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Craniofacial disorders and headaches. A narrative review

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A B S T R A C T

Objectives: Craniofacial- and headache disorders are common co-morbid disorders. The aim of this review is to provide an overview of the research discussing craniofacial pain, especially temporomandibular disorders, and its relationship and impact on headaches, as well as suggestions for diagnostic assessment tools and physical therapeutic management strategies.
Method: A narrative structured review was performed. A search was conducted in MEDLINE using terms related to craniofacial pain and headaches. Additionally, papers regarding this topic were also extracted from the authors' personal libraries. Any study design (i.e., RCT, observational studies, systematic review, narrative review) that reported the concepts of interest was included, using Covidence. Results were narratively synthesized and described.
Results: From an epidemiological perspective, craniofacial pain and headaches are strongly related and often co-existing. This may be due to the neuroanatomical connection with the trigeminal cervical complex, or due to shared predisposing factors such as age, gender, and psychosocial factors. Pain drawings, questionnaires, and physical tests can be used to determine the cause of pain, as well as other perpetuating factors in patients with headaches and craniofacial pain. The evidence supports different forms of exercise and a combination of hands-on and hands-off strategies aimed at both the craniofacial pain as well as the headache.
Conclusion: Headaches may be caused or aggravated by different disorders in the craniofacial region. Proper use of terminology and classification may help in understanding these complaints. Future research should look into the specific craniofacial areas and how headaches may arise from problems from those regions. (249 words)

1. Introduction

Disorders of the cervical, cranial, and orofacial regions are prevalent and disabling conditions (Ananthan and Benoliel, 2020; Safiri et al., 2020; Saylor and Steiner, 2018). The prevalence of these disorders is increasing as well as their social impact and costs related to their treatment (Breckons et al., 2018, Saylor and Steiner, 2018, Vos et al., 2014). Examples of these disorders are neck pain (NP), headaches, and orofacial pain (including temporomandibular disorders) among others. Most of these disorders could occur concomitantly and overlap to a great extent due to their multiple interactions. The close neuro-anatomical, physiological and functional connections between the brainstem nuclei, the (upper) neck, and the facial structures must be incorporated in the diagnosis and treatment of cervical, cranial, and orofacial disorders (Castien and Hertogh, 2019). Very often, treatment for these disorders is performed concurrently (Kang, 2020) to provide a more comprehensive approach.

Before discussing head, neck, craniofacial, and orofacial disorders and pain, these types of complaints need to be clearly defined. Different terminology is often used in the literature to describe these disorders; however, there is not one single term that can embrace all of them. Most of the time, these terms are described based on the location of the pain (neck pain, craniofacial, orofacial, headache); this is somehow confusing as some of these terms have an anatomical overlap. Craniofacial pain is a collective term used to include several disorders involving the head, facial, and craniocervical areas (Kapur et al., 2003). Headaches are defined as pain primarily above the orbitomeatal and/or nuchal ridge (Olesen, 2018), whilst facial pain is defined as pain occurring mainly or exclusively below the infra-orbitomeatal line, anterior to the pinnae, and above the neck, which includes temporomandibular disorders (International Classification of Orofacial Pain 2020; Ziegeler and May 2020). Neck pain has been defined as "pain located in the anatomic region of the neck (…), with or without radiation to the head, trunk, and upper limbs." (Guzman et al., 2009) They define the anatomic region of the neck as the area between the superior nuchal line, the spines of the scapulae, along the superior border of the clavicles to the suprasternal notch. In the last few years there has been a suggestion to upgrade the anatomical landmark for facial pain upwards to the orbitomeatal line

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(Ananthan and Benoliel, 2020). This anatomical classification is frequently debated in the literature because orofacial pain cannot be separated from established headache forms such as migraine-type and tension-type headaches (TTH). (Ananthan and Benoliel, 2020) Hence, craniofacial pain may be a suitable term to describe these disorders as it combines facial pain with cranial (head) pain. However, in the opinion of the authors, as described above, this term is not specific to the etiology or pathology of the disorders and only provides a general idea of the pain location (See Fig. 1).

Although strict anatomical classifications are somehow impractical due to the great overlap of symptoms in patients, they help to have a common language and standards to be able to diagnose, investigate, and manage these disorders (Ziegeler and May 2020). Therefore, it is important that clinicians and researchers agree on a common terminology.

In recent years, research, especially in the field of physiotherapy, has grown rapidly to justify several treatments targeted at the neck, orofacial region, and also other areas in the treatment of recurrent headaches (in particular, cervicogenic, migraine, tension-type headaches and headaches associated with temporomandibular dysfunction). Therefore, it is important for clinicians to understand the relationship between these disorders to provide a clearer picture on mechanisms, differential diagnosis, and treatments of these conditions, to improve decision making when facing patients with these disorders.

The objective of this manuscript is to provide an overview of the research discussing craniofacial pain, focusing specifically on orofacial pain including temporomandibular disorders (TMD), and their relationship and impact on headaches. This article addresses the following topics: a) Epidemiology of headaches linked to orofacial pain disorders; b) association between orofacial disorders (especially TMD) and headaches c) overview of assessments, such as questionnaires and physical tests, that could aid in the clinical assessment of headache-related complaints linked to orofacial disorders; d) overview of risk and prognostic factors that are associated with orofacial pain headaches; and e) overview of interventions for orofacial disorders, especially TMD that have the potential to alleviate persistent headache complaints.

2. Methods

2.1. Study design

The present study is a narrative review that followed a systematic approach for searching and selecting the evidence.

2.2. Searches

The search strategy was developed by team members in cooperation with a health librarian and included relevant terms related to headaches and craniofacial pain. The search was run in MEDLINE (Ovid MEDLINE (R) ALL databases −1946 to January 11, 2023) up to January 11, 2023; no limits for date or language were applied. In addition, the authors of this manuscript had personal databases of studies looking at this topic; all of these articles were reviewed as well. The investigators' team selected relevant studies, which exemplified the most pertinent information related to headaches and craniofacial pain. The complete list of terms and search strategy for MEDLINE can be found in Appendix 1.

2.3. Inclusion criteria and exclusion criteria

We included any study design (i.e., RCT, observational studies, systematic review, narrative review) that reported the concepts of interest. We favored primary studies that directly investigated the concepts of interest and systematic reviews, that summarized the evidence mainly in adults (>18 years of age). If two studies described similar information, the most updated/complete study was included in this manuscript. Commentaries, letters to editors, protocols, trial registrations, case reports, conference proceedings, as well as studies describing an intervention out of the physical therapy scope were excluded from this review.

2.4. Screening

The study selection was conducted by two independent reviewers following the eligibility criteria established previously. Firstly, studies were assessed by title and abstract, followed by full-text screening where only one reviewer decided inclusion. The Covidence software (www.covidence.org) was used to screen articles for inclusion. In case of disagreements, a consensus meeting was scheduled between the two assessors, when a consensus was not possible, a third reviewer was invited to participate in the consensus and a final decision was made between the three assessors.

2.5. Analysis

All of the information collected by this review was summarized and organized qualitatively following an outline previously defined by the team: (1) background, (2) epidemiology, (3) risk and prognostic factors, (4) association between craniofacial and headaches, (5) comorbidities,

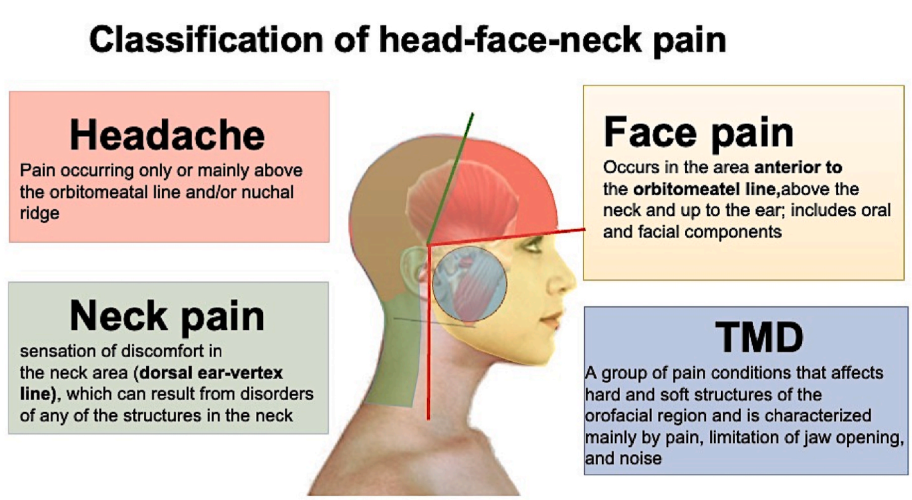

Fig. 1. The international headache Society (IHS) and the international Classification of Orofacial Pain prefer to classify head-face and neck pain in anatomical landmarks.

(6) assessment/tests/differential diagnosis (7) physical therapy interventions (8) other relevant topics. We summarized and narratively synthesized the information provided by studies and presented it using tables and figures in the section below.

3. Results

3.1. Epidemiology

Headache is a common disorder in the general population, where 46% of the adults have an active headache complaint (Stovner and Andree, 2010). Patients with headache often have co-morbidities, including orofacial pain or temporomandibular disorders (TMDs), resulting in a strong association between these two disorders (Reus et al, 2022, Slade et al., 2020, Storm and Wanman, 2006). In patients with a unilateral headache and facial pain who visited a tertiary outpatient neurology clinic, most received a primary headache diagnosis (58%). Interestingly, from the secondary headache, cervicogenic headache was more prevalent (7%) than headache attributed to TMD (2%) (Prakash et al., 2016). This is different in patients from a TMD clinic, where headache attributed to TMD is prevalent in 5% and headache related to neck disorders 2% (Di Paolo et al., 2017, van der Meer et al., 2017). The prevalence of TMD in patients with headache is 56.1% and specifically jaw pain is more common in those with a severe headache or migraine compared to those without a headache (Plesh et al., 2012), but the prevalence of TMD tends to be higher in those with combined migraine and TTH compared to migraine or TTH alone (Ballegaard et al., 2008). Interestingly, painful TMD diagnoses are more common in patients with headache compared to people without headache, where tenderness and myofascial pain are more prevalent than arthralgia (Glaros et al., 2007, Stuginski-Barbosa et al., 2010). More specifically, we see that myogenous painful TMD is more prevalent in patients with migraine compared to those without migraine, with an OR of 5.067 (Nazeri et al., 2018). This suggest a strong association between painful TMDs and migraine, which is confirmed in multiple studies (Fernandes et al., 2013, Franco et al., 2010, Reus et al., 2022, van der Meer et al., 2017).

