ISSN: 0975-3583, 0976-2833 || VOL 15, ISSUE 12, 2024

Orthodontics and Temporomandibular Disorders: An Overview

Tanupriya Tiwari [a], Sujit Panda[b] , Karuna Singh Sawhny[c]

a. Tanupriya Tiwari- Post Graduate Student, Department of Orthodontics and Dentofacial Orthopedics, Rama Dental College Hospital and Research Centre, Kanpur, India. tanupriyatiwari1997@gmail.com
b. Sujit Panda- Head of the Department, Professor, Department of Orthodontics and Dentofacial Orthopedics, Rama Dental College Hospital and Research Centre, Kanpur, India. drsujit.rdc@ramauniversity.ac.in
c. Karuna Singh Sawhny- Professor, Department of Orthodontics and Dentofacial Orthopedics, Rama Dental College Hospital and Research Centre, Kanpur, India. drkarunachib@yahoo.co.in
d. Zeba Siddiqi- Senior Lecturer, Department of Orthodontics and Dentofacial Orthopaedics, Rama Dental College Hospital and Research Centre, Kanpur, India. Lib8737@gmail.com
e. Ankita Das- Reader, Department of Orthodontics and Dentofacial Orthopaedics, Rama Dental College Hospital and Research Centre, Kanpur, India. Ankitadas9848@gmail.com

ABSTRACT-

The connection between orthodontics and temporomandibular disorders (TMDs) is a critical area of focus in dental and craniofacial health. This abstract provides a thorough exploration of the complex relationship between orthodontic treatments and TMD, with an emphasis on understanding how orthodontic interventions affect the health and function of the temporomandibular joint (TMJ).

The analysis examines the interaction between orthodontic procedures and TMD through a review of academic studies and practical research. It considers how treatments such as occlusal adjustments and changes in jaw alignment may influence the onset and management of TMD symptoms. The investigation covers various TMD conditions, exploring the effects of orthodontic approaches on occlusal stability, condylar positioning, and overall TMJ functionality.

By synthesizing the existing research, this abstract aims to provide dental professionals, orthodontists, and researchers with a deeper understanding of the complex dynamics between orthodontics and TMD. This knowledge helps guide clinical decisions and the development of effective treatment plans for patients with TMD symptoms. Ultimately, this review enhances clinical practices, contributing to better patient outcomes and overall well-being in the context of both orthodontic care and TMD management.

ISSN: 0975-3583, 0976-2833 || VOL 15, ISSUE 12, 2024

Keywords- temporomandibular joint, temporomandibular disorders, tmd, dental malocclusion, invisalign, orthodontic therapy, tmj disorders

INTRODUCTION-

Occlusion has long been considered a key factor, either directly or indirectly, in the development of temporomandibular disorders (TMDs) by both clinicians and researchers [1]. TMD is a broad term that refers to conditions involving dysfunction and pain in the masticatory muscles, temporomandibular joints (TMJs), and surrounding tissues. It is a significant public health concern and is the leading cause of non-dental orofacial pain [2-4]. Following chronic low back pain, it is the second most common musculoskeletal disorder [5]. The anatomical link between tooth position and jaw function has long been recognized as a fundamental factor in the cause-and-effect relationship between occlusion and TMD, with studies showing that individuals with dental malocclusion experience TMD more frequently than the general population[6-7]. In 1934, otolaryngologist Dr. J. Costen associated the development of TMJ pain, sounds, headaches, restricted jaw movement, myofascial tenderness, and ear-related symptoms—collectively known as "Costen's syndrome"—with occlusal changes, particularly an increase in overbite [8]. Thirty years later, Thompson proposed that dental malocclusion might cause the superior and posterior displacement of the condyle, suggesting that treating malocclusion could alleviate TMD symptoms **9**. Various studies have explored how occlusion and malocclusion-related factors might contribute to the onset of TMD signs and symptoms [10]. For example, a recent online survey found that over half of the websites reviewed linked TMD to malocclusion or occlusal problems and recommended treating these issues to address TMD [11].

Many studies have explored the connection between malocclusion and TMD, though with varying levels of success. Both TMDs and malocclusions are broad terms that encompass a wide range of different conditions. TMDs can involve muscle and joint pain, disc displacement with or without joint sounds, and pathologies that result in bone remodeling of the temporomandibular joint (TMJ), while malocclusion, whether skeletal or dental, is characterized by imbalances in the sagittal, transverse [12], and vertical planes [13].

In this review, we aim to offer an overview of the intricate relationship between orthodontics and TMDs. By reviewing the existing research, we will examine how malocclusion influences the development of TMD, discuss treatment options, and identify areas for future investigation. Through a thorough analysis, we hope to improve our understanding of how orthodontics can play a role in managing and preventing TMDs.

ISSN: 0975-3583, 0976-2833 || VOL 15, ISSUE 12, 2024

Transverse dental malocclusions

Unilateral posterior crossbite (UPCB) is a common transverse malocclusion often studied in relation to TMD, especially regarding TMJ clicking and myofascial pain. UPCB is found more frequently in younger populations (5%-15%) and is believed to significantly affect the stomatognathic system [14-15]. It is speculated that abnormal occlusal contacts in UPCB patients may influence the relationship between the condyle and the fossa. Furthermore, the asymmetrical activation of the masticatory muscles caused by uneven tooth contacts on both sides might overload one side more than the other [16]. These anatomical and functional changes are thought to increase the likelihood of TMJ clicking and myofascial pain in individuals with UPCB. However, conflicting findings exist in the literature [15] . For example, while an initial study in adolescence found no link between UPCB and TMJ clicking, a follow-up 10 years later revealed an association with TMJ clicking and self-reported clicking [17]. Despite this, orthodontic treatment did not reduce the incidence of TMJ sounds, raising doubts about the role of occlusion and suggesting that anatomical factors, such as asymmetries in the glenoid fossa and condyle, may influence joint function in UPCB patients [18]. A recent long-term study that tracked 903 individuals over 30 years found no connection between posterior crossbite and an increased risk of TMJ clicking. Interestingly, while orthodontic treatment didn't affect self-reported TMJ clicking, emotional factors and reports of sleep bruxism were linked to it. Given the variability of TMJ clicking, the significance of anatomical and psychological factors, and the lack of improvement with crossbite correction, there is insufficient evidence to support a direct link between crossbite and TMJ clicking.

The relationship between UPCB and masticatory muscle discomfort has also been widely studied, though many studies failed to consider factors such as muscle activity and psychological factors. One study using electromyography to measure muscle activity in children with and without UPCB found asymmetric muscle activity that was unrelated to the presence of UPCB [19]. In adults, normal occlusion was associated with balanced muscle activation, while significant malocclusions resulted in asymmetric activation. These findings suggest that asymmetric muscle activity is common in developing children without signs of TMD [20, 21]. In adults, asymmetrical muscle activity may or may not be linked to chronic muscle pain or myalgia [22].

ISSN: 0975-3583, 0976-2833 || VOL 15, ISSUE 12, 2024

Sagittal dental malocclusions

A recent systematic review of research on dental occlusion and TMD found only weak, inconsistent, and sporadic links between both sagittal and vertical malocclusions [23] . However, studies have identified a connection between open bite, hyperdivergent growth patterns, and degenerative TMJ diseases, though a clear cause-and-effect relationship has not been established. While evidence is limited, it is possible that the association between hyperdivergent growth patterns and TMJ disorders is linked to the early onset of these conditions, which could lead to abnormal condyle development [24,25].

The etiology of TMD is multifactorial, with various factors, including comorbidities, oral parafunctions, psychosocial stress, muscle overload, somatic symptoms, and genetic factors, being well-supported as contributors [26] . Since occlusal changes may sometimes be a consequence of TMD rather than a cause, the role of occlusion in the development of TMD has not been fully examined and should not be overemphasized [27] .

TMD and orthodontic treatment

It has been suggested that orthodontic treatment may help prevent or reduce TMD due to the proposed links between jaw misalignment, occlusal factors, and TMD. The goal of TMD treatment is often to achieve occlusal balance by repositioning the mandibular condyles into their optimal position in the glenoid fossae or by attaining a presumed ideal skeletal or occlusal relationship. However, it is important to recognize that some traditional orthodontic techniques, which do not follow functional occlusion principles, have been identified as potential causes and contributors to TMD symptoms. On the other hand, extensive research conducted over the years consistently shows that conventional orthodontic treatments have a neutral effect on both the TMJ and TMDs [28]. These studies provide strong evidence that traditional orthodontic interventions do not significantly cause or worsen TMJ-related problems [29]. For instance, research on orthodontic or functional treatments for skeletal class II and class III malocclusions has found no association between these treatments and an increased risk of TMD during treatment or a decreased risk of TMD after treatment completion [30-33].

Studies using cone-beam computed tomography to assess premolar extractions, often recommended for maxillary teeth retraction, have shown signs of posterior condylar

ISSN: 0975-3583, 0976-2833 || VOL 15, ISSUE 12, 2024

positioning after treatment. However, the clinical relevance of these findings has been questioned since they did not show a higher incidence of disc displacement [34]. Recent finite element research has examined the use of intermaxillary elastics in fixed orthodontic treatment. One study found that these elastic forces increased strain on the TMJ, especially in class II patients [35]. However, the potential link between this increased strain and the onset of TMD symptoms is still unclear.

In modern orthodontics, many adult patients choose clear aligner treatments due to their aesthetic compatibility with daily life [36]. Newer research on clear aligners has shown increased electromyographic activity in the masticatory muscles within six months of treatment [37, 38]. Additionally, thermoplastic orthodontic devices that cover the entire occlusion may be a beneficial treatment option for individuals with sleep bruxism, as they help protect tooth surfaces from wear [39]. However, a study by Manfredini et al. found no significant effect of invisible orthodontic retainers on the frequency of sleep bruxism in healthy individuals [40]. Despite no statistically significant differences between nights with and without the appliance, the study observed a slight increase in masticatory muscle activity during sleep when the orthodontic retainer was used.

The effects of orthodontic treatment on TMDs have been explored in multiple studies. One study found that after a month of regular orthodontic treatment, the number of patients reporting muscle soreness upon waking increased. Examination of the TMJ and orofacial muscles showed a significant rise in the severity and number of painful areas. However, these symptoms were temporary and gradually returned to normal over time [41]. In studies related to clear aligners, both passive and active aligners were examined for their impact on the jaw. These studies indicated that while minor jaw discomfort might occur briefly, none of the participants developed significant TMD symptoms [42]. Notably, the evidence suggests that clear aligners may increase, rather than decrease, masticatory muscle activity [43]. However, it is important to recognize that further well-designed studies are needed to confirm these findings. Therefore, caution should be taken when prescribing clear aligners to patients who may be prone to jaw muscle discomfort.

Moreover, it is crucial to acknowledge that orthodontic treatment cannot both cause and resolve TMD, as supported by existing research [44]. As such, there is no scientific foundation for attempting to prevent or treat TMD by achieving an "ideal" occlusion through orthodontic treatment, regardless of the type of appliance used [23].

Occlusion and orthodontics

Recent scientific advancements have shifted the focus of TMD's etiology from a purely biomedical perspective to a more complex, multifactorial biopsychosocial model that considers biological, psychological, and social factors [44] . This shift has contributed to ongoing debates about the cause-and-effect relationship between occlusion and TMD [45]. Occlusion is traditionally viewed mechanically as the static or dynamic connection between the upper and lower teeth and jaws, often deviating from what is considered "ideal." However, occlusion can also be seen as a highly complex system that integrates

ISSN: 0975-3583, 0976-2833 || VOL 15, ISSUE 12, 2024

neurological impulses from periodontal, dental, and connective tissue receptors. The central nervous system (CNS) continually adapts this system to regulate and adjust jaw position and movement in response to peripheral inputs [46].

Therefore, the definition of occlusion extends beyond simple tooth-to-tooth contact, incorporating the brain's interpretation of these interactions. A person's ability to adjust to any occlusal and oral changes following dental treatment largely depends on CNS adaptations, a process known as "sensorimotor neuroplasticity." Occlusal tactile acuity (OTA)—the ability to detect and differentiate small objects between the teeth during maximal intercuspation—plays a key role in this adaptation process, as it is highly variable among individuals and relies on a complex neural pathway [47]. OTA information primarily comes from the TMJ capsule, masticatory muscles (muscle spindles), dental pulp, and mechanoreceptors in the periodontium. Sensory feedback from the masticatory system during chewing helps regulate occlusal force and triggers the jaw-opening reflex. Research has shown that increased OTA, or a heightened ability to sense small thicknesses between molars, is associated with reported daytime dental parafunctions and TMD pain [48, 49].

Based on these findings, individuals with parafunctional habits or TMD pain may be more vulnerable to changes in occlusion following dental treatments, potentially leading to maladaptive behaviors. Interestingly, however, the OTA remained unchanged when myalgia was artificially induced in healthy participants without TMD [50]. This could be because psychosocial factors, which are often compromised in TMD patients but not in healthy individuals with induced pain, have a significant impact on somatosensory function. Different people may interpret the same external signal (such as the thin space between opposing teeth) in various ways, depending on several factors affecting exteroception and proprioception throughout the body.

Perception is a cognitive somatosensory experience, influenced not only by the intensity of the stimulus but also by the mental state that governs how the stimulus is processed. The variation in sensory interpretation is largely driven by top-down regulation of the input signal by higher brain centers and the reorganization of cortical regions [51]. Therefore, understanding the relationship between "occlusion" and TMD is crucial, but this requires a shift toward a more comprehensive understanding of the terms "occlusion" and "maxillo-mandibular relationship." The role of malocclusion in the pathophysiology of craniomandibular disorders should be downplayed, as there is no established causal link. Instead, clinicians should take patients' concerns about occlusion seriously during general and dental exams, as a specific subset of patients may display maladaptive behaviors induced by treatment.

ISSN: 0975-3583, 0976-2833 || VOL 15, ISSUE 12, 2024

Conclusions

Recent research suggests that dental professionals and orthodontists should move away from the traditional mechanical assessment of occlusion and instead focus on identifying and treating TMD with gentle, reversible methods. When appropriate, they should seek the help of other dental and medical experts for a multidisciplinary approach. It is common for patients to have prior experiences of orofacial pain, so conducting a routine TMD-related assessment before starting orthodontic treatment is essential.

This assessment should begin with a comprehensive patient history and an in-depth TMD examination to evaluate pain intensity, how pain affects function, and overall distress. Clinicians can use reliable clinical and diagnostic techniques to assess patients who may be at risk for developing orofacial disorders. The standardized diagnostic criteria for TMD include two components: Axis I for physical evaluation and Axis II for psychosocial assessment. These tools help gather necessary data to establish a diagnosis and to assess cognitive, emotional, and behavioral factors that might contribute to or worsen pain, which can also affect prognosis and treatment planning.

By using these diagnostic tools, general dentists and orthodontists can make more informed decisions about patients with facial discomfort, who may not be suitable candidates for restorative or orthodontic treatments until the pain is managed. If TMD symptoms arise during orthodontic or dental treatments, it is generally recommended to pause active treatment and focus on alleviating the discomfort. Once the patient is pain-free or their pain is under control, dental and orthodontic treatments can be resumed as initially planned, or adjusted according to the patient's condition.

References

1. Dodić S, Sinobad V, Obradović-Djuricić K, Medić V: The role of occlusal factor in the etiology of
temporomandibular dysfunction. Srp Arh Celok Lek. 2009, 137:613-8.

2. Perrotta S, Bucci R, Simeon V, Martina S, Michelotti A, Valletta R: Prevalence of malocclusion, oral
parafunctions and temporomandibular disorder-pain in Italian schoolchildren: an epidemiological study. J
Oral Rehabil. 2019, 46:611-6.

3. Paduano S, Bucci R, Rongo R, Silva R, Michelotti A: Prevalence of temporomandibular disorders and oral
parafunctions in adolescents from public schools in Southern Italy. Cranio. 2020, 38:370-5.

4. Sperry MM, Kartha S, Winkelstein BA, Granquist EJ: Experimental methods to inform diagnostic approaches

ISSN: 0975-3583, 0976-2833 || VOL 15, ISSUE 12, 2024

for painful TMJ osteoarthritis. J Dent Res. 2019, 98:388-97.

5. Wieckiewicz M, Shiau YY, Boening K: Pain of temporomandibular disorders: from etiology to management .
Pain Res Manag. 2018, 2018:4517042.

6. Shroff B: Malocclusion as a cause for temporomandibular disorders and orthodontics as a treatment . Oral
Maxillofac Surg Clin North Am. 2018, 30:299-302.

7. Lai YC, Yap AU, Türp JC: Prevalence of temporomandibular disorders in patients seeking orthodontic
treatment: a systematic review. J Oral Rehabil. 2020, 47:270-80.

8. Costen JB: A syndrome of ear and sinus symptoms dependent upon disturbed function of the
temporomandibular joint. Ann Otol Rhinol Laryngol. 1997, 106:805-19.

9. Gauer RL, Semidey MJ: Diagnosis and treatment of temporomandibular disorders . Am Fam Physician. 2015,
91:378-86.

10. McNamara JA Jr, Seligman DA, Okeson JP: Occlusion, orthodontic treatment, and temporomandibular
disorders: a review. J Orofac Pain. 1995, 9:73-90.
11. Desai B, Alkandari N, Laskin DM: How accurate is information about diagnosis and management of
temporomandibular disorders on dentist websites?. Oral Surg Oral Med Oral Pathol Oral Radiol. 2016,
122:306-9.

12. de Bont LG, van der Kuijl B, Stegenga B, Vencken LM, Boering G: Computed tomography in differential
diagnosis of temporomandibular joint disorders. Int J Oral Maxillofac Surg. 1993, 22:200-9.

13. Schiffman E, Ohrbach R, Truelove E, et al.: Diagnostic criteria for temporomandibular disorders (DC/TMD)
for clinical and research applications: recommendations of the International RDC/TMD Consortium
Network* and Orofacial Pain Special Interest Group†. J Oral Facial Pain Headache. 2014, 28:6-27.

ISSN: 0975-3583, 0976-2833 || VOL 15, ISSUE 12, 2024

14. Farella M, Michelotti A, Iodice G, Milani S, Martina R: Unilateral posterior crossbite is not associated with
TMJ clicking in young adolescents. J Dent Res. 2007, 86:137-41.

15. Iodice G, Danzi G, Cimino R, Paduano S, Michelotti A: Association between posterior crossbite, masticatory
muscle pain, and disc displacement: a systematic review. Eur J Orthod. 2013, 35:737-44.

16. Sonnesen L, Bakke M, Solow B: Bite force in pre-orthodontic children with unilateral crossbite . Eur J Orthod.
2001, 23:741-9.

17. Michelotti A, Iodice G, Piergentili M, Farella M, Martina R: Incidence of temporomandibular joint clicking in
adolescents with and without unilateral posterior cross-bite: a 10-year follow-up study. J Oral Rehabil. 2016,
43:16-22.

18. Olliver SJ, Broadbent JM, Thomson WM, Farella M: Occlusal features and TMJ clicking: a 30-year evaluation
from a cohort study. J Dent Res. 2020, 99:1245-51.

19. Michelotti A, Rongo R, Valentino R, D'Antò V, Bucci R, Danzi G, Cioffi I: Evaluation of masticatory muscle
activity in patients with unilateral posterior crossbite before and after rapid maxillary expansion. Eur J
Orthod. 2019, 41:46-53.

20. De Felício CM, Sidequersky FV, Tartaglia GM, Sforza C: Electromyographic standardized indices in healthy
Brazilian young adults and data reproducibility. J Oral Rehabil. 2009, 36:577-83.

21. Farronato G, Giannini L, Galbiati G, Sesso G, Maspero C: Orthodontic-surgical treatment: neuromuscular
evaluation in skeletal class II and class III patients. Prog Orthod. 2012, 13:226-36.

22. Valentino R, Cioffi I, Vollaro S, Cimino R, Baiano R, Michelotti A: Jaw muscle activity patterns in women
with chronic TMD myalgia during standardized clenching and chewing tasks. Cranio. 2021, 39:157-63.

23. Manfredini D, Lombardo L, Siciliani G: Temporomandibular disorders and dental occlusion. A systematic
review of association studies: end of an era?. J Oral Rehabil. 2017, 44:908-23.

24. Manfredini D, Segù M, Arveda N, Lombardo L, Siciliani G, Alessandro Rossi, Guarda-Nardini L:
Temporomandibular joint disorders in patients with different facial morphology. A systematic review of the literature. J Oral Maxillofac Surg. 2016, 74:29-46.

25. Paduano S, Rongo R, Bucci R, et al.: Is there an association between various aspects of oral health in
Southern Italy children? An epidemiological study assessing dental decays, periodontal status,
malocclusions and temporomandibular joint function. Eur J Paediatr Dent. 2018, 19:176-80.

26. Bair E, Ohrbach R, Fillingim RB, et al.: Multivariable modeling of phenotypic risk factors for first-onset
TMD: the OPPERA prospective cohort study. J Pain. 2013, 14:T102-15.

27. Pullinger AG, Seligman DA: Quantification and validation of predictive values of occlusal variables in
temporomandibular disorders using a multifactorial analysis. J Prosthet Dent. 2000, 83:66-75.

28. Kandasamy S, Greene CS: The evolution of temporomandibular disorders: a shift from experience to
evidence. J Oral Pathol Med. 2020, 49:461-9.

29. Macfarlane TV, Kenealy P, Kingdon HA, Mohlin BO, Pilley JR, Richmond S, Shaw WC: Twenty-year cohort
study of health gain from orthodontic treatment: temporomandibular disorders. Am J Orthod Dentofacial
Orthop. 2009, 135:692.e1-8.

30. Ruf S, Bock NC: Long-term (≥15 years) effects of class II treatment: a longitudinal and cross-sectional study
on signs and symptoms of temporomandibular disorders. Eur J Orthod. 2019, 41:172-9.
31. Pancherz H, Salé H, Bjerklin K: Signs and symptoms of TMJ disorders in adults after adolescent Herbst
therapy: a 6-year and 32-year radiographic and clinical follow-up study. Angle Orthod. 2015, 85:735-42.

32. Huang X, Cen X, Liu J: Effect of protraction facemask on the temporomandibular joint: a systematic review .
BMC Oral Health. 2018, 18:38.

33. Zurfluh MA, Kloukos D, Patcas R, Eliades T: Effect of chin-cup treatment on the temporomandibular joint: a

systematic review. Eur J Orthod. 2015, 37:314-24. 10.1093/ejo/cju048

34. Alhammadi MS, Fayed MS, Labib A: Three-dimensional assessment of condylar position and joint spaces
after maxillary first premolar extraction in skeletal class II malocclusion. Orthod Craniofac Res. 2017, 20:71-8.

35. Gurbanov V, Bas B, Öz AA: Evaluation of stresses on temporomandibular joint in the use of class II and III
orthodontic elastics: a three-dimensional finite element study. J Oral Maxillofac Surg. 2020, 78:705-16.

36. Bucci R, Rongo R, Levatè C, Michelotti A, Barone S, Razionale AV, D'Antò V: Thickness of orthodontic clear
aligners after thermoforming and after 10 days of intraoral exposure: a prospective clinical study. Prog
Orthod. 2019, 20:36.

37. Liu P, Wu G, Liu J, Jiao D, Guo J: Assessment of oral parafunctional behaviors and electromyographic
activities of the masticatory muscles in young female patients with orthodontic Invisalign treatment. Int J
Clin Exp Med. 2017, 10:15323-8.

38. Castroflorio T, Bargellini A, Lucchese A, et al.: Effects of clear aligners on sleep bruxism: randomized
controlled trial. J Biol Regul Homeost Agents. 2018, 32:21-9

39. Macedo CR, Silva AB, Machado MA, Saconato H, Prado GF: Occlusal splints for treating sleep bruxism (tooth
grinding).
40. Manfredini D, Lombardo L, Vigiani L, Arreghini A, Siciliani G: Effects of invisible orthodontic retainers on
masticatory muscles activity during sleep: a controlled trial. Prog Orthod. 2018, 19:24.

41. Université de Montréal. Effets du port continu de coquilles correctrices Invisalign® sur l'articulation
temporo-mandibulaire et les muscles du complexe facial. (2015).
https://papyrus.bib.umontreal.ca/xmlui/handle/1866/13107.

42. Pereira D, Machado V, Botelho J, Proença L, Mendes JJ, Delgado AS: Comparison of pain perception between
clear aligners and fixed appliances: a systematic review and meta-analysis. Appl Sci. 2020, 10:4276.

43. Lou T, Tran J, Castroflorio T, Tassi A, Cioffi I: Evaluation of masticatory muscle response to clear aligner
therapy using ambulatory electromyographic recording. Am J Orthod Dentofacial Orthop. 2021, 159:e25-33.

44. Suvinen TI, Reade PC, Kemppainen P, Könönen M, Dworkin SF: Review of aetiological concepts of
temporomandibular pain disorders: towards a biopsychosocial model for integration of physical disorder
factors with psychological and psychosocial illness impact factors. Eur J Pain. 2005, 9:613-33.

45. de Kanter RJ, Battistuzzi PG, Truin GJ: Temporomandibular disorders: "occlusion" matters! . Pain Res
Manag. 2018, 2018:8746858.

46. Svensson P, Graven-Nielsen T: Craniofacial muscle pain: review of mechanisms and clinical manifestations .
J Orofac Pain. 2001, 15:117-45.

47. Jacobs R, van Steenberghe D: Role of periodontal ligament receptors in the tactile function of teeth: a
review. J Periodontal Res. 1994, 29:153-67

48. Bucci R, Koutris M, Lobbezoo F, Michelotti A: Occlusal sensitivity in individuals with different frequencies
of oral parafunction. J Prosthet Dent. 2019, 122:119-22.

49. Bucci R, Koutris M, Palla S, Sepúlveda Rebaudo GF, Lobbezoo F, Michelotti A: Occlusal tactile acuity in
temporomandibular disorder pain patients: a case-control study. J Oral Rehabil. 2020, 47:923-9.
10.1111
50. Bucci R, Lobbezoo F, Michelotti A, Orfanou C, Koutris M: Delayed-onset muscle soreness does not influence
occlusal sensitivity and position sense of the mandible. J Oral Rehabil. 2017,10.1111

51. Forschack N, Nierhaus T, Müller MM, Villringer A: Alpha-band brain oscillations shape the processing of
perceptible as well as imperceptible somatosensory stimuli during selective attention. J Neurosci. 2017,
37:6983-94. 10.1523