1 millimeter increase in overjet has 1.16 odds of having lateral click ( 95% CI= 1.00—1.33). Finally, lateral click subjects have 1.2 odds of headache reported in years compared to non-click subjects ( 95% CI: 1—1.3).

**Dental and skeletal measurement with TMJ crepitus upon right lateral, left lateral, and protrusive movement of the mandible**

In this study we tested right lateral, left lateral, and protrusive movement crepitus (Lateral crepitus) in subject with different dental and skeletal measurements, table 11 shows the t-test results. We found that steep mandibular plane is significant (*MD*=-7.2, *SD*=6.1,*P*= 0.002) with lateral crepitus according to FMA values. While retrusive mandible (SNB) is associated significantly with lateral crepitus (MD=4, SD=4.6, P=0.02). Also, steep occlusal plane was significantly higher in subjects presented with lateral crepitus upon clinical examination with P-value of (P=0.0006) (MD=-7.4, SD=5.6).

Table 19 shows the logistic regression model after adjusting for (Age, gender, race, and dental classification), the Caucasian group have 0.022 odds of having lateral crepitus compared to Hispanic and other group (OR, 0.22; 95% CI: 0.20–0.41). One angle degree increase in FMA has 1.19 odds of having of lateral crepitus (95% CI= 1.06—1.3). Retrusive maxilla and mandible were found significant in association with lateral crepitus SNA (OR=0.8, 95% CI= 0.7—1), and SNB (OR=0.7, 95% CI= 0.6—0.9). Finally, steep occlusal plane was found significant with lateral click with an odds of 1.2 ( 95% CI=1—1.4).

**Dental and skeletal measurement with Self-reported TMJ click**

In this study we tested self-reported click (Self-click) in subject with different dental and skeletal measurements, table 13 shows the t-test results. We found that class I skeletal is significantly associated with self-click (MD=1.9, SD=3.5, P=0.003). Retrusive maxilla is significant as well (*MD*=1.9, *SD*=4.6, *P*= 0.004) with self-click according to SNA values. While upright (IMPA) lower incisor showed that it is associated significantly with self-click (*P*=0.003) (MD=4, SD=9.2). Also, Protruded lower (L.Lip-E) and upper (U.lip-E) lips were significantly higher in subjects who reported click in the self-conducted questionnaire with P-values of (P=0.01) (MD=1.5, SD=4.2) and (0.0006) (MD=1.9, SD=3.8) respectively. On the other hand, reduced overjet was statistically significant with self-click (MD=0.9, SD=2.7, P=0.02), and shallow overbite showed to be significant also (MD= 1.1, SD=2.7, P=0.006).

Finally, subjects who reported headache period extending in years were higher in the self-click group (P= 0.01, MD=-0.2, SD=0.6).

Table 22 shows the logistic regression model after adjusting for (Age, gender, race, and dental classification), the African-American group has 0.24 odds of having self-click compared to the Hispanic and other group after adjusting for covariates age and gender (95% CI: 0.10–0.54). While, class I dental have 0.22 odds of having self-click compared to class III after controlling for age, gender, and race (95% CI: 0.10–0.49). Class III skeletal according to ANB value was statistically significant in association with self-click OR (0.88, 95% CI: 0.81–0.95). Retrusive maxilla was also significant with self-click based on

SNA (OR: 0.93, 95% CI=0.86—1.00). Protruded upper incisor have 1.09 odds of having self-click compared to normally positioned or retrusive upper incisor (95% CI=1.01—1.18). upright lower incisors were significant with self-click (OR: 0.96, 95% CI=0.93—99). Protruded lower (L.Lip-E) and upper (U.lip-E) lips were significantly associated with self-click (OR: 0.97, 95% CI= 0.88—1.07) and (OR:0.90, 95% CI= 0.81—0.99) respectively. Finally, 1 millimeter increased in overjet has 0.88 odds of having self-click (95% CI= 0.79—0.99), and one millimeter increased in overbite has 0.95 odds of having self-click (95% CI=0.76—0.94).

**Dental and skeletal measurement with TMJ pain**

In this study we tested TMJ pain in subject with different dental and skeletal measurements, table 14 shows the t-test results. We found that older age is significant (*MD*=-5.5, *SD*=13.7, *P*= 0.02) with pain. Moreover, retrusive maxilla is significant (*MD*=2.1, *SD*=4.6,*P*= 0.01) with pain according to SNA values. Also, retrusive (L1-NB) and upright (IMPA) lower incisor showed that it is associated significantly with TMJ pain (*P*=0.001) for both with (MD=2.1, SD=3.7) L1-NB and (MD=5.5, SD=9.2) IMPA. Furthermore, Protruded lower (L.Lip-E) and upper (U.lip-E) lips were significantly higher in subjects presented with pain in TMJ upon clinical examination with P-values of (P=0.0005) (MD=2.6, SD=4.1) and (P=0.0002) (MD=2.6, SD=3.7) respectively. Finally, subjects who reported headache

period extending in years were higher in the TMJ pain group (P= <.0001, MD=-4.6, SD=1.9).

