Modulation of Jaw Muscle Motor Response with Music in Individuals with Muscular Temporomandibular Disorders

by

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A thesis submitted in conformity with the requirements for the degree of Master of Science Orthodontics

Faculty of Dentistry
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Abstract

Oral behaviours, such as wake-time tooth clenching and awake bruxism, are strongly associated with mood disorders, and are risk factors for temporomandibular disorders (TMD). Guided Music Listening (GML), a complimentary therapy based on mood mediation, reduces anxiety and depression in patients with chronic pain. This study tested the effects of GML on wake-time tooth clenching in individuals with chronic TMD myalgia (mTMD).

The electromyographic (EMG) activity of the right masseter of fourteen women with mTMD and fifteen TMD-free controls was recorded during three music (stressful, relaxing, and favorite) and a control (pink noise) tasks.

GML affected the EMG amplitude of the masseter in both groups (all p<0.001). In mTMD patients, favorite music reduced the EMG amplitude of clenching episodes by 55% as compared to the control task (p<0.001). GML did not affect the frequency and duration of tooth clenching episodes in both groups. GML could benefit patients with chronic mTMD.
Acknowledgments

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List of Acronyms

AP: Activity periods  
BDI: Beck’s depression inventory  
BTX-A: Botulinum toxin type A  
CBT: Cognitive Behavioral Therapy  
CNS: Central nervous system  
COMT: Catechol-O-methyltransferase  
DC/TMD: Diagnostic criteria for temporomandibular joint disorder  
EEG: Electroencephalography  
EMA: Ecological momentary assessment  
EMG: Electromyography  
GAD: Generalized anxiety disorder  
GML: Guided music listening  
MVC: Maximum voluntary contractions  
NSAID: Nonsteroidal anti-inflammatory drug  
OBC: Oral behavior checklist  
OPPERA: Orofacial Pain Prospective Evaluation and Risk Assessment  
PCS: Pain catastrophizing scale  
PPT: Pressure pain threshold  
PHQ: Patient health questionnaire  
QST: Quantitative sensory testing  
RMS: Root mean square  
SNP: Single-nucleotide polymorphism  
SSAS: Somatosensory amplification scale  
STAI: State-trait anxiety inventory  
TMD: Temporomandibular joint disorders  
TMJ: Temporomandibular joint  
VAS: Visual analogue scales
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Appendix A

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B3. Experimental task VAS scales
Chapter 1

Introduction

Temporomandibular disorders (TMD) encompass several clinical pathological conditions involving the temporomandibular joints (TMJ), the muscles of mastication and/or their supporting structures. About 5-12% of the general population suffer from signs and symptoms of TMD (NIDCR, 2014); these can be severe enough to affect quality of life and daily activities.\(^{205, 217, 115}\)

Research in TMD has increased in recent years because of the difficulty to treat and manage chronic TMD. The difficulty arises mainly from its multifactorial etiology.\(^{192}\) Common risk factors thought to impact the onset of TMD include traumatic, anatomic, genetic and psychosocial risk factors, and oral parafunctional behaviors.\(^{149, 165, 181}\)

Oral parafunctional behaviours are habits that involve the oral structures other than for normal function, such as wake-time tooth clenching and awake bruxism, which is a masticatory muscle activity during wakefulness that is characterised by repetitive or sustained tooth contact (i.e. tooth clenching), and/or by bracing or thrusting of the mandible.\(^{165, 181, 140}\) Oral behaviors have been suggested as risk factors for myofascial pain and disk displacement.\(^{165, 181}\) In fact, individuals with masticatory muscle pain have a higher frequency and duration of wake-time clenching episodes, corresponding to a five-fold increase in the number of clenching episodes when compared to pain-free individuals.\(^{35, 46}\) Wake-time tooth clenching can also initiate TMD-like pain symptoms in otherwise pain-free individuals.\(^{84, 181}\) Although oral parafunctions are typically harmless, they can be detrimental when forces go beyond each individual’s tolerance point.\(^{162}\)

Mood disorders are also prevalent in patients with TMD, as well as in pain-free individuals with frequent wake-time tooth clenching episodes and awake bruxism.\(^{20, 69, 199}\) Stress and anxiety increase the frequency of oral parafunctional activities,\(^{75}\) and both awake bruxism and altered mood states contribute to the increase in pain-related TMD.\(^{75, 88}\) Interestingly, habit reversal has been shown to decrease pain symptoms in patients with TMD myalgia.\(^{86}\) Therefore, a therapy
aimed at reducing awake bruxism by modulating mood could be beneficial to patients with TMD myalgia.

It is well known that music influences mood states such as anxiety. The therapeutic benefit of guided music listening (GML) — an intervention based on mood mediation and attention modulation — has been exploited to manage pain symptoms in individuals with chronic pain. Recently, our lab has shown that GML can also modulate the activity of the masticatory muscles in pain-free individuals. It was found that both favorite and stressful music decrease the amplitude of wake-time tooth clenching episodes in pain-free individuals, possibly through distraction, as opposed to relaxing music that may stimulate focus and concentration. Therefore, music could potentially be used as a multimodal treatment approach to improve pain and reduce masticatory muscle overload in patients with TMD.

Objectives of Study

This study aims to evaluate the impact of GML on masticatory muscle activity of patients with chronic TMD myalgia. In particular, this investigation aims to determine the effect of GML on the amplitude, frequency, and duration of wake-time clenching episodes in women with chronic TMD myalgia compared to TMD-free women serving as controls.

Hypothesis

It is hypothesized that favorite music positively influences mood and decreases the activity of the masticatory muscles by reducing the frequency, electromyographic amplitude, and duration of tooth clenching episodes.

The findings of this project could pave the way for developing a non-invasive, non-pharmacologic, and inexpensive therapeutic option for managing muscular pain related to TMD.
Chapter 2
Literature Review

Temporomandibular Disorders

The temporomandibular joints (TMJ) are composed of the mandibular condyles, the glenoid fossa and articular eminence of the temporal bone, the joint capsule, the articular disc and the attached soft tissue components such as the temporomandibular, sphenomandibular and stylomandibular ligaments and the lateral pterygoid muscles. These bilateral diarthrodial joints in conjunction with the muscles of mastication (right and left masseter, temporalis, medial pterygoid and lateral pterygoid muscles) allow for movement of the mandible and distribution of stresses during functional (speaking, chewing, swallowing, etc.) and parafunctional activities.

Temporomandibular disorder (TMD) is a term encompassing multiple clinical pathological musculoskeletal conditions associated with the TMJ, the muscles of mastication and/or the supporting tissues. The morphological and functional deformities that can be associated with these conditions typically lead to recurrent pain and dysfunction. TMD is in fact the leading cause of chronic orofacial pain. The most common symptoms of TMD are localized pain of the muscles of mastication and/or the TMJ, generalized myofascial pain, joint noises upon opening, closing, protrusive and/or lateral movements, decreased mandibular range of motion and functional limitations.

Pain caused by TMD can be acute or chronic and can be characterized as either peripheral nociceptive, peripheral neuropathic or central neuropathic pain. Peripheral nociceptive pain is localized. It arises from tissue damage—such as hypoxia and tissue ischemia—and inflammation which stimulates nociceptors at the area of potential or actual injury. For example, in muscular anaerobic environments, lactic acid, bradykinins, and proteolytic enzymes accumulate and sensitize nociceptors. Alternatively, in muscle spasms, peripheral nociceptive pain can occur due to blood vessel compression. Peripheral sensitization suggests an increased sensitivity of nerve endings, spontaneous activity of deep nociceptive afferents, as well as lower activation thresholds. In these instances, pain is thought to subside if the nociceptors cease to be stimulated.
Peripheral neuropathic pain affects broader areas innervated by a particular nerve called dermatomes. It can be transient or permanent and is caused by injury of the primary nociceptive afferents.

Central neuropathic pain is caused by a dysregulation of the nociceptive pathway in the CNS (central sensitization) and encompasses structural, functional and/or metabolic changes. It is the most difficult to manage since it often involves additional comorbid chronic disorders and individuals often experience widespread hyperalgesia. Quantitative sensory testing (QST) studies have shown that individuals with chronic pain have higher pain sensitivity to noxious stimuli (hyperalgesia) and pain with non-noxious stimuli (allodynia) which are clinical manifestations of central sensitization.

**Incidence and Prevalence**

TMD signs and symptoms’ incidence and prevalence have been studied in different population samples. A survey in the United-States in 2008 reported the overall prevalence of pain-related TMD to be estimated at 4.6%. The Orofacial pain prospective evaluation and risk assessment (OPPERA) study reported that 3.9% of individuals per year presented with a first-onset of TMD with approximately 65% of them having episodes of recurrent symptoms. According to the National Institute of Dental and Craniofacial Research (NIDCR), TMD affects 5 to 12% of the general population (NIDCR, 2014). In addition, 15% of all TMD are reported as being chronic (having symptoms that recur or persist for a duration of ≥3 months) (NIDCR, 2014). The incidence is greater in women than in men with a ratio of 2:1 to 8:1 with most individuals being between the ages of 20 and 50 years.

TMD have an impact on both the individual and social level. In fact, as high as 50% of individuals suffering from TMD have symptoms affecting their daily life severely enough to seek treatment. In the United States, approximately 17.8 million work days per year for every 100 million working adults are lost because of TMD, and TMD is estimated to cost USD 4 billion per year due to loss of productivity and treatment (NIDCR, 2014).
Diagnosis and Classification

Diagnostic Criteria for Temporomandibular Disorders

TMD can be classified into disorders involving the articulation and non-articular disorders.\cite{139,213} They can be diagnosed according to several classification systems that are based on the physical evaluation of signs, symptoms and history with an added radiographic diagnostic tool, when indicated. The diagnostic criteria for TMD (DC/TMD; Refer to Table 1) and the classification of the American Academy of Orofacial Pain (AAOP) are examples of the classification systems (AAOP 4\textsuperscript{th} edition).\cite{65} The DC/TMD identify four diagnostic groups: TMJ disorders, muscular disorders, headaches, and TMD of associated structures. The assessment instruments provided by the DC/TMD are separated into two axes. Axis I includes the TMD-pain screener and validated diagnostic criteria to distinguish pain-related TMD, as well as four intra-articular disorders.\cite{213} The TMD-Pain Screener is a preliminary 6-question screening tool for the presence of pain due to TMD (Refer to Appendix B1.1.). This questionnaire has a sensitivity of approximately 99\% and a specificity of more than 96\%.\cite{92} Axis II includes questionnaires to establish pain-related disability and functional limitations, pain-related psychological distress, parafunctional habits, generalized anxiety and comorbid pain conditions.\cite{213}
Table 1. Classification for Temporomandibular Disorders (DC/TMD).
(Adapted from Schiffman et al. 2014)

<table>
<thead>
<tr>
<th>Temporomandibular Joint Disorders</th>
<th>4) Fractures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Joint pain</td>
<td>5) Congenital/developmental disorders</td>
</tr>
<tr>
<td>• Arthralgia</td>
<td>• Aplasia</td>
</tr>
<tr>
<td>• Arthritis</td>
<td>• Hypoplasia</td>
</tr>
<tr>
<td>2) Joint Disorders</td>
<td>• Hyperplasia</td>
</tr>
<tr>
<td>• Disc Disorders</td>
<td></td>
</tr>
<tr>
<td>✓ Disc displacement with reduction</td>
<td></td>
</tr>
<tr>
<td>✓ Disc displacement with reduction with intermittent locking</td>
<td></td>
</tr>
<tr>
<td>✓ Disc displacement without reduction with limited opening</td>
<td></td>
</tr>
<tr>
<td>✓ Disc displacement without reduction without limited opening</td>
<td></td>
</tr>
<tr>
<td>• Hypomobility disorders other than disc disorders</td>
<td></td>
</tr>
<tr>
<td>✓ Adhesions/adherence</td>
<td></td>
</tr>
<tr>
<td>✓ Ankylosis (Fibrous or Osseous)</td>
<td></td>
</tr>
<tr>
<td>• Hypermobility disorders</td>
<td></td>
</tr>
<tr>
<td>✓ Dislocations (Subluxation or Luxation)</td>
<td></td>
</tr>
<tr>
<td>3) Joint Diseases</td>
<td></td>
</tr>
<tr>
<td>• Degenerative joint disease</td>
<td></td>
</tr>
<tr>
<td>✓ Osteoarthrosis</td>
<td></td>
</tr>
<tr>
<td>✓ Osteoarthritis</td>
<td></td>
</tr>
<tr>
<td>• Systemic arthritides</td>
<td></td>
</tr>
<tr>
<td>• Condylysis/idiopathic condylar resorption</td>
<td></td>
</tr>
<tr>
<td>• Osteochondritis dissecans</td>
<td></td>
</tr>
<tr>
<td>• Osteonecrosis</td>
<td></td>
</tr>
<tr>
<td>• Neoplasm</td>
<td></td>
</tr>
<tr>
<td>• Synovial chondromatosis</td>
<td></td>
</tr>
</tbody>
</table>

| Masticatory Muscle Disorders      |             |
| 1) Muscle Pain                    |             |
| • Myalgia                          |             |
| ✓ Local myalgia                    |             |
| ✓ Myofascial pain                  |             |
| ✓ Myofascial pain with referral    |             |
| • Tendonitis                       |             |
| • Myositis                         |             |
| • Spasm                            |             |
| 2) Contracture                     |             |
| 3) Hypertrophy                     |             |
| 4) Neoplasm                        |             |
| 5) Movement disorders              |             |
| • Orofacial dyskinesia             |             |
| • Oromandibular dystonia           |             |
| 6) Masticatory muscle pain attributed to systemic/central pain disorders |             |
| • Fibromyalgia/widespread pain     |             |

| Headache                          |             |
| 1) Headache attributed to TMD     |             |

| Associated Structures             |             |
| 1) Coronoid hyperplasia           |             |
Temperomandibular Joint Disorder

TMJ disorder, or TMD arthralgia, is defined as pain occurring only in the area of the TMJ.\textsuperscript{213, 189} TMD arthralgia can be described as pain in the jaw, temple or ear with jaw movement, function, or parafunction originating in the joint itself.\textsuperscript{213, 189} Upon clinical examination, familiar pain (pain resembling the painful symptoms that was experienced by the patient throughout) in the TMJ with either palpation of the lateral pole or during maximum unassisted or assisted opening, lateral or protrusive movements should be present to confirm diagnosis.\textsuperscript{213, 189} A diagnosis of arthritis is suggested when pain in the TMJ arises from localized inflammation or infection with or without edema, erythema and an increase in temperature.\textsuperscript{189} When unilateral, this condition can clinically cause occlusal changes, such as a posterior open bite.\textsuperscript{189}

Disc disorder is an umbrella term that includes the diagnoses of disc displacement with or without reduction.\textsuperscript{213, 189} The diagnosis of disc displacement with reduction is concomitant with TMJ noises with jaw movement within the last 30 days. Upon clinical examination, clicking, popping, and/or snapping should be detected with palpation during opening or closing movements and/or lateral or protrusive movements.\textsuperscript{213, 189} The disc is anterior to the condylar head and reduces between the condylar head and the articular eminence upon opening.\textsuperscript{213, 189} Diagnosis is confirmed by MRI imaging.\textsuperscript{213, 189} If limited mandibular opening occurs intermittently due to the disc not reducing properly, this suggests a diagnosis of disc displacement with reduction with intermittent locking.\textsuperscript{213, 189} Disc displacement without reduction with limited opening is diagnosed if the disc is permanently dislocated and there is persistent limited opening with a maximum assisted opening of less than 40 mm.\textsuperscript{213} When the maximum assisted opening is more than 40 mm with a disc permanently dislocated, this suggests a diagnosis of disc displacement without reduction without limited opening.\textsuperscript{213, 189}

Hypomobility disorders include the diagnoses of adhesions, adherences and ankylosis.\textsuperscript{189} These disorders limit mandibular movement and, especially if unilateral, can cause deflection upon opening in the direction of the affected condyle.\textsuperscript{189} Fibrous adhesions occur more frequently in the superior compartment of the TMJ, responsible for mandibular translation.\textsuperscript{189} Inflammation within the joint, due to trauma, systemic condition or increased loading, is thought to give rise to joint adhesions.\textsuperscript{189} Clinically, individuals typically have reduced mobility without a history of clicking.\textsuperscript{189} Arthrography, MRI, or arthroscopy is used to confirm the presence of adhesions.
within the joint. A more severe form of adhesion/adherence is fibrous ankylosis. Ankylosis can be subcategorized into fibrous or osseous ankylosis. Joints affected with ankylosis risk being completely immobilized. Computed tomography or cone beam computed tomography (CBCT) distinguishes fibrous ankylosis (presence of a disc space between the condyle and the eminence) from osseous ankylosis (elimination of part or all of the joint space). The joint space in the latter is replaced by bony proliferation.