Inversely, the majority of patients who report symptoms of TMD, also show other clinical signs during clinical examination. Symptoms most commonly reported on the questionnaire included (i) craniofacial- or back pain (96.1%), (ii) headache (79.3%), (iii) temporomandibular joint discomfort or dysfunction (75.0%) and (iv) ear discomfort or dysfunction (82.4%). The headaches were most often in the temple region, followed by the occipital region, then forehead and sinus (Cooper and Kleinberg, 2007). Patients with at least one TMD symptom reported having a headache in 56.5% of the cases, compared to 31.9% in those with no symptoms. The prevalence of headache increased to 65.1% when two TMD symptoms were present and 72.8% when at least three TMD symptoms were present (Goncalves et al., 2010). More specifically, migraine is most prevalent in patients with a (painful) TMD, followed by TTH and headache attributed to TMD (Fernandes et al., 2013; Franco et al., 2010; Reus, Polmann, 2022; van der Meer et al., 2017).

In a large adult population, 4.6% presented with TMD pain, of which 53% had a severe headache or migraine in the last three months (Plesh et al., 2011). So even in a non-clinical setting, migraine and painful TMDs are highly co-morbid.

3.2. Neurophysiological model for the association orofacial pain and headaches

Based on the literature, there is a high level of comorbidity between orofacial pain including TMD, and headaches. Although these two conditions are highly correlated and both can influence each other, the underlying mechanisms for this comorbidity are largely unstudied. This substantial overlap is substantiated on one hand by neurobiological evidence and on the other by the neuroanatomical features, wherein the Trigeminal Cervical Nucleus (TCN) plays a significant role.

One recent systematic review found that the *ESR1* gene was present in both disorders and thus could contribute to this comorbidity (Cruz et al., 2022). The neurological connection of these areas at the level of the trigeminocervical nucleus has been extensively discussed in the literature (Bernstein and Burstein, 2012; Graff-Radford and Abbott, 2016; Teruel and Romero-Reyes, 2022) and might explain why therapies targeted to orofacial pain and TMD or to the neck can be useful for patients with headaches. Although orofacial pain and especially TMD and headaches could have different origins, these conditions are mediated by the same system: the trigeminal system. It has been shown that peripheral sensitization of facial regions could through the trigeminal cervical nucleus produce headaches. (Bernstein and Burstein, 2012; Teruel and Romero-Reyes, 2022). One of the peptides that links TMD and migraine is the α-calcitonin gene-related peptide (CGRP). This neuropeptide is thought to cause migraine as well as being involved in TMD pathogenesis and explain in part this comorbidity. A recent study (Akerman and Romero-Reyes, 2020) looked at the connection between these two entities by the molecular link through the CGRP which drives migraine-like dural-trigeminovascular neuronal activation and sensitization. They found that using a myofascial TMD-like inflammation model using masseteric-complete Freund's adjuvant (CFA), could produce neuronal activation and sensitization of intracranial dural-responsive trigeminal neurons. This could produce an intracranial headache like response and cutaneous facial allodynia, which correlates to what is seen in patients and the current International Classification of Headache Disorders (ICHD) and the International Classification of Orofacial Pain (ICOP).

Neuronal responses at the level of the TCN were prevented by pretreatment with a CGRP receptor antagonist, which supports the notion that CGRP increases neuronal activity at the trigeminal system and has a crucial role as a molecular link between headaches and TMD disorders. Taking this evidence together, this suggest that convergence of extracranial masseteric trigeminal (V3) neuronal projections onto nociceptive intracranial (V1) dural-trigeminovascular neurons exists. This evidence could explain how extracranial input such as pain coming from masticatory muscles (i.e., TMD) or other facial structures (Bičanić et al., 2019, Scrivani and Spierings, 2016) could increase headache symptoms and the association between these two conditions (Akerman and Romero-Reyes, 2020; Teruel and Romero-Reyes, 2022). In addition, patients with TMD present brain changes in pathways responsible for abnormal pain perception, especially the classic trigemino-thalamo-cortical system and the lateral and medial pain systems (Yin et al., 2020). These alterations could explain why subjects with TMD may be more susceptible to other painful conditions linked to the trigeminocervical system, such as headaches.

3.3. Shared predisposing and perpetuating factors

Besides the neurophysiological or neuroanatomical relationship, the high co-morbidity of orofacial pain and headaches can also be explained by the shared predisposing and perpetuating factors. Predisposing factors are risk factors that increase the likelihood of a person developing a problem, whereas perpetuating factors are prognostic factors that maintain a problem once it has developed (Wright et al., 2019).

One clear risk factor for the presence of orofacial pain and headaches is trauma. For example, sportsmen exposed to repetitive craniofacial trauma are at higher risk for craniofacial complaints (Mendoza-Puente et al., 2014). Even though playing a woodwind instrument is associated with TMD pain, this association is not found for headaches. Furthermore, besides playing a woodwind instrument, other factors such as losing interest in playing the instrument or having oral behaviors were also related to TMD pain. Hence, the specific role of playing a musical instrument as a predisposing factor for TMD-pain or headache is still unclear (van Selms et al., 2020).

The onset of complaints is often not clearly related to trauma, so other risk factors have to be taken into consideration. Masticatory muscle pain, psychosomatic complaints, sleeping disorders, age below 50, and female gender are risk factors for frequent headaches in general. In men specifically, tinnitus was a risk factor (Bernhardt et al. 2005). Patients with existing facial pain and/or presence of psychosocial factors such as anxiety and depression are at higher risk of developing post-traumatic headache after whiplash trauma (Obermann et al., 2010). For patients with migraine, the presence of TMD may act as a perpetuating factor and contribute to the chronification of the migraine complaintsHary. (Bevilaqua Grossi et al., 2009, Florencio et al., 2017) Inversely, the presence of (frequent) headache increased the risk of developing TMD. In those who developed TMD, there was an increased risk of worsening of the pre-existing headache complaints (Tchivileva et al., 2017).

Furthermore, the impact of headache is associated with neck disability, jaw disability, and jaw pain intensity in patients with chronic TMD complaints, where a higher impact is related to higher disability and pain intensity (Gil-Martinez et al., 2016). Psychosocial factors such as anxiety and depression are important predisposing factors for both orofacial pain and headaches, as well as the co-morbidity of these complaints. The risk of a co-morbid migraine is nine times higher in those with TMD + depression/anxiety, compared to patients with TMD without psychosocial factors present (Nazeri et al., 2018). Higher levels of different psychosocial factors such as depression, anxiety and pain catastrophizing have been reported in patients with headache or TMD, where patients with both disorders report the highest levels (Cioffi et al., 2014, Dahan et al., 2015, Gil-Martinez et al., 2016, Jerjes et al., 2007, Ostrc et al., 2022, Rantala et al., 2003). The presence of chronic TTH in patients with chronic TMD even increases the risk of higher depression levels, somatization, and pain-related disability, compared to patients with chronic TMD without TTH (Emshoff et al., 2017). Furthermore, the presence of psychosocial factors such as depression and anxiety are related to muscle tenderness in patients with primary headaches. The male gender and having an arthrogenous TMD were found to be protective factors for increased muscle tenderness in this population (Mongini, 2007).

Another important factor to consider as either predisposing or perpetuating factor, is the presence of bruxism. The association between sleep bruxism and painful TMD greatly increased the risk for episodic migraine, episodic TTH, and especially for chronic migraine. Sleep bruxism alone is not associated with the presence of headache (Fernandes et al., 2013). Bruxism is also a confounder in the association between migraine and painful TMD, just as somatic complaints. (van der Meer et al., 2017). This was not the case in those with TTH, showing that bruxism may not be a predisposing factor for TTH (Wagner and Moreira Filho, 2018). This is confirmed in a study where an experimental clenching task did not provoke TTH more than a control task did (Exposto et al., 2019).

In summary, (see also Fig. 2), female gender, the presence of psychosocial factors, and having multiple somatic complaints including headache or orofacial pain, are all predisposing and in some cases perpetuating factors for the presence and chronification of orofacial pain and headache. Possible targets for therapeutic intervention include perceived performance, disability, anxious mood, depressed mood, and catastrophizing. TMD was reported to be less painful, more controllable, and possibly less responsive to reassurance (Jerjes et al., 2007).

