ORIGINAL RESEARCH

Clinical and Functional Analyses of the Musculoskeletal Balance with Oral Electromyography and Stabilometric Platform in Athletes of Different Disciplines

Bianco Edoardo[1], Nanussi Alessandro[2], Bellotti Davide[3], Attuati Sara[4], Maddalone Marcello[5]

Abstract

Aim of study: No evidence is found in literature to assess that malocclusion can lead to postural or craniocervical–mandibular disorders. The aim of this study is to investigate with surface electromyography (EMG) of masticatory muscles and stabilometric analysis the relationship between malocclusion and presence of temporomandibular disorders (TMDs) or postural variations in a group of athletes of different sports.

Materials and methods: Seventy-four athletes belonging to different sport societies were included in this study. Chi-square test, taking as significance index $\chi^2 > 0.05$, was used to compare in pairs the postural interference, muscle disharmony, malocclusion, and TMDs.

Results: No statistical significance emerged, correlating postural interference and muscle disharmony ($\chi^2 = 0.15$), muscular imbalance, and anatomical findings of malocclusion ($\chi^2 = 0.62$), muscular imbalance and TMDs ($\chi^2 = 0.15$), and TMDs and malocclusion ($\chi^2 = 0.09$). Statistically significant association [$\chi^2 = 0.019$, odds ratio (OR) = 3.10] emerged from the correlation between TMDs and postural interference.

Conclusion: A correlation between posture and occlusion is very difficult to be demonstrated. A multidisciplinary approach is required for TMDs: therapy with oral splints allows to give greater compliance to the system by allowing muscles to guide the jaw in a position of functional equilibrium.

Clinical significance: Gnathological treatment evaluated through EMG and stabilometric platform allows to obtain improvements in the occlusal balance.

Keywords: Electromyography, Gnathology, Occlusion, Orthodontics, Posture, Sport dentistry, Stabilometric, Temporomandibular disorders.

World Journal of Dentistry (2020): 10.5005/jp-journals-10015-1722

What is Already Known on this Topic?

Up to now, in literature, there is no evidence to assess that malocclusion can lead to craniocervical mandibular disorders. Nevertheless, the etiopathogenesis of these problems is due to several factors and a multidisciplinary approach is needed to identify the origins of them.

Introduction

Athletes stress the musculoskeletal system more and recruit the elevator muscles of the jaw heavily compared to other people, so it is important to evaluate the muscular activity and postural control as well as occlusion stability; this is the reason why they were chosen as statistic sample in this study.[1]

The electromyography (EMG) is a noninvasive exam which evaluates the masticatory muscle activity by facial application of electrodes on masseter and temporal muscles. In the last 10 years, several studies demonstrated the effectiveness and reproducibility of surface EMG in the objective evaluation of temporal and masseter muscle activities, thus evaluating the effect of occlusion on the muscle balance.[2–10]

Stabilometric platform can be used to evaluate the cervical, occlusal, and ocular interference in posture.

There is a growing interest in the relationship between occlusion and posture because of a greater incidence of neck and trunk pain in patients with occlusal dysfunction. This topic was well debated but still no evidence is available in sport dentistry that any kind of gnathologic, orthodontic, or prosthodontic treatment can somehow improve sport performances.

[1,2,4,5]Department of Medicine and Surgery, University of Milano Bicocca, San Gerardo Hospital, Monza, Italy

[3]Private Practitioner, Milan, Italy

Corresponding Author: Bianco Edoardo, Department of Medicine and Surgery, University of Milano Bicocca, San Gerardo Hospital, Monza, Italy, Phone: +39 3487268209, e-mail: edoardowhite@gmail.com

How to cite this article: Edoardo B, Alessandro N, Davide B, *et al.* Clinical and Functional Analyses of the Musculoskeletal Balance with Oral Electromyography and Stabilometric Platform in Athletes of Different Disciplines. World J Dent 2020;11(3):166–171.

Source of support: Nil

Conflict of interest: None

Aim of Study

The aim of this study is to investigate the relationship between malocclusion and presence of temporomandibular disorders (TMDs) or postural sway variations in a group of athletes of several sports.