Table 21 shows the logistic regression model after adjusting for (Age, gender, race, and dental classification), older ages were significantly associated with TMJ pain after adjusting for gender and race (OR:1.03, 95% CI= 1-1.05). Males have 0.2 odds of having TMJ pain compared to females (95% CI: 0.09—0.7) after the adjustment for age and race. African-American group has 0.1 odds of having pain compared to Hispanic and other group (95% CI: 0.05–0.5). It was also found that class III has 0.1 odd of having pain compared to class I after controlling for age, gender, and race (CI: 0.05–0.4). Retrusive maxilla (SNA) was boarder line with TMJ pain (OR: 0.9, 95% CI=0.8—1). . Also, retrusive (L1-NB) and upright (IMPA) lower incisor showed that it is associated significantly with TMJ pain for both (OR=0.8, 95% CI=0.7—0.9) and (OR: 0.94, 95% CI=0.90—0.98). Protruded upper lip was statistically significant in association with TMJ pain OR (0.8, 95% CI: 0.7–0.9). Finally, TMJ pain present subjects have 2 odds of headache reported in years compared to non-pain subjects ( 95% CI: 1.4—2.9).

**Dental and skeletal measurement with Headache**

In this study we tested headache in subject with different dental and skeletal measurements, table 12 shows the t-test results. We found that older age is significant (*MD*=-5.6, *SD*=13.7, *P*= 0.03) with headache. Moreover, retrusive (L1-NB) lower incisor showed that it is associated significantly with headache (MD=1.6, SD=3.7, P=0.02). Finally, Protruded lower (L.Lip-E) and upper (U.lip-E) lips were significantly higher in subjects who reported headache upon clinical examination with P-values of (P=0.007) (MD=2.2, SD=4.2) and (P=0.01) (MD=1.7, SD=3.8) respectively.

Table 20 shows the logistic regression model after adjusting for (Age, gender, race, and dental classification), older ages were significantly associated with headache after adjusting for gender and race (OR:1.02, 95% CI= 1.00-1.05). Males have the odds of having headache is 0.3 compared to females (95% CI: 0.1—0.8) after the adjustment for age and race. the African-American group has 0.12 odds of having headache compared to the Hispanic and other group after adjusting for covariates age and gender (95% CI: 0.03–0.4). Finally, class I have the odds of 0.3 of having headache compared to class III (95% CI= 0.1—1.05).

**TMJ click with headache and TMJ pain**

Headache was tested with TMJ clicking in table 23 with a logistic regression, we found that males with TMJ click have 0.3 odds of having headache compared to females (95% CI= 0.1—1) after adjusting for covariates age and race. Opening/closing click group was highly significant with headache (OR:10, 95% CI=4.2—23.7). Subjected with lateral excursion click have 20 odds of having headache compared to non-click subjects (95% CI=7.4—54.5). Finally, self-reported click group was significantly associated with headache with the odds of 4.7 (95% CI= 1.9—11.3).

In table 24 we tested the association between pain and TMJ clicking using logistic regression. It was found out that males have 0.29 odds of having pain in the TMJ compared to females (95% CI= 0.1—0.8) after adjusting for age and race. Also, African-American group have 0.28 odds of having TMJ pain compared to Hispanic and other group (95% CI= 0.08—0.9). Opening/closing click and lateral excursion click groups were both found significantly associated with TMJ pain with (OR:7.6, 95% CI=3.4—17.1) and (OR:14.4, 95% CI= 5.6—36.9) respectively. Finally, subjects who reported click upon self-conducted questionnaire have 7.7 odds of having TMJ pain compared to those who did not report clicking.

# DISCUSSION

## Discussion

In this study we have screened 460 subjects who were seeking orthodontic treatment at Boston University. The distribution of the sample as shown earlier in the results were fairly proportional. Our results in the bivariate analysis suggested that females have more headache with a prevalence of 8.12%. This is supported by majority of the literature.[27-29] This is due to several factors such as, fluctuation and changes of hormones, and changes in phases of life.[27] Ciancaglini and Radaeli found that females were higher in TMJ pain but was not significant. [30] However, in our study they were higher in the bivariate with a prevalence of 9.54% and was significantly different, this was in agreement with Tecco et al, where pain was significantly more in females.[31]