3.3.1. *Chronic sinusitis*

Although, not commonly referred in the literature as a possible cause of headache coming from the orofacial region, it is important to give additional attention to chronic sinusitis due to the significant spread of pain in the head, face, and temporomandibular joint (TMJ) area. Sinusitis is a common condition characterized by inflammation of the paranasal sinuses. While it primarily affects the respiratory system, it can also cause headaches and pain in the TMJ region and are often associated with other sinus-related symptoms like facial pain or pressure nasal congestion or obstruction, discolored nasal discharge, post-nasal drip, fever, fatigue, fore throat, and breath and coughing (Kennedy et al., 2013). Sinus headaches are often associated with other types of headaches, such as tension-type headaches and migraines (Patel et al., 2013). The majority of those who self-diagnose themselves as having a sinus headache actually have migraine or an undefined headache based on the IHS criteria (Al-Hashel et al., 2013). Although limited research

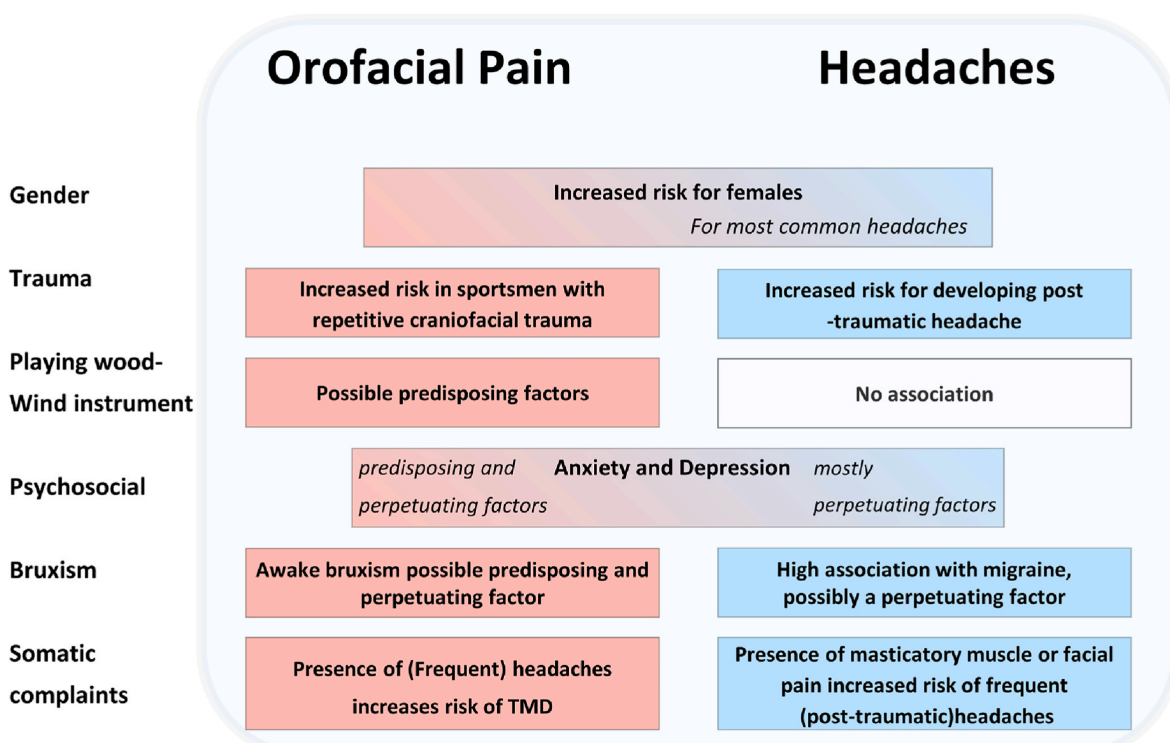

Fig. 2. Shared predisposing and perpetuating factors of orofacial pain and headaches.

has been conducted on the co-occurrence of sinus headaches with other types of headaches and temporomandibular disorders (TMDs) these conditions may also be associated. It has been reported that patients with nasal polyposis may also experience facial pain and/or headaches, which decrease after proper treatment of the nasal polyposis (Nguyen et al., 2016).

4. Assessments

The following text briefly describes the various assessments that are potentially relevant to the detection of headache symptoms in orofacial dysfunction and pain. Tables 1 and 2 show the current questionnaires and physical tests respectively with their clinical applications.

4.1. Pain drawings

Pain drawings in a body chart with a grid template may be useful for visual representation, optimal communication, objective documentation, and support of the diagnosis when looking at headaches and cranio-orofacial disorders. (Barbero et al., 2020). For example, a recent study of 90 patients with TMD showed that pain affected all facial areas and was concentrated on the temporomandibular joint and the masseter origin (Herpel et al., 2023). In addition, those with bilateral pain and those with a greater spatial spread of pain had higher levels of emotional distress, pain chronicity, and somatization, but minor functional impairment. Unilateral reporting of pain was associated with more intra-articular disorders and functional impairments. The study suggests that head and neck pain drawings can be a useful tool for stratifying TMD patients based on their pain extent and localization (Herpel et al., 2023).

4.2. Questionnaires/surveys

After evaluating the patient's pain distribution using a body chart, during the subjective examination, the clinician may choose to administer orofacial/TMD and headache related questionnaires as needed. There are several questionnaires that can be used to determine the diagnosis of TMD and orofacial pain conditions as well as determine their impairments and how these conditions affect daily functioning. Similarly, there are several questionnaires targeted at headaches. An overview of these questionnaires can be found in Table 1.

Based on the literature, we could not identify any questionnaire that can directly indicate headaches related to temporomandibular disorders (TMD). On the other hand, there is some literature that suggests that the presence of TMD increases the impact of headache complaints. For example, a study (Almoznino et al., 2015) examined the relationship between TMD and headache in a group of patients with TMD. They found that the HIT-6 scores were significantly higher in patients with TMD, and headache compared to those with TMD alone, suggesting a greater impact of headache on quality of life in these patients (Almoznino et al., 2015).Another study investigated the impact of TMD on headache-related disability in patients with both TMD and headache. The authors found that TMD-related symptoms, such as pain on jaw movement and jaw locking, were associated with higher HIT-6 scores, indicating a greater impact of TMD on headache-related disability (Speciali and Dach, 2015). Overall, while the HIT-6 may not directly diagnose TMD or its relationship with headache, it can provide valuable information on the impact of headache and TMD on a patient's quality of life and disability.

Another study (Kim and Kim, 2006) has shown that the ID Migraine questionnaire, a screening instrument specifically developed for migraine, can be successfully applied to assess patients with migraine patients who can also have TMD. The study found that patients with migraine and TMD have nausea, photophobia, and headache-related disability with the highest sensitivities and specificities. The conclusion from this study was that the three-item screener was found to be

Table 1
Questionnaires for determining diagnosis/impairments/disability due to TMD and headaches.

Condition	Questionnaire	Application Characteristics
TMD/ Orofacial pain	• *Jaw Functional Limitation Scale:* This sub-scale assesses the degree to which TMD symptoms interfere with jaw function and activities of daily living. (Ohrbach et al., 2008) • *Fonseca Anamnestic Index (FAI)*: The FAI is a self-administered questionnaire that assesses the presence of TMD symptoms and their severity. It consists of 10 questions addressing factors such as pain, joint noises, and limitations in jaw movement. (Yarasca-Berrocal et al., 2022) • *Temporomandibular Index (TMI):* The TMI is a diagnostic tool that evaluates TMD by combining subjective (self-reported) and objective (clinical examination) data. It assesses pain, joint noises, mandibular range of motion, and muscle tenderness (Pehling et al., 2002) • *Oral Health Impact Profile (OHIP):* Though not specific to TMD, the OHIP is a questionnaire to assess the impact of oral health conditions on an individual's quality of life. It can be used to evaluate how TMD symptoms affect a patient's daily functioning, well-being, and overall oral health-related quality of life. (Paśnik-Chwalik and Konopka, 2020) • *The Craniofacial Pain Disability Index (CF-PDI)*: specifically designed to assess the impact of TMD and craniofacial pain on a patient's function and quality of life. The CF-PDI includes items related to physical, emotional, and social functioning, such as eating, speaking, sleeping, mood, and work/school activities. (La Touche et al., 2014) • *TMD Pain Screener:* this brief screening questionnaire is part of the diagnostic criteria for TMD (DC/TMD) questionnaire package and can be used to screen for the presence of a painful TMD. (Gonzalez et al., 2011) This screening questionnaire has a good diagnostic accuracy in the general population, TMD population, and headache population. (Gonzalez et al., 2011, van der Meer et al., 2021),	• Quick and easy to administer. • Comprehensive but a limited scope (function of the TMJ) • Easily administered during a routine patient visit. • Relies heavily on subjective information provided by the patient. • Testing the severity of TMD but does not diagnosing certain types of TMDs or in identifying underlying causes of the condition. • It helps identify specific areas of dysfunction, like arthrogenic and myogenic aspects which can guide treatment planning. • Requires specialized training and equipment to administer. • May help identify specific areas of concern for the patient, which can guide treatment planning and improve patient satisfaction (patient centered) • It relies heavily on self-reported information provided by the patient. • Because it identifies specific areas of disability in craniofacial pain, it supports treatment planning and monitoring of treatment outcomes. • Relies on subjective information provided by the patient, which can be influenced by factors such as mood, personality, and cultural background. • Simple and efficient way to identify painful TMDs. • It is a screening tool based on self-reported information
Headaches	*Headache dominance.* There are several questionnaires that are commonly used to assess headaches, and the most accurate ones can vary depending on the specific	• Give a comprehensive overview of the impact of migraine headaches on a patient's life.

(*continued on next page*)

Table 1 (*continued*)

Condition	Questionnaire	Application Characteristics
	population being studied and the type of headache being assessed. Here are five commonly used headache questionnaires. • *Migraine Disability Assessment (MIDAS):* The MIDAS questionnaire assesses the impact of migraine on daily activities and functioning, and has been shown to have good reliability and validity (Stewart et al., 2001) • *Headache Impact Test (HIT-6)*: It is six-item questionnaire that measures various aspects of headache-related disability and has been shown to have good reliability and validity in various populations. (Kosinski et al., 2003) • *Migraine-Specific Quality of Life Questionnaire (MSQ):* The MSQ assesses the impact of migraine on a patient's quality of life in three domains: pain, physical and emotional functioning. It has been validated in multiple languages and has a good reliability and validity. (Martin et al., 2000) • *Headache Disability Inventory (HDI):* The HDI assesses the impact of headache on daily activities, social interactions, work activities and emotional well-being. It has been shown to have good reliability and validity in multiple studies. (Jacobson et al., 1994) • *ID migraine headaches;* It consists of three questions that ask about the presence of nausea, sensitivity to light, and headache-related disability, (Kim and Kim, 2006) and is the questionnaire with highest level of evidence specifically for migraine. (van der Meer et al., 2019)	• Assesses disability but does not pain intensity or associated symptoms. • Assesses the impact of headaches on daily life, including pain intensity, social functioning, cognitive functioning, and emotional well-being. • Self-reported questionnaire • Give an impression of the impact on daily activities, and the effect on social relationships. • May be a guide for treatment planning and reassessment. • Self-reported questionnaire • See also MSQ • Simple, quick, and easy-to-use valid tool that can be used in clinical practice and research. • Self-reporting screening stool and cannot provide a definitive diagnosis of migraine.
Neuropathic pain	• *LANSS questionnaire;* The Leeds Assessment of Neuropathic Symptoms and Signs (LANSS) questionnaire is a tool used to screen for neuropathic pain, which is pain caused by damage or dysfunction of the nervous system. It consists of five symptom questions and two examination questions, which aim to distinguish between neuropathic and non-neuropathic pain. (Bennett et al., 2007) • *PainDETECT; A* nine-question screening tool used to identify neuropathic pain in patients with chronic pain conditions and has been validated in multiple languages and cultural settings. (Freynhagen et al., 2016)	• Relatively simple and quick to administer (less than 5 min) • Screening tool and self-reported • It may support the diagnosis of cranio-neuropathic pain with other diagnostic tests. (Von Piekartz and Hall, 2018) • Tool for daily practice and research as for screening of neuropathic/nerve trunk pain • Self-reporting. Should be used in conjunction with other clinical/diagnostic tests.

relatively efficient in detecting migraine headaches in patients with TMD and orofacial pain (Kim and Kim, 2006).