Materials and Methods

Seventy-four athletes belonging to different sport societies (Dinamo Sassari, CUS Rugby Genova, Gruppo Sportivo Atletica Brugherio, Società Educazione Fisica Torres e Torres Tennis) were included in this study, and the informed consent was obtained to do the research.

The protocol used was based on AIG (Accademia Italiana di Gnatologia—Italian Academy of Gnathology) guidelines, and

considered occlusal evaluation, analysis of mandibular movements, and temporomandibular joint (TMJ) clinical exam.

The term malocclusion, in this research, comprehended at least one of these occlusal features: partial edentulism, median line deviation, increased overjet, deep or open bite, crossbite, dental crowding, or classes II and III malocclusions according to the angle.

During the analysis of mandibular movements, mandibular deviation, limitation in opening, protrusion and laterotrusion, pain during the mandibular retrusion were analyzed.

In TMJ, clinical exam was considered the presence of articular noises, irregularities in the condylar movement, sagittal asymmetries, and pain on palpation.

A four-canal surface EMG of jaw elevators muscles (masseter superficial head and the anterior temporal muscle) was obtained by using BTS TMJoint® (BTS Bioengineering) and its percentage overlap coefficient (POC) 4 protocol.

The postural stabilometric evaluation was made with Lizard stabilometric platform (Lizard S.r.l.) with three load cells.

The position of each athlete on the stabilometric platform was repeatable, so that the initial conditions were the same for the whole statistical sample: feet were placed with an inclination of 30° between them; this position is pre-set in the platform with guidance lines (Fig. 1).

Calcaneal tendon, external malleolus, and second root toe were used as points of reference and placed on the traced lines above the footboard.

For each athlete, four postural stabilometric measurements of 51.20 seconds (according to Pierre-Marie Gagey protocols) were obtained in the following conditions:

- Rest positions with open eyes and no occlusal interferences
- Rest positions with closed eyes and no occlusal interferences
- Maximum intercuspation and open eyes
- Interposition of dental cotton rolls between dental arches and open eyes.

In the postural analysis, the area and length of oscillation of the body's center of gravity were evaluated to assess the efficiency of postural strategies of balance control.

Surface EMG was performed using electromyography analysis, according to the validated protocols with two Bluetooth probes on the anterior temporal muscles and two on masseters.

Fig. 1: Positioning of the athlete on the stabilometric platform

The electrodes used were bipolar circular shaped with a diameter of 1 cm and pre-gelled with saline base conductive gel. After cleansing the skin with gauze soaked in 90% denatured ethyl alcohol to remove the sebum, they were placed at the belly of the masseters and along the line parallel to the major axis of frontal bone zygomatic process on the temporal muscles.

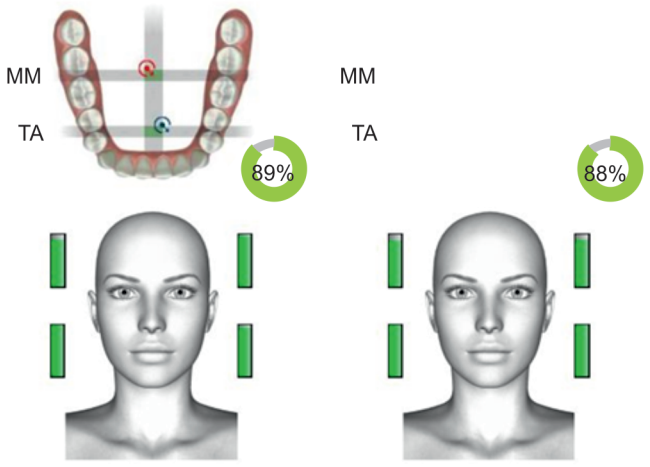
A 5-second clenching test was made in these conditions:

- Dental cotton rolls' interposition between the arches and open eyes
- Dental cotton rolls' interposition between the arches and closed eyes
- Maximum intercuspation and open eyes

The test on cotton rolls allowed to calibrate the electromyograph on the specific patient analyzed. If the calibration were not performed, the investigations would have been influenced by several factors such as cross talk (analysis of the nearby muscles), skin conductivity (variable depending on the tissue composition), skin condition (sweating), and position of the probes. What was analyzed during the calibration is not the occlusion, but the maximum muscle activity expressed as the electrical activity that the muscles can express without the dental contact (ideal condition) (Fig. 2).