For races we found that Hispanic and other group had the highest occurrence of TMJ click, self-reported click, presence of TMJ pain, and headache (Table 4). To the best of our knowledge there were no studies in the literature that compared TMJ clicking among Caucasian, African-American, and Hispanic. However, there was a study where they compared Caucasian and African-American kindergarten kids and they found that TMJ symptoms were higher in African-American group. [32]

Moreover, after testing dental class III classification, our data showed that it had higher incidents of TMJ click, self-reported click, and presence of TMJ pain compared to class I and class II. Class III been investigated vastly in the literature for skeletal features and how the disc position can be impacted through different skeletal characteristics, in one study they concluded that increased gonial angle of the mandible and steeper mandibular plane

angle represents a risk toward the development of disc displacement.[33] However, headache was closely distributed among class II and III. Studies been trying to establish the association between malocclusion and headache, one of those studies found that malocclusion is associated with headache in adolescents especially lower anterior crowding. They hypothesized that it could be due to masticatory muscles, including temporalis, tension and that in effect could contribute to the development of headache.[34] This calls for further studies to investigate deeper and establish causality.

**TMJ click with headache**

In our study we found that subjects who presented with TMJ click have a high chance of having headache simultaneously. We tested the TMJ click in a variety of patterns such as click during opening and closing, lateral, protrusive movements, and even clicks reported by the subjects with the presence of headache and found them all to be significantly correlated. We adjusted for the covariates age and race and found that, females with TMJ click have 3 times the risk of having headache compared to males (95% CI= 0.1—1). This is in agreement with author's findings, females had higher chances of having click and headache in general than males. [30]

Subjects with opening and closing TMJ click had 10 times the risk of having headache, and this could be due to several factors, it could be due to disc dislocation either with or

without reduction and triggering the associated muscles of mastication. Muscle of mastication tension could contribute to the initiation of headache and this in turn could explain the correlation. Lateral pterygoid attachment is on the disc and neck of the condyle, the exact percentage of this attachment is debated, if the attachment is greater on the articular disc this means it will influence its position when the muscles is stretched.[1] We can hypothesize that this relationship could be in reverse, when the disc is displaced and the tendons are elongated which allows the disc to be displaced antero-medially as it usually does.[1,35] It could affect the superior head of the lateral pterygoid, and could affect other muscles of mastication if function of the mandible is altered. Therefore, pain could originate in the muscles but referred and presents as headache. There are a lot of contributing factors to this relation. For example, myofascial pain and tension type headache both have clinical features that are befitting with central and peripheral sensitization of the nociceptive pathways.[36] However, The causality is out of the scope of this study, but this finding raise the importance and need to further investigate clicking and headache coexistence and not overlook clicking as clinicians used to if asymptomatic.

Moreover, lateral excursion click presentation on the subject showed higher chance of having headache than open click even, it was found that the risk is 20 times higher when lateral click exist. Finally, when subjects report that they have a click of any sort, it showed that they often have headache as well with a risk of 4.7 times than those who do not report any click. In the literature, there are several studies that investigated headache with TMD or TMD's symptoms in general.[30,37,38] But, no one investigated the association between TMJ click specifically with headache. In our study we focused on TMJ click particularly

because TMD symptoms can vary either in TMJ pain, limited mouth opening, clicking, and muscle pain, which patients usually report. Clicking can be overlooked by the patient or the clinician if asymptomatic, but in this study we shed light on the importance of screening for other problems, as we show how click can be associated with different factors including headache. Now, the etiology and pathophysiology is beyond the focus of this paper, but it shows the desire for future research to look further into the mechanism of how click can contribute to the presence of headache.

**TMJ click with TMJ pain**

It has been established that TMJ clicking should not be treated if no pain is accompanied. On the other hand, there were some modalities of treatment suggested when intolerable loud sounds and/or pain persist such as arthrocentesis, and disc anchorage when conservative treatment is insufficient.[39] Most clinicians opt to not treat if asymptomatic based on data shown in the literature, which is reasonable enough to provide a pure beneficial clinical decision to the patient. However, clicking is a result of disc displacement which when displaced anteriorly or antero-medially, ligaments that holds the disc posteriorly are elongated and damaged. The bilaminar zone is compressed and pain is initiated. Sometimes pain radiates to ears, TMJ, and surrounding structures aggravated by opening the mouth and chewing. Many studies have reported that disc displacement usually

go hand in hand with pain.[40,4142] So, we wanted to highlight in this study the association between TMJ clicking and the presence of pain upon screening and we found some key points that emphasize the strong relationship between clicking and pain.