Hypermobility disorders include the diagnoses of subluxation and luxation. In both diagnoses, the disc-condyle complex is trapped anterior to the articular eminence. The diagnosis of subluxation is given when the individual is capable of reducing the dislocation without the help of a clinician. If the clinician is required, the dislocation is diagnosed as a luxation.

Degenerative joint disease is the most common joint disease in which osseous changes in the condyle and/or articular eminence are noted on CT scans. This commonly occurs in conjunction with a deterioration of the articular disc. Upon clinical examination, crepitus is perceived during mandibular movements. A diagnosis of osteoarthrosis is made if the degenerative joint disease is not linked with arthralgia whereas a diagnosis of osteoarthritis is made if it is concomitant with arthralgia. Radiographic evidence of osteophytes, erosion, subchondral cyst and/or generalized sclerosis confirms the diagnosis of degenerative joint disease.

Systemic arthritides is another joint disease defined as inflammation in the joint causing structural changes and pain due to a generalized systemic inflammatory disease. Inflammatory diseases such as juvenile idiopathic arthritis, rheumatoid arthritis, spondyloarthropathies, gout, lupus, etc. can affect the joint space by creating swelling, pain and/or tissue destruction. Radiographic imaging is similar to degenerative joint diseases when osseous degradation is present. Rheumatologists typically treat these systemic conditions.

Condylysis or idiopathic condylar resorption is most often diagnosed in young females. This leads researchers to believe that estrogen may be a factor involved in the cause of bilateral progressive condylar resorption. Occlusal changes, such as anterior open bites, can be seen once the disease progresses. Osteochondritis dissecans is another type of joint disease from which cartilage and bony fragments dissociate from the condyle. Osteonecrosis or avascular necrosis is a type of joint disease diagnosed by MRI. Synovial chondromatosis is defined as...
cartilaginous changes of the mesenchymal remnants of the synovial tissue causing pain, limited function, swelling and/or crepitus.\textsuperscript{189}

The most severe types of joint diseases are neoplasms.\textsuperscript{189} They can be benign, such as osteochondromas, or malignant, including metastatic.\textsuperscript{189} Signs and symptoms can mimic those of other joint diseases with the addition of sensory-motor abnormalities.\textsuperscript{189} Biopsies are indicated for diagnosis of malignancies.\textsuperscript{189}

Fractures commonly occur with trauma. The subcondylar fracture is the most common fracture within the TMJ.\textsuperscript{189}

The last subtype of TMD occurring within the joint is a group of congenital and developmental disorders.\textsuperscript{189} Clinically, these are typically first noticed due to an asymmetry of the mandible when unilateral or micro/macroglossia when bilateral.\textsuperscript{189} Aplasia refers to the absence of one or two condyles.\textsuperscript{189} It is most often associated with other disorders such as Goldenhar Syndrome, hemifacial microsomia and mandibulofacial dysostosis.\textsuperscript{189} Condylar hypoplasia is defined as an underdevelopment of the condyle whereas condylar hyperplasia is defined as the overdevelopment of the condyle.\textsuperscript{189}

**Masticatory Muscle Disorders**

Myalgia is an umbrella term that includes diagnoses of local myalgia, myofascial pain as well as myofascial pain with referral. TMD myalgia can be described as pain originating in the masticatory muscles that impacts the function or parafunction of the jaw.\textsuperscript{213} The diagnosis of TMD myalgia is concomitant with a history of pain in the last 30 days in the jaw, temple, or ear in addition to a change in pain during function or parafunction.\textsuperscript{213} To confirm diagnosis, familiar pain in the temporalis or masseter muscles with either palpation with a force of 1 kg or maximum unassisted or assisted opening should be present during clinical examination.\textsuperscript{213} The provoked pain can either be localized at the site of palpation (local myalgia), spreading beyond the site of palpation within the same muscle (myofascial pain) or referring beyond the muscular boundary (myofascial pain with referral).\textsuperscript{213} Headaches can also be triggered by palpation.\textsuperscript{213}
Tendonitis refers to pain that occurs in the tendon of a particular muscle that can be replicated by palpation.\textsuperscript{189} The most common location of tendonitis is within the tendon of the temporalis muscle.\textsuperscript{189} On the other hand, signs and symptoms of inflammation and/or infection in addition to pain within the muscle are suggestive of myositis.\textsuperscript{189} Rarely, the muscle calcifies which is termed myositis ossificans.\textsuperscript{189} Spasms are defined as being abrupt, spontaneous, involuntary, non-permanent muscular contractions.\textsuperscript{189} Elevated muscle tone measured by EMG confirms this diagnosis.\textsuperscript{189} Trauma, infection and radiation can also lead to a diagnosis of contracture, most often in the masseter or medial pterygoid muscles.\textsuperscript{189} This diagnosis is made when there is a progressive decrease in size of a muscle caused by fibrosis of the muscle itself, the ligaments or tendons.\textsuperscript{189} Hypertrophy, on the other hand, reveals an increase in size of the muscle generally due to overuse.\textsuperscript{189}

Benign and malignant neoplasms can also rarely be present within the soft tissues.\textsuperscript{189} Similarly to those within the hard tissues, neoplastic lesions require a biopsy for definitive diagnosis.\textsuperscript{189}

Movement disorders include orofacial dyskinesia, involuntary uncoordinated movements, and oromandibular dystonia, disproportionate, involuntary and continuous muscular contractions.\textsuperscript{189}

Pain in the masticatory muscles can also be due to systemic pain disorders such as fibromyalgia.\textsuperscript{189} Symptoms are however usually bilateral and include pain above and below the waist.\textsuperscript{259}

**Headache Attributed to TMD**

Headache attributed to TMD is defined as pain in the temple area, modified by jaw movement, function or parafunction that can be directly attributed to pain-related TMD.\textsuperscript{213} Upon clinical examination, familiar headache with palpation of the temporalis muscle or during maximum unassisted or assisted opening, lateral or protrusive movements should be present to confirm diagnosis.\textsuperscript{213}
Etiology

The etiology of TMD is largely debated in the literature. It is however agreed upon that the etiology of TMD is multifactorial. Historically, the onset of TMD was thought to be due to dental and/or structural abnormalities. Today, studies have shown that multiple risk factors are involved in the onset of TMD, including traumatic, genetic, anatomical, psychosocial factors, and oral behaviors. Generalized pain conditions, functional disorders, health status as well as a history of pain symptoms, or current pain upon examination can also be risk factors to TMD. These factors can either be initiating factors contributing to the onset of TMD, predisposing factors increasing the risk of TMD and/or perpetuating factors hindering the healing or heightening the progression of TMD. The difficulty in treating TMD stems from the fact that although technological advances in medicine allow for recognition of several factors contributing to pain related to TMD, no single risk factor was found to be necessary or sufficient for the onset of TMD.

Health Status

Patient’s health status is one of the strongest predictor of TMD onset. A clinical review of the OPPERA study suggests that a checklist of 20 health conditions significantly predict the incidence of TMD. These conditions are however not clear and are likely to be comorbid conditions that are a result of mechanisms that are contributing to TMD.

The OPPERA study indicated that most pain disorders were associated with an increase in TMD incidence. The more episodes of other pain disorders, such as lower back pain, irritable bowel syndrome, genital pain symptoms and headaches, the higher the likelihood of TMD incidence. Other conditions including a history of neural conditions, comorbid conditions, respiratory conditions, usage of 3 or more medications, cigarette smoking and decreased self-rating of general health status were also associated with an increased incidence of TMD. Overall indicators of poor health are therefore thought to be associated with an increased risk of TMD onset.
**Trauma**

Whether or not trauma is a significant etiological factor to the onset of TMD is controversial. One study found that 79% of individuals with disc displacement without reduction and 54% of individuals with myalgia had a history of trauma.\(^{190}\) It has been proposed that trauma either participates solely to the onset of TMD acutely, immediately after the traumatic event or participates in the delayed response contributing to the transition from acute to chronic TMD.\(^{181}\)

A recent review also found an increase in prevalence and severity of TMD as well as an altered psychological function in patients with a history of whiplash trauma.\(^{104}, 103\) The high prevalence of history of traumatic events does not necessarily imply that trauma would be essential etiological factor to TMD due to recall bias; it can also be an aggravating factor or a comorbid condition.

**Sleep patterns**

Sleep disorders are common comorbidities associated with chronic pain.\(^{133}\) In fact, 36% of individuals with TMD are thought to have insomnia\(^{132}, 118\) and approximately 20% of individuals with TMD self-report having a poor quality discontinued sleep pattern.\(^{18}, 215\) A recent study indicates the possibility of a hyperarousal effect contributing to pain maintenance in TMD: patients with TMD seem to have an increase in continuous low-grade masseteric EMG muscle activity while sleeping.\(^{194}\) This occurs even though an increase in sleep bruxism was not found.\(^{194}\)

The relationship between sleep patterns and pain onset is bidirectional and complex. Although sensory transmission is typically reduced during sleep, chronic pain can disturb sleep quality, which is related to increased pain perception and reduced pain tolerance.\(^{133}, 131\) However, dysfunctional sleep patterns predict the onset of pain more than the contrary.\(^{76}\) This vicious circle is not found in acute pain since sleep tends to return to normal with reduction of acute pain.\(^{133}\)

According to the OPPERA case-control study, there is a 40% increase in the incidence of first-onset TMD for every decrease in standard deviation in sleep quality assessed by the Pittsburgh Sleep Quality Index.\(^{211}\) This decrease in sleep quality is progressive and independent of pain sensitivity, psychosocial stresses and other etiological factors predicting TMD.\(^{211}\) The OPPERA
study also indicates a 3-fold increase in incidence of first-onset TMD in individuals with signs and symptoms of obstructive sleep apnea.\textsuperscript{210}

**Genetics**

Certain genetic variants impacting intermediate phenotypes, such as psychological distress and pain amplification, combined with environmental factors can result in an increased susceptibility to TMD.\textsuperscript{149} Genetic factors actually contribute and influence clinical and experimental pain perception.\textsuperscript{37, 59, 170, 177, 266} To date, several genes were found to be associated with TMD pain, anxiety, depression, somatic awareness, stress response, and affective disorders.\textsuperscript{149}

The OPPERA case-control study evaluated 2924 single-nucleotide polymorphisms (SNPs) within 358 genes known to be involved in pain pathways.\textsuperscript{220} Within these SNPs were six that had greater associations with chronic TMD.\textsuperscript{220} SNPs within the glucocorticoid receptor gene and the serotonin receptor gene suggest that the hypothalamic-pituitary-adrenal system may be involved in the development of chronic TMD.\textsuperscript{220}

Catechol-O-methyltrasferase (COMT) regulates catechol neurotransmitter catabolism, responsible for stress response.\textsuperscript{221} Individuals with lower COMT activity experience higher levels of experimental pain with increased stress due to compromised catabolism of catecholamines.\textsuperscript{160} Three COMT haplotypes were found to be associated with experimental pain and increased risk of clinical TMD.\textsuperscript{59, 58} The OPPERA study evaluated the association between COMT haplotypes and the incidence of first-onset TMD.\textsuperscript{221} In individuals with low-activity COMT, stress was increased more in incident TMD cases than in individuals who did not develop TMD.\textsuperscript{221} In addition, individuals with low-activity COMT haplotypes had a doubled rate of incident TMD with increased stress.\textsuperscript{221} This interaction is not seen in individuals with high-activity COMT haplotypes.\textsuperscript{221}

Given the close relationship between psychological factors and chronic TMD, many genes involved in the development of TMD will also affect some psychological variables.\textsuperscript{149} To date, there remains a gap in the literature in determining the heritability of pain associated with TMD.\textsuperscript{149}
Parafuncational Habits (Oral Behaviors)

Oral parafunctions are indicated as being one of the strongest predictors of onset of TMD. These include wake-time tooth clenching, which is associated with awake bruxism, holding the jaw in a rigid position (bracing), and other activities such as nail biting and gum chewing. In a study comparing parafunctional habits to trauma amongst university students over a span of 3 years, oral parafunctions were 3 times more likely than trauma to predict TMD symptoms. Another study using the oral behavior checklist (OBC), a validated questionnaire assessing self-reported oral behaviors, reported that an increased risk of TMD was found in individuals with either a greater number of parafunctional habits or a greater frequency of parafunctional habits. This led to the hypothesis that a central nervous system (CNS) dysregulation is necessary to allow for such an increased concentration of parafunctional habits leading to the increased risk of TMD. The central dysregulation could be either due to increased motor activation, decreased motor inhibition, loss of proprioception and/or persistent psychophysiologic reactivity in the masticatory system and/or in the general motor system.

Most studies do not discriminate between different parafunctional habits (tooth clenching, tooth grinding, gum chewing and nail biting), which explains the ongoing debate on the effect of parafunctions on TMD. These habits are thought to play a role in the etiological factors of TMD when they overload the masticatory system to a point that is beyond the individual’s tolerance level. Nail biting has been shown to create changes in the joint space. In contrast, tooth clenching and grinding have been shown to provoke myogenous pain. More precisely, wake-time tooth clenching and grinding are associated with myofascial pain and disc displacement. The frequency and duration of wake-time tooth clenching episodes are increased in individuals with TMD experiencing masticatory muscle pain. In fact, individuals with myogenous pain keep their teeth in contact for longer periods of time. In individuals with myogenous pain, intense masticatory muscle contractions during parafunctional activity may impede normal blood flow affecting muscle oxygenation, muscle reperfusion during recovery and evacuation of cellular by-products. The concurrent symptoms of pain, fatigue and/or spasms can be due to the buildup of metabolic waste products and the release of inflammatory mediators. This mechanism is reinforced by the fact that wake-time bruxism can elicit TMD symptoms in otherwise pain-free individuals, and experimental tooth clenching can induce TMD-like pain.
Assessment of Parafunctional Habits

The OBC is a 21-item questionnaire (Refer to Appendix B1.3.) used to evaluate the degree of self-reported daytime oral parafunctions.\textsuperscript{106, 153, 180, 140} To date, no clear norms have been validated, and therefore the score solely indicates the degree of parafunctions.\textsuperscript{180} Previous studies have suggested that scores ranging between 0-16 are considered normal whereas scores ranging between 25-62 can potentially be risk factors for the onset of TMD.\textsuperscript{180}

EMG is a technique used to record and evaluate the electric signals arising from the muscles during rest, functional and parafunctional activities.\textsuperscript{114, 140} Muscles respond to neural control with their semi-permeable membranes containing a Na\textsuperscript{+}K\textsuperscript{+} ion pump.\textsuperscript{119} When the CNS activates an alpha-motor neuron, the excitation is conducted along the nerve, which then releases a transmitter at its endplate.\textsuperscript{119} If a threshold level is exceeded, an action potential is formed at the muscle fiber innervated by the motor unit, which depolarizes the membrane.\textsuperscript{119} This is followed by a period of repolarization and after hyperpolarization.\textsuperscript{119} An electric dipole is created along the surface of a muscle fiber.\textsuperscript{119} The EMG signal detects these actions potentials.\textsuperscript{119} When using this technique, it is important to take into consideration that several factors can influence raw EMG signals such as tissue thickness, tissue temperature, neighboring muscles, distance between the muscle and electrode, external noise, electrode amplifiers and skin preparation techniques.\textsuperscript{119}

Awake bruxism and tooth clenching can also be assessed by ecological momentary assessments (EMA).\textsuperscript{166, 43, 35, 140, 265} This approach begins with educating the individual on what clenching and bracing mean followed by a self-monitoring process over a period of one to two weeks.\textsuperscript{140} The informed individual therefore self assesses the level of tooth contact for activities other than swallowing.\textsuperscript{140} The data collection is then either done at one time point at the end of the one to two weeks or throughout the evaluation with diaries at the end of each day.\textsuperscript{140} This method has also been used to collect pain reports in TMD patients.\textsuperscript{41, 67}
### Psychological Factors

**Psychological Determinants**

Psychological and emotional alterations have been described in individuals with chronic pain syndromes. Studies have found greater levels of anxiety, depression and stress-induced symptoms in individuals with TMD as opposed to pain-free individuals. In 2016, a study reported that the prevalence of depression amongst patients with TMD was 30.4% and the prevalence of anxiety was 28.9%. These psychological factors are however not uniformly distributed within the TMD population. Individuals with chronic pain of muscular origin present more commonly with psychological disturbances when compared to individuals with non-symptomatic disk and joint issues. Depression was however not found to be a predictive factor for the onset of TMD. A prospective study by Slade et al. conducted on 171 TMD-free females concluded that anxiety, depression and perceived stress increased the risk of TMD of 2 to 3-fold. A retrospective study revealed that 22% of patients with TMD report severe depression, 24.6% report severe anxiety and 38.6% have concurrent severe somatization.