In addition to the above-mentioned questionnaires, subjects with orofacial conditions can present neural tissue disorders in the head-neck and face pain region. These disorders can be subclassified into Neuropathic Pain with Sensory Hypersensitivity (NPSH), Compression Neuropathy (CN) (Von Piekartz and Hall, 2018). Peripheral Nerve Sensitization (PNS), and Musculoskeletal Pain (MP). Self-reported screening tools like the LANSS questionnaire and the Pain DETECT can help identify a neuropathic/neurogenic (trunk) pain component (Bennett et al., 2007, Freynhagen et al., 2016) in these conditions. Please see Table 1, describing these questionnaires.

5. Physical tests

Physical tests are commonly conducted by clinicians to determine which structures or tissues could be related to the condition of interest. In the case of orofacial and TMDs, the diagnostic test battery proposed by the DC/TMD is primarily focused on the diagnosis and assessment of temporomandibular disorders (TMD), orofacial pain, and jaw disorders. While headaches may be a symptom associated with these conditions, the DC/TMD was not specifically designed or validated as a diagnostic tool for headaches except for headaches attributed to TMD and is not well established in the literature (Schiffman et al., 2012). Other assessment tools like the nature of pain (quality, intensity, behavior and localization) and questionnaires as mentioned above, such as the HIT-6 or CF- PDI, may support the role of orofacial dysfunction in headaches. However, despite its usefulness to guide clinicians and musculoskeletal experts in sub-classifying clinical groups, the DC/TMD has some limitations in evaluating these conditions, as reported by 84% of experts from 11 countries in a recent Delphi study on TMD assessment (von Piekartz et al., 2020). For instance, neurogenic TMD and subtle orofacial motor control dysfunction are not included as a clinical sub-classification in the DC/TMD model currently used in dentistry. In the same study, experts reported using DC/TMD screening tools in combination with other clinical tests to gain more information about the relationship between tissue-related dysfunction, pain mechanisms, and to inform treatment for these patients (23% of respondents).

Table 1 describes some useful physical tests that can be used to evaluate and demonstrate whether craniofacial structures may be associated with headache symptoms. These tests can be targeted to the TMJ specifically, but also to muscles and structures surrounding the joint. In addition, other tests used to determine neurological involvement and whether sinus structures could be related to headaches can be used (see Fig. 3). Table 2 highlights the objectives, ways of administering these tests and relevant evidence supporting them.

6. Management

The management of orofacial pain conditions, specifically TMD has evolved through the years and has been fed by the growing evidence in the field in the last decades (Armijo-Olivo et al. , 2018). A few decades ago, the treatment of orofacial pain conditions was localized and focused only on structures of the TMJ and surrounded areas. Through the years, and the evolution of evidence-based practice in physical therapy decisions, the management of these disorders has been broader, including therapies targeted to the head, neck, and the whole craniomandibular system (including the thoracic spine) as well as therapies that go beyond the simplistic approach of these disorders. For example, therapies like general and global aerobic exercises, other forms of exercises that modify visual feedback (Don et al., 2017), strategies to train the brain (La Touche et al., 2020b, Suso-Marti et al., 2020), motivational interviews, mindfulness-based stress management, and cognitive behavioural therapy (CBT) have been used to manage these conditions. Due to the complexity of this condition, the management of TMD, and especially chronic TMD has been interdisciplinary. According to the

Table 2
Commonly used physical tests to determine whether orofacial structures are related to headache sign and symptoms.

Test Name	Objective	Evidence	Clinical Application
Masticatory system			
Physiological Movements	• Assessing the range, pain, and quality of active physiological movements, including mouth opening, lateral deviation, retrusion, and protrusion, with overpressure as needed, can provide important information about the pathobiological mechanism of pain and tissue involvement. (von Piekartz, 2007)	• Clustering of relevant musculoskeletal tests related to the subjective examination and multi-test scores (combination of several pain-related variables) increases the diagnostic value. (Steenks et al., 2007, von Piekartz et al., 2016)	• Standardisation of the head is important due to different outcome physiological range and sensory response (La Touche et al., 2011) • A standardisation which is easy to perform is the Upright Posture Position of the Mandibula. (von Piekartz, 2007)
Dynamic/static tests	• Within the field of physical therapy, dynamic and static tests are often used for pain provocation purposes. For TMD, the static and dynamic tests can be used to gain information on the presence and location of masticatory pain. (Schiffman et al., 2014)	• Dynamic/static tests have acceptable validity for diagnosing a painful TMD. (Visscher et al., 2009) • Diagnostic tests for TMD-pain diagnoses (i.e., palpation and dynamic/static testing) are negatively influenced by the presence of comorbidity like depression and somatization. This influence is decreased when the presence of familiar pain is used as outcome measure. (Koutris et al., 2013)	• The tests may be executed in all physiological directions of movement, such as mouth opening, left and right lateral deviation, re-and propulsion. • During static testing, the patient is instructed to keep the mandible motionless while the therapist gradually increased manual counterpressure until either the patient or the examiner reached maximum effort. • During dynamic testing, the patient performs movements while the therapist applies manual counterpressure to the movement. (Schiffman et al., 2014)
Accessory movement	• The evaluation of accessory movements, such as longitudinal caudal, cranial, medial, and lateral transverse, anteroposterior, and posterior-anterior movements. • The primary aim is to analyze resistance, spasm, and sensory responses, such as pain, dizziness, and tinnitus and can help identify clinical patterns of arthrogenic, myogenic, mixed TMD, and cranial neuropathies. (Banks and Hengeveld, 2014; von Piekartz, 2007)	• However, the reliability and validity of end feel of separate accessory movements is poor, even when used as a multi-test battery. (Lobbezoo-Scholte et al. , 1994, Steenks et al., 2007)	• It is advisable to analyze the ratio of the six ranges of accessory movements that will cluster with the findings of active movements and palpation to evaluate the dominant structure that may be involved (arthrogenic, myogenic, neurogenic or combinations) and the pathobiological mechanism of pain and tissue involvement) (Fernández-de-las-Peñas et al., 2018)
Palpation(joint)	• Palpation of the TMJ Identify which structures are primarily involved and confirm clinical findings. However, due to the small surface area and numerous structures in the TMJ, palpation can be challenging.	• The optimal pressure for identifying joint structures with good accuracy is 1.4 kg/cm2, which can differentiate between TMD and non-TMD cases. (Camacho et al., 2014) • Rocabado's Pain Map as a palpation strategy for patients with TMD, which tests for pain and eight structures within a 2 cm2 area, is reproducible and reliable in the synovial and ligamentous zones, but not effective in differentiating between hypermobility and hypomobility of the TMJ. (Espinoza et al., 2023)	• By increasing local sensitivity and reproducing TMJ symptoms or headaches, the joint is more likely to be the source of the complaint. (Osiewicz et al., 2018)
Palpation(muscle)	• Masticatory muscle palpation mosty performed either provoke pain complaints, or to determine the pain threshold. (Schiffman et al., 2014) • This may give indication of the anatomical structures involved. • in the perceived pain, and the palpation should be done in a standardized manner (intensity and duration of pressure during palpation) • The execution of the muscle palpation can be done with a pressure algometer or with the fingertips, both procedures have shown excellent inter-rater reliability. (Bernhardt et al., 2007)	• It has a high inter-rater reliability during structural differentiation within painful tissue. (Espinoza et al., 2023) • During palpation, the presence of regional pain, widespread pain, and somatization have negatively influenced the results of pain provocation palpation tests. (Koutris et al., 2013) • Subjects with myogenous TMD during migraine have reduced lower pressure pain thresholds of the masticatory muscles. (Gil-Martinez et al., 2016) • Bilateral lower pressure pain thresholds of the temporalis muscle are associated with the migraine headache in patients with (out) craniofacial pain. (Costa et al., 2015) • Using an algometer, the normal pressure pain threshold (PPT) of the masticatory muscles in healthy subjects has been estimated to be approximately 1.5–2.0 kg/cm2 (extra-oral) and 1 kg/cm2 (intra-oral).	• Palpation to determine the pain threshold may give the clinician input on peripheral or central sensitization. Reduction of pain thresholds (manual or with algometer) on the masticatory muscles may be associated with headaches like migraine. (Schiffman et al., 2014)
Total Tenderness Score	• The Total Tenderness Score (TTS) assesses the tenderness of areas in the craniofacial region where the discomfort of the patient during palpation is assessed (Almoznino et al., 2019)	• Patients with TMD and/or TTH have higher tenderness scores. (Benoliel and Sharav, 2009)	• Eight myofascial structures are being palpated bilaterally: m. masseter, m.pterygoideus lateralis, m. temporalis, m.frontalis, processus mastoideus, m.sternocleidomastaideus, m.trapezius and the base of the skull. • With two or three fingers, structures are palpated in a circular movement for 2–5 s. Patients are asked about their level of discomfort from 0 to 3 (none, light, moderate, or severe).

