CORRELATION BETWEEN THE STOMATOGNATHIC SYSTEM AND BODY POSTURE IN CHILDHOOD: A REVIEW OF THE LITERATURE

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ABSTRACT

Background In recent years, the relationship between the stomatognathic system and body posture has an increasing importance in the field of dental problems and it's a topic much debated in the science. Understanding this correlation implies a multidisciplinary approach with orthodontic and orthopedic figures, working in team to improve the treatment's effectiveness. Objectives Evaluate the literature regarding correlation between postural *alteration and stomatognathic* disorders in *patients of developmental age. Methods Literature researches given in Medline, Pedro, and Central database. Non-english articles and repeated articles were excluded. The selection of articles was carried out on the basis of the reading of the title, abstract and full-text. Results The search produced 165 items. The reading of the title, abstract and full text led to the selection of 18 articles. Associations were found between alterations of the stomatognathic system as well as malocclusions, temporomandibular disorders (TMD), bruxism and oral postures in relation to cervical alterations, scoliosis and posture* of the *feet. No studies have been able to report a cause-and-effect relationship between* the *stomatognathic system* and *body posture. All authors agree in supporting the importance of the multidisciplinary approach in the treatment of these pathologies. Conclusions The high prevalence of postural alterations in patients with orthodontic problems suggests an interaction between* the *disciplines of orthopedics and orthodontics. The limit of this review is the methodological variability, therefore is hoped in the future a consolidated methodology used in the study of these issues.*

INTRODUCTION

During the human body development, teeth, jaws and facial structures emerge in a complex adaptive system (CAS). The final result of this process is the mature stomatognathic system, an interactive network between the temporomandibular joints, the cervical spine, the hyoid bone, the pharyngeal complex, the teeth, the tongue, the vascular, lymphatic and neuromuscular systems. From the biomechanical point of view, this system is the junction between the anterior and posterior muscle chains. The hyoid bone in particular provides attachment to the muscles, ligaments and fascia of the pharynx, jaw, skull and cervical spine. From the neurological perspective the proprioceptive afferent nerve fibers of the stomatognathic system originate from the neuromuscular spindles of the lingual and masticatory muscles, from tendon proprioceptors, from articular mechanoreceptors and from periodontal pressoreceptors. These afferent nerve fibers reach the sensory nuclei of the facial, trigeminal and hypoglossal nerves, connecting the cerebellum and the lateral vestibular nucleus. Due to the convergence of this information, a series of reflex checks are made possible for both the posture of the stomatognathic system and, more generally, for the whole body. The interest in the relationship between posture and malocclusion has increased over the last two decades, however the opinions in the literature are conflicting. The presence of evidence relating to this correlation could imply the need for a multidisciplinary team with orthodontic and orthopedic figures to improve effectiveness in the treatment of stomatognathic problems. The aim of this review is to evaluate the material present in the literature regarding the correlation between postural alterations and disorders of the stomatognathic system during childhood

METHODS

A single operator reviewed the literature of the last 30 years, conducting a research in the following databases: MEDLINE with the PubMed interface; PEDro or Physiotherapy Evidence Database; CENTRAL (Cochrane Library); Gray literature (Google Scholar, conference proceedings). The deadline for the research was set to the 3rd of September 2021. It was also decided to investigate sources of gray literature to ensure greater sensitivity to the research. The selected keywords were combined through the Boolean operators AND, OR, NOT, using free words in order to produce specific search strings for each database. *Inclusion criteria*: studies focusing on disorders of the stomatognathic system in relation to posture in patients of developmental age. Study design: Randomized Controlled Trial (RCT), Systematic reviews, Systematic reviews with meta-analysis, Guidelines, Consensus conference; experimental studies. *Exclusion criteria*: studies that do not concern the population in developmental age, studies that do not relate disorders of the stomatognathic system to posture, studies not in English.