The comorbidity of depression and anxiety in chronic musculoskeletal pain is usually associated with an increase in pain severity and disability due to a decreased ability to develop effective coping skills decreasing quality of life. A study involving 207 patients with TMD reported a comorbidity of severe anxiety and depression of 17.9%. The level of depression and somatization is greater in patients with chronic TMD than in patients with acute TMD, which corresponds to the patients with the greatest disability.

### Assessment of Anxiety and Depression

The adult version of the State-Trait Anxiety Inventory (STAI) forms Y1 and Y2 are used to determine individuals’ level of anxiety. This self-report questionnaire includes 20 questions evaluating trait anxiety and 20 questions evaluating state anxiety scored on a 4-point scale per question. State anxiety is defined as being a current, temporary feeling of anxiety whereas trait anxiety refers to a generalized feeling of anxiety as well as proneness to anxiety. Both state and trait anxiety are also related to awake bruxism.

Beck’s Depression Inventory (Refer to Appendix B1.6.) is used to evaluate the extent of behaviors suggesting depression. The questions address the following behaviors:
• Mood
• Pessimism
• Sense of Failure
• Lack of Satisfaction
• Guilty Feeling
• Sense of Punishment
• Self-hate
• Self Accusations
• Self Punitive Wishes
• Crying Spells
• Irritability
• Social Withdrawal
• Indecisiveness
• Body Image
• Work Inhibition
• Sleep Disturbance
• Fatigability
• Loss of Appetite
• Weight Loss
• Somatic Preoccupation
• Loss of Libido

Generalized anxiety disorder (GAD), one of the most common anxiety disorders, can be assessed using the GAD-7 questionnaire. This questionnaire includes 7 questions evaluating anxious mood and behavior as well as its interference with daily life. The Primary Care Evaluation of Mental Disorders 2, 4 or 9-item Patient Health Questionnaire (PHQ) are also used as reliable screening tools for anxiety and depression.

Pain Amplification and Catastrophizing

Pain amplification is defined as a heightened perceptual response to nociceptive stimuli due to changes in the peripheral and central nervous system. Individuals with chronic TMD have been reported to have lower pain thresholds to mechanical pressure. In addition, individuals with a heightened sensitivity to noxious stimuli are 2.7 times more likely to develop a painful TMD than individuals with lower pain sensitivity. Individuals with TMD are also associated with high levels of somatic awareness. Five years after the pain decreases, there is a reduction in the tendency to report physical symptoms in a greater extent than the clinical signs.

Somatic sensations include those resulting from the skin (touch, pressure, temperature, pain, etc.) as well as from the muscles, tendons and joints (pain, position of limbs, etc.). The Somatosensory Amplification Scale (Refer to Appendix B1.4.) is used to evaluate individuals’
sensitivity to these sensations. Somatosensory amplification is defined as being “the tendency to experience somatic sensation as intense, noxious, and disturbing”.\textsuperscript{175}

The 13-question pain catastrophizing scale (PCS) (Refer to Appendix B1.5.) is used to evaluate individuals’ psychological and emotional response to actual or anticipated painful experiences.\textsuperscript{228} This scale allows for analysis of different aspects of catastrophizing including “rumination”, “magnification” and “helplessness”.\textsuperscript{226} According to Sullivan et al., individuals that are considered high catastrophizers do not seem to adapt as well to pain and therefore present with an exaggerated pain experience and are more expressive while experiencing pain.\textsuperscript{228} Pain catastrophizing increases the odds for high pain persistence more than 6-fold in TMD patients.\textsuperscript{197}

### Relationship between awake bruxism and psychological factors

Stress and anxiety are related to an increase in awake bruxism.\textsuperscript{144} A systematic review concluded that psychosocial factors and psychopathological symptoms are involved in awake bruxism, but not to nocturnal bruxism.\textsuperscript{150} Awake bruxism is also hypothesized to be a result of either a transitory anxious reaction to daily stressors, which are commonly referred to as state-anxiety or a result of a complex psychopathological disorder, which is classified as trait-anxiety.\textsuperscript{150} The hypothalamus, the reticular system, and the limbic system are responsible for one’s emotional state.\textsuperscript{80} Stress activates the hypothalamic-pituitary-adrenal (HPA) axis, which raises the activity of the gamma efferents.\textsuperscript{80} These gamma efferents produce contraction of the intrafusal fibers of the muscle spindles.\textsuperscript{80} This phenomenon is not voluntary and is produced through the autonomic nervous system.\textsuperscript{80} Stress can also modulate the sympathetic activity, which can in turn also increase muscle tone.\textsuperscript{80} In addition, tooth clenching is also believed to decrease stress and increase relaxation.\textsuperscript{233} A study conducted in 2007 has demonstrated that chewing and clenching reduces the level of salivary cortisol, a hormone produced by the adrenal gland in the HPA in response to stress.\textsuperscript{233}

Stressors are encountered either positively or negatively throughout one’s life. However, prolonged exposure or chronic increased levels of emotional stress may impede the body’s capacity to adapt, and can even have adverse effects.\textsuperscript{214}
Central Sensitization

Central sensitization is defined as changes occurring in the central nervous system (CNS) such as to increased membrane excitability, reduced inhibition and/or increase of synaptic efficacy.\textsuperscript{126,125} These result in an increase in function of nociceptive pathways, and therefore increased pain sensitivity.\textsuperscript{130} Central sensitization usually occurs in individuals with chronic TMD, in particular myalgia.\textsuperscript{263} A prospective study established that individuals with hyperalgesia (heightened sensitivity to pain) were 2.7 times more likely to develop a painful TMD than individuals with decreased pain sensitivity.\textsuperscript{59} Individuals with TMD have increased tactile and thermal pain sensitivity as well as increased generalized pain sensitivity with isometric contraction of the orofacial muscles.\textsuperscript{73} Most individuals with TMD also have increased sensitivity to noxious pressure, pinprick and heat stimuli.\textsuperscript{97} Since pressure pain thresholds (PPTs) remain unchanged by peripheral local anesthesia injections at painful trigger point areas, this hyperalgesia is thought to be centrally mediated by hyperexcited second-order nociceptive neurons in the brain stem.\textsuperscript{157}

The association between pressure sensitivity and TMD is greater than with other types of stimuli.\textsuperscript{97} The PPT of the thenar muscle of the hand is also used to verify if central sensitization is present.\textsuperscript{191}

Treatment Options

The management and/or treatment of TMD is challenging since the etiology and pathogenesis of these pathological conditions remains controversial, poorly understood and with an absence of strong evidence in the literature. Current treatment options therefore rely on preventing further damage and limiting acute and chronic symptoms rather than preventing the onset of the disorders by targeting the etiological factors. Most treatment options generate short-term benefits that do not address young individuals’ long-term functional pain-free demands throughout life.\textsuperscript{174}

Current treatment options vary according to the diagnosis as well as the severity of the disorder.\textsuperscript{139} Because of the multiple initiating and perpetuating factors involved in TMD, treatment options most commonly include a multidisciplinary team of specialists such as the general dentist, the orthodontist, the oral medicine and orofacial pain specialist, the oral surgeon, the physiotherapist, the chiropractor, the psychiatrist, etc.\textsuperscript{139} Initial treatments are typically
conservative. The goals of treatment include reducing pain, preventing further damage, increasing function and improving quality of life.

Non-Invasive Treatment Options

Self-Management

A non-invasive treatment option for TMD includes patient education and self-care, including stress management, identification and avoidance of oral behaviors, coping behaviors and personalized exercises with feedback. An RCT by Dworkin et al. compared the effects of personalized self-care methods to those of traditional TMD treatment on 124 participants with painful symptoms of TMD excluding headaches. Traditional treatments included patient education, physiotherapy, pharmacotherapy and occlusal appliances. Personalized self-care management included patient education, stress management therapy, guided reading with structured feedback, self-monitoring of signs and symptoms with detection of factors that modify their symptoms, personalized self-care plan with coping methods, support and feedback by their dentist and maintenance and relapse prevention. This study reported positive changes in both groups with the self-care group having an even greater reduction in pain, number of muscles involved and dental visits relating to TMD.

A recent Delphi-process evaluated non-invasive self-management treatment options to standardize and find a consistent approach to self-management modalities for the treatment of TMD. It was determined that the following are appropriate to be selected as treatment options for TMD: Education, self-exercise, self-massage, thermal therapy, dietary advice and nutrition, and parafunctional behavior identification, monitoring and avoidance. Briefly, education encompasses the explanation of the diagnosis; etiology and prognosis as well as everyday behaviours such as sleep hygiene, caffeine usage, etc. Thermal modalities include heat or ice in the painful area. Self-massage therapy included massage limited to the painful area. Lastly diet and nutrition includes the explanation of chewing restrictions for a 2-week period.
Cognitive Behavioral Therapy

Cognitive behavioral therapy (CBT) incorporates different behavioral and cognitive interventions that address symptoms exacerbated from behavior avoidance or from emotional disturbances. Since there is a psychological component to the etiology of TMD, CBT seems to be a widely accepted, non-invasive treatment for this disorder. In fact, a systematic review has found CBT to have similar results in terms of pain and disability management than self-care management with patient education with the added benefit of improved depression symptoms, coping skills and interference with daily activities. CBT has been shown to be most effective in individuals with low somatization or good self-assurance to manage their pain.

Occlusal Splints

The occlusal splint is the most commonly prescribed treatment for pain related to TMD. Different types of occlusal splints are available with the most readily prescribed being hard stabilization appliances, soft stabilization appliances, anterior positioning appliances and anterior bite appliances. Some studies have suggested that hard stabilization appliances reduce pain related to TMD compared to non-occluding appliances and no-treatment. Proposed pain management theories include repositioning of the condyle and articular disc, decrease in masticatory muscle activity, changes in vertical dimension, behavioral changes and occlusal changes. However, the literature is inconclusive. A randomized controlled clinical trial by Dao et al. evaluated the effect of full coverage occlusal splints compared to a passive control and an active control (palatal splint worn full time). Pain and quality of life improved within all 3 groups over the span of 10 weeks with no significant differences between groups. The reduction in pain was therefore suspected to be due to other factors or to the placebo effect rather than the occlusal splint treatment. Although the effect of occlusal splints on the TMJ and muscles of mastication is controversial, splints can also be fabricated to allow for a decrease in abfraction lesions, tooth wear, and enamel fractures that are caused by nocturnal bruxism.
Pharmacotherapy

Pharmacologic therapy is typically prescribed in addition to other treatment options for aiding in the reduction of symptoms related to TMD. One or a combination of the following classes of medication is indicated depending on the diagnosis, clinical evaluation and severity of the disorder.

Table 2. Pharmacotherapy and its contribution to the management of TMD
(Adapted from Liu et al. 2013)

<table>
<thead>
<tr>
<th>Class of Medication</th>
<th>Examples</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonsteroidal Anti-inflammatory Drugs (NSAID)</td>
<td>Ibuprofen, naproxen, diflunisal, ketorolac, etc.</td>
<td>Decrease inflammation</td>
</tr>
<tr>
<td>Corticosteroids</td>
<td>Triamcinolone, hexacetonide, methylprednisolone, etc.</td>
<td>Decrease inflammation</td>
</tr>
<tr>
<td>Muscle relaxants</td>
<td>Carisoprodol, cyclobenzaprine, matalalone, methocarbamol, etc.</td>
<td>Decrease muscle tension and spasms</td>
</tr>
<tr>
<td>Antidepressants</td>
<td>Tricyclic antidepressants (amitriptyline, nortriptyline, desipramine, etc.), selective serotonin reuptake inhibitors (citalopram, paroxetine, etc.)</td>
<td>Decrease muscle tension</td>
</tr>
<tr>
<td>Anxiolytics</td>
<td>Benzodiazepines</td>
<td>Decrease muscle tension and spasms</td>
</tr>
<tr>
<td>Opioids</td>
<td>Codeine, oxycodone, hydromorphone, etc.</td>
<td>Decrease pain</td>
</tr>
<tr>
<td>Anticonvulsants</td>
<td>Gabapentin, pregabalin, etc.</td>
<td>Decrease pain</td>
</tr>
</tbody>
</table>

NSAIDs inhibit the formation of prostaglandins through inhibiting cyclooxygenases. They are commonly prescribed and effective in reducing pain caused by mild to moderate inflammation in the TMJ due to acute disc displacement with reduction or trauma. The anti-inflammatory effect is only seen after a 2 week NSAID regimen. Although, this class of drug is available over the counter, precaution should be taken due to the large interaction with several medications as well as the side effects on the gastrointestinal tract that may lead to gastric bleeding.
Oral opioids are prescribed for chronic TMD when other drugs prove unsuccessful in relieving the chronic moderate to severe pain. Serious side effects should be considered, such as tolerance and physical dependence, which can lead to substance abuse. In some instances, it has been thought that due to the presence of µ-opioid receptors in the TMJ, intra-articular opioids such as morphine could help manage the pain associated with articular TMD. This pharmacologic treatment remains controversial, and the use of opioids for TMD is not supported by the current literature.

Oral or intra-articular injections of corticosteroid are also used for moderate to severe TMD, most commonly in individuals with arthritis. They decrease prostaglandin and leukotriene production by inhibiting phospholipase A2. Side effects such as acute adrenal crisis, bone resorption and hypertension limit their use.

Muscle relaxants are sometimes considered when wanting to alleviate muscular TMD pain due to their efficacy in reducing muscle activity and spasms. These drugs are usually only prescribed in a small dose since they cause significant sedation. This class of drugs causes interactions with monoamine oxidase inhibitors and tramadol (an opioid analgesic) and is contraindicated in patients with congestive heart failure, hyperthyroidism, myocardial infarction and arrhythmias.