Females had greater risk of having TMJ pain, after we adjusted for covariates as shown in (table 24). This is in agreement with the literature.[43] Furthermore, Hispanic and other group had the greatest odds of having pain compared to other races especially African-American group, this adds to the factors that we list for suspecting TMJ pain and TMJ clicking. In contrast, Plesh et al, found that Whites reported TMJ and muscles disorder pain more than Hispanics and Blacks in a national survey. However, Their sample consisted of 73% White which is greater than 11% and 12% for Hispanic and Black respectively.[44]

Furthermore , we found that subjects with open and close click were more likely to suffer from TMJ pain, even after we adjusted for age, gender, and race. As mentioned earlier this is in agreement with the literature. [40,41] In addition, lateral click subjects showed they are at greater risk of having TMJ pain as well in the same adjusted model (OR:14.4), this shows how significant the association between TMJ clicking and TMJ pain presence concomitantly.

Finally, when patients report to the dental clinic for any kind of reason, they should be screened for TMJ click, because we found that those who reported TMJ click of any sort in the self-conducted questionnaire had a risk of 7.7 of having TMJ pain. So, when subjects report click they are usually accompanied with pain in the same region that should raise the need for further screening. Patients usually live with that kind of symptoms because they don't feel the need for treatment or postpone treatment until pain presents.[45]

**Dental and skeletal measurement with TMJ click upon opening and closing movement of the mandible**

TMJ clicking can present is different motions of the mandible, either during opening and closing or during lateral and protrusive movement of the mandible. We investigated different dental and skeletal measurements with TMJ clicking shown in tables (8,16).

As discussed earlier the following findings confirms the association after adjusting for covariates in the logistic model. Data showed that open click often found in the Hispanic and other group significantly in terms of race distribution. While in dental classification, class III had a higher risk of having open click.

Protruded lip position has been significantly associated with TMJ click in the bivariate analysis in this study, which has no explanation except for decreased inter-labial gap which may be a result of certain mandibular position and its degree of inclination. However, in the adjusted logistic model only the upper lip position was significant with open click. This indicate that there might be an underlying cause for this kind of relation that can be investigated further in future research. To the best of our knowledge, there are no studies in the literature that looked at this kind of association.

Finally, as we discussed earlier that open click is highly associated with headache, in the adjusted multivariate analysis. Subjects with open click had a risk of 1.12 of reporting headache in years. Chronic daily headache is defined as *"15 or more headache episodes per month for at least 3 months"* based on the International Headache Society.[46] So, we can say that subjects who reported headache period in years have chronic headache, which

means chronic headache condition can be detected through persistent clicking sound of the TMJ during screening or can be considered as a valid predictor.

**Study Limitation:**

- Sample size included ages from 7- 50 years old, but it was adjusted for all the logistic models.
- Sample was obtained from an Orthodontic department which may cause selection bias.
- Did not include a headache screening tool to differentiate types of headache.

**Conclusion:**

In conclusion TMJ click upon opening and closing, lateral excursion, and self-reported click is highly associated with headache and chronic headache in general with a prevalence higher in females. Pain was highly associated with TMJ click of all sorts, with a higher prevalence in females and the Hispanic and other group. Finally, TMJ click was found more in the Hispanic and other group and class III dental occlusion subjects.

## LIST OF ABBREVIATED JOURNALS

Adv Clin Exp Med…… Advances in Clinical and Experimental Medicine

Am J Anat ……..……. American Journal of Anatomy

Clin Oral Investig……..… Clinical Oral Investigations

Community Dent Oral Epidemiol……...… Community Dentistry and Oral Epidemiology

Curr Opin Neurol ……. Current Opinion in Neurobiology Journal

Dtsch Arztebl Int …….……. Deutsches Arzteblatt International

Eur Rev Med Pharmacol Sci…… European Review for Medical and Pharmacological Sciences

Int J Adult Orthodon Orthognath Surg……..… International Journal of Adult Orthodontics and Orthognathic Surgery

Int J Oral Maxillofac Implants ……..... International Journal of Oral & Maxillofacial Implants

JAMA ……..…… Journal of the American Medical Association

J Am Dent Assoc. ……Journal of American Dental Association

J Craniomandib Disord ……..……Journal of Craniomandibular Disorders

J Dent ……..……. Journal of Dentistry

J Dent Res…….……. Journal of Dental Research

J Headache Pain ……...…… Journal of Headache and Pain

J Oral Facial Pain Headache ……... Journal of Oral & Facial Pain and Headache

J Oral Maxillofac Surg ..…… Journal of Oral and Maxillofacial Surgery

J Oral Rehabil ……...…… Journal of Oral Rehabilitation

J Orofac Pain ……...……..….. Journal of Orofacial Pain

J Prosthet Dent. ……...…….....Journal of Prosthetic Dentistry

Rev Paul Pediatr……..…...…… Revista Paulista De Pediatria

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## CURRICULUM VITAE