This value is used to normalize the data. It means that the software automatically compares the calibration with the subsequent tests and evaluates, through electromyographic indices, how the neuromuscular activity changes once the dental contact is inserted. The software established the role of the occlusion based on the neuromuscular equilibrium, providing the following indices:

- The POC: it is an index that compares standardized contraction symmetry within the same muscular couple in maximum voluntary contraction to homologous standardized value



Indices	Pre		Post		Normality
POC TA	85.89%	Sx	85.45%	Sx	83≤(%)≤100
POC MM	88.39%	Dx	86.09%	Sx	83≤(%)≤100
BAR	90.48%	P	88.8%	P	90≤(%)≤100
TORS	89.97%	Sx	89.83%	Sx	90≤(%)≤100
IMP	88.12%		81.87%		85≤(%)≤115
ASIM	–0.25%		–0.41%		–10≤(%)≤10

Fig. 2: Example of an electromyographic analysis

(detected on the cotton rolls). If contraction is symmetric and bilateral, POC is expected to result near 100%. If the POC is less than 83%, there is a precontact in dental occlusion that influences the patient's muscular balance.

- The occlusal center of gravity [barycenter (BAR)]: it is obtained by calculating the POC between the activities of the pair of anterior temporal muscles and the activities of the pair of masseters. When the contacts are mainly localized on the molars, the masseters register a greater contraction than the corresponding temporal muscles (posterior center of gravity). Whereas if the dental contacts are mainly in the anterolateral sectors, the temporal muscles express greater contraction forces (anterior center of gravity).
- The torque coefficient [torsion (TORS)]: it provides an estimate of the torsional position of the mandible in the horizontal plane when it is in occlusion. It is obtained by comparing the torque of the right temporal pair with the left masseter (conventionally torque to the right) with the torque of the left temporal pair and the right masseter (for convention torque to the left). If this index is less than 90%, muscles tend to twist the jaw to the right or to the left depending on which muscle prevails, due to the presence of occlusal fulcrums. This analysis is done in a static condition, so no effective torsion of the jaw is observed. Any clinical condition that can be assimilated to the precontacts and therefore to slipping of the contact of the teeth has therefore already taken place.
- The maximum voluntary force expressed buy masticatory muscles (IMPACT) index: it evaluates the muscular work. Values higher than the normal can suggest that the patient clenches his or her teeth. Values lower than normal can express a condition of acute proprioceptive inhibition and therefore the presence of pain or a protective reflex.

In the present study it was defined "muscular interference of occlusal origin" a muscular disharmony detected by a surface EMG, performed comparing the ability to clench on dental cotton rolls (without any influence of occlusal contact) to occlusion on teeth. Difference was calculated analyzing the global index of neuromuscular balance represented by a percentage from 0 to 100 and the electromyographic indices aforementioned.

Results

The orthodontic clinical exam showed that 58 of 70 athletes presented with malocclusion problems (Fig. 3).

The TMJ evaluation showed that 42 athletes (87.5%) had TMDs, according to the criteria mentioned above (Fig. 4).

In 30 of 74 athletes, no occlusal interference was observed because there was no differences between electromyographic test on cotton rolls and occlusion on teeth, thus not showing any muscular imbalance.

The analysis of the data obtained from the stabilometric platform shows that in maximum intercuspation 37 of 74 athletes showed increases in the oscillation area with worsening of postural balance, compared to what was observed with the examination carried out on the cotton rolls (Fig. 5).

The statistical analysis was performed with SocSciStatistic software, using the chi-square test, taking as significance index $\chi^2 > 0.05$. The following parameters were compared in pairs:

- Postural interference,
- Muscle disharmony,
- Malocclusion,
- Temporomandibular disorders.

No statistical significance emerged correlating postural interference and muscular disharmony ($\chi^2 = 0.15$), muscular disharmony and anatomical findings of malocclusion ($\chi^2 = 0.62$), nor muscular disharmony and TMDs ($\chi^2 = 0.15$) (Tables 1 to 3).

Not even the association between TMDs and malocclusion shows a level of statistical significance ($\chi^2 = 0.09$) and neither the correlation between malocclusion and postural imbalance (Tables 4 and 5).