Antidepressants have also been prescribed to modulate chronic orofacial pain, especially in patients who have comorbid depression and sleep disorders. Amongst the antidepressants prescribed, the most common are the tricyclic antidepressants, which are thought to inhibit the serotonin and noradrenaline reuptake, and the selective serotonin reuptake inhibitors, which block the neuronal transport of serotonin leading to an increase in postsynaptic serotonin receptors.

Anticonvulsants are thought to prevent neuronal excitation while increasing neuronal inhibition through their action on voltage-gated ion channels, ligand-gated ion channels, excitatory receptors for glutamate and N-methyl-D-aspartate and inhibitory receptors for gamma-aminobutyric acid and glycine.
Although anxiolytics such as benzodiazepines are shown to decrease chronic TMD pain, they are prescribed with caution for TMD due to their copious adverse reactions and numerous interactions with food and other classes of drugs.\textsuperscript{187}

A Cochrane Review in 2010 indicated that the literature neither supports nor discourages the use of pharmacotherapy for management of TMD symptoms.\textsuperscript{173} However, a systematic review with network meta-analysis in 2017 indicates that chronic pain from TMD of muscular origin can be effectively managed with the muscle relaxant cyclobenzaprine.\textsuperscript{102} In addition, pain arising from the joint itself can be well managed with NSAIDs, corticosteroid and hyaluronate injections.\textsuperscript{102} Considering the negative side effects of certain drugs, including dependence and tolerance, pharmacotherapy should still be used with caution.\textsuperscript{139}

**Physical Therapy**

The aim of physical therapy as an adjunctive therapeutic modality for TMD is to reduce pain and inflammation as well as to re-establish initial motor function.\textsuperscript{158} This can be accomplished by electrophysical modalities (ultrasound, microwave, laser and transcutaneous electrical nerve stimulation (TENS)), therapeutic exercises and manual therapy.\textsuperscript{158} Besides their positive effect on TMD symptoms, additional physical therapy modalities can assist in improving any related impairments such as muscle spasms, referred pain as well as poor posture.\textsuperscript{158}

Electrophysical modalities are clinically used for decreasing inflammation, muscle relaxation and increasing blood flow.\textsuperscript{94} Although range of motion seems to be positively affected, there is no evidence supporting its impact on pain management.\textsuperscript{158}

Manual therapy and muscle stretching and strengthening exercises target the musculature by increasing coordination, range of motion and strength.\textsuperscript{31} Postural exercises are used to correct the alignment of the neck, cervical spine, maxillofacial bones, TMJ, and related muscles.\textsuperscript{204} Although positive clinical outcomes are shown in the literature, additional studies are required to determine precise treatment protocols.\textsuperscript{52, 93}
Acupuncture is also administered by certain physiotherapists for pain reduction.\textsuperscript{245, 252} The lack of evidence supporting pain reduction with this modality can be due to the weak research protocols evaluating the effect of acupuncture on reduction of pain related to TMD.\textsuperscript{158, 72}

Behavioral changes can also be added to the physical therapy by increasing awareness to posture diet and stress-induced habits.\textsuperscript{174} A recent literature review indicated that there is great uncertainty about the effectiveness of exercise and manual therapy for treatment of TMD, mostly because of the low quality of the available studies.\textsuperscript{7}

**Minimally Invasive Treatment Options**

**Injections**

**Intra-Articular Injections**

Intra-articular injections of therapeutic solutions (sodium hyaluronate, corticosteroid etc.) described in the pharmacotherapy section allow for localized management of inflammation and joint degeneration.\textsuperscript{139} Injections can be administered in the upper and/or lower TMJ space.\textsuperscript{139} According to a systematic review, the effectiveness of sodium hyaluronate injections is similar to that of corticosteroid injections for the treatment of intracapsular TMD.\textsuperscript{171}

**Intra-Muscular Injections**

Intra-muscular injections can be of therapeutic value for muscular TMD. Botulinum toxin type A (BTX-A) temporarily impedes the production of acetylcholine and deactivates the calcium channels in the nerve endings which paralyzes skeletal muscle activity.\textsuperscript{8} A systematic review concluded that there is therapeutic value in using injections of BTX-A in lateral pterygoid muscles for decrease in pain, dysfunction, muscle hyperactivity as well as clicks.\textsuperscript{8} BTX-A was also reported to be successful in reducing pain in individuals with trigeminal neuralgia.\textsuperscript{24, 264} These injections seem to have short-term effects. In addition, side effects such as transient facial asymmetry, facial edema, muscle weakness, dysphagia and flu-like symptoms were noted.\textsuperscript{188, 264} If BTX-A enters the circulatory system, immune-related complications can also occur.\textsuperscript{188}
Arthrocentesis and Arthroscopy

Arthrocentesis is defined as the irrigation of the superior joint space with saline or corticosteroids. This procedure is typically performed in patients diagnosed with internal derangement and/or osteoarthritis to eliminate inflammatory mediators and release adhesions. A study in 2012 demonstrated that, this procedure improved function and reduce pain in approximately 83.5% of people suffering from internal derangement and osteoarthritis.

Arthroscopy is a more invasive procedure that involves irrigating the joint space, removing adhesions while examining the TMJ with an arthroscope. According to a Cochrane Review in 2011, arthroscopy seems to have a more positive impact on function than arthrocentesis with no difference in terms of pain relief.

These procedures are usually reserved for patients that do not respond positively to conservative treatment modalities. They are also typically prescribed in addition to other less invasive treatment options.

Invasive Treatment Options

Discectomy, joint reshaping or reconstruction as well as total joint replacements are invasive surgical treatment options prescribed solely when range of motion and orofacial pain is not improved with other less invasive treatment options.

Disectomy

Discectomies are typically performed to repair unilateral or bilateral discs within the TMJ to recreate normal anatomical structures, reduce pain and improve function in patients with internal derangements. Disks can be repositioned, repaired or removed with or without the addition of a graft during the procedure depending on the severity of damage. According to a retrospective cohort study of 18 patients undergoing surgical TMJ discectomy without replacement, patients who failed non-surgical treatment options for internal derangements benefit from a discectomy.
by increasing maximal incisal opening approximately 10 mm. More studies are however necessary to determine the effectiveness of this method to decrease articular pain.

**Arthroplasty**

TMJ arthroplasty is defined as a surgical treatment during which the articular surface is reshaped. This technique is most commonly performed to allow for removal of irregularities, osteophytes and areas of erosion in individuals with refractory osteoarthritis. Discectomies can be performed in conjunction with arthroplasty if there is disk displacement or degeneration. More studies are required to evaluate the effectiveness of this surgical procedure.

**Total Joint Replacement**

TMJ replacement is normally restricted to severe end-stage disease after failed attempts at conservative treatment options. Autogenous costochondral bone grafts and alloplastic grafts are both used for this purpose. Autogenous grafts have the advantage of having growth potential, being similar in shape to the mandibular condyle and easily adaptable. However, the titanium alloplastic grafts have the advantage of reducing harvest-site morbidity. Both custom and stock alloplastic grafts show similar improvements in function and pain.

A systematic review and meta-analysis compared the effectiveness of arthroscopic lysis and lavage, arthroscopic surgery and open surgery for the treatment of persistent and chronic TMD with internal derangements. Pain decrease was greater in patients who underwent open surgery compared to patients who had arthroscopic surgery although the improvement in function was similar in both groups. Pain reduction was similar in patients with arthroscopic lysis and lavage compared with arthroscopic surgery. The improvement in function was greater in individuals who underwent arthroscopic surgery compared to arthroscopic lysis and lavage.
Guided Music Listening

Music interventions can be separated in two distinct categories, music medicine and music therapy. Music medicine is proposed as an intervention of passive music listening where no assessment of music suitability is provided. On the other hand, music therapy is a type of treatment administered by a music therapist with the intent of therapeutic goals. This intervention of music listening requires a systematic process to determine the tailored music experience for each individual. Guided music listening (GML) falls in the category of music therapy. Music therapy has increased in popularity for pain management due to its accessibility, cost-effectiveness, non-invasiveness and lack of secondary effects.

Effect on pain

Studies have found that music has a positive impact on chronic and acute pain management. A meta-analysis evaluating the effect of music on overall pain noticed an improvement of pain of 1.13 on a 0-10 scale. This meta-analysis reported large variations across studies on the music-induced analgesic effect. Many studies evaluated in this meta-analysis concluded that the emotional distress involved with pain was diminished with music listening validating the Gate Control theory of pain to which the activation of the descending pain inhibitors are caused by the cognitive understanding and emotional response to pain. In fact, music therapy seemed to reduce the amount of pharmacological treatment usage after medical procedures and reduced the patient’s perception of pain intensity.

Pain reduction was also noted in studies involving patients with chronic musculoskeletal pain. A study involving patients with fibromyalgia noted a significant decrease in pain following 1, 7 and 14 days of listening to relaxing music twice per day for 25 minutes each. Another study determined that music actually improved the control individuals with fibromyalgia had on managing their pain rather than diminishing the intensity of the pain.
Overall, although the mechanism involving pain reduction with music therapy is unclear, the lack of secondary effects make music an interesting adjunctive tool to decrease pain in chronic pain conditions.

### Effect on stress and anxiety

Music has been used subjectively for a long time as a means of emotional expression while actively creating music or to change one’s mood while passively listening to musical excerpts. The exact mechanism contributing to the emotional alteration by music is however not fully understood. Stress can be divided in two aspects, the cognitive/physiologic stress component controlled by the central nervous system (sympathetic nervous system) and the emotional stress component, corresponding to anxiety, modulated by the limbic system (hypothalamus-pituitary-adrenal axis). A study evaluating the changes in mesolimbic structures involved in the reward pathway determined that listening to music activated the hypothalamus, the nucleus accumbens, and the ventral tegmental area. The hypothalamus is responsible for changes in the autonomic system such as respiration and heart rate. In fact, music inducing a sensation of pleasure is shown to cause changes in heart rate and respiration and increase in blood flow to areas of the brain involved in emotion. The ventral tegmental area, on the other hand, is responsible for dopamine release. The increase in dopamine release can be a factor involved in the positive effect of music on mood. Another study has evaluated the effect of relaxing music to an experimental stressor. This study indicated that relaxing music was able to aid in the recovery of the autonomic nervous system to a stressor measured by salivary alpha-amylase levels.

In addition to the modulation of the autonomic and limbic system activities, different hypothesis on how music reduces stress and anxiety has been proposed in the literature. Music is thought to decrease physiological arousal, and therefore lowering the adrenergic and neuromuscular arousal by synchronizing the body rhythms to the rhythm of the music. Another hypothesis is that positive emotions counteract negative emotions by mood mediation. In addition, other studies have suggested that music increases the
perceived personal control that individuals have on situations that are stressful. Distraction has also been hypothesized to be a way of decreasing anxiety during music listening.

In addition, emotions seem to have a direct link to motor function since movements are normally generated following somatic events in order to either avoid danger or obtain a rewarding stimulus.

**Effect on the motor cortex**

The literature suggests a relationship between the auditory and the motor systems. Music has therefore been used in the medical field as a motor rehabilitation therapy to enhance motor function in patients affected by a stroke or Parkinson’s disease. Music allows for auditory feedback to reinforce the control and timing of movements as well as recruit motor units in a more regular pattern. The audio-motor coupling allows for the perception of rhythmic stimuli to bring about responses in the motor system. Studies have shown that metrically strong rhythms will intensify corticospinal excitability. In fact, passively listening to a preferred tempo will increase premotor activity. The motor response can be altered by the metrical strength, emotional valence, rhythmic complexity, tempo and groove. It has been shown in an MRI study that 3 premotor regions are activated during music listening. The ventral premotor cortex is active when listening to music with the addition of anticipation of a movement with the rhythm such as tapping. The activation of the dorsal premotor cortex is associated with synchronization and metrical organization. The mid premotor cortex, supplementary motor area and cerebellum lobule VI, on the other hand, are active during passive music listening, even in the absence of anticipation of movement.
Chapter 3
Manuscript

Music Modulates Jaw Muscle Behavior and Wake-Time Tooth Clenching in Patients with Temporomandibular Disorders

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Abstract

Awake bruxism, a masticatory muscle activity during wakefulness that is characterised by repetitive or sustained tooth contact (i.e. tooth clenching), and/or by bracing or thrusting of the mandible, is highly prevalent in individuals with temporomandibular disorders (TMD) and is associated with mood disorders, such as depression and anxiety. Guided music listening (GML) has been widely used for its positive effects on mood and pain in several chronic pain disorders. This study aimed to evaluate, for the first time, the effects of GML on masticatory muscle behavior and on tooth clenching episodes in individuals with chronic myogenous temporomandibular disorders (TMD myalgia) as compared to healthy TMD-free controls.

Fourteen women with chronic TMD myalgia (mTMD group, mean ± SD age = 38.3 ± 14.7 years) and fifteen TMD-free women (CTR group, mean ± SD age = 32.1 ± 3.2 years) had electromyographic (EMG) activity of the right masseter muscle recorded during three pre-selected music tasks (stressful, relaxing and favorite) and one control no-music task (pink noise) for 15 minutes each. EMG activity periods (AP) greater than 10% of the maximum voluntary contraction (MVC) – i.e. parafunctional tooth clenching – and activity of the masseter at rest were assessed.

GML affected average EMG activity at rest in both groups (all P<0.001), which was the greatest during stressful music and smallest during the favorite music task (all P<0.001). Favorite music significantly decreased the amplitude of tooth clenching episodes in mTMD (P<0.001). GML did not significantly affect tooth clenching episodes of healthy controls.

GML modulates masticatory muscle activity. Favorite music can be beneficial to patients with TMD myalgia. Future research can aid in using GML for developing a multimodal approach for the management of TMD.
Introduction

Temporomandibular disorders (TMD), a set of pathological conditions involving the temporomandibular joints and/or the muscles of mastication, affect approximately 5 to 12% of the general population with 15% developing chronic pain. Although the etiology of TMD is multifactorial, a recent report has identified oral parafunctional behaviors—e.g. wake-time tooth clenching, nail biting, etc.—as the strongest predictors of TMD incidence. Awake bruxism, a masticatory muscle activity during wakefulness that is characterised by repetitive or sustained tooth contact (i.e. tooth clenching), and/or by bracing or thrusting of the mandible, is strongly associated with TMD. Experimental tooth clenching leads to muscle overloading, tenderness, and soreness in elevator jaw muscles in healthy subjects. Also, the frequency of wake-time clenching episodes and their amplitude is increased in individuals with TMD myalgia, compared to TMD-free controls.

Mood disorders, such as depression and anxiety, are highly prevalent in TMD (30% and 28% respectively) and contribute to heightened pain perception. In addition, they are common in individuals with awake bruxism. This finding suggests that mood disorders play a significant role in the maintenance of parafunctional oral behaviors. Interestingly, the relationship between anxiety and oral behaviors is enhanced by concurrent facial pain.

The treatment of chronic TMD is often challenging for clinicians. Most current treatment modalities for TMD target the management of symptoms rather than the factors contributing to the onset of the condition. Some treatment options include intraoral appliances and pharmacological treatments. These treatments aim to promote muscle relaxation and improve mood. However, they can be costly or have adverse effects such as dependence and toxicity.

It is well known that habit reversal can be an effective way to manage pain in individuals with muscular TMD. Similarly, a bio-psychosocial approach to pain aimed at improving mood may be successful in TMD. Therefore, therapies aiming to reverse or reduce awake bruxism by way of modulating mood states can be beneficial to
patients with TMD myalgia, by reducing muscle overload and pain.