RESULTS

Non-English articles and duplicates in the four databases were excluded. The selection of the articles was carried out reading titles, abstracts and full-texts. The research initially revealed 165 articles. After reading titles and abstracts, 11 articles were excluded, as they were not relevant to the objective of the study. Initial-

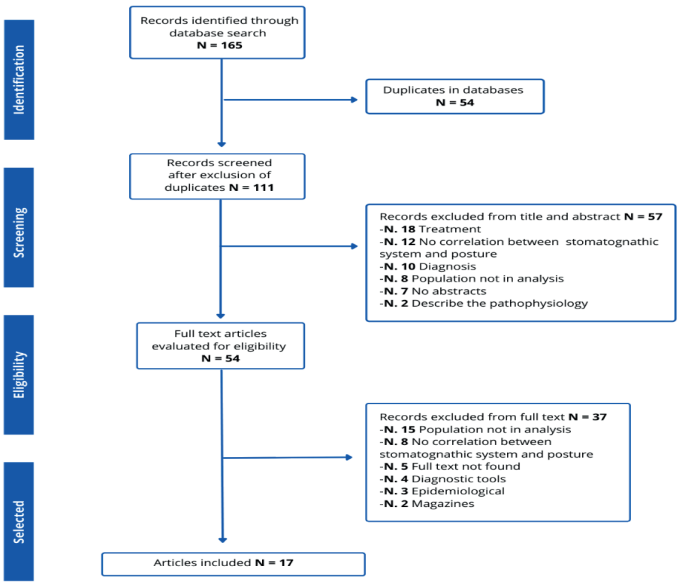

Fig. 1 - *Flow chart of the included studies*

ly, 165 articles were revealed and 111 were excluded after reading their titles and abstracts as they were not relevant to the objective of the study. A more precise selection was made reading the full-text of the remaining articles which led to the exclusion of 37 more articles, as they were not relevant in the discussion of the work. The flow-chart (fig. 1) shows the methodological procedures that led to the selection of the 17 articles. Tables I, II, III, IV summarize the results. According to the subject, the references are divided into four categories: TMD and posture in childhood (Table I), Malocclusion and posture in childhood (Table II), Bruxism and posture in childhood (Table III), Mouth breating and posture in childhood (Table IV).

TMD and posture in childhood

Five studies investigated the relationship between temporomandibular disorders and posture in young subjects. In the study conducted by Sonnesen et al. (2001) an association was found between postural alterations and 3 signs of TMJ dysfunction: the click assessed by auscultation with a stethoscope, the locking of the jaw and the asymmetrical opening of the jaw. Those three signs were associated with a marked forward tilt of the cervical spine. On average, children with clicks and reduced TMJ mobility had a marked forward tilt of the upper cervical spine and an increased craniocervical angle. Various explanatory models have been proposed for this relationship, but no studies have documented so far whether the symptoms and signs of TMDs are the results or causes of cervical forward tilt, or whether they are triggered by other factors. Similar results were observed by Motta et al. (2012) in the evaluation of TMD and cervical posture among adolescents, a greater cervical angle was observed in those with TMD. Cortese et al. (2017) observed a high incidence of postural changes and TMD. The higher incidence of changes in the cervical region, head and shoulders is related to the biomechanical adaptation mechanism of the masticatory muscles. This biomechanical adaptation pulls the shoulder superiorly or anteriorly. Chaves et al. (2017) show a high frequency of postural changes in children aged 10 to 15 years, in line with previous reported results showing an association between head posture and TMD. Regarding scoliosis, Vegh et al. (2012)[10] observed numerous pathological symptoms of the TMJ together with the many asymmetric indices found for lateral movements. The studies used different methods of TMJ assessment, which include dental assessments, pain questionnaires, while cephalometries and frames were used for postural assessments. A positive result was found in all studies regarding the association between temporomandibular disorders and cervical posture.

List of abbreviations: Temporomandibular Disorders (TMD), Female (F), Male (M), Temporomandibular joint (TMJ), Diagnostic Criteria for Temporomandibular Disorders (RDC / TMD), Body Mass Index (BMI), Higher frequency (HF), Scheuermann disease (MSCH), Scoliosis (SC).