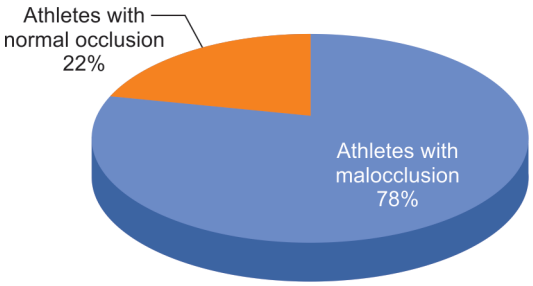


Fig. 3: Athletes with normal occlusion/malocclusion

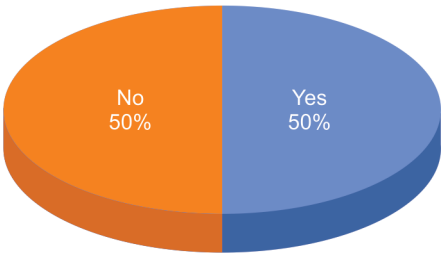


Fig. 5: Athletes with/without postural interference

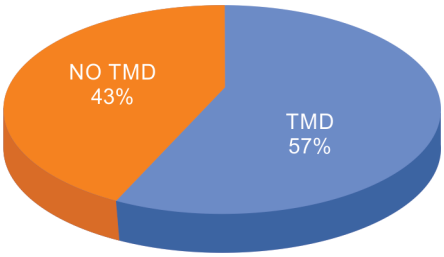


Fig. 4: Athletes with/without temporomandibular disorders

Table 1: Postural imbalance by muscular disharmony

	Muscular disharmony			
Postural imbalance	*No*	*Yes*	*Total*	*Chi-square*
No	18	19	37	0.1554
	24.32	25.68	50	
	48.65	51.35		
	60	43.18		
Yes	12	25	37	
	16.22	33.78	50	
	32.43	67.57		
	40	56.82		
Total	30	44	74	
	40.54	59.46	100	

Table 2: Muscular disharmony by malocclusion

	Malocclusion			
Muscular disharmony	*No*	*Yes*	*Total*	*Chi-square*
No	4	26	30	0.1527
	5.41	35.14	40.54	
	13.33	86.67		
	25	44.83		
Yes	12	32	44	
	16.22	43.24	59.46	
	27.27	72.73		
	75	55.17		
Total	16	58	74	
	21.62	78.38	100	

Table 3: Muscular disharmony by temporomandibular disorder (TMD)

	TMD			
Muscular disharmony	*No*	*Yes*	*Total*	*Chi-square*
No	14	16	30	0.6235
	18.92	21.62	40.54	
	46.67	53.33		
	43.75	38.1		
Yes	18	26	44	
	24.32	35.14	59.46	
	40.91	59.09		
	56.25	61.9		
Total	32	42	74	
	43.24	56.76	100	

Table 4: Malocclusion by temporomandibular disorder (TMD)

	TMD			
Malocclusion	*No*	*Yes*	*Total*	*Chi-square*
No	4	12	16	0.0962
	5.41	16.22	21.62	
	25	75		
	12.5	28.57		
Yes	28	30	58	
	37.84	40.54	78.38	
	48.28	51.72		
	87.5	71.43		
Total	32	42	74	
	43.24	56.76	100	

The only significant association ($\chi^2 = 0.019$, OR = 3.10) emerged from the correlation between TMDs and postural interference (Table 6).

Discussion

The 87.5% of the athletes that had a malocclusion diagnosis suffered from TMDs; however, it is not possible to find a correlation between these parameters because there is a high percentage of TMDs even in the group with a normal occlusion. It is important to underline that a bad dental alignment can have no functional consequences, on the contrary, people with altered mandibular skull relationship hidden by a good dental alignment can manifest functional problems. Indeed, the term malocclusion also comprehends an incongruous cranial–mandibular spatial relationship.[11–13]

Table 5: Postural imbalance by malocclusion

	Malocclusion			
Postural imbalance	*No*	*Yes*	*Total*	*Chi-square*
No	10	27	37	0.2587
	13.51	36.49	50	
	27.03	72.97		
	62.5	46.55		
Yes	6	31	37	
	8.11	41.89	50	
	16.22	83.78		
	37.5	53.45		
Total	16	58	74	
	21.62	78.38	100	