Guided music listening (GML) is based on models of mood mediation and attention modulation and is a widely used and accepted intervention aimed at reducing pain in individuals suffering from chronic pain\textsuperscript{34}, including those that are musculoskeletal in nature (e.g. fibromyalgia).\textsuperscript{136} Guided music listening (GML) has been used as a therapy for chronic pain by influencing mood, modulating attention and diminishing stress and anxiety.\textsuperscript{134, 239, 240} Music listening also affects muscle activity by acting on specific brain areas involved in motor preparation and control, modulates corticospinal excitability and affects motor nerve response.\textsuperscript{163} Because of the relationship between altered mood states and oral behaviors, it can be hypothesized that GML can modulate the activity of masticatory muscles and that pleasant music may be beneficial to patients with TMD.

The aim of this study was to measure the effect of GML on the electromyographic activity of the masticatory muscles in patients affected by chronic TMD myalgia and healthy controls, and to test whether pleasant music impacts positively on wake-time tooth clenching episodes.

**Materials and Methods**

**Participants**

Thirty women between the ages of 18 to 65 were recruited from the University of Toronto, Mount Sinai Hospital and clinics in the Greater Toronto Area. Participants were screened by phone using the TMD Pain Screener questionnaire.\textsuperscript{92} Those with a score >3 were invited for a clinical TMD examination\textsuperscript{92} by a single trained examiner (TVI). Fourteen individuals (mTMD group; mean ± SD age = 38.3 ± 14.7 years) with a diagnosis of chronic TMD myalgia (> 6 months) according to the Diagnostic Criteria for TMD (DC/TMD)\textsuperscript{212} were recruited to participate in the study. Fifteen healthy women without orofacial pain were recruited (CTR group; mean ± SD age = 32.1 ± 3.2 years). Exclusion criteria for both groups included wearing extended dental fixed prosthesis of greater than 3 teeth, ongoing orthodontic and/or dental treatment, neurological disorders,
intake of drugs affecting the central nervous system and muscle relaxants, or the refusal to participate in the study.

![Experimental design](image)

**Figure 1.** Experimental design

**Questionnaires**

Prior to the experimental phase, all participants were asked to complete the Oral Behavior Checklist (OBC), the State-Trait Anxiety Inventory (STAI), the Somatosensory Amplification Scale (SSAS), the Pain Catastrophizing Scale (PCS) and the Beck’s Depression Inventory (BDI). The participants in the mTMD group were also asked to complete additional questionnaires including the DC/TMD symptom questionnaire.

**Pressure Pain Thresholds**

Before the experimental procedure, pressure pain thresholds (PPTs) were measured with an electronic pressure algometer (Medoc Wagner Inc.) with a rubber tip measuring 1 cm² at both trigeminal and extratrigeminal locations (bilateral superficial masseter muscle, bilateral anterior temporalis muscle and bilateral thenar muscles in the palmar side of the hands). For the masseter muscle, PPTs were measured midway between the origin and the insertion of the muscle and 1 cm posterior to its anterior boundary. For the temporalis muscle, PPTs were measured on the line from the top edge of the eyebrow to the highest point of the pinna of the ear and 2 cm behind the anterior margin of the muscle. For the thenar muscle, PPTs were measured on the thenar eminence located on the palmar side of the hand. The algometer was positioned perpendicular to the skin. A single operator (TVI) increased the pressure at a rate of 20 kPa/sec using visual feedback.
Participants were asked to press a button the moment the pressure stimulus applied to their muscles changed from a pressure sensation to a painful sensation. The value on the screen was stored. Each measurement was repeated four times in a row for each muscle site with a 1-minute interval between each measurement.

**Surface Electromyographic Recording**

The electromyographic (EMG) signals of the right masseter muscle were recorded using a wireless EMG device (BTS TMJoint, Milan, Italy). The signal was sampled at 1,024Hz. A hardware filter was used (bandbass 10-500 Hz). Disposable bipolar self-adhesive concentric electrodes (Covidien Kendall, Medtronic) with a 24 mm diameter were used. The EMG electrodes were placed approximately 20 mm above the mandibular angle along the ling extending from the mandibular angle to the outer canthus. The skin was gently cleaned with abrasive gel (Everi – Spes Medica, Genova, Italy) to allow for the conductive paste to adequately moisten the skin and decrease impedance. During data collection, participants sat upright with their head unsupported in a silent room with a single investigator present (TVI). Maximum voluntary contractions (MVC) at maximum intercuspal position were recorded prior to each experimental task at three consecutive time periods separated by 5-second intervals. Verbal encouragement was given to the participant to ensure that they were clenching at maximum force for 3 seconds. Four EMG recordings lasting 15 minutes each were collected for each participant (see experimental protocol).

The raw EMG signal was processed using the OTBiolab® software (OT Biolettonica, Torino, Italy). Root mean square (RMS) values were computed. The average root mean square (RMS) value of the three MVC tests for each participant was set as 100% MVC. EMG activity periods greater than 10% (AP10) of the MVC were considered wake-time tooth clenching episodes and identified by the software. The frequency, amplitude and duration of AP10 episodes were computed.

**Experimental Protocol**

Prior to the start of the experiment, participants were informed that the EMG assessment was monitoring the activity of the jaw muscles. All recordings were performed in the
same laboratory at the Faculty of Dentistry of the University of Toronto. Patients were instructed to turn off their mobile phones, not chew gum or other candies, not speak and not touch the electrodes during the recordings.

All participants signed an informed consent. The research was reviewed and approved by the Research Ethics Boards at the University of Toronto (#34188) and Mount Sinai Hospital, Toronto (26-0081-E).

**Music Pretest**

Prior to the experimental task, a pretest was conducted to select the music to be played during the experiment. During the pretest, participants were asked to listen to 5 minutes of their favorite music playlist after which they rated their physical activation, pleasure intensity and associations triggered by the music on three separate 100 mm VAS (Physical Activation – Endpoints: highly physically activating versus not activating at all; Pleasure Intensity – very pleasurable versus not pleasurable at all; Associations and memories – many memories are triggered versus no memories at all). This served as confirmation that this was indeed the participants’ favorite music choice. Participants were also subjected to two pre-selected lists of 12 musical excerpts of 1 minute each to select the appropriate music to be played during the relaxing and stressful music experimental tasks. An expert musicologist selected the playlists. Each excerpt was rated on a 0-100 mm VAS where the endpoints corresponded to “no relaxation” and “maximum relaxation” for the relaxing excerpts and “no stress” and “maximum stress” for the stressful excerpts. The relaxing pre-selected list of excerpts comprised music from 4 different genres (classic, new age, pop and rock) with slow tempo range and harmonic tonality base. The stressful pre-selected list of excerpts comprised highly dissonant, atonal and rhythmically unstable music from the same 4 genres. The total score for each genre was computed to determine which music genre would be played during the experiment. The relaxing playlist or the stressful playlist to be used during the experimental task was selected by using the highest score among the three excerpts for each genre. The music selection for the actual experiment consisted of new pieces with the same tempo range and tonality base as predetermined by the experimenter during the
Experimental Tasks
The EMG activity of the right masseter was recorded while the participant was listening to pink noise, an auditory signal with a constant power spectral density (task 1), and to three different music sessions including stressful music (task 2), relaxing music (task 3), and favorite music (task 4). The order of the tasks was random. Each task lasted 15 minutes. Participants were invited to report the perceived stress and relaxation levels at the end of each task using two visual analogue scales (VAS) where the endpoints correspond to “no stress” / “maximum stress” and “no relaxation” / “maximum relaxation”. Participants also scored the music experience on three other VAS scales indicating physical activation, pleasure intensity and associations and memories. The separate VAS scales were intended to measure different dimensions of the music perception experience. The procedure was monitored by a single examiner (TVI) and movement artifacts were recorded (e.g. touching electrodes, coughing, etc.). Patients were asked to bring their own earphones to ensure a comfortable music experience.

Statistical Analysis
The primary outcome measure of this study was the EMG of the masseter muscle. Secondary outcome measures were PPTs and questionnaire outcomes. The Kolgomorov-Smirnov test was used to test whether data were normally distributed.

The mean of the three trials for each PPT location was measured after discarding the first measurement. A paired T-test indicated that there was no statistically significant difference between right and left sides at each muscle location (all P>0.05). Therefore, data from both sides were pooled. Student T-Tests were used to test between-group differences in PPTs at each location, and in questionnaire scores (STAI, SSAS, OBC, PCS, and SSAS). The Mann-Whitney test was used to test between-group differences in BDI scores.

A multivariate analysis of covariance (MANCOVA) was used to detect between group
and within-group differences in music VAS ratings using transformed data.

The average root mean square (RMS) of the three MVC trials at the beginning of the experimental task was calculated and used to calibrate the EMG signal. The average MVC therefore corresponded to 100%. The muscle activity required to bring teeth in contact is approximately 5% MVC. Therefore, similarly to previous studies, parafunctional episodes were defined as being muscle activity equal or greater than 10% MVC. These parafunctional activity periods were identified and measured for frequency, amplitude and duration. A mixed effect model with pairwise comparisons and values adjusted using the Bonferroni method was used to identify differences between groups and tasks. SPSS software (IBM, Armonk, New York) was used for all statistical analyses. Statistical significance was set as a P<0.05. The statistical analysis was conducted with the operator blinded (dataset masking) to group assignment of participants.

Results

PPTs and Questionnaires

mTMD patients had higher PCS (mean±SD; mTMD:17.1±9.6; CTR: 10.6±5.6; P=0.041), SSAS (mTMD: 19.4±14.3; CTR: 14.4±5.3; P=0.05), and BDI scores (median [IQR]; mTMD: 9 [11]; CTR: 3 [5]; P=0.008) than CTR group. No between-group differences were found in state (mTMD: 36.8±10.7; CTR: 32.1±10.3; P=0.268) and trait anxiety (mTMD: 43.2±15.6; CTR: 38.6±6.1; P=0.326).

Table 2. Demographic and pain characteristics of the TMD group

<table>
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<tr>
<th>mTMD</th>
<th>Age</th>
<th>Diagnosis</th>
<th>Characteristic Pain Intensity (CPI)</th>
<th>Graded Chronic Pain Scale (GCPS)</th>
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<tbody>
<tr>
<td>1</td>
<td>34</td>
<td>Right masseter myalgia</td>
<td>67</td>
<td>III</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>Bilateral masseter myalgia and left arthralgia</td>
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<td>I</td>
</tr>
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<td>3</td>
<td>45</td>
<td>Bilateral temporalis and masseter myalgia</td>
<td>60</td>
<td>III</td>
</tr>
<tr>
<td>4</td>
<td>63</td>
<td>Bilateral masseter and right temporalis myalgia and arthralgia</td>
<td>60</td>
<td>II</td>
</tr>
<tr>
<td>5</td>
<td>26</td>
<td>Bilateral temporalis and masseter myalgia and arthralgia</td>
<td>60</td>
<td>III</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
<td>Bilateral temporalis and masseter myalgia and arthralgia with</td>
<td>80</td>
<td>III</td>
</tr>
</tbody>
</table>
headache associated to TMD

<p>| | | | |</p>
<table>
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<th></th>
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</thead>
<tbody>
<tr>
<td>7</td>
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<td>Bilateral masseter myalgia and arthralgia</td>
<td>47</td>
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<td>8</td>
<td>27</td>
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<td>70</td>
</tr>
<tr>
<td>9</td>
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<tr>
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</tr>
<tr>
<td>14</td>
<td>31</td>
<td>Bilateral masseter and temporalis myalgia</td>
<td>40</td>
</tr>
</tbody>
</table>

Music Selection

Based on the music pretest, during the relaxing music task, in the CTR group, five participants listened to classical music, six listened to new age, three listened to pop and one listened to rock. In the mTMD group, four participants listened to classical, three to new age, three to pop and four to rock music. During the stressful music task, in the CTR group, two participants listened to classical music, one listened to new age, one listened to pop and eleven listened to rock. In the mTMD group, three listened to new age and eleven to rock music with no participants listening to classical and pop music.

PPTs were not statistically significant different between groups (Superficial masseter: mTMD: 134.3±43.2 KPa; CTR: 127.4 ±41.8 KPa, P=0.669; Anterior temporalis: mTMD: 132.8±34.8 KPa; CTR: 144.5 ±49.8 KPa, P=0.472; Thenar eminence: mTMD: 258.1±70.0 KPa; CTR: 268.5±102.5 KPa.

Table 3. Descriptive analysis of the preselected musical genres based on each participant’s relaxing and stressful scores on VAS scales.

<table>
<thead>
<tr>
<th></th>
<th>Classical</th>
<th>New Age</th>
<th>Pop</th>
<th>Rock</th>
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</thead>
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<td><strong>CTR group</strong></td>
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<td></td>
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</tr>
<tr>
<td>Relaxing task</td>
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<td>6</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Stressful task</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td><strong>mTMD group</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relaxing task</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Stressful task</td>
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<td>3</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relaxing task</td>
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<td>9</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Stressful task</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>22</td>
</tr>
</tbody>
</table>

VAS ratings for each of the tasks differed significantly across the experimental conditions (F[15,279] = 14.2, P<0.001. The group-by-task interaction was not statistically significant (P=0.421). VAS scores (relaxation, stress, physical activation, pleasure
intensity, and associations and memories) and post-hoc comparisons are reported in Figures 1 and 2.

**Figure 1.** Mean VAS (0-100 mm) scores of participants’ level of relaxation (A) and stress (B) during the four music tasks (pink noise, stress, relaxation and favorite). Since no differences were found between the mTMD and the CTR group, pooled data are reported. Significant pairwise comparisons are reported at *P<0.05, **P<0.005, and ***P<0.001. Error bars indicate ± Standard errors of the mean.
Figure 2. Mean VAS (0-100 mm) scores of participants’ level of pleasure intensity (A), physical intensity (B), and associations and memories (C) during the four music tasks (pink noise, stress, relaxation and favorite). Since no differences were found between the mTMD and the CTR group, pooled data are reported. Significant pairwise comparisons are reported at *P<0.05, **P<0.005, and ***P<0.001. Error bars indicate ± Standard errors of the mean.
Effect of GML on masseter EMG activity

The average EMG activity (%MVC) was significantly different between tasks for both the CTR and mTMD group (all P<0.001, Figure 3) being the highest during the stress music task and the lowest during the favorite music condition (ascending order - mTMD group: favorite, relax, pink noise, and stress; CTR: favorite, pink noise, relax, and stress). A similar pattern was found while analyzing the postural EMG activity, i.e. the EMG activity <10% MVC (Figure 4). During the stress music task, the average EMG amplitude of the masseter was greater in mTMD patients than CTR subjects (P=0.016). The postural EMG activity was greater in mTMD than CTR during the favorite music (P=0.019) and the pink noise task (P=0.014).

Figure 3. Mean EMG activity of the right masseter muscle in both mTMD (red) and CTR (black) groups during the four music tasks. Within-group significant differences are indicated by different small letters (CTR) or capital letters (mTMD). Different letters indicate a statistically significant different at P<0.05 * Statistically significant difference at P<0.05.

Figure 4. Mean postural EMG activity (EMG activity<10%MVC - Maximum Voluntary contraction) of the right masseter muscle in both mTMD (red) and CTR (black) groups during the four music tasks. Within-group significant differences are indicated by different small letters (CTR) or capital letters (mTMD). Different letters indicate a statistically significant different at P<0.05 * Statistically significant difference at P<0.05.
The average EMG amplitude of awake bruxism episodes during the four music tasks for each group is reported in Figure 5. GML did not affect the EMG amplitude of bruxism episodes in the CTR group (all P>0.05). In mTMD patients, it was the lowest during the favorite condition and the highest during the stress music task (all P<0.001). The amplitude of bruxism episodes was significantly greater in mTMD than CTR during the stressful music task (P=0.026).

The frequency of awake bruxism episodes was greater in mTMD than CTR during the pink noise task (P<0.05). GML did not affect significantly the frequency and the duration of awake bruxism episodes in both groups (all P>0.05). Overall, no significant between-group differences were found in overall parafunctional activity duration (median [IQR], TMD: 25 [89.50] s; CTR: 14.5 [41.50] s; P=0.413).

Discussion

Our study was the first to evaluate the effect of GML on the EMG activity of the masseter muscle, in patients presenting with chronic TMD myalgia. So far, music-induced analgesia has already been reported in several studies.\textsuperscript{145} It has gained popularity in the medical field because of its safety and cost effectiveness.\textsuperscript{145} However, the literature is limited in understanding its precise mechanism of action.\textsuperscript{145} Studies have reported analgesic effects due to the introduction of an additional stimulus that induces
distraction.\textsuperscript{145, 6, 148, 30, 110} Music has also been reported to decrease pain secondarily by increasing positive emotions and decreasing anxiety.\textsuperscript{109, 145, 248, 127, 178} Additionally, newer imaging studies are focusing on the effect of favorite music on changes in neural activity involved in the descending pain-modulatory system.\textsuperscript{145, 61} TMD are a set of conditions that can induce pain severe enough to affect quality of life at a young age.\textsuperscript{217, 115} The difficulty in managing these patients stems from the multifactorial etiological factors involved in the onset of these conditions.\textsuperscript{192} Recently, TMD myalgia has been shown to be highly associated with awake bruxism\textsuperscript{165, 181}, the latter being associated with increased anxiety and depression.\textsuperscript{88, 75} Since music is believed to positively affect emotion and anxiety, we hypothesized that awake bruxism can also be modulated by music.

Our findings reveal that GML can modulate masseter muscle activity at rest (postural EMG activity) (Figures 4 and 5) and during tooth clenching, and that favorite music is associated with the lowest EMG amplitude of tooth clenching episodes in patients with muscular TMD. Indeed, in individuals with TMD myalgia, the EMG amplitude of tooth clenching episodes while passively listening to self-selected favorite music represented an average of 14.5\% MVC and was approximately 55\% of activity during the pink noise session. In contrast, stressful music generated the greatest EMG amplitude during tooth clenching episodes, with an average amplitude of 35.4\% MVC. Differences in the amplitude of parafunctional tooth clenching episodes were not found between tasks in the CTR group. A recent study conducted on 255 university students concluded that the presence of orofacial pain substantiated the relationship between anxiety and self-reported oral parafunctional behaviors.\textsuperscript{39} Music is thought to play a role in the psychological stress response through the autonomic nervous system (ANS).\textsuperscript{126} The differences in amplitude of wake-time tooth clenching episodes between tasks seen in the mTMD group could therefore be potentiated by the presence of facial pain.

This study builds on our previous work where we evaluated the effect of GML on activity of masseter of pain-free individuals with self-reported high and low frequency of wake-time tooth clenching.\textsuperscript{48} Similar to that study, we found that the average EMG activity of the masseter was the greatest during the stressful music condition and the lowest during
the favorite and relaxing music tasks in those reporting very frequent oral parafunctional behaviors. However, contrary to the previous investigation that found that stressful and favorite music decreased the amplitude of clenching episodes\(^9\), in this study, the EMG amplitude of tooth clenching episodes was lowest in the favorite and the relaxing music tasks. Patients with painful TMD respond differently to stressful music than individuals with high parafunctional activity and no pain. The pattern seen with the amplitude of wake-time clenching episodes between tasks in the mTMD group parallels that of their pleasure intensity and association to memories. This leads us to believe that the musical perceived experience may also have an effect on patients’ emotional states and parafunctional habit. The way patients’ relate to the music is therefore of importance.

In addition, we found that the masseter EMG activity at rest was greater in mTMD group than CTR group during the pink noise session. In addition, overall, the mTMD group had an increased muscle tone compared to the CTR group. This finding is in contrast to the pain adaptation model, in which the activity of the agonist muscle would be reduced as a form of protective adaptation to the chronic muscle pain.\(^{144}\) Conversely, it is likely that pain could in fact be due to the increased muscle tone, which may contribute to decreased muscle oxygen extraction capacity, which has been observed in TMD,\(^{57,231}\) and causes the accumulation of pro-nociceptive mediators.\(^{57}\) Recent studies have shown that blood flow and oxygen supply is reduced in hyper-functioning muscles as in patients with parafunctional habits.\(^{74,230}\) Patients with myalgia have actually been reported to have less muscle oxygenation than controls with the same muscle contraction.\(^{74}\) The pain that is reported by patients with TMD myalgia could therefore be due to the increase in metabolites from the decreased muscle oxygen extraction capacity in the form of local ischemia.\(^{230,74}\)

No significant differences in frequency of wake-time tooth clenching were found within and between groups. This finding contradicts studies that have shown an increase in wake-time tooth clenching in patients with TMD. Patients with a high frequency of parafunctional habits and no signs or symptoms of TMD were not excluded from the CTR group. Therefore, the assessment of the amplitude and duration of parafunctional activity may be of greater significance than the frequency.
Our findings show that, in general, patients with TMD myalgia seem to be more responsive to music. A study using fMRI reported an increased brain activity in areas involved in emotional processes (medial prefrontal cortex, pregenual anterior cingulate cortex, and amygdala) in individuals with pain related to TMD. Pain related to chronic TMD seemed to increase the demands of the emotional neural networks which decreased the individual’s ability to perform in other tasks. Patients with chronic TMD have also been reported to have an increased somatosensory amplification. They could therefore be more emotionally labile or more sensitive to external stimuli, which can explain the increased response with emotionally stimulating music.

The PPTs measured in both groups in the current study were not significantly different. It was expected that patients with mTMD had lower PPTs as compared to TMD-free controls as reported in previous studies. This contradicting finding may be explained by the fluctuating pain pattern in mTMD. For this study, we recruited patients who reported to have had pain in the last 30 days (DC/TMD criteria) and were positive to muscle palpation. Since the severity of pain was not considered a selection criterion, it is possible that PPTs at muscle locations were not significantly reduced in those individuals who reported to have had mild or no pain before the experiment. Hence, differences in PPTs could not be detected.

Contrary to previous reports, state and trait anxiety did not differ between groups. It has been reported that anxiety and stress-induced symptoms are increased in patients with TMD pain. In TMD patients, this increased anxiety and depression is associated with the amplitude of the pain, disability and decreased quality of life. Patients participating in this study were already seen for their first appointment at Mount Sinai Hospital. Hence, the previous relationship with their health care provider may have encouraged the patient to have trust and hope that the condition will improve, thereby impacting on anxiety. TMD patients had higher SSAS and PCS scores than the pain-free individuals. These results are consistent with previous studies reporting that patients with pain associated with TMD have an increase in somatosensory amplification and pain catastrophizing.
GML has been used as a therapy in pain disorders to reduce chronic and acute pain by diminishing stress and anxiety and improving mood.\textsuperscript{134, 239, 240, 79} GML has been thought to promote relaxation through the autonomic nervous system.\textsuperscript{23} There is also evidence that if individuals relate to music, this can affect their emotional and psychological well-being by distraction, pleasure or simply by eliciting a feeling.\textsuperscript{19, 243} In addition, music modulates the contraction pattern of skeletal muscles by affecting the motor and premotor cortices.\textsuperscript{16, 257} It is therefore likely that in our experiment, the favorite music, to which the individuals relate to the most, and which positively affected mood, influenced significantly jaw motor behavior. It is likely that the psychological and motor therapeutic effects of GML would have an impact on masticatory muscle function by modulating the corticobulbar excitability due to musical rhythm as well as by affecting the autonomic nervous system due to musical valence.\textsuperscript{48} However, further studies are needed to determine the mechanisms of masticatory muscle modulation with music in patients with TMD myalgia.

This study has some limitations. First, the assessment of relaxation and perceived stress during the music tasks were based on self-reports on VAS. More accurate measurements could have included the assessment of cortisol levels before and after each experimental task.\textsuperscript{233} Second, awake-bruxism encompasses not only tooth clenching, but also bracing or thrusting of the mandible, which are difficult to isolate.\textsuperscript{141} Some functional activities such as swallowing were also difficult to isolate even though participants were examined throughout the EMG protocol for artifacts arising from touching the electrodes, yawning, talking, etc. Salivary flow can be altered with increased stress and anxiety.\textsuperscript{81} We therefore assumed that the swallowing patterns in both groups were similar since no significant differences were found in levels of stress. Our EMG protocol was not designed to detect these activities. Finally, the study focused on women and therefore no conclusions can be drawn about men with TMD.
Conclusions
This study indicated that GML modulates masseter activity by affecting the amplitude of wake-time tooth clenching, an etiologic factor of TMD. Patients with chronic TMD myalgia have a greater muscle overall amplitude of contraction during certain music tasks that are highly dissonant and stressful and may benefit from favorite music, which reduces the intensity of wake-time tooth clenching episodes by half.

Future research can aid in using GML for developing a multimodal approach for the management of chronic orofacial pain due to TMD and determining the mechanisms of jaw muscle motor modulation with music.

Acknowledgments
The authors want to acknowledge the American Academy of Orofacial Pain (AAOP) for funding the research.

Compliance with Ethical Standards
Conflict of Interest
All authors declare that they have no conflict of interest.

Funding
This study was supported by the American Academy of Orofacial Pain (AAOP).

Ethical Approval
The protocol was approved by the Research Ethics Boards of both the University of Toronto (Protocol # 34188) and Mount Sinai Hospital (Protocol # 17-0081-E) (Refer to Appendix A1 and A2).

Informed Consent
Participants were given an informed consent form (Refer to Appendix A3) to sign acknowledging the receipt of information and confirming their willingness to participate in the study.
Significance of the Study

GML is shown to be effective in managing pain symptoms in multiple chronic pain conditions. The mechanism of action involved is however not well understood. Studies have concluded that music affects the emotional state and modulates attention. Since altered mood states increase parafunctional activity, an important etiological factor to painful TMD of muscular origin, there was a need to further investigate whether music could positively impact parafunctional activity. A previous study conducted in our lab has shown that GML can modulate the activity of masticatory muscles in pain-free individuals, especially in those with high self-reported frequency of oral behaviors. This study explored the effect of GML on the masticatory muscle activity, in particular on the masseter muscle, in patients diagnosed with TMD myalgia and pain-free individuals. The study assessed the changes in muscle tone at rest as well as the changes in amplitude, frequency and duration of wake-time tooth clenching episodes in the population sample. Our current study is the first to evaluate whether the muscle activity of patients with pain related to TMD myalgia, frequently associated with an increase parafunctional habits, would behave differently when subjected to distinctive music tasks.

Conclusions

The results of this study confirmed the hypothesis that self-selected favorite music decreases the habitual activity of the masticatory muscles more than experimenter-selected music and that stress-inducing music increased the habitual activity of masticatory muscles. The hypothesis stating that the trends would be similar in both individuals with TMD myalgia and pain-free individuals was however rejected.

GML modulates the activity of masticatory muscles by targeting one of the etiological factors of TMD, the amplitude of wake-time tooth clenching episodes. Favorite music
reduces the intensity of wake-time tooth clenching episodes up to 55% in patients with TMD myalgia. On the other hand, the overall amplitude of masticatory muscle activity increases while passively listening to music tasks that are highly dissonant and self-reported as stressful. There were no significant differences in frequency and duration of wake-time tooth clenching with different music tasks.

**Future Directions**

Future research is necessary to further our understanding of the mechanisms involved in the link between masticatory muscle modulation and auditory stimuli. The future goal is to develop a multimodal approach for the management of pain in patients with TMD of muscular origin that is cost effective, non-invasive and readily available as compared to current treatment modalities. Besides improving the symptoms related to TMD myalgia, GML would target one of the main etiological factors involved with the onset of TMD myalgia. This could lead to a therapy that would decrease the incidence of TMD as well as improve the symptoms in patients who are affected with painful TMD.
Appendix A

A1. Ethics approval from the Research Ethics Board – University of Toronto

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<th>ETHICS APPROVAL</th>
<th>Original Approval Date: April 28, 2017</th>
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<td>Expiry Date: April 27, 2018</td>
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Dr. Isacpo Cioffi  
Dr. Tina Imbriglio  
FACULTY OF DENTISTRY  
FACULTY OF DENTISTRY

Dear Dr. Cioffi and Dr. Tina Imbriglio,

Re: Your research protocol entitled, "The effect of music on the habitual activity of masticatory muscles and daytime tooth clenching in patients affected with masticatory muscle pain and pain-free volunteers."

We are writing to advise you that the Health Sciences Research Ethics Board (REB) has granted approval to the above-named research protocol under the REB's delegated review process. Your protocol has been approved for a period of one year and ongoing research under this protocol must be renewed prior to the expiry date.

Any changes to the approved protocol or consent materials must be reviewed and approved through the amendment process prior to its implementation. Any adverse or unanticipated events in the research should be reported to the Research Oversight and Compliance Office - Human Research Ethics Program as soon as possible.

Please ensure that you submit an Ethics Renewal Form or a Study Completion/Closure Report 15 to 30 days prior to the expiry date of your current ethics approval. Note that ethics renewals for studies cannot be accepted more than 30 days prior to the date of expiry.

If your research is funded by a third party, please contact the assigned Research Funding Officer in Research Services to ensure that your funds are released.

Please note, all approved research studies are eligible for a routine Post-Approval Review (PAR) site visit. If chosen, you will receive a notification letter from our office. For information on PAR, please see http://www.research.utoronto.ca/wp-content/uploads/documents/2014/09/PAR-Program-Description.pdf

Best wishes for the successful completion of your research.

Yours sincerely,

Elizabeth Peter, Ph.D.  
REB Chair
A2. Ethics approval from the Research Ethics Board – Mount Sinai Hospital

Research Ethics Board
700 University Avenue, 8th fl., Suite 8-600
Toronto, Ontario, Canada, M5G 1Z5
t: (416) 586-4875  f: (416) 586-4715
www.mtsinai.on.ca

Notification of REB Initial Approval (Delegated)

Date: September 11, 2017
To: Dr. Iacopo Cioffi
Department of Dentistry
124 Edward Street
Faculty of Dentistry, Room 519b
Toronto, Ontario M5G 1G6

Re: 17-0081-E
The Effects of Music on the Habitual Activity of Masticatory Muscles and Daytime Tooth Clenching in Patients Affected with Masticatory Muscle Pain and Pain-Free Volunteers

Sponsor: UofT Faculty of Dentistry
REB Review Type: Delegated
REB Initial Approval Date: 11 September 2017
REB Expiry Date: 11 September 2018
Documents Approved:
- Protocol (Rec. 17-Aug-2017)
- Budget (Rec. 17-Aug-2017)
- Poster (Dated: 01-Sep-2017)
- Telephone Script for Initial Recruitment (Dated: 01-Sep-2017)
- Consent Form (Dated: 01-Sep-2017)
- DC/TMD Examination Form (Rec. 14-Jul-2017)
- TMD Pain Screener (Rec. 14-Jul-2017)
- Diagnostic Criteria for Temporomandibular Disorders Symptom Questionnaire (Rec. 14-Jul-2017)
- Demographics Survey (Rec. 14-Jul-2017)
- Pain Drawing Questionnaire (Rec. 14-Jul-2017)
- Graded Chronic Pain Scale (Rec. 14-Jul-2017)
- The Oral Behavior Checklist (Rec. 14-Jul-2017)
- GAD-7 (Rec. 14-Jul-2017)
- State-Trait Anxiety Inventory (Rec. 14-Jul-2017)
- Somatosensory Amplification Scale (Rec. 14-Jul-2017)
- Pain Catastrophizing Scale (Rec. 14-Jul-2017)
- Beck's Depression Inventory (Rec. 14-Jul-2017)

Documents Acknowledged:
Health Records Access: Yes

The above named study has been reviewed and approved by the Mount Sinai Hospital Research Ethics Board. If, during the course of the research, there are any serious adverse events, confidentiality concerns, changes in the approved project, or any new information that must be considered with respect to the project, these should be brought to the immediate attention of the REB. In the event of a privacy breach, you are responsible for reporting the breach to the MSH REB and the MSH Corporate Privacy Office (in accordance with Ontario health privacy legislation – Personal Health Information Protection Act, 2004). Additionally, the MSH REB
requires reports of inappropriate/unauthorized use of the information.

If the study is expected to continue beyond the expiry date, you are responsible for ensuring the study receives re-approval. The REB must be notified of the completion or termination of this study and a final report provided. As the Principal Investigator, you are responsible for the ethical conduct of this study.


Sincerely,

Ronald Heslegrave, Ph.D.
Chair, Mount Sinai Hospital Research Ethics Board
A3. Participant Informed Consent and Privacy Statement

Informed Consent

The current study evaluates the effects of music on the activity of masticatory muscles. Our research aims to determine whether the habitual activity of the chewing muscles is influenced by acoustic stimuli and in particular by music. Data retrieved with this research will be helpful in designing new research studies aiming in developing new treatment strategies for people affected with chronic orofacial pain conditions related to muscular disorders. The study is supported by the American Academy of Orofacial Pain and by the Faculty of Dentistry, University of Toronto through Dr. Cioffi’s research funds.

For this study we are recruiting people with temporomandibular disorders, a painful condition of the jaws and/or temples, and healthy subjects who do not have temporomandibular disorders.

We would like to monitor the activity of your masticatory muscles while you are listening to different music genres (3 tasks) and while you are listening to pink sound (1 task). Moreover, the activity of your brain will be also monitored in order to assess how your feelings and emotions affect the activity of the muscles.

The entire research procedure will require approximately 2.5 hours and will take place in only one session. All the procedures will be conducted at the Faculty of Dentistry, University of Toronto, in Dr. Cioffi’s research lab.

You will be involved with the following procedures:

- Dental visit
- Music pre-test
- Measurement of pressure pain thresholds
- Electromyographic and encephalographic assessment while listening to music (3 tasks) and while listening to pink sound (1 task).

Dental Visit

We will assess the function of your masticatory (chewing) muscles by palpation, and evaluate your oral hygiene status and your occlusion (bite). This will require approximately 5 minutes of your time. If we find a condition (for example, caries) that needs treatment, we will refer you to your dentist or to the local dental clinic.

Music Pre-test

Before coming here, you were asked to bring with you 15 minutes of your preferred music playlist. We would like you to listen to 5 minutes of your music and rate the amount of physical activation and the pleasurableness triggered by your music, and to report whether your preferred music triggered some associations (memories, pictures etc). Thereafter you will listen to 24 music excerpts (1 minute each) and invited to rate the stress/relaxation triggered by each of them.

Electromyographic Test

We will use an electronic device to assess the behavior of your masticatory (chewing) muscles while you listen to a podcast (15 minutes), listen to your preferred music playlist (15 minutes), to music able to trigger your stress (15 minutes), and to music able to trigger your relaxation (15 minutes).
minutes), and music that promotes your relaxation (15 minutes). This task will require approximately 80 minutes.

In order to record the activity of the muscles, two plastic probes (figure) will be placed onto your cheeks. You will not experience any electrical shocks and/or discomfort during this test. We will apply a conductive gel on your skin before positioning the probes. The probes will stay in place through conductive stickers (electrodes). It is possible that after the procedure your cheeks and temples will present the impression of the electrodes. This will disappear few minutes after the procedures. Allergies are rare.

**Electroencephalography (EEG)**

The electrical activity of the brain will be recorded during the experimental tasks by using a wifi electroencephalograph, which is worn as a headband (figure). You will not experience any electrical shocks and/or discomfort during this test.

**Measurement of Pressure Pain Thresholds**

This test will measure your pressure pain threshold. We will press your cheeks and temples with a special instrument called an algometer, which is similar to the rubber tip of an eraser-end of a pencil. Pressure will be placed with said instrument onto the surface of your cheek and temple in both sides. This will continue until the point in time where you indicate and decide that the pressure sensation has changed into a discomforting sensation. The instrument will be withdrawn immediately. We will do three tests for each cheek (masseter) and temple (temporalis). This test will require approximately 20 minutes.

**Possible risks**

All the procedures that will be used in the experimental phase have no significant risks. The recording of pressure pain thresholds by means of pressure algometry may be uncomfortable and may be painful for some individuals. However, all participants will be asked to stop the procedure (by pushing a button) when the pressure stimulus becomes painful. Indeed, the outcome measure to be collected is the minimal pressure able to determine the sensation of pain. Irritation to skin due to the positioning of the electrodes can occur. Alteration of the emotional status may occur as a consequence to the exposure to different music conditions. You may decide to quit the experiment any time.

We would like to kindly invite you to take part in this study. Again, you may refuse to participate or withdraw at any moment without any repercussions. If you agree to participate in this study, upon successful completion we will give you a gift card valued 60 CAN for your participation.

Compensation will be provided as follows:

- Baseline assessments + pink sound task= 15 dollar gift card
- Baseline assessments + pink sound task + 1 music task= 25 dollar gift card
- Baseline assessments + pink sound task + 2 music tasks= 35 dollar gift card
- Baseline assessments + pink sound task + 3 music tasks= 60 dollar gift card

Compensation will be provided for parking or transportation expenses up to a maximum of 20$.  

Do you give consent to use the data collected during the research phases for future research studies aiming at further testing the effects of music on temporomandibular disorders and orofacial pain and psychological variables on masticatory muscle activity?

YES  NO
Privacy Statement

We are committed to protecting your personal information and respecting your privacy. Personal information is defined as any details that will enable you to be identified, such as ID numbers, telephone numbers, address, email address etc. When designing and executing our research, it is our policy to take all necessary steps to ensure that personal information you provide is processed fairly and lawfully. Only authorized staff has access to personal information and they are obliged to respect its confidentiality. We do not sell, rent or exchange any personal information supplied by you to any third party. Nor do we use any of the information you provide for direct marketing or other non-research activities.

All the information you will provide will be property of the faculty of Dentistry of the University of Toronto. Only the investigators listed in this document will have access to the data. Your personal data will be stored at the Faculty of Dentistry. The data will be kept and used for further research studies.

In obtaining your cooperation to participate in the research, we undertake not to mislead you in any way about the nature of the research we are conducting, the way in which the data is collected and the use that will be made of the results. All of the information that you provide will be treated as confidential and together with your research data will only be used for this or other research purposes. Your comments will not be identified as belonging to you; instead they will be combined with those gathered from other research participants, and will be analyzed as part of a group.

We do not use any of the information you provide for direct marketing or other non-research activities. If we ask you for personal information that enables you to be identified - e.g. your name, ID numbers, email address or telephone number, we will clearly state why we are asking for it and for your permission to use it for that purpose. For example, it might be to contact you for other research studies. Your participation is voluntary. You are entitled to ask that part, or all, of the record of your involvement in the research be deleted or destroyed.

The results of this research study will be object of publication or research presentations. You can request a summary of the research results to the investigators, who will be pleased to send it to you by email. While it is not possible to fully explain the study in advance, participants will be provided with a full debriefing at the end.

This research is economically supported by the research funds of the Research Supervisor and by the Faculty of Dentistry, University of Toronto.

This study may be reviewed for quality assurance. One of more representatives of the Human Research Ethics Program may access the data and consent materials to assure that the required laws and guidelines are followed. The same confidentiality guidelines will be followed.

You can contact the Office of Research Ethics at ethics.review@utoronto.ca or 416-946-3273 if you have questions about your rights as participant.

Contact information of the investigator:
Dr. Isaojo Ciffi
Department of Orthodontics
University of Toronto, Faculty of Dentistry
970 Bay St., 124 Edward Street
Toronto, Ontario, Canada M5G 1G6
Phone: 416-979-4900 Ext: 4614
isciffi@dentistry.utoronto.ca

I voluntarily consent to participate in this study and will be given a signed copy of this form to take home with me.

Name: ___________________ Surname: ___________________
☐ I agree ☐ I disagree Date___________

Signature: ___________________
A summary of the research results will be sent to you, after the research has been completed
ASSIGNED ID________________________

UT - ROCO-HREP – Application Form for Supervised/Sponsored Research 44 of 52
Appendix B

B1. Questionnaires

B1.1. TMD-Pain Screener

TMD-PAIN SCREENER

1. In the last 30 days, how long did any pain last in your jaw or temple area on either side?
   a. No pain
   b. Pain comes and goes
   c. Pain is always present

2. In the last 30 days, have you had pain or stiffness in your jaw on awakening?
   a. No
   b. Yes

3. In the last 30 days, did the following activities change any pain (that is, make it better or make it worse) in your jaw or temple area on either side?
   A. Chewing hard or tough food
      a. No
      b. Yes
   B. Opening your mouth or moving your jaw forward or to the side
      a. No
      b. Yes
   C. Jaw habits such as holding teeth together, clenching, grinding, or chewing gum
      a. No
      b. Yes
   D. Other jaw activities such as talking, kissing, or yawning
      a. No
      b. Yes
B1.2. Diagnostic Criteria for Temporomandibular Disorders

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?
   □ No pain
   □ Pain comes and goes
   □ Pain is always present
   Select ONE response.
   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?

   A. Chewing hard or tough food
      No □ Yes □

   B. Opening your mouth, or moving your jaw forward or to the side
      No □ Yes □

   C. Jaw habits such as holding teeth together, clenching/grinding teeth, or chewing gum
      No □ Yes □

   D. Other jaw activities such as talking, kissing, or yawning
      No □ Yes □

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?

   A. Chewing hard or tough food
      No □ Yes □

   B. Opening your mouth, or moving your jaw forward or to the side
      No □ Yes □

   C. Jaw habits such as holding teeth together, clenching/grinding, or chewing gum
      No □ Yes □

   D. Other jaw activities such as talking, kissing, or yawning
      No □ Yes □
### JAW JOINT NOISES

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?  
   - Yes □  
   - No □

   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?  
    - Yes □  
    - No □  
    - R □  
    - L □  
    - DNK □

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?  
    - Yes □  
    - No □  
    - R □  
    - L □  
    - DNK □

   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?  
    - Yes □  
    - No □  
    - R □  
    - L □  
    - DNK □

### 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?  
    - Yes □  
    - No □  
    - R □  
    - L □  
    - DNK □

   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?  
    - Yes □  
    - No □  
    - R □  
    - L □  
    - DNK □
## Demographics

1. What is your current marital status?
   - □ Married
   - □ Living as married
   - □ Divorced
   - □ Separated
   - □ Widowed
   - □ Never married

2. What is your ethnicity?
   - □ Hispanic or Latino
   - □ Not Hispanic or Latino
   - □ Unknown
   - □ Other_______

3. What is your race? Mark all that apply.
   - □ American Indian or Alaska Native
   - □ Asian
   - □ Black or African American
   - □ Native Hawaiian or Other Pacific
   - □ White
   - □ Other_______

4. What is the highest grade or level of schooling that you have completed?
   - □ Through high school
   - □ Some college
   - □ College graduate
   - □ Professional or Post-graduate level

5. What is your family’s current annual household income? Please include all sources of income for all family members such as wages, salaries, investments, etc.
   - □ $0 - $19,999
   - □ $20,000 - $39,999
   - □ $40,000 - $59,999
   - □ $60,000 - $79,999
   - □ $80,000 - $99,999
   - □ $100,000 - $149,999
   - □ $150,000 or higher
DC/TMD Examination Form

1a. Location of Pain: Last 30 days (Select all that apply)
   - **RIGHT PAIN**
     - None
     - Temporals
     - Other m. muscles
     - Non-mast structures
   - **LEFT PAIN**
     - None
     - Temporals
     - Other m. muscles
     - Non-mast structures

1b. Location of Headache: Last 30 days (Select all that apply)
   - None
   - Temporal
   - Other

2. Incisal Relationships
   - Reference tooth: ○ FDI #11 ○ FDI #21 ○ Other
   - Horizontal Incisal Overjet: [ ] mm
   - Vertical Incisal Overlap: [ ] mm
   - Midline Deviation: ○ ○ N/A

3. Opening Pattern (Supplemental; Select all that apply)
   - Unrected Deviation
   - Straight
   - Corrected deviation

4. Opening Movements
   - A. Pain Free Opening: [ ] mm
   - B. Maximum Unassisted Opening: [ ] mm
   - C. Maximum Assisted Opening: [ ] mm

5. Lateral and Protrusive Movements
   - A. Right Lateral: [ ] mm
   - B. Left Lateral: [ ] mm
   - C. Protrusion: [ ] mm

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<th>Familiar Headache</th>
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<td>Masseter</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>TMI</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>Other M Musc</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>Non-mast</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td><strong>LEFT SIDE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temporals</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>Masseter</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>TMI</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>Other M Musc</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>Non-mast</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
</tbody>
</table>
6. TMJ Noises During Open & Close Movements

<table>
<thead>
<tr>
<th></th>
<th>RIGHT TMJ</th>
<th></th>
<th>LEFT TMJ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Examiner</td>
<td>Patient</td>
<td>Pain w/ Click</td>
</tr>
<tr>
<td>Click</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
<tr>
<td>Creptus</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
</tbody>
</table>

7. TMJ Noises During Lateral & Protrusive Movements

<table>
<thead>
<tr>
<th></th>
<th>RIGHT TMJ</th>
<th></th>
<th>LEFT TMJ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Examiner</td>
<td>Patient</td>
<td>Pain w/ Click</td>
</tr>
<tr>
<td>Click</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
<tr>
<td>Creptus</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
</tbody>
</table>

8. Joint Locking

<table>
<thead>
<tr>
<th></th>
<th>RIGHT TMJ</th>
<th></th>
<th>LEFT TMJ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Examiner</td>
<td>Patient</td>
<td>Pain w/ Click</td>
</tr>
<tr>
<td>While Opening</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
<tr>
<td>Wide Open Position</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
</tbody>
</table>

9. Muscle & TMJ Pain with Palpation

<table>
<thead>
<tr>
<th></th>
<th>RIGHT SIDE</th>
<th></th>
<th>LEFT SIDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1 kg)</td>
<td>Pain</td>
<td>Familiar Pain</td>
<td>Familiar Headache</td>
</tr>
<tr>
<td>Temporalis (posterior)</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
<tr>
<td>Temporalis (midline)</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
<tr>
<td>Temporalis (anterior)</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
<tr>
<td>Masseter (origin)</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
<tr>
<td>Masseter (body)</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
<tr>
<td>Masseter (insertion)</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
<tr>
<td>TMJ</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
<tr>
<td>Lateral pole (0.5 kg)</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
<tr>
<td>Around lateral pole (1 kg)</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
</tbody>
</table>

10. Supplemental Muscle Pain with Palpation

<table>
<thead>
<tr>
<th></th>
<th>RIGHT SIDE</th>
<th></th>
<th>LEFT SIDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.5 kg)</td>
<td>Pain</td>
<td>Familiar Pain</td>
<td>Referred Pain</td>
</tr>
<tr>
<td>Posterior mandibular region</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
<tr>
<td>Submandibular region</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
<tr>
<td>Lateral pterygoid area</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
<tr>
<td>Temporalis tendon</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
<tr>
<td>(0.5 kg)</td>
<td>Pain</td>
<td>Familiar Pain</td>
<td>Referred Pain</td>
</tr>
<tr>
<td>Posterior mandibular region</td>
<td>[▲] [口]</td>
<td>[▲] [▲]</td>
<td>[▲] [口]</td>
</tr>
<tr>
<td>Submandibular region</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
<tr>
<td>Lateral pterygoid area</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
<tr>
<td>Temporalis tendon</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
<td>[▲] [口]</td>
</tr>
</tbody>
</table>

11. Diagnoses

<table>
<thead>
<tr>
<th>Pain Disorders</th>
<th>Right TMJ Disorders</th>
<th>Left TMJ Disorders</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Myalgia</td>
<td>Disc displacement (select one)</td>
<td>Disc displacement (select one)</td>
</tr>
<tr>
<td>Myofascial pain with referral</td>
<td>...with reduction</td>
<td>...with reduction</td>
</tr>
<tr>
<td>Right Arthralgia</td>
<td>...with reduction, with intermittent locking</td>
<td>...with reduction, with intermittent locking</td>
</tr>
<tr>
<td>Left Arthralgia</td>
<td>...without reduction, with limited opening</td>
<td>...without reduction, with limited opening</td>
</tr>
<tr>
<td>Headache attributed to TMD</td>
<td>Degenerative joint disease</td>
<td>Degenerative joint disease</td>
</tr>
<tr>
<td>12. Comments</td>
<td>Dislocation</td>
<td>Dislocation</td>
</tr>
</tbody>
</table>

PAIN DRAWING

Indicate the location of ALL of your different pains by shading in the area, using the diagrams that are most relevant. If there is an exact spot where the pain is located, indicate with a solid dot (●). If your pain moves from one location to another, use arrows to show the path.

Mouth and teeth

Right face

Left face

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Graded Chronic Pain Scale Version 2.0

1. On how many days in the last 6 months have you had facial pain? _______ Days

2. How would you rate your facial pain RIGHT NOW? Use a scale from 0 to 10, where 0 is "no pain" and 10 is "pain as bad as could be".

   No pain                      Pain as bad as could be
   0   1   2   3   4   5   6   7   8   9   10

3. In the LAST 30 DAYS, how would you rate your WORST facial pain? Use the same scale, where 0 is "no pain" and 10 is "pain as bad as could be".

   No pain                      Pain as bad as could be
   0   1   2   3   4   5   6   7   8   9   10

4. In the LAST 30 DAYS, ON AVERAGE, how would you rate your facial pain? Use the same scale, where 0 is "no pain" and 10 is "pain as bad as could be". [That is, your usual pain at times you were in pain.]

   No pain                      Pain as bad as could be
   0   1   2   3   4   5   6   7   8   9   10

5. In the LAST 30 DAYS, how many days did your facial pain keep you from doing your USUAL ACTIVITIES like work, school, or housework? (every day = 30 days) _______ Days

6. In the LAST 30 DAYS, how much has facial pain interfered with your DAILY ACTIVITIES? Use a 0-10 scale, where 0 is "no interference: and 10 is "unable to carry on any activities".

   No interference               Unable to carry on any activities
   0   1   2   3   4   5   6   7   8   9   10

7. In the LAST 30 DAYS, how much has facial pain interfered with your RECREATIONAL, SOCIAL AND FAMILY ACTIVITIES? Use the same scale, where 0 is "no interference: and 10 is "unable to carry on any activities".

   No interference               Unable to carry on any activities
   0   1   2   3   4   5   6   7   8   9   10

8. In the LAST 30 DAYS, how much has facial pain interfered with your ABILITY TO WORK, including housework? Use the same scale, where 0 is "no interference: and 10 is "unable to carry on any activities".

   No interference               Unable to carry on any activities
   0   1   2   3   4   5   6   7   8   9   10

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Jaw Functional Limitation Scale – 8

For each of the items below, please indicate the level of limitation during the last month. If the activity has been completely avoided because it is too difficult, then circle ‘10’. If you avoid an activity for reasons other than pain or difficulty, leave the item blank.

<table>
<thead>
<tr>
<th></th>
<th>No limitation</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Severe Limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Chew tough food</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>2.</td>
<td>Chew chicken (e.g., prepared in oven)</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>3.</td>
<td>Eat soft food requiring no chewing (e.g., mashed potatoes, apple sauce, pudding, pureed food)</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>4.</td>
<td>Open wide enough to drink from a cup</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>5.</td>
<td>Swallow</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>6.</td>
<td>Yawn</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>7.</td>
<td>Talk</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>8.</td>
<td>Smile</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>
**Patient Health Questionnaire-15: Physical Symptoms**

During the **last 4 weeks**, how much have you been bothered by any of the following problems? Please place a check mark in the box to indicate your answer.

<table>
<thead>
<tr>
<th></th>
<th>Not bothered</th>
<th>Bothered a little</th>
<th>Bothered a lot</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Stomach pain</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2. Back pain</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. Pain in your arms, legs, or joints (knees, hips, etc)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. Menstrual cramps or other problems with your periods [women only]</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. Headaches</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6. Chest pain</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7. Dizziness</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8. Fainting spells</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>9. Feeling your heart pound or race</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>10. Shortness of breath</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>11. Pain or problems during sexual intercourse</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>12. Constipation, loose bowels, or diarrhea</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>13. Nausea, gas, or indigestion</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>14. Feeling tired or having low energy</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>15. Trouble sleeping</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

**TOTAL SCORE =**
**GAD - 7**

Over the last 2 weeks, how often have you been bothered by the following problems? Place a check mark in the box to indicate your answer.

<table>
<thead>
<tr>
<th></th>
<th>Not at all (0)</th>
<th>Several days (1)</th>
<th>More than half the days (2)</th>
<th>Nearly every day (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Feeling nervous, anxious or on edge</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>2. Not being able to stop or control worrying</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>3. Worrying too much about different things</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>4. Trouble relaxing</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>5. Being so restless that it is hard to sit still</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>6. Becoming easily annoyed or irritable</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>7. Feeling afraid as if something awful might happen</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

**TOTAL SCORE =**

---

If you checked off any problems, how difficult have these problems made it for you to do your work, take care of things at home, or get along with other people?

<table>
<thead>
<tr>
<th></th>
<th>Not difficult at all</th>
<th>Somewhat difficult</th>
<th>Very difficult</th>
<th>Extremely difficult</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>
## B1.3 The Oral Behavior Checklist

The Oral Behavior Checklist

How often do you do each of the following activities, based on the last month? If the frequency of the activity varies, choose the higher option. Please place a (✓) response for each item and do not skip any items.

<table>
<thead>
<tr>
<th>Activities During Sleep</th>
<th>None of the time</th>
<th>&lt; 1 Night /Month</th>
<th>1-3 Nights /Month</th>
<th>1-3 Nights /Week</th>
<th>All of the Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clench or grind teeth when asleep, based on any information you may have</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep in a position that puts pressure on the jaw (for example, on stomach, on the side)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Activities During Waking Hours</th>
<th>None of the time</th>
<th>A little of the time</th>
<th>Some of the time</th>
<th>Most of the time</th>
<th>All of the time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grind teeth together during waking hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clench teeth together during waking hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Press, touch, or hold teeth together other than while eating (that is, contact between upper and lower teeth)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hold, tighten, or tense muscles without clenching or bringing teeth together</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hold or jut jaw forward or to the side</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Press tongue forcibly against teeth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Place tongue between teeth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bite, chew, or play with your tongue, cheeks or lips</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hold jaw in rigid or tense position, such as to brace or protect the jaw</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hold between the teeth or bite objects such as hair, pipe, pencil, pens, fingers, fingernails, etc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use chewing gum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Play musical instrument that involves use of mouth or jaw (for example, woodwind, brass, string instruments)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lean with your hand on the jaw, such as cupping or resting the chin in the hand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chew food on one side only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating between meals (that is, food that requires chewing)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustained talking (for example, teaching, sales, customer service)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Singing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yawning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hold telephone between your head and shoulders</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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B1.4. Somatosensory Amplification Scale

<table>
<thead>
<tr>
<th>Somatosensory Amplification Scale (SSAS)</th>
<th>Not at all</th>
<th>A little</th>
<th>Moderately</th>
<th>Quite a bit</th>
<th>Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudden loud noises really bother me</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I hate to be too hot or too cold</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I have a low tolerance for pain</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I am often aware of various things happening within my body</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I am a quick to sense the hunger contractions in my stomach</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>When someone else coughs, it makes me cough too</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I can't stand smoke, smog, or pollutants in the air</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I can sometimes hear my pulse or my heartbeat throbbing in my ear</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Even something minor, like an insect bite or a splinter, really bothers me</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>When I bruise myself, it stays noticeable for a long time</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

(c) Include a list of appendices here for all additional materials submitted (e.g., Appendix A – Informed Consent; Appendix B – Interview Guide, etc.):
B1.5. Pain Catastrophizing Scale

0 – not at all  1 – to a slight degree  2 – to a moderate degree  3 – to a great degree  4 – all the time

When I’m in pain ...

☐ I worry all the time about whether the pain will end.
☐ I feel I can’t go on.
☐ It’s terrible and I think it’s never going to get any better.
☐ It’s awful and I feel that it overwhelms me.
☐ I feel I can’t stand it anymore.
☐ I become afraid that the pain will get worse.
☐ I keep thinking of other painful events.
☐ I anxiously want the pain to go away.
☐ I can’t seem to keep it out of my mind.
☐ I keep thinking about how much it hurts.
☐ I keep thinking about how badly I want the pain to stop.
☐ There’s nothing I can do to reduce the intensity of the pain.
☐ I wonder whether something serious may happen.

...Total
B1.6. Beck's Depression Inventory

Beck's Depression Inventory
This depression inventory can be self-scored. The scoring scale is at the end of the questionnaire.

1. 
0  I do not feel sad.
1  I feel sad.
2  I am sad all the time and I can't snap out of it.
3  I am so sad and unhappy that I can't stand it.

2. 
0  I am not particularly discouraged about the future.
1  I feel discouraged about the future.
2  I feel I have nothing to look forward to.
3  I feel the future is hopeless and that things cannot improve.

3. 
0  I do not feel like a failure.
1  I feel I have failed more than the average person.
2  As I look back on my life, all I can see is a lot of failures.
3  I feel I am a complete failure as a person.

4. 
0  I get as much satisfaction out of things as I used to.
1  I don't enjoy things the way I used to.
2  I don't get real satisfaction out of anything anymore.
3  I am dissatisfied or bored with everything.

5. 
0  I don't feel particularly guilty.
1  I feel guilty a good part of the time.
2  I feel quite guilty most of the time.
3  I feel guilty all of the time.

6. 
0  I don't feel I am being punished.
1  I feel I may be punished.
2  I expect to be punished.
3  I feel I am being punished.

7. 
0  I don't feel disappointed in myself.
1  I am disappointed in myself.
2  I am disgusted with myself.
3  I hate myself.

8. 
0  I don't feel I am any worse than anybody else.
1  I am critical of myself for my weaknesses or mistakes.
2  I blame myself all the time for my faults.
3  I blame myself for everything bad that happens.

9. 
0  I don't have any thoughts of killing myself.
1  I have thoughts of killing myself, but I would not carry them out.
2  I would like to kill myself.
3  I would kill myself if I had the chance.

10. 
0  I don't cry any more than usual.
1  I cry more now than I used to.
2  I cry all the time now.
3  I used to be able to cry, but now I can't cry even though I want to.
11.  
0  I am no more irritated by things than I ever was.  
1  I am slightly more irritated now than usual.  
2  I am quite annoyed or irritated a good deal of the time.  
3  I feel irritated all the time.  
12.  
0  I have not lost interest in other people.  
1  I am less interested in other people than I used to be.  
2  I have lost most of my interest in other people.  
3  I have lost all of my interest in other people.  
13.  
0  I make decisions about as well as I ever could.  
1  I put off making decisions more than I used to.  
2  I have greater difficulty in making decisions more than I used to.  
3  I can't make decisions at all anymore.  
14.  
0  I don't feel that I look any worse than I used to.  
1  I am worried that I am looking old or unattractive.  
2  I feel there are permanent changes in my appearance that make me look unattractive.  
3  I believe that I look ugly.  
15.  
0  I can work about as well as before.  
1  It takes an extra effort to get started at doing something.  
2  I have to push myself very hard to do anything.  
3  I can't do any work at all.  
16.  
0  I can sleep as well as usual.  
1  I don't sleep as well as I used to.  
2  I wake up 1-2 hours earlier than usual and find it hard to get back to sleep.  
3  I wake up several hours earlier than I used to and cannot get back to sleep.  
17.  
0  I don't get more tired than usual.  
1  I get tired more easily than I used to.  
2  I get tired from doing almost anything.  
3  I am too tired to do anything.  
18.  
0  My appetite is no worse than usual.  
1  My appetite is not as good as it used to be.  
2  My appetite is much worse now.  
3  I have no appetite at all anymore.  
19.  
0  I haven't lost much weight, if any, lately.  
1  I have lost more than five pounds.  
2  I have lost more than ten pounds.  
3  I have lost more than fifteen pounds.
20.  
0  I am no more worried about my health than usual.  
1  I am worried about physical problems like aches, pains, upset stomach, or constipation.  
2  I am very worried about physical problems and it's hard to think of much else.  
3  I am so worried about my physical problems that I cannot think of anything else.  
21.  
0  I have not noticed any recent change in my interest in sex.  
1  I am less interested in sex than I used to be.  
2  I have almost no interest in sex.  
3  I have lost interest in sex completely.  

INTERPRETING THE BECK DEPRESSION INVENTORY

Now that you have completed the questionnaire, add up the score for each of the twenty-one questions by counting the number to the right of each question you marked. The highest possible total for the whole test would be sixty-three. This would mean you circled number three on all twenty-one questions. Since the lowest possible score for each question is zero, the lowest possible score for the test would be zero. This would mean you circles zero on each question. You can evaluate your depression according to the Table below.

<table>
<thead>
<tr>
<th>Total Score</th>
<th>Levels of Depression</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10</td>
<td>These ups and downs are considered normal</td>
</tr>
<tr>
<td>11-16</td>
<td>Mild mood disturbance</td>
</tr>
<tr>
<td>17-20</td>
<td>Borderline clinical depression</td>
</tr>
<tr>
<td>21-30</td>
<td>Moderate depression</td>
</tr>
<tr>
<td>31-40</td>
<td>Severe depression</td>
</tr>
<tr>
<td>over 40</td>
<td>Extreme depression</td>
</tr>
</tbody>
</table>
## B2. Pre-test VAS scale

**YOUR FAVOURITE MUSIC**

Please rate the intensity of physical activation/pleasure intensity and whether association/memories were triggered by the music task by drawing a vertical line.

<table>
<thead>
<tr>
<th>Rate the intensity of your physical activation during this music task (left endpoint: no physical activation – right endpoint: maximum physical activation)</th>
<th>SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rate the pleasure intensity of this music task (left endpoint: no pleasure – right endpoint: maximum pleasure)</th>
<th>SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Were associations (memories, pictures etc.) triggered by this music task? (left endpoint: no associations at all – right endpoint: maximum amount of associations)</th>
<th>SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td></td>
</tr>
</tbody>
</table>
Please rate the **level of relaxation** triggered by each music excerpt (left endpoint: no relaxation – right endpoint: maximum relaxation) by drawing a vertical line.
Please rate the level of stress triggered by each music excerpt (left endpoint: no stress – right endpoint: maximum stress) by drawing a vertical line.
B3. Experimental Music Task VAS Scales

**Experimental music task __**
(15 minutes)

Please rate the amount of relaxation/stress triggered by each experimental music task (left endpoint: no relaxation/stress – right endpoint maximum relaxation/stress), the intensity of physical activation/pleasure intensity, and whether association/memories were triggered by the music task.
References


L. J. Julian, 'Measures of Anxiety: State-Trait Anxiety Inventory (Stai), Beck Anxiety Inventory (Bai), and Hospital Anxiety and Depression Scale-Anxiety (Hads-a)', *Arthritis Care Res (Hoboken)*, 63 Suppl 11 (2011), S467-72.


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