Malocclusion and posture in childhood

The relationships between posture and malocclusion were analyzed in ten studies. Vegh et al. (2012) showed an higher frequency of overbite in patients with Scheuermann's disease (MSCH) compared to scoliosis (SC) (60%), a higher frequency of overjet in SC (96.42%) compared to MSCH (78.26%). In both groups, alterations in the ROM of bilateral mandibular movements and a significant facial asymmetry in patients with MSCH compared to SC were highlighted. Different results, for different patient samples, were found by Motta et al. (2012) in relation to the occlusal class. Higher values for cervical angulation were observed in class II compared to class I and class III, regardless of the presence or absence of postural alterations as analyzed by Vegh et al. (2012). Moreno et al. (2013) found a correlation between malocclusion and postural alterations. However, the types of postural alterations and the parts of the body were not specified. On the opposite, Perinetti et al. (2012) deny the existence of clinically relevant correlations between malocclusion and body posture, as they claim that all posturographic parameters had great variability and were very similar between the two recorded conditions. Furthermore, only a limited number of merely significant correlations were observed, mainly between the overbite phase and posture. Šidlauskienė et al. (2014) state that there is a significant association between the sagittal position of the mandible and a kyphotic posture; kyphotic posture was more common among patients with nasopharyngeal obstruction. For what concerns the correlation between foot posture and malocclusion, two studies out of a total of three Marchena Rodriguez et al. (2017), Cabrera Dominguez et al. (2021) agree that there is in fact a correlation between malocclusion of II class, and a significant increase in the Foot Posture Index (FPI). However, this result is refused by Pérez Belloso et al. (2020), who claim that no correlation was found between FPI and malocclusion, although they agree with Cabrera Dominguez et al. (2021) in affirming the prevalence of an anteriorized center of gravity in subjects with class II malocclusion, and a posteriorized center of gravity in subjects with class III malocclusion. With reference to scoliosis, Saccuci et al. (2011) in a systematic review confirm that there is plausible

Autors, year, study design	Purpose	N° Patients, age, ethnicity, inclusion	Methods	Results
Sonnesen et al. (2001)[6] cross-sectional study	Relationship between TMD, skull position and bite force in children selected for dental treatment.	96 children (51 F, 45 M), age 7-13, Danes. No craniofacial anomalies or systemic muscle / joint pathologies.	Evaluation of mandibular mobility, joint sounds, pain in chewing muscles, neck and shoulders. Bite force. Cefalometry. Dental arch width.	TMD observed in connection with marked forward tilt of the superior cervical spine and increased craniocervical angulation. Muscle pain associated with "long snout" craniofacial morphology and lower bite strength. Headache associated with greater maxillary length and increased maxillary prognathism.
Motta et al. (2012)[7] Cross-sectional observational study	Relationship between temporomandibular dysfunctions, cervical posture and occlusion in adolescents.	296 children. 143 M, 153 F. age 13±2.02, Brasilian. With and without TMD. No open bite, cross bite, overbite, craniofacial malformations, orthodontic and orthopedic appliances.	Helkimo questionnaire. Evaluation of cervical angles with photogrammetry and Alcimagem® software.	48% (n = 142) don't have dysfunction, while 52% (n = 154) have some degree of TMD. In relation to the occlusal class, higher values for cervical angulation were observed in class II compared to class I and class III.
Cortese et al. (2017)[8] Cross-sectional, descriptive, prospective study	Determine if postural changes are a risk factor for TMD.	243 subjects, age 10-15, average 12.6), argentines. No developmental disorders, and other health problems.	TMD evaluation carried out by 4 dentists using the RDC / TMD protocol. Postural evaluation carried out by physiotherapists, with photographs on the 3 floors following the Kendall model.	A) No TMD = 133 B) Muscle TMD = 61 C) TMJ dislocation = 49. Greater frequency of postural alterations group B. Most frequent alteration: position of the skull. Frequent alterations of the spinal, head, and lower limbs curves in group B. Most frequent alterations in groups A and B: lumbar hyperlordosis (23.30 and 32.78%), head anteposition (39.85 and 52.45%), valgus knee (33.08 and 45.90%).
Chaves et al. (2017)[9] Descriptive study	Incidence of postural changes and temporomandibular disorders in students.	117 children, age 10-18 state school in Minas Gerais	Body weight, height, BMI. Postural evaluation. Questionnaires for TMD. Fonseca questionnaire	10% No TMD, 50.9% Moderate TMD, 21.8% severe TMD of which 64% shoulder elevation and 24% shoulder protrusion. Others Cervical and lumbar hyperlordosis, scoliosis. 55.6% cranial postural alterations: 12% protrusion and 44% lateral deviation, 44% no cranial postural alterations, 67.25% pelvic alterations (anteversion / retroversion) of which 24.3% moderate and severe TMD. Among these 26% valgus knee, varus.
Vegh et al. (2012)[10] Epidemiological study	Orofacial characteristics in adolescents diagnosed with skeletal disorders.	23 children with MSCH, age 14±1.8. 28 children with SC, age 14±2.3.	Standard protocol of dental evaluation: occlusal characteristics in the sagittal, vertical, horizontal plane, state of the TMJ, facial asymmetries.	HF of overbite in patients with MSCH (75%) compared to HF (60%). HF of overjet in SC (96.42%) than in MSCH (78.26%). Increased frequency of TMD in patients with HF. Differences in ROM in bilateral mandibular movements in both groups. Significant facial asymmetry in patients with MSCH compared to SC.

Tab. 1 - *Summary of results: TMD and posture in childhood*

Autors, year, study design	Purpose	N° Patients, age, ethnicity, inclusion	Methods	Results
Motta et al. (2012)[7] Cross-sectional observational study	Relationship between temporomandibular dysfunction, cervical posture and occlusion in adolescents.	296 teenagers. 143 M, 153 F. Age 13±2.02. Brazilians. With and without TMD No open, crossed bite, overbite, craniofacial malformations, orthodontic and orthopedic appliances.	Helkimo questionnaire. Evaluation of cervical angles (A1 and A2) with photogrammetry and Alcimagem® software. cervical angles (A1 or A2) were used for comparison.	48% (n = 142) did not have dysfunction, while 52% (n = 154) had some degree of TMD. In relation to the occlusal class, higher values for cervical angulation were observed in class II compared to class I and class III.
Vegh et al. (2012)[10] Epidemiological study	Orofacial characteristics in adolescents diagnosed with skeletal disorders.	23 children with Scheuermann disease (MSCH), age 14±1,8. 28 children with scoliosis (SC), ag 14±2.3.	Standard protocol of dental evaluation: occlusal characteristics in the sagittal, vertical, horizontal plane, state of the TMJ, facial asymmetries.	Higher frequency of overbite in patients with MSCH (75%) compared to HF (60%). Higher frequency of overjet in SC (96.42%) than in MSCH (78.26%). Increased frequency of TMD in patients with HF. Differences in ROM in bilateral mandibular movements in both groups. Significant facial asymmetry in patients with MSCH compared to SC.
Moreno et al. (2013)[11] Observational, prospective, transversal study	Establish the frequency of malocclusion in association with postural problems in Mexican school-age children. “	375 children, (188 M, 187 F), age 8.8 (±1.7), Mexican. No previous orthodontic treatments	Malocclusion classification by Angle. WHO criteria for postural evaluation, associated with the observation of the Column and possible alterations in the frontal and sagittal plane.	The association between malocclusion and posture changes are statistically significant. Class II malocclusion and postural alterations occurred in 55.4% (n = 109) of the students.
Perinetti et al. (2012)[12] Retrospective study	Relationship between dental malocclusion and body posture in young subjects.	22 subjects, 86 M, 36 F, ages 10.8-16.3. No presence of stomatognathic disorders, except malocclusions.	Evaluation of dental occlusion Postural evaluation through force platform in mandibular RP and ICP.	All posturographic parameters had great variability and were very similar between the two recording conditions. Furthermore, a limited number of weakly significant correlations were observed, mainly for the overbite phase with posture. This study does not support the existence of clinically relevant correlations between malocclusal traits and body posture.
Šidlauskienė et al. (2014)[13] Cross-sectional study	Correlation between malocclusion, body posture and nasopharyngeal pathologies in children before dental treatment.	94 children (44 M, 50 F), age 7-14, Lithuanian. No maxillofacial trauma or surgical intervention, no dental treatments, no trauma to the spine, pelvis, limbs.	Orthodontic evaluation with cephalometries, orthopedic evaluation of posture, otolaryngologist (rhinoscopy and pharyngoscopy).	Postural disorders were observed in 72 (76.6%) patients. Hypertrophy of the adenoids was diagnosed in 54 (57.4%) patients, hypertrophy of the tonsils in 85 (90.3%), nasal septum deviation in 51 (54.3%), and allergic rhinitis in 19 (20.2%) patients. There is a significant association between the sagittal position of the mandible and a kyphotic posture; kyphotic posture was significantly more common among patients with nasopharyngeal obstruction .
Marchena-Rodríguez et al. (2017)[14] cross-sectional study	Relationship between foot posture and dental malocclusion in children aged 6 to 9 years.	189 children (95 M and 94 F) age 6-9, Spanis.	Questionnaire on postural habits, oral breathing, sucking, trauma or orthodontic treatments. Orthodontic assessment: Angle classes - Podiatrist assessment: FPI, Clark index.	Significant correlation of FPI scores (right foot) and Clarke’s angle (right foot) with malocclusions. Of all supinated feet, 38.46% were Class II and none were Class III. Of the pronated feet, 48.57% were Class III, 42.85% were Class I, and 8.57% were Class II. Clarke’s angle decreases with progression from Class I to III, while FPI increases with that of Class I to III.

Cabrera-Domínguez et al. (2021)[15] cross-sectional, descriptive study	Relationship between podal system malocclusion.	409 children, (222 M, 187 F), age 8-14. No orthodontic treatments, no trauma that they have modified posture; no surgery.	Occlusal evaluation by Angle classification. The contact between the foot and the ground and the center of mass were evaluated using a stabilometric platform.	Statistically significant relationship between malocclusion, contact surface and center of gravity. In molar class II, an anterior center of gravity was predominant, in class I it was centered and in class III it was posterior. There was significant correlation between malocclusions and FPI and scaphoid height in the right foot.
Pérez-Belloso et al. (2020)[16] cross-sectional study	Influence of dental malocclusions on body and foot posture in children.	289 children (158 M, 131 F), age 8-14. Presence of malocclusion. No spine surgery and invasive or non-invasive orthopedic surgery.	Angle class in relation with FPI.	The center of gravity is anteriorized in class II malocclusion. No relationship was found between FPI and dental classification. No relationship was found between pitch type and dental malocclusion.
Saccucci et al. (2011)[17] Review of the literature	Relationship between scoliosis and dental occlusion.	Adolescents with malocclusions e scoliosis. Studies reporting the incidence and description of malocclusion associated with scoliosis.	Randomized controlled trials published as full articles or abstracts reporting quantitative data on the outcomes of malocclusion in subjects with scoliosis.	Prevalence of unilateral Class II malocclusions associated with scoliosis and increased risk of lateral crossbite, midline deviation in children with scoliosis. Reduced range of lateral motion and scoliosis seem convincing.
Sambataro et al. (2019)[18] cross-sectional study	Correlations between malocclusions and postural abnormalities in children with mixed dentition.	127 children (45 M and 82 F), age 9.8). Absence of anomalies or craniofacial trauma.	Molar and canine relationship recording, crossbite, midline deviation. Evaluation of scoliosis, false scoliosis, kyphosis and lordosis.	18 orthopedically normal, 80 false scoliosis, 22 scoliosis and 7 kyphosis. Crossbite is more common when scoliosis worsens. The relationship between crossbite and the contralateral side of spinal deviation is statistically significant.

Tab. 2 - *Summary of results: Malocclusion and posture in childhood*

Autors, year, study design	Purpose	N° Patients, age, ethnicity, inclusion	Methods	Results
Velez et al. (2007) Case-control study	Evaluation of the head posture and dental wear of bruxist children with deciduous teeth.	53 children, 33 with bruxism, 20 no bruxism. Age 3-6 years, Colombians.	Dental wear drawn in dental casts. Physiotherapeutic evaluation and cephalometry.	Anterior and downward head tilt in the bruxist group, with statistically significant differences compared to controls. Significant dental wear in the bruxist group.
Motta et al. (2011)[20] Cross-sectional, observational study	Relationship between craniocervical posture and bruxism in children.	21 children, age 3-6 years, with bruxism. 21 children without bruxism for the control group.	Postural evaluation through ALCimage® Software.	Significant difference in mean cervical angle between controls (89.58°±8.03°) and bruxism (98.99°±8.1 °). Children with bruxism showed more changes in head posture than the control group.

Tab. 3 - *Summary of results: bruxism and posture in childhood*

evidence for the increased prevalence of unilateral Class II malocclusions associated with scoliosis, increased risk of lateral crossbite and midline deviation in children with scoliosis. Furthermore, data on the association between plagiocephaly and scoliosis is also cited. A recent study by Sambataro et al. (2019) confirms the conclusions reported by Saccuci. It founds significantly high correlations between crossbites and lower midline deviation, in the group of patients with structured scoliosis and with false scoliosis, suggesting that spine abnormalities correlate with malocclusions, like the contraction of the upper arch, and with a mandibular deviation in the three planes of space.

List of abbreviations: Temporomandibular Disorders (TMD), female (F), male (M), World Health Organization (WHO), Mandibular rest Position (RP), Dental Intercuspid Position (ICP), Posture Index (FPI).

Bruxism and posture in childhood

Only two studies were found about the correlation between bruxism and posture, and they both achieved similar results, even if using different methodologies. Velez et al. (2007) found a correlation between an-

Autors, year, study design	Purpose	N° Patients, age, ethnicity, inclusion	Methods	Results
Neiva et al. (2009) Cross-sectional observational study	Relationship between orientation and position of the head, scapula, and thoracic spine in children with oral breathing.	42 children (21 M, 21F) age 8-12, Brazilian, with upper airway obstruction and MB and NB.	Stereophotogrammetry to measure: internal rotation, upward rotation, anterior tilt, elevation and scapular ABD. Thoracic kyphosis, head position and shoulder protrusion.	Children with MB have higher shoulder blades than children with NB probably due to the forward position of the head, which leads to an alteration of the positioning of the jaw.
Neiva et al. (2017) Systematic Review	Establish the presence of postural disorders in children with oral breathing.	10 studies including a total of 417 children, age 5-14.	2 postural assessment studies in New York, 7 photography and 1 motion capture. -Postural Analysis Software, Fisiometer, ALCimagem and Matlab.	Six studies found forward head posture, 6 found a higher percentage of misalignment of the body and 2 studies reported scapular deviations. Quality assessment led to low scores (<14) for all studies.

Tab. 4 - *Summary of results: Mouth breathing and posture in childhood*

teriorized and downward head posture in the bruxist group, with statistically significant differences compared to controls, as well as greater dental wear. Similarly the study by Motta et al. (2011) observed significant differences in the cervical angle between patients with bruxism and people from the control group.

Mouth breathing and posture in childhood

Neiva et al. (2009) observed that children with oral breathing have higher scapula than children with nasal breathing, probably due to the forward position of the head, which leads to an alteration of the positioning of the jaw. The results of this study were incorporated into an interesting systematic review (2017) of 10 studies, conducted by the same authors. According to the review, six studies observed anteriorized head posture, six found a higher percentage of full body misalignment, and two studies reported scapular deviations. However, the quality assessment assigned low scores (<14) to all the studies.

List of abbreviations: Female (F), Male (M), Mouth Breathing (MB), Nasal Breathing (NB).

DISCUSSION

While it is possible to obtain information from the studies available to date, the topic is still the subject of numerous discussions and different currents of thought. In recent years, many researchers have investigated various factors that can affect body posture. Ever-growing evidence show that untreated diseases of the stomatognathic system, especially temporomandibular disorders and malocclusions and parafunctions, carry a risk of developing postural disorders. However, due to the complexity of the factors involved, existing studies have left important gaps in understanding. Positive results were obtained in this review about the correlation between the stomatognathic system and posture. Studies have shown a relationship between TMD and posture. Patients with TMD present an anterior head position, usually associated with shortening of the posterior cervical extensor muscles (suboccipital, semispinal, splenium, and superior trapezius), and shortening of the SCM. Similarly, changes in the cervical region can cause TMD, by changing the orientation of the head and consequently the mandibular position. In regard to the role of occlusion, correlations were found between different craniofacial morphologies and postural attitudes, such as an anteriorly shifted posture in patients with class II malocclusion and a posteriorly shifted posture in patients with class III malocclusion. The foot posture index also appears to be associated with the occlusal class. Patients with idiopathic scoliosis show higher rates of malocclusion than control patients; these include Class II malocclusions, lateral crossbites, inferior midline deviation and asymmetries. The hypothesis of the relationship between malocclusion and cervical posture is that the mandible may affect the muscles, causing the neck and the vertebral column to change position. Even the most common oral habits in children, such as bruxism and oral breathing, appear to be associated with postural alterations, especially in relation to the posture of the skull. Regardless of the reliability and reproducibility of the results, a concept that has emerged from many studies is the importance of multidisciplinary treatment and of an early approach in the treatment of pathologies affecting the stomatognathic system.

Study limits

The limitation of this review is the great variability in terms of patients, methodology, definition of pathology and problems; therefore a comparison is often difficult to make. In order to give the studies greater accuracy and sense of interpretation, an increasingly rigorous integration between statistical data, clin-

ical-instrumental parameters and an overall critical framework of the individual case will be desirable in the future, taking into account the inevitable influence of variables linked to history and specific characteristics of each individual.

CONCLUSION

The high prevalence of orthodontic problems in patients with cervical spine deformity suggests pathogenic correlations that interest both orthodontics and orthopedics. In particular, associations were observed between malocclusions, TMD, bruxism and oral respiration in relation to cervical postural alterations, scoliosis and even posture of the feet. No study has been able to indicate a cause-effect correlation between the stomatognathic system and posture, given the numerous factors that contribute to the etiopathology of temporomandibular disorders and malocclusions. Many studies agree in supporting the importance of the multidisciplinary approach in the treatment of these diseases. The limitation of this review is the methodological variability, therefore further studies are needed to verify its validity. The use of a consolidated methodology is wished for future studies.

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