Table 6: Postural imbalance by temporomandibular disorder (TMD)

	TMD			
Postural imbalance	*No*	*Yes*	*Total*	*Chi-square*
No	11	26	37	0.019
	14.86	35.14	50	
	29.73	70.27		
	34.38	61.9		
Yes	21	16	37	
	28.38	21.62	50	
	56.76	43.24		
	65.63	38.1		
Total	32	42	74	
	43.24	56.76	100	

In some cases, dental alignment can influence the position of the jaw and can determine a postural adaptation, mainly at a craniocervical level.

Data analysis shows that malocclusion could not be an etiological cause of TMDs. Temporomandibular disorders have many etiological factors: occlusal or skeletal disharmonic relationships, degenerative diseases, rheumatologic, endocrine, or postural alterations. The predisposing factors, though, cannot generate the pathology without the contribution of triggering factors such as parafunctions, traumas, or incongruous therapies. Also structural or psychological factors have to be added.

It is necessary to say that the population taken into account by the authors is that of healthy young athletes; they stress the musculoskeletal system more and recruit the elevator muscles of the jaw heavily than other people so results in different population may differ.

Stomatognathic system is considered to be fundamental in postural control. Rugh et al. in 1981 demonstrated that in rest position the electromyographic activity of the muscles is at its minimum, indeed gravity strength is balanced by elevator muscles and soft tissues.[14] The interposition of dental cotton rolls can modulate periodontal proprioception, Scarpa's ganglion, and muscular proprioception inputs; cottons are placed, so that the occlusal load is distributed on several teeth, minimizing the effect of incongruous dental contacts.[2,15]

By comparing the tests carried out with cotton rolls in maximum intercuspation is possible to define the presence of a postural

interference of occlusal origin: if the area and the oscillation length of the center of gravity are more extensive in the examination carried out in maximum intercuspation, it can be assumed that postural management is strongly conditioned by dental contact. In this case, the occlusion induces negative alterations in the postural strategies of balance control. A direct correlation between TMDs and postural interference of occlusal origin was found in this study. Proprioceptive information (depending on muscles, tendons, and joints), vestibular, visual, and information from cortical and subcortical motor areas take part in postural control.

In particular, mandibular proprioception is based on pieces of information derived from masticatory muscles and periodontal ligaments: these structures give a contribution in controlling the head posture through the sternocleidomastoid muscle. Any dysfunction of these sensory receptors is compensated by postural strategies in particular by position of the head, neck, and cervical tract.[16–23]

Many studies have shown a functional connection between the motor system of the jaw and the cervical one, which probably allows the trigeminal system to modulate the cervical movements during mastication.[13,24,25]

Indeed, trigeminal inputs derived from periodontal receptors, TMJ receptors (due to the rotation and/or translation of the condyles), and muscular receptors (due to the variation in the mandibular position) can modulate the neuronal motor of the cervical muscles.[26]

Eriksson et al. in 1998 suggested that orofacial inputs can influence motor control mechanisms of the head and neck. This could be due to the existing relationship between the descending trigeminal nerve and the dorsal roots of the cervical tract. The neurons of the V cranial nerve and those of the VII, IX, and X cranial nerves share the same neuronal pools of the upper part of the cervical tract.[27,28]

Balance maintenance is a complex process in which neuronal, muscular, skeletal, visual, and vestibular components are involved. Brain stem and cerebellum centers are activated by pieces of information received from sensory system. An alteration in one body district can induce pain or dysfunction in another, through the activation of the central nervous system. From a pilot study carried out on rats demonstrated a reciprocal influence between dental malocclusion and postural deficits.[29–31]

No significant correlations were found between malocclusion and postural control in this study. However, patients with TMDs have a higher prevalence of cervical and neck muscle activity dysfunctions, which can influence the masticatory muscles. An inadequate position of the head requires an additional strain on the cervical region, altering the entire masticatory.[32]

Jaw muscles' activity is associated with that of the neck and trunk muscles. Alterations in muscle balance could influence the mandibular position. On the contrary, changes in the mandibular posture, regardless of whether they are caused by occlusion, muscle disorders, or temporomandibular dysfunctions, can affect the neck muscles and posture.[33–35]

When the patient's ability to compensate is reduced, he or she is not able to manage the occlusal disharmony and presents TMDs.

According to this, postural aspect plays a key role in the genesis of TMDs. The therapeutic approaches for TMDs vary greatly depending on the different etiological theories. The pathogenesis mechanism of these disorders has not yet been completely clarified. It has been shown that the multidisciplinary approach allows to achieve the best results in pain management.[33,36,37]

When the compensation capacity is reduced, there is a worsening in balance control strategies which manifest itself in maximum intercuspation more than through cotton rolls interposition.

Ferrario et al. in 1996 highlighted that, although there were no variations in the center of pressure, the center of gravity oscillations were reduced during the cotton roll test in patients with TMDs.[15]

Temporomandibular disorders patients, compared with healthy patients respond with a greater risk of developing pain on muscle palpation when occlusal interferences are iatrogenically introduced.[38]

A limitation of this study is the small population analyzed, and also the interpersonal variability such as tolerance to malocclusion or pain in case of TMD could play an important role in the statistical results. This topic has to be deeply analyzed in the future to better understand the complex relationship behind occlusion, postural stability, and TMJ.

Conclusion

The lack of significance in the correlation between TMDs and muscular interference of occlusal origin found in this study is not surprising as said in literature. Indeed, muscular compensations seem not to be related to postural imbalance, but the postural aspect may play a key role in the genesis of TMDs.

A multidisciplinary approach is required for TMDs: therapy with oral splints allows to give greater compliance to the system by acting only on the local aspect of the problem since splints allow muscles to guide the jaw in a position of functional equilibrium by deleting proprioceptive information of the periodontal ligament mechanoceptors.[10]

Many authors recommend a rehabilitation of the craniomandibular system due to the correlation between posture and TMJ function. The American Academy of Craniomandibular Disorders and the Minnesota Dental Association indicate physiotherapy as an important treatment to decrease musculoskeletal pain, reduce inflammation, and restore the function of the stomatognathic apparatus; and also osteopathy may induce changes in the dynamics of the stomatognathic apparatus, offering a valid support to the clinical approach of TMDs.[16,32,39,40]

What does this Study Add?

This is the first study to compare with chi-square test the athlete's occlusion, TMDs, postural balance, and masticatory muscular balance to find statistically significant correlations. We did not detect any significant correlation except between TMDs and postural imbalance, and this can be related to ascending or descending compensations. It is important for athletes to have good occlusal balance, in order to achieve a good postural balance, which could lead to greater results during competitions, prevent injuries, and may also increase the muscular force. Gnathological treatment evaluated through EMG allows to obtain improvements in the occlusal balance.

References

1. D'Ercole S, Tieri M, Martinelli D, et al. The effect of swimming on oral health status: competitive versus non-competitive athletes. J Appl Oral Sci 2016;24(2):107–113. DOI: 10.1590/1678-775720150324.
2. Maddalone M, Bianco E, Nanussi A, et al. Treatment of temporomandibular disorders of muscular origin with a silicon oral device (Alifix®): electromyographic analysis. J Contemp Dent Pract 2019;20(12):1367–1374. DOI: 10.5005/jp-journals-10024-2704.

3. Bianco E, Attuati S, Brugali C, et al. Restoration of the vertical posterior dimension in a grinding patient before orthodontic treatment: a case-report with electromyographic evaluation of masticatory muscles balance. J Dent 2019;1:38–42. DOI: 10.12974/2311-8695.2019.07.6.
4. Mapelli A, Tartaglia GM, Connelly ST, et al. Normalizing surface electromyographic measures of the masticatory muscles: Comparison of two different methods for clinical purpose. J Electromyogr Kinesiol 2016;30:238–242. DOI: 10.1016/j.jelekin.2016.08.004.
5. Ferrario VF, Sforza C, Tartaglia GM, et al. Immediate effect of a stabilization splint on masticatory muscle activity in temporomandibular disorder patients. J Oral Rehabil 2002;29(9): 810–815. DOI: 10.1046/j.1365-2842.2002.00927.x.
6. Ferrario VF, Tartaglia GM, Luraghi FE, et al. The use of surface electromyography as a tool in differentiating temporomandibular disorders from neck disorders. Man Ther 2007;12(4):372–379. DOI: 10.1016/j.math.2006.07.013.
7. Kacprzak A, Strzecki A. Methods of accelerating orthodontic tooth movement: a review of contemporary literature. Dent Med Probl 2018;55(2):197–206. DOI: 10.17219/dmp/90989.
8. Tartaglia GM, Moreira Rodrigues da Silva MA, Bottini S, et al. Masticatory muscle activity during maximum voluntary clench in different research diagnostic criteria for temporomandibular disorders (RDC/TMD) groups. Man Ther 2008;13(5):434–440. DOI: 10.1016/j.math.2007.05.011.
9. Ferrario VF, Tartaglia GM, Galletta A, et al. The influence of occlusion on jaw and neck muscle activity: a surface EMG study in healthy young audults. J Oral Rehabil 2006;33(5):341–348. DOI: 10.1111/j.1365-2842.2005.01558.x.
10. Landulpho AB, Silva WAB, Silva FA, et al. Electromyographic evaluation of masseter and anterior temporalis muscles in patients with temporomandibular disorders following interocclusal appliance treatment. J Oral Rehabil 2004;31(2):95–98. DOI: 10.1046/j.0305-182X.2003.01204.x.
11. Bathgate A, Best JP, Craig G, et al. A prospective study of injuries to elite Australian rugby union players. Br J Sports Med 2002;36(4): 265–269. DOI: 10.1136/bjsm.36.4.265.
12. Maddalone M, Bonfanti E, Pellegatta A, et al. Digital orthopantomography vs cone beam computed tomography-part 1: detection of periapical lesions. J Contemp Dent Pract 2019;20(5): 593–597. DOI: 10.5005/jp-journals-10024-2564.
13. Monaco A, Cozzolino V, Cattaneo R, et al. Osteopathic manipulative treatment (OMT) effects on mandibular kinetics: kinesiographic study. Eur J Paediatr Dent 2008;9(1):37–42. DOI: 10.1007/BF03321594.
14. Rugh JD, Drago CJ. Vertical dimension: a study of clinical rest position and jaw muscle activity. J Prosthet Dent 1981;45(6):670–675. DOI: 10.1016/0022-3913(81)90426-1.
15. Ferrario VF, Sforza C, Schmitz JH, et al. Occlusion and center of foot pressure variation: is there a relationship? J Prosthet Dent 1996;76(3):302–308. DOI: 10.1016/S0022-3913(96)90176-6.
16. Kibana Y, Ishijima T, Hirai T. Occlusal support and head posture. J Oral Rehabil 2002;29(1):58–63. DOI: 10.1046/j.1365-2842.2002.00794.x.
17. Söderman K, Werner S, Pietilä T, et al. Balance board training: prevention of traumatic injuries of the lower extremities in female soccer players? A prospective randomized intervention study. Knee Surg Sports Traumatol Arthrosc 2000;8(6):356–363. DOI: 10.1007/s001670000147.
18. Ries LGK, Bérzin F. Analysis of the postural stability in individuals with or without signs and symptoms of temporomandibular disorder. Braz Oral Res 2008;22(4):378–383. DOI: 10.1590/S1806-83242008000400016.
19. Bianco E, Rota D. Oral findings in Rett syndrome: an update and review of the literature. Dent Med Probl 2018;55(4):441–445. DOI: 10.17219/dmp/99203.
20. Bianco E, Maddalone M, Porcaro G, et al. Treatment of osteoradionecrosis of the jaw with ozone in the form of oil-based gel: 1-year follow-up. J Contemp Dent Pract 2019;20(2):270–276. DOI: 10.5005/jp-journals-10024-2508.
21. Cornwall MW, Murrell P. Postural Sway following inversion sprain of the ankle. J Am Podiat Med Assoc 1991;81(5):243–247. DOI: 10.7547/87507315-81-5-243.
22. Porcaro G, Busa A, Bianco E, et al. Use of a partial-thickness flap for guided bone regeneration in the upper jaw. J Contemp Dent Pract 2017;18(12):1117–1121. DOI: 10.5005/jp-journals-10024-2186.
23. Fujii Y. Orthodontic treatment to improve hip joint mobility and balance. J Dent 2015;3(1):29–32. DOI: 10.12974/2311-8695.2015.03.01.5.
24. Igarashi N, Yamamura K, Yamada Y, et al. Head movements and neck muscle activities associated with the jaw movement during mastication in the rabbit authors. Brain Res 2000;871(1):151–155. DOI: 10.1016/S0006-8993(00)02433-1.
25. Zuniga C, Miralles R, Mena B, et al. Influence of variation in jaw posture on sternocleidomastoid and trapezius electromyographic activity. Cranio 1995;13(3):157–162. DOI: 10.1080/08869634.1995.11678061.
26. Miralles R, Moya H, Ravera MJ, et al. Increase of the vertical occlusal dimension by means of a removable orthodontic appliance and its effect on craniocervical relationship and position of the cervical spine in children. Cranio 1997;15(3):221–228. DOI: 10.1080/08869634.1997.11746015.
27. Eriksson PO, Zafar H, Nordh E. Concomitant mandibular and head-neck movements during jaw opening-closing in man. J Oral Rehabil 1998;25(11):859–870. DOI: 10.1046/j.1365-2842.1998.00333.x.
28. Miralles R, Doods C, Manns A, et al. Vertical dimension. Part 2: the changes in electrical activity of the cervical muscles upon varying the vertical dimension. Cranio 2002;20(1):39–47. DOI: 10.1080/08869634.2002.11746189.
29. Morasso PG, Schieppati M. Can muscle stiffness alone stabilize upright standing? J Neurophysiol 1999;82(3):1622–1626. DOI: 10.1152/jn.1999.82.3.1622.
30. Browne PA, Clark GT, Kuboki T, et al. Concurrent cervical and craniofacial pain. A review of empiric and basic science evidence. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1998;86(6):633–640. DOI: 10.1016/S1079-2104(98)90195-0.
31. D'Attilio M, Filippi MR, Femminella B, et al. The influence of an experimentally-induced malocclusion on vertebral alignment in rats: a controlled pilot study. Cranio 2005;23(2):119–129. DOI: 10.1179/crn.2005.017.
32. Wright A, Sluka KA. Nonpharmacological treatments for musculoskeletal pain. Clin J Pain 2001;17(1):33–46. DOI: 10.1097/00002508-200103000-00006.
33. Kiliaridis S, Katsaros C, Karlsson S. Effect of masticatory muscle fatigue on crania-vertical head posture and rest position of the mandible. Eur J Oral Sci 1995;103(3):127–132. DOI: 10.1111/j.1600-0722.1995.tb00013.x.
34. Huggare JA, Raustia AM. Head posture and cervicovertebral and craniofacial morphology in patients with craniomandibular dysfunction. Cranio 1992;10(3):173–177. DOI: 10.1080/08869634.1992.11677908.
35. Salonen MA, Raustia AM, Huggare JA. Changes in head and cervicalspine postures and EMG activities of masticatory muscles following treatment with complete upper and partial lower denture. Cranio 1994;12(4):222–226. DOI: 10.1080/08869634.1994.11678025.
36. McNeely ML, Armco OS, Magee DJ. A systematic review of the effectiveness of physical therapy interventions for temporomandibular disorders. Phys Ther 2006;86(5):710–725. DOI: 10.1093/ptj/86.5.710.
37. Okeson JP. Management of Temporomandibular Disorders and Occlusion, 5th ed., St. Louis: Mosby; 2003. pp. 371–393.
38. Le Bell Y, Jamsa T, Korri S, et al. Effect of artificial occlusal interferences depends on previous experience of temporomandibular disorders. Acta Odontol Scand 2002;60(4):219–222. DOI: 10.1080/000163502760147981.
39. Oladimeji AA, Kesiena SY, Babatunde OA, et al. Presentations, management and outcomes of temporomandibular disorders (TMDs) in Port Harcourt: one-year prospective analysis. J Dent 2016;4(2):47–56. DOI: 10.12974/2311-8695.2016.04.02.2.
40. Al-Ani Z. Occlusion and temporomandibular disorders: a long-standing controversy in dentistry. Prim Dent J 2020;9(1):43–48.