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DENTAL MALOCCLUSION AND BODY POSTURE IN YOUNG SUBJECTS: A MULTIPLE REGRESSION STUDY

Giuseppe Perinetti[I], Luca Contardo[I], Armando Silvestrini

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INTRODUCTION

Over the last few years, a growing number of investigations have focused on potential correlations between the stomatognathic system (i.e., mouth, jaws and closely associated structures) and whole-body posture.[1,2] However, most of the information available to date is not conclusive, and recent reviews have reported contrasting conclusions in favor[1,3] or against[2] clinically significant correlations. As a consequence, several clinical applications that might arise from potential correlations have not been correctly or fully addressed.

Several aspects of stomatognathic system conditions have been found to be associated with body posture alterations. Among these aspects are i) mandible position,[4-7] ii) dentition phase,[8] iii) dental[9-11] or skeletal[12,13] malocclusion and iv) temporomandibular disorders.[14-16]

In particular, dental malocclusion has a very high prevalence among children and young subjects,[17,18] and as such, potential effects of malocclusal traits on body posture may provide further indications for orthodontic treatments. Previous studies have reported both significant[8,9,19] and non-significant[10,11,14,20] correlations between dental/skeletal malocclusion and body posture. One study reported only a weak correlation in a case of severe class II malocclusion.[12] However, the few studies that have specifically focused on dental malocclusion have been hampered by a limited

[I] **Department of Biomedicine, University of Trieste - Trieste/ITA.**
[II] **Department of Orthodontics, University of Genova - Genova/ITA.**
Email: g.perinetti@fmc.units.it
Tel: +390403992062
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number of subjects[9,14] or by unmatched studied groups.[8,9,19] Other limitations of most previous studies include incomplete sample descriptions and a limited number of tested parameters and/or conditions. See Perinetti and Contardo[2] for a systematic review of recent studies.

Due to the clinical impact that a correlation between dental malocclusion and body posture may have and because of the poor data available on the topic, further investigation is warranted. Therefore, this study was designed to investigate whether malocclusal traits correlate with body posture alterations at a detectable level. To determine whether a clinical application can be derived, we employed static posturography in young subjects.

MATERIALS AND METHODS

Study population and design

A total of 122 subjects (86 males and 36 females aged 10.8-16.3 years, with mean age 13.1 ± 1.6 years) were enrolled in the study after a signed informed consent was obtained from their parents. The study protocol was reviewed and approved by the local ethics committee.

All subjects were recruited from a local sport center and had to fulfill the following inclusion criteria: i) good general health according to medical history and clinical judgment; ii) negative history of vertigo due to central nervous disease; iii) negative for symptoms caused by any previous trauma or surgery; iv) absence of any neurological, vestibular and lower leg sensory problems; v) absence of any particular episode of psychosocial and psychological stress profile in the last month; vi) presence of a late mixed or permanent dentition; vii) absence of cast restorations and extensive occlusal restoration; viii) absence of any temporomandibular disorders, as detailed previously;[15] and ix) lacking any previous orthodontic treatment.

Following a dental occlusion assessment, body posture was recorded through static posturography in all subjects.

Dental occlusion assessment

Occlusion assessment for all subjects was performed by the same trained operator and data were recorded in a dedicated database. Phase of dentition, molar class, overjet, overbite, anterior and posterior crossbite, scissorbite, mandibular crowding and dental midline deviation were recorded as detailed below, either directly in the oral cavity or on stone models. All relationships between dental arches were recorded with dental arches in maximum intercuspidation (ICP, see below).