(*continued on next page*)

Table 2 (*continued*)

Test Name	Objective	Evidence	Clinical Application
			• The total score is calculated by adding the score per structure.
Cranial nervous system (Trigeminal nerve dominance)			
Quantitative sensory testing (QST)	• Quantitative sensory testing (QST) is a diagnostic tool that can assess the sensory function of the nervous system. It involves measuring an individual's response to different stimuli, such as heat, cold, and pressure, and can provide objective data about sensory thresholds, pain tolerance, and pain sensitivity. (Lang et al., 2005)	• Its ability to differentiate between craniofacial pain, TMD, and headache may be limited. • QST was able to differentiate between TMD and craniofacial pain, but not between TMD and headache. (Greenspan et al., 2020)	• Optimal implementation of the QST requires high-quality precious devices and is for daily practice time-consuming.
Bedside Testing of craniofacial sensory function	• Clinical Cluster of tests including pinprick, brush, temperature, vibration, pressure tests • A quick and non-invasive clinical test that can serve as a viable substitute for QST.	• A quick and non-invasive clinical test that evaluates the sensory function of the nervous system can serve as a viable substitute for Quantitative Sensory Testing (QST) in assessing face pain. (Fernández-de-las-Peñas et al., 2018) • This test is considered to be a valid method for assessing sensory function. However, the sensitivity and specificity of each test can vary, and false positives or false negatives are possible. Therefore, it is important that the clinician use a combination of bedside tests and other clinical assessments as described in a recent article. (Koulouris et al., 2020)	• Easy to administer, efficient, cost-effective, and can be performed in any clinical setting, ensuring good accessibility for patients. (Gierthmühlen and Baron, 2016)
Neurodynamic testing	• To challenge nerve mechano-sensitivity in a patient with cranial Peripheral Nerve Sensitivity (PNS) (Von Piekartz and Hall, 2018) • This test involves a specific sequence of movements that mainly focuses on the nerve trunk anatomy. (Nee and Butler, 2006) • The main cranial nerves which may be related with headache and orofacial are Trigeminal(V) and facial (VII) nerve. (von Piekartz, 2007)	• Actual external evidence is lacking. A case study supports the existence of a PNS pattern during persistent facial. pain. (Geerse and von Piekartz, 2015)	• Increased mechano-sensitivity of neurodynamic testing and nerve palpation of the Auriculotemporal as well as the Zygoma, temporal branches of the facial Nerve (VIII), and branches of the maxillary (V2) and Ophthalmic Nerve (V1) may be linked in with ongoing headache.
Nerve palpation	• During palpation, increased pain provocation and changes in consistency may be associated with abnormal mechanical stress and chemical stimuli within the nerve trunk (Nee and Butler 2006).	• Actual external evidence is lacking. A case study supports the existence of a PNS pattern during persistent facial pain. (Geerse and von Piekartz, 2015)	• The superficial branches of the facial (VII) and the trigeminal nerve(V) are potentially palpable, and the "twanging" technique is suggested as appropriate for the palpation of cranial nerves. (von Piekartz, 2007) • Palpation of the branches of the cranial nerves in headache as described in the paragraph Neurodynamic tests maybe appropriate.
Maxillofacial complex			
Passive accessory movements	• Accessory movement on facial bones is based on the mechanostat mechanism were mechanical stress and strain within the body can lead to tissue adaptation and remodeling, as well as changes in tissue function and pain sensitive structures like the dura mater. (Schueler et al., 2014)	• The concept of accessory movement in facial bones is linked to the mechanostat mechanism, which suggests that mechanical stress and strain in the body can result in tissue adaptation, remodeling, and changes in pain sensitivity and function. (Pivonka et al., 2018)	• Three parameters can be assessed: resistance, rebound (return of the tissue to its original position after compression or stretching) and sensory response of the patient. (Hanskamp et al., 2019, Méndez-Sánchez et al., 2012) (Fig. 3)
Percussion test	• Gentle tap on the maxillary bone, usually in a slight cervical flexion. During an increase sensitivity (localized or projected into other regions (such as TMJ of the head) the test is positive (Van Duijn et al., 1992)	• Percussion, palpation may be also sensitive during chronic sinusitis, odontogenic infection, and after (face) traumas. (Cohenca et al., 2007)	• This test can be used in conjunction with the other tests of the maxillofacial complex, hypothesizing the pain may be associated with this region.
Valsalva maneuver	• Forcefully exhaling against a closed airway, such as by pinching the nose and closing the mouth while trying to breathe out. This creates pressure changes in the sinuses and eustachian tube and can cause pain or discomfort in patients with maxillofaxial sensitivity. (Tarabichi and Najmi, 2015)	• High sensitivity by dysfunctions of airspaces in the face like sinuses and eustachian tube. (Tarabichi and Najmi, 2015)	• See percussion.

American Academy of Orofacial pain (Leeuw and Klasser, 2019), evidence-based treatments for patients with orofacial pain include several procedures including physical therapy (PT) in all forms (e.g., manual therapy, exercises), patient education and self-management, behavioural therapy, pharmacologic management, orthopaedic appliance therapy, dental and occlusal therapy, and surgery among others.

Within all approaches to manage TMD, PT has been recognized as one of the most common and helpful treatments to help patients with this condition due to its effectiveness, low cost, and minimal side effects. (Armijo-Olivo, Bizetti Pelai, 2018) Several physical therapy treatment strategies can be used to manage orofacial pain, and especially TMD, such as manual therapy (MT), exercises (Barbosa et al., 2019), thermotherapy (Xu et al., 2018), acupuncture (Fernandes et al., 2017), phototherapy (Al-Quisi et al., 2019, de Pedro et al., 2019),

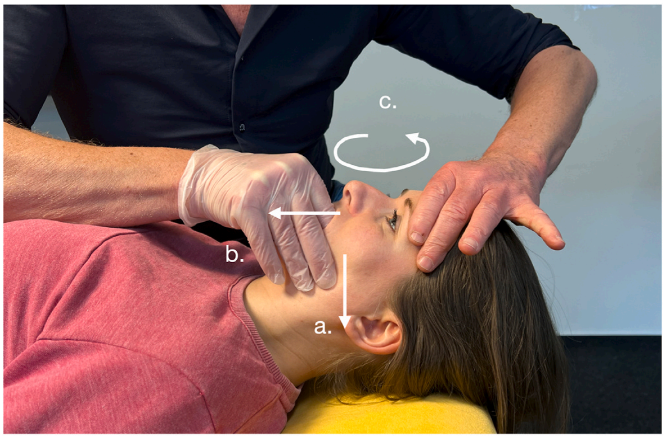

Fig. 3. Example of assessment of maxilla dysfunction (resistance, rebound quality) and sensory response such as temporomandibular and/or head pain by accessory movements such as anterior-posterior (a), longitudinal caudal (b) and rotation around the sagittal plane (c).

electrotherapy (Chipaila et al., 2014), biofeedback (Watanabe et al., 2011) among others. The type of modality used from the PT spectrum to treat orofacial pain will depend on the etiology of the dysfunction and the specialist's expertise (Badel et al., 2019). In the last few decades, the production of systematic reviews looking at the effectiveness of different physical therapy treatments to manage TMD has grown rapidly. It has been found that at least 19 systematic reviews (Armijo-Olivo et al., 2016, Asquini et al., 2022, Brantingham et al., 2013, Butts et al., 2017, Calixtre et al., 2015, de Castro et al., 2017, de Melo et al., 2020, Ferrillo et al., 2022, Idáñez-Robles et al., 2023, La Touche et al., 2020a, La Touche et al., 2022, La Touche et al., 2020c, Lee et al., 2023, Martins et al., 2016, McNeely et al., 2006, Medlicott and Harris, 2006, Melis et al., 2019, Paco et al., 2016, Tournavitis et al., 2023, van der Meer et al., 2020, Zhang et al., 2021) have investigated any form of PT to manage this condition. Within the most used therapies, manual therapy and exercises have been the most popular and effective according to several reviews (Armijo-Olivo et al., 2018, Armijo-Olivo et al., 2016, Brantingham et al., 2013, Butts et al., 2017, Calixtre et al., 2015, Cunha et al., 2016, de Castro, da Silva, 2017, La Touche, Boo-Mallo, 2020a, La Touche, Martinez Garcia, 2020c, Martins et al., 2016, Paco et al., 2016, van der Meer et al., 2020).

When looking specifically at which therapies could be effective to target headache in patients with TMD or other cranial facial structures the evidence is more restrictive. From all the reviews investigated, only one review (van der Meer et al., 2020) looked specifically at headache outcomes. In fact, another recent review (Ooi et al., 2022) highlighted that headache outcomes are not very commonly evaluated and reported in trials involving patients with TMD. The review by Van deer Meer et al. (van der Meer et al., 2020), identified five studies (Costa et al., 2015, Maluf et al., 2010, Michelotti et al. , 2012, Michelotti et al., 2004, von Piekartz and Hall, 2013) looking at the effectiveness of physical therapy interventions to reduce headache outcomes, especially headache intensity. Therapies used by these studies were diverse; counselling and exercise, static and global stretching, and orofacial and manual therapy. The limited number of studies plus their diversity made pooling of the studies challenging.

When looking at the effect of overall physical therapy on headache intensity compared with other therapies, it can be observed that PT could be beneficial to reduce headache intensity. Effect sizes within groups for PT ranged from 0.02 to 9.99, and most of the studies had moderate to high effect sizes (standardized mean differences [SMD]-Cohen "d") (Fig. 4). However, PT in general was not superior to other therapies such as counselling/education or splint therapy (van der Meer et al., 2020).

When looking at the combined effect of counselling plus exercise versus counselling alone to reduce headache intensity (Michelotti et al., 2004), a moderate effect (SMD: 0.40 [−0.17, 0.96]) in favour of the combined therapy was obtained, indicating that the added value of exercise therapy to counselling for decreasing headache intensity was relevant (Fig. 5; 1.1.1). However, when counselling and exercises were compared to splint therapy (Costa et al., 2015, Michelotti, Iodice, 2012), mixed results were found. For example Michelotti et al. (2012) found no positive effect either by exercise plus education (SMD: 0.02 [95%CI: 0.60, 0.56]) or splint therapy (SMD: 0.01 [95%CI: 0.44, 0.46]) for reducing headache intensity after the treatment (Fig. 4), but Costa et al. (Costa et al., 2015), found that both therapies were effective in reducing headache intensity. Both therapies had large effect sizes; counselling plus exercise had a SMD: 1.34 [95%CI: 0.78, 1.90] and splint had SMD:1.59 [95%CI 1.01, 2.18] (Fig. 4) demonstrating a positive effect for managing headache intensity. However, no significant difference was obtained between these therapies, showing a very small between groups effect (SMD: 0.10 [95%CI: 0.49, 0.28]) (Fig. 5; 1.1.2). Thus, clinicians could use both therapies to manage headache intensity in these patients.

Another study included in this review looked at exercises for the upper quarter in the form of static stretching, cervical spine, upper limbs, and mandibular muscles when compared with global posture alone. These two physical therapy treatments demonstrated positive effects and high effect sizes on their own to reduce headache intensity (SMD: 2.46 [95%CI: 1.36, 3.57] for stretching and SMD: 1.18 [0.30, 2.06] for global postural re-education respectively; Fig. 4) being stretching of the upper quarter better than global postural re-education based on the magnitude of the effect and the 95% CIs (SDM:0.79 [95% CI: 0.05, 1.62]; p = 0.06; Fig. 5; 1.1.4).

	Before			After				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Michelotti et al., 2012_Exercise plus counseling	33.3	19.6	23	33.7	19.2	23		-0.02 [-0.60, 0.56]
Michelotti et al., 2012_Splint	33.9	21.1	21	33.7	33.7	192		0.01 [-0.44, 0.46]
Michelotti et al., 2004_Education alone	13.3	19.7	23	12.1	17	23		0.06 [-0.51, 0.64]
Von Piekartz et al., 2013_Neck manual therapy	7.1	1.1	21	6.7	1.2	22		0.34 [-0.26, 0.94]
Calixtre et al., 2018_Waiting_list	62.5	6.1	29	60	6.6	29		0.39 [-0.13, 0.91]
Micchelotti et al., 2004_Exercise plus counseling	26.1	29.7	26	11.2	17.4	26		0.60 [0.05, 1.16]
Garrigos-Pedron, 2018_cervical_alone_Tx	66.59	6.05	22	62.23	6.23	22		0.70 [0.09, 1.31]
Garrigos-Pedron, 2018_cervical_plus_OF	65.52	3.69	23	60.87	6.68	23		0.85 [0.24, 1.45]
Moleirinho-Alves, 2021_Aerobic_Ex	5.53	1.12	15	3.33	2.554	15		1.09 [0.31, 1.86]
Maluf et al., 2010_Global_posture_reeducation	73.5	26.2	12	39.2	29.8	12		1.18 [0.30, 2.06]
Calixtre et al., 2018_Cervical MT + motor control	61.4	6	29	52.1	8.5	29		1.25 [0.68, 1.81]
Costa el tal., 2015 Counseling plus exercises	7.6	2.2	30	4.4	2.5	30		1.34 [0.78, 1.90]
Costa et al., 2015_Counseling plus splint	6.5	1.6	30	3.4	2.2	30		1.59 [1.01, 2.18]
Von Piekartz et al., 2013_Orofacial plus cervical	7.4	1.1	22	3.5	2	22		2.37 [1.59, 3.16]
Maluf et al., 2010_Exercises_Upper_Quarter	65.7	21.7	12	16.4	16.6	12		2.46 [1.36, 3.57]
Moleirinho-Alves, 2021_Str+MT	5.53	1.68	15	0.33	0.724	15		3.91 [2.63, 5.19]
Moleirinho-Alves, 2021_AE+Str+MT	6	0.826	15	0	0.01	15		9.99 [7.19, 12.80]

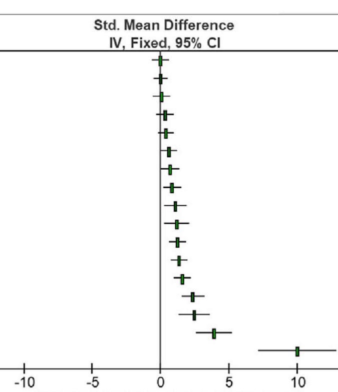

Fig. 4. Effect sizes (standardized mean differences) for different PT interventions on headache Intensity (before and after interventions) in patients with TMD and associated headache. Tx: treatment; OF: Orofacial; EX: exercise; MT: manual therapy; Str: strength exercise; AE: Aerobic exercise.

Study or Subgroup	Therapy of interest Mean	SD	Total	Comparator Mean	SD	Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
1.1.1 Counseling/education plus exercise vs. education/counseling plus splint/splint alone								
Costa et al., 2015	1.34	1.4997	30	1.59	1.5533	30	39.5%	-0.16 [-0.67, 0.35]
Michelotti et al., 2004	0.6	1.3617	26	0.06	1.3181	23	31.6%	0.40 [-0.17, 0.96]
Michelotti et al., 2012	-0.02	1.3413	23	0.01	0.9886	21	29.0%	-0.02 [-0.62, 0.57]
Subtotal (95% CI)			**79**			**74**	**100.0%**	**0.05 [-0.26, 0.37]**
Heterogeneity: Chi² = 2.16, df = 2 (P = 0.34); I² = 7%								
Test for overall effect: Z = 0.33 (P = 0.74)								
1.1.2 Counseling/education plus exercise vs. splint alone /splint plus counseling								
Costa et al., 2015	1.34	1.4997	30	1.59	1.5533	30	57.7%	-0.16 [-0.67, 0.35]
Michelotti et al., 2012	-0.02	1.3413	23	0.01	0.9886	21	42.3%	-0.02 [-0.62, 0.57]
Subtotal (95% CI)			**53**			**51**	**100.0%**	**-0.10 [-0.49, 0.28]**
Heterogeneity: Chi² = 0.12, df = 1 (P = 0.73); I² = 0%								
Test for overall effect: Z = 0.53 (P = 0.60)								
1.1.3 Education plus exercises vs. education alone								
Michelotti et al., 2004	0.6	1.3617	26	0.06	1.3181	23	100.0%	0.40 [-0.17, 0.96]
Subtotal (95% CI)			**26**			**23**	**100.0%**	**0.40 [-0.17, 0.96]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 1.37 (P = 0.17)								
1.1.4 Stretching upper quarter vs. global postural re-education								
Maluf et al., 2010	2.46	1.7313	12	1.18	1.385	12	100.0%	0.79 [-0.05, 1.62]
Subtotal (95% CI)			**12**			**12**	**100.0%**	**0.79 [-0.05, 1.62]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 1.85 (P = 0.06)								
1.1.5 orofacial exercises plus cervical MT vs. cervical MT alone								
Von Piekartz et al., 2013	2.37	1.7592	22	0.34	1.3181	21	100.0%	1.28 [0.62, 1.94]
Subtotal (95% CI)			**22**			**21**	**100.0%**	**1.28 [0.62, 1.94]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 3.78 (P = 0.0002)								
1.1.6 Aerobic exercise vs Str Ex plus MT								
Moleirinho-Alves 2021(a)	-3.58	1.26	7	-1.32	1.29	7	48.5%	-1.66 [-2.93, -0.39]
Moleirinho-Alves 2021(c)	-3.3	1.5	8	-0.3	1.5	8	51.5%	-1.89 [-3.13, -0.65]
Subtotal (95% CI)			**15**			**15**	**100.0%**	**-1.78 [-2.67, -0.89]**
Heterogeneity: Chi² = 0.07, df = 1 (P = 0.80); I² = 0%								
Test for overall effect: Z = 3.93 (P < 0.0001)								
1.1.7 Aerobic vs. Str Ex plus MT plus Aerobic								
Moleirinho-Alves 2021(a)	-3.58	1.26	7	-1.05	1.29	7	48.9%	-1.86 [-3.18, -0.53]
Moleirinho-Alves 2021(c)	-3.3	1.5	8	0	1.44	8	51.1%	-2.12 [-3.42, -0.83]
Subtotal (95% CI)			**15**			**15**	**100.0%**	**-1.99 [-2.92, -1.07]**
Heterogeneity: Chi² = 0.08, df = 1 (P = 0.78); I² = 0%								
Test for overall effect: Z = 4.22 (P < 0.0001)								
1.1.8 Aerobic plus Str Ex plus MT vs. Str Ex plus MT								
Moleirinho-Alves 2021(a)	-1.05	1.29	7	-1.32	1.29	7	46.7%	0.20 [-0.86, 1.25]
Moleirinho-Alves 2021(c)	0	1.44	8	-0.3	1.5	8	53.3%	0.19 [-0.79, 1.18]
Subtotal (95% CI)			**15**			**15**	**100.0%**	**0.19 [-0.52, 0.91]**
Heterogeneity: Chi² = 0.00, df = 1 (P = 1.00); I² = 0%								
Test for overall effect: Z = 0.53 (P = 0.60)								

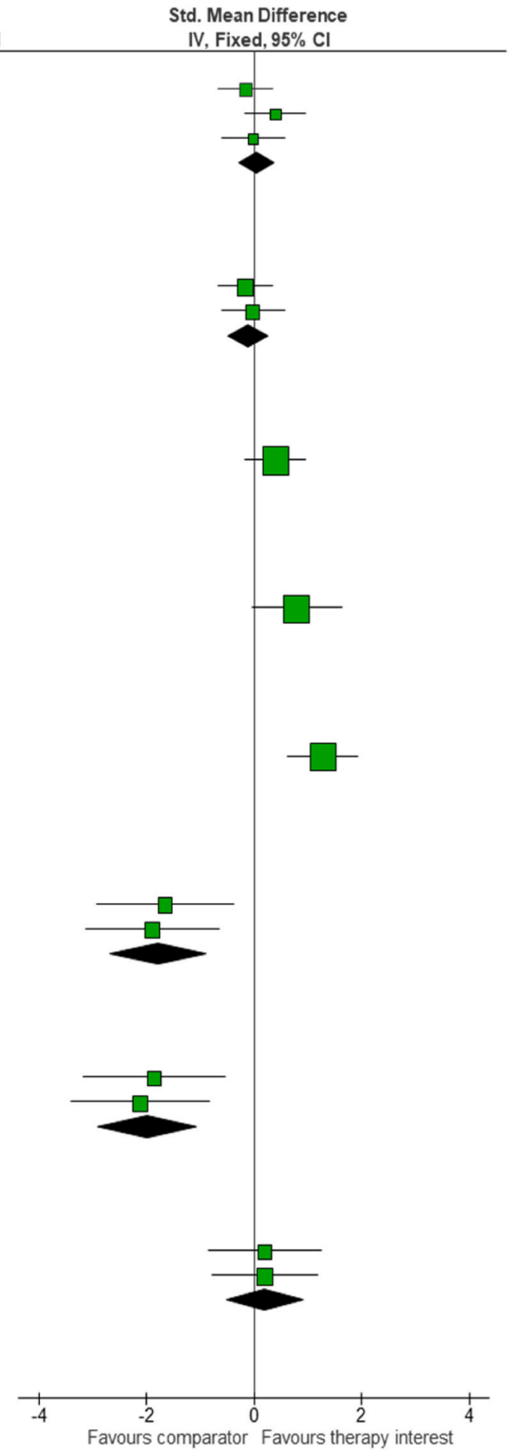

Fig. 5. Effect sizes (standardized mean differences) for different PT interventions when compared with other therapies on headache intensity in patients with TMD and associated headache. Tx: treatment; OF: Orofacial; EX: exercise; MT: manual therapy; Str: strength exercise; AE: Aerobic exercise.

Another type of approach that has been implemented in the last years for the management of orofacial pain and especially TMD is the combination between techniques applied to the orofacial plus neck therapies. In this regard, one study (von Piekartz and Hall, 2013) evaluated the effect of a combined treatment, targeted to both areas (orofacial exercises plus neck manual therapy) contrasted to manual therapy targeted to the cervical spine in subjects with cervicogenic headache and symptoms of TMD. The combined therapy had a very large effect on reducing headache intensity in these subjects (SMD: 2.37 [95%CI: 1.59, 3.16]; Fig. 4). However, manual therapy techniques targeted to the neck alone did not have an important effect, only a small-moderate effect was seen after this therapy (SMD:0.34 [95%CI: 0.26, 0.94]; Fig. 4). The between effect between these two therapies favored the combined treatment with a large effect (SMD: 1.28 [95%CI: 0.62, 1.94]; Fig. 5; 1.1.5). Similarly, Calixtre et al. (Calixtre et al., 2020, Calixtre et al., 2019), found that therapies targeted to the neck in the form of manual therapy and motor control exercises for the deep neck flexors improved the impact of headache (measured with the HIT-6) in patients with TMD (Fig. 6). In addition, this study (Calixtre et al., 2020) found that the minimal important difference to differentiate subjects with moderate

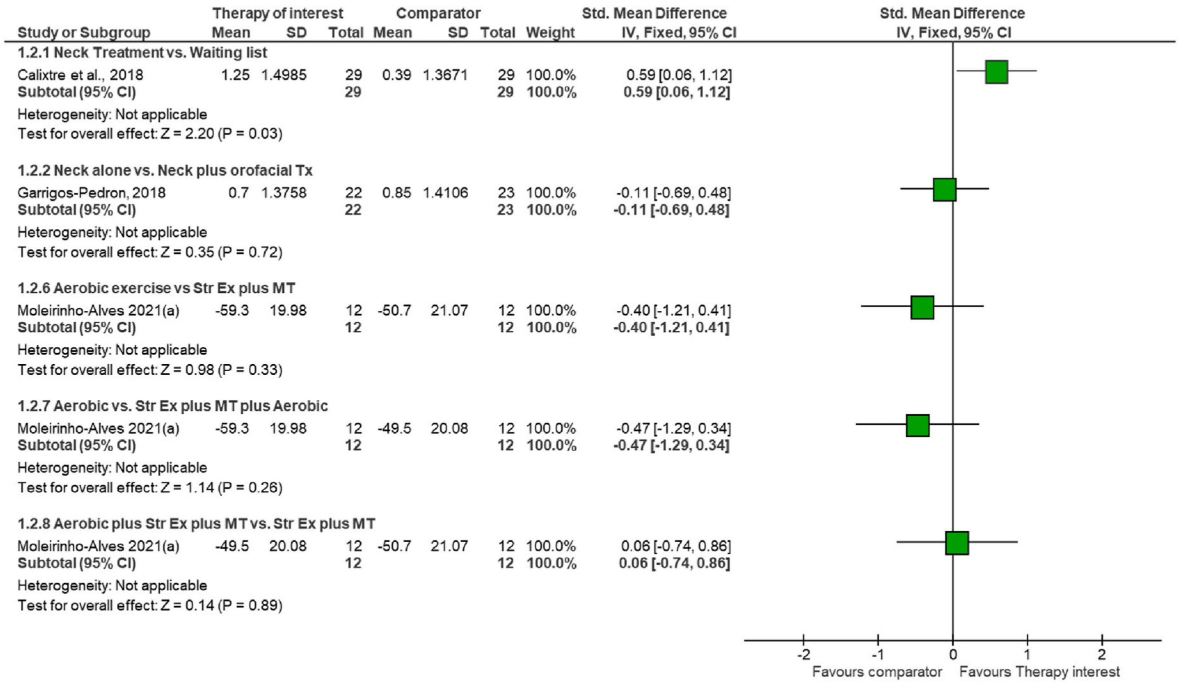

Fig. 6. Effect sizes (standardized mean differences) for different PT interventions when compared with other therapies on HIT-6 outcome in patients with TMD and associated headache. Tx: treatment; OF: Orofacial; EX: exercise; MT: manual therapy; Str: strength exercise; AE: Aerobic exercise.

and large improvement on HIT-6 outcomes after the therapy were 3 and 6.26 points respectively (Fig. 6 HIT-6). In this line of research, another study (Garrigos-Pedron et al., 2018) investigated the impact of combined treatment targeted to the neck and the OF region in patients with migraine associated with TMD. They designed this study based on early evidence supporting neck therapy of patients with migraine and tension type headache. In addition, based on the assumption that treatment targeted to TMD disorders could be also helpful to reduce headache (Goncalves et al., 2013). They compared both treatments on the HIT-6 outcome. Both treatment options were similar on HIT-6 having both large effect sizes (cervical alone: SMD: 0.70 [95%CI 0.09, 1.31]; cervical plus OF: SMD:0.85 [95%CI 0.24, 1.45]) (Garrigos-Pedron et al., 2018) (Fig. 4). The difference between these treatments was neither statistical nor clinically relevant (SDM: 0.11 [95%: 0.69, 0.48]; Fig. 6; 1.2.2) demonstrating that both approaches could be effective; although a trend to favour the combined treatment (cervical plus orofacial treatment) was observed.

Another form of exercise that has been suggested to help with headaches is aerobic exercise in the form of walking, cycling, running among others (Lemmens et al., 2019). Specifically in migraine evidence has suggested that aerobic exercise was useful to reduce the number of migraine attacks per month (Lemmens et al., 2019). In the area of orofacial pain and headache, however, the literature looking at orofacial pain and AE is scarce. We conducted a recent systematic review (Guelker et al., 2023) to determine the effects of aerobic exercise for patients with orofacial pain, and after an extensive search, we found only one study (Moleirinho-Alves et al., 2021a, Moleirinho-Alves et al., 2021b, Moleirinho-Alves et al. , 2021) reported in three manuscripts that looked specifically at different forms of exercise for patients with TMD and associated headaches. Participants were divided into one of three treatment groups: strength exercise and manual therapy (G1), strength exercise, manual therapy, and aerobic exercise (cycling ergometer with moderate intensity) (G2) or aerobic exercise alone (cycling ergometer with moderate intensity) (G3). The intensity of AE was measured by HRreserve; all interventions were performed and supervised by a physiotherapist. When looking at headache intensity, it was found that strength plus manual therapy was superior to aerobic exercise alone at the end of treatment (MD: 2.59 points; [95%CI 1.61, 3.58]) and at 8–12 weeks follow-up (MD: 3.06 points; 95%CI [2.04, 4.07]. Both improvements were considered clinically significant with large, standardized effect sizes (SMD: 1.78 [95%CI: 0.89, 2.67] and SMD 2.05 [1.11, 2.99] respectively). Surprisingly, differences between these two groups (strength plus MT vs. AE) were small regarding the headache impact measured with the HIT-6 questionnaire (8.60 points [95%CI-7.83, 25.03] at post-treatment and 4.70 points [95%CI -10.60, 20.00] at follow-up. The SMD for these differences ranged between small 0.24 [−0.57, 1.04] at follow-up and moderate at post-treatment (SMD 0.40 [−0.41, 1.21]); although the change after treatment was considered clinically relevant as stated in the literature. (Calixtre et al., 2020). When looking at the combination between strength exercises plus manual therapy and aerobic exercises vs. aerobic exercises alone, similar results as the previous comparisons were found; the combined treatment program was more favorable on pain intensity 2.89 points [95%CI 1.91, 3.87] at post treatment and follow up (3.43 points [95%CI 2.16, 4.71], but not significantly superior when evaluated by the HIT-6 (Fig. 5). A non-significant difference of 9.80 points [95%CI: 6.23, 25.83] at the end of the treatment and 8.10 points [95%CI: 7.16, 23.36] follow-up was also observed. No significant difference was also obtained between strength training plus manual therapy vs. the combined effect of these two strategies plus the addition of aerobic exercise neither in pain intensity (SMD: 0.19 [95%CI-0.52, 0.91, Fig. 5; 1.1.8] nor in HIT-6 (SMD-0.06points [−0.74, 0.86] (Fig. 6; 1.2.8);

Figs. 5 and 6 show the effect sizes of the differences between interventions analyzed by the studies looking at headache intensity and HIT-6 impact respectively.

When evaluating all of these interventions; most of them produce significant improvements after treatment (Fig. 4- before-after treatment). However, most of these therapies do not show a great superiority over others. However, large effect sizes and important differences were obtained for the combined effect of aerobic exercise plus strength and manual therapy, as well as strength plus manual therapy, exercises of the upper quarter, and the combination of orofacial plus cervical spine. These therapies show a clinically relevant superiority over the other therapies to reduce pain intensity in patients with TMD and associated headache (Fig. 4).

7. Discussion

In the current review, a few themes regarding craniofacial pain and headaches are discussed. There is a high co-occurrence between these two disorders, and a strong association. Clinically, there is some overlap between signs and symptoms, despite the fact that craniofacial pain and headaches are most often distinct disorders driven by medical classifications. The overview of the current review gives clinicians knowledge on the comorbidity of these disorders and their shared predisposing and perpetuating factors. Also, this review provides some methods to approach their evaluation through questionnaires and clinical tests during the diagnostic process and how to create a treatment plan for patients with both craniofacial pain and headaches.

8. Overall remarks

A recent systematic review discussed the strong association between primary headaches and painful temporomandibular disorders (TMDs). (Reus, Polmann, 2022) In our review, we discuss the same findings, where most specifically migraine headache has a strong association to painful TMDs. When looking at clinical symptoms, migraine and TMD have different symptoms; for example, migraine often has severe pulsating pain, whereas TMD gives a mild, pressing pain. The clinical symptoms of a painful TMD have more overlap with the symptoms of TTH, which can create challenges during the diagnostic process. This gets increasingly more challenging as there are a lot of shared predisposing and perpetuating factors between these two disorders (see also Fig. 2) (Conti et al., 2016), and both have a strong neuro-anatomical/physiological overlap within the trigeminal-cervical complex as described in the current review (Akerman and Romero-Reyes, 2020; Bernstein and Burstein, 2012). As these disorders are separate entities, a proper diagnostic process is needed, where the clinical examination can help distinguish between TTH and TMD. During the clinical examination as described in the current review and Table 2, the TMD complaints should be provoked or aggravated. In case the headache gets provoked or aggravated during clinical examination of the masticatory system, this may be an indication of the presence of a headache attributed to TMD (Schiffman et al., 2012).

Besides needing to differentiate between different types of craniofacial pain and headaches for intervention purposes, it is important to identify these disorders as they may impact each other or the treatment. The presence of primary headaches may interfere with the efficacy of TMD-treatment, or a combined intervention needs to be applied to get a full treatment effect (Porporatti et al., 2015). Furthermore, the presence of TMD in patients with headache may increase the impact of the headache (Almoznino et al., 2015). The impact of headache in patients with TMD and concurrent headache is also influenced by psychosocial factors, especially in patients with TMD and TTH or headache attributed to TMD. Hence, treatment approaches should focus on the entire biopsychosocial model in patients with craniofacial pain and headaches (Adams and Turk, 2015).

9. Clinical implications

Using the information from this review, clinicians can improve their clinical reasoning during the diagnostic- and therapeutic process in patients with craniofacial pain and headaches. Clinicians can use epidemiological information as well as information regarding the shared neurophysiology, predisposing factors, and perpetuating factors, whilst taking the history of the patient. Multiple questionnaires and clinical tests are described, including the objective of use and evidence when available, which can be used during the diagnostic process. Lastly, an overview is given of the effective physiotherapeutic interventions for this population. Several approaches are described, although the evidence for specific intervention types is limited. Exercise interventions in combination with manual therapy targeted to the neck and orofacial system showed larger effects. In addition, this approach can be combined with aerobic exercises. No clear differences between approaches were found. Clinicians are encouraged to use the knowledge from this review to determine the best patient specific approach in their individual patient's case.

It should also be noted that the influence of the maxillofacial complex as a driver of headache has received little or no attention in the literature. There are a few case studies or series describing problems in the maxillofacial region that caused headaches, but there are no larger epidemiological studies (Farronato et al., 2008, María Clara et al., 2002). One of the reasons for changes or strain to the maxilla could be an orthodontic intervention. However, to the best of the authors' knowledge, there is no literature on the relationship between orthodontic treatment and headache during and after treatment. A traditional statement from medical classifications and textbooks is that (chronic) maxillary or mandibular neuropathies, which are part of the maxillofacial complex, do not typically cause headache, but there are doubts (Hegarty and Zakrzewska, 2011). It is, however, known that sinus-related issues may cause headaches, though little is known about the increased sensitivity of the sinuses to headache and craniofacial pain. Therefore, we include an example for clinicians on how to screen the maxillofacial complex for increased sensitivity (Fig. 3 and Table 2). In the case that the patient has increased sensitivity related to their headache, this assessment may be the first step in the clinical reasoning process to determine a proper treatment plan. However, future studies should examine this relationship further.

10. Limitations of our review

The current review is a structured narrative review, which included a literature search to include most relevant literature for the topic of craniofacial disorders and headaches. However, literature from the authors' personal databases was also included, which makes it less reproducible. Also, exhaustive literature searches were not conducted, and this might not be representative of all available evidence. Furthermore, included literature did not undergo risk of bias assessment. Although available estimates for treatment effectiveness were pooled (when possible), there was no analysis of the certainty of the evidence and we did not weigh the quality of the evidence in the conclusions. Therefore, some of the information included in this review may not be of a high methodological standard and should be interpreted with caution but provides an overview of the current evidence in addition to the knowledge and clinical expertise of the authors.

11. Further research

Because the current review included multiple themes into one review, we propose that future reviews could be performed on each theme separately and then include risk of bias assessments, certainty of the evidence, and when possible, a meta-analysis to inform practice.

Currently, there is no assessment protocol for questionnaires and tests to apply in patients with both craniofacial pain and headaches. Having a validated cluster of tests of the entire craniofacial region could help clinicians distinguish between the different craniofacial pains and headaches, and their relationship to each other. When assessment is only focused on the masticatory system, other important regions such as the cervical spine or maxillofacial region (including sinus) may be forgotten even though there could be a link to the headache from those regions as well. Future research should focus on creating such clusters of diagnostic questionnaires and tests and validate them for different types of craniofacial pain and headaches.

12. Conclusions

- There is a high correlation between the presence of craniofacial pain and headaches, which is partly related to their shared predisposing factors.
- Additionally, there is a large overlap of pain areas, which may be based on the strong neural relationship of both regions to the cervical trigeminal nucleus (TCN). Regions, such as the maxillofacial region, upper cervical spine, and orofacial could be potential sources of craniofacial pain and headaches.
- This systematic narrative review suggests that there are no questionnaires or clinical tests that map craniofacial pain, headache, and their correlations.
- Primary systematic reviews on separate topics within this domain are needed, followed by clustering of diagnostic questionnaires and clinical tests to distinguish between different head, neck, and facial pains.

Contributions of the authors

In the completion of this article, all three authors equally contributed. Their shared responsibilities spanned all aspects of the project, including conception and design, data collection and analysis, and manuscript writing and revision.

Declaration of competing interest

The authors declare that they have no competing interests or conflicts of interest in relation to this study.

Appendix 1. Search Strategy

Ovid MEDLINE(R) ALL <1946 to January 11, 2023>

1 exp craniomandibular disorders/or exp temporomandibular joint disorders/18883
2 Facial Pain/7037
3 (((temporomandibular or craniomandibular) adj4 (disorder* or disease* or syndrome* or pain*)) or tmj or tmd or costen*). mp. 28514
4 ((facial or orofacial or craniofacial or jaw or mandibular) adj2 pain*). mp. 12643
5 (Orofacial migraine or burning mouth syndrome). mp. 1436
6 (exp Temporomandibular Joint/or exp Masticatory Muscles/or ((Masticatory or Masseter or pterygoid or Temporal) adj2 Muscl*). mp.) and (pain* or ache* or discomfort or sore*). mp. 5242
7 (exp Myofascial Pain Syndromes/or (myofascial adj2 pain). mp.) and (face or facial or orofacial or craniofacial or jaw or head or neck or mandib* or craniomandibular). mp. 3693
8 or/1–7 39847
9 exp Headache/30871
10 ((migraine* or cervicogenic or tension) adj3 headache*). mp. 13587
11 (cluster headache* or cephalgi* or primary headache* or cephalodyni* or cranial pain* or head ach*). mp. 7165
12 ((sick or primary or tension or stress) adj3 headache). mp. 7467
13 (sick headache* or primary headache* or primary cephalalgia* or tension headache* or stress headache* or histamine cephalagia* or megrim or migrainous or cephalalgia* or cephalalgy). mp. 6459
14 exp *migraine disorders/or exp *alice in wonderland syndrome/or exp *migraine with aura/or exp *migraine without aura/or exp *ophthalmoplegic migraine/26239
15 migraine disorders. mp. 29072
16 exp *trigeminal autonomic cephalalgias/or exp *cluster headache/or exp *paroxysmal hemicrania/or exp *sunct syndrome/2747
17 or/9–16 67435
18 8 and 17 2100
19 limit 18 to (humans and “all adult (19 plus years)" and last 20 years) 631

Appendix 2

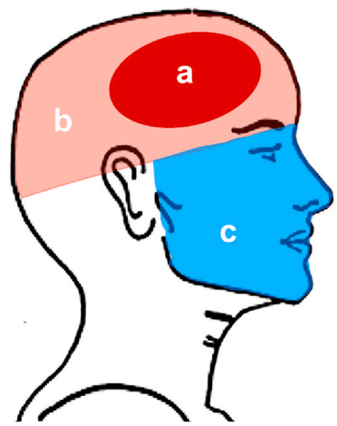

Fig. 2A. Anatomical representation of headaches and orofacial pain. The dark area (a) (lateral of the head) represents the temporalis muscle, which when in pain, resembles the classical headache due to TMD. The light dark area (b) is the region of the headaches. The region (c) represents facial pain. Modified after Conti et al. (2016) (Conti et al., 2016).

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