Angle classification was used to describe molar relationships. Molar classes I, II and III were recorded using the permanent first molars as reference teeth. Cases with a half cusp or less than normal displacement were marked as class I.[18] Finally, subjects with subdivision malocclusions were sorted into the proper class based according to the relationship between the canines. Overjet was defined as the horizontal distance between the labial surface of the anterior upper maxillary and the anterior mandibular central incisor, parallel to the occlusal plane. Overjet values between 1 and 4 mm were considered normal, whereas values greater than 4 mm were considered increased. Values less than 1 mm (including negative) values were considered decreased. Overbite was defined as the overlap of the upper incisors to the lower incisors. Values between 1 and 4 mm were considered normal, whereas values greater than 4 mm were considered increased. Values less than 1 mm were considered decreased. For both overjet and overbite, incisors on the right side were used.[18] If the right central incisors were missing, fractured or extensively decayed, then the left central incisors were considered.[17] Anterior crossbite was recorded if any of the anterior maxillary deciduous canines or permanent incisors and canines totally occluded lingually or in an edge-to-edge position to antagonistic mandibular teeth.[18] Posterior crossbite was noted when the buccal cusps of at least one of the maxillary primary molars or permanent premolars and molars were at least in an edge-to-edge position to the buccal cusps of the antagonistic mandibular teeth.[18] A scissorbite was recorded when any primary molars or maxillary premolars and molars totally occluded to the buccal surface of the antagonistic mandibular teeth.[18] Mandibular crowding was recorded when the corresponding Little's irregularity index was at least 5 mm.[21] Dental midline deviation was recorded when there was a deviation of at least 2 mm between the upper and lower midlines.

Posturographic recordings

Posturography recordings were performed using a 10-Hz sampling frequency vertical force platform (Bio Postural System, AXA S.r.l., Vimercate [Mi], Italy) with subjects placed in a quiet stance. This platform includes load cells with an internal circuit that changes electrical resistance upon the application of force. Subjects were required to remain relaxed but as stable as possible, with their arms hanging free beside their trunk and facing the wall (150 cm away). Moreover, all subjects were asked to avoid alcohol and heavy exercise during the 24 h before the clinical recordings.

Two different occlusion states (i.e., conditions) with eyes open were used during static posturography, namely, mandibular rest position (RP) and ICP. RP was defined as habitual postural position of the mandible when at rest, with the condyles in a neutral, unstrained position in the glenoid fossa; the ICP (without clenching) was defined as the most closed, static position that the mandible can assume with the full interdigitation of opposing teeth.[22]

Each recording lasted 51 s, and four posturographic parameters were recorded, including i) projected sway area (in mm^2); ii) sway velocity (in mm); iv) antero-posterior load differences (in percentage) and v) right-left load differences (in percentage). Load differences were calculated by using anterior and posterior and left and right loads as a percentage of the total body height. Absolute differences between the two loads within the same direction (i.e., antero-posterior and right-left) were then used as outcomes. A difference of zero represented a perfect balance between the distribution of the two loads. Moreover, the most 10% external projections of bodily center of pressure projections were not considered in the final estimation of each of the outcomes in order to limit unwanted variability. Finally, each recording was repeated twice, and the mean value represented the statistical unit.

To assess the method error of the static posturographic recordings, 10 subjects matched with the study population were recorded twice under similar conditions. These subjects were asked to rest for 5 min between the two time points so that within each time point, duplicate measurements were performed. Dahlberg's formula yielded errors of 5.8%, 6.6%, 9.5% and 10.6% for sway area, velocity and antero-posterior and right-left load differences, respectively.

Data analysis

Malocclusal traits are reported as follows: dentition phase (late mixed, permanent); molar class (I, II, III); overjet and overbite (normal, decreased, increased); anterior and posterior crossbite (no, yes); scissorbite (no, yes); mandibular crowding (no, yes) and dental midline deviation (no, yes). Distribution of these malocclusal traits are presented as percentages and integers.

Although most of the continuous datasets had a skewed distribution, parametric methods were used because the central limit theorem ensures that sample means are normally distributed for large enough samples (i.e., those above 100 units).[23] The significance of the differences in each of the four posturographic variables between the two RP and ICP conditions was assessed by a paired Student's t-test. To further assess the clinical significance of the differences in the four posturographic variables between the two RP and ICP conditions, an effects size (ES) coefficient[24] was calculated. The ES coefficient is the ratio of the difference between the recordings of the two occlusal states divided by the within-subject standard deviation.[25] Importantly, an ES coefficient must be greater than 0.20 to be regarded as biologically significant (i.e., a weak correlation exists but with no or poor clinical meaning) or greater than 0.80 to be regarded as clinically relevant.[25]

The adjusted correlations between each occlusal trait with the posturographic parameters were evaluated by multiple linear regressions for both the RP and ICP conditions. In particular, for each model, age, sex and malocclusal traits (entered as continuous, dummy and dummy variables, respectively) were explanatory variables, and each posturographic parameters were dependent variables. To further analyze the effects of the number of malocclusal traits on the posturographic parameters, further multiple linear regressions were run by using age, sex and total number of malocclusal traits as explanatory variables. The cut-off levels of significance used were 0.05 and 0.10 for entry and removal, respectively. For each multiple regression model, multi-colinearity among the explanatory variables was also checked.

SPSS 13.0 (SPSS® Inc., Chicago, Illinois, USA) was used to perform the statistical analyses. A p value of less than 0.05 was considered statistically significant.

RESULTS

The prevalence of each occlusal trait in the sample is shown in Table 1. The number of malocclusal traits ranged from 0 (23.8% of the sample) to 5 (1.6% of the sample). The overall mean ± standard deviation (SD) of the number of malocclusal traits was 1.7 ± 1.3. About two-thirds of subjects had a permanent dentition, with the remaining subjects having a late mixed dentition. Molar class was normal (class I) in 61.5% of the sample, and molar classes II and III were observed in 34.4% and 4.1% of subjects, respectively. Overjet was normal in about two-thirds of subjects. It increased in about one-third of the sample and decreased in only two subjects (1.2%). Overbite was normal in 56.6% of subjects, and it decreased and increased in 7.4% and 36.1% of subjects, respectively. The prevalence of anterior and posterior crossbites was 4.9% and 11.5%, respectively. No scissorbite was detected in the sample. Finally, mandibular crowding and dental midline deviation were observed in 30.3% and 91.0% of the sample, respectively.

The results obtained for the four posturographic parameters are shown in Table 2. All of these parameters had large variability within each dataset and were very similar between the two recording conditions, with no significant differences. Moreover, the ES coefficients calculated for each posturographic variable were extremely low, ranging from 0.01 (for right-left load difference) to 0.09 (for sway velocity).

The results of the multivariate regression analyses are shown in Table 3. All models had a low R^2, ranging

Table 1- Prevalence of occlusal traits as % (count) in the sample (n = 122)

Trait	
Dentition phase	
Late mixed	32.0 (39)
Permanent	68.0 (83)
Molar class	
I	61.5 (75)
II	34.4 (42)
III	4.1 (5)
Overjet	
Normal	68.0 (83)
Decreased	1.6 (2)
Increased	30.3 (37)
Overbite	
Normal	56.6 (69)
Decreased	7.4 (9)
Increased	36.1 (44)
Anterior crossbite	
No	95.1 (116)
Yes	4.9 (6)
Posterior crossbite	
No	88.5 (108)
Yes	11.5 (14)
Scissorbite	
No	100.0 (122)
Yes	0.0 (0)
Mandibular crowding	
No	69.7 (85)
Yes	30.3 (37)
Dental midline deviation	
No	91.0 (111)
Yes	9.0 (11)

from 0.03 (sway area for both conditions) to 0.09 (antero-posterior load difference for ICP condition). Generally, comparisons between the two recording conditions for each posturographic parameter yielded similar results, with the exception of the right-left load difference. More specifically, sway area yielded final models that included only the male sex and decreased overjet for the RP and ICP conditions, respectively, although these results were not significant. The sway velocity was negatively correlated with age, male sex and molar class II under both recording conditions and positively correlated with increased overbite under the ICP condition. However, only age and sex under the RP condition were significant. Under both recording conditions, antero-posterior load difference was negatively correlated with permanent dentition at a significant level as well as negatively correlated with midline deviation at a significant level. The right-left load difference was positively correlated with decreased overjet and negatively correlated with increased overbite at significant levels under RP condition. Conversely, under ICP condition, variables in the final model were permanent dentition, increased overjet and mandibular crowding, although none were statistically significant.

Finally, all multiple regression models that included age, sex and total number of malocclusal traits as explanatory variables failed to show any significant correlation between malocclusal traits and any posturographic parameter, regardless of the recording condition (results not shown).

DISCUSSION

By monitoring a large sample of young subjects, the present study aimed to determine whether any malocclusal

Table 2 - Posturographic parameters between the two experimental conditions (n = 122)

Parameter	Condition	Median (25th-75th percentile)	Effect size
Sway area (mm^2)	RP	3613.5 (2779.3-4774.5)	0.02
	ICP	3742.0 (2658.8-4798.0)	
	Diff.	**NS**	
Sway velocity (mm/s)	RP	0.8 (0.6-1.3)	0.09
	ICP	0.8 (0.7-1.3)	
	Diff.	**NS**	
Antero-posterior load difference (%)	RP	9.1 (4.8-14.8)	0.05
	ICP	8.8 (3.9-14.3)	
	Diff.	**NS**	
Right-left load difference (%)	RP	11.3 (6.5-16.1)	0.01
	ICP	11.6 (6.8-16.8)	
	Diff.	**NS**	

RP = rest position; **ICP** = intercuspidal position; **Diff.** = difference among the experimental conditions; **NS** = difference not statistically significant.

Table 3 - Results of the backward multiple linear regressions for estimating the correlations between the postural parameters and each explanatory variable in the rest and intercuspidal mandible positions (n = 122)

Explanatory variable	Sway area (mm^2)		Sway velocity (mm/s)		Antero-posterior load difference (%)		Right-left load difference (%)	
	RP	ICP	RP	ICP	RP	ICP	RP	ICP
	R^2 =0.03	R^2 =0.03	R^2 =0.08	R^2 =0.06	R^2 =0.07	R^2 =0.09	R^2 =0.08	R^2 =0.08
Age	--	--	-0.10 (0.05)*	-0.10 (0.05)	--	--	--	--
Male sex	-655.2 (368.3)	--	-0.40 (0.17)*	-0.34 (0.20)	--	--	--	--
Permanent dentition	--	--	--	--	-2.67 (1.27)*	-3.28 (1.29)*	--	2.31 (1.26)
Molar class II	--	--	-0.12 (0.06)	-0.13 (0.07)	--	--	--	--
Molar class III	--	--	--	--	--	--	--	--
Increased overjet	--	--	--	--	--	--	--	--
Decreased overjet	--	--	--	--	--	--	-1.67 (0.65)*	-1.16 (0.64)
Increased overbite	--	403.0 (209.5)	--	--	--	--	3.30 (1.63)*	--
Decreased overbite	--	--	--	0.13 (0.08)	--	--	--	--
Anterior crossbite	--	--	--	--	--	--	--	--
Posterior crossbite	--	--	--	--	--	--	--	--
Mandibular crowding	--	--	--	--	--	--	--	-2.31 (1.28)
Midline deviation	--	--	--	--	-4.08 (2.07)	-4.70 (2.11)*	--	--

Results of the multiple linear regressions are presented as β (Standard error); R^2 = coefficient of determination; **RP** = rest position; **ICP** = intercuspidal position; **--** = excluded from the final model. Level of significance is *$p < 0.05$.

traits were significantly correlated with body posture. Very few correlations were observed, the clinical implications of which may be not relevant. Considering that sample size needed to detect an ES coefficient of 0.2 with a power of 0.80 and an alpha set at 0.05 is 99 subjects,[25] it is unlikely that a lack of statistical power is responsible for the present results. Moreover, although duplicate measurements were performed to reduce variability,[26] the error analysis performed revealed a range of 5.8% to 10.6% variability for the four posturographic parameters included in this paper. Thus, this error must be considered when evaluating the present results, primarily when referring to antero-posterior and right-left load differences.

Recording conditions

In the present study, none of the posturographic parameters were influenced by occlusion state (or mandible position), as the ES coefficients were below the biologically relevant threshold (Table 2). In addition, the results were very similar between the RP and ICP conditions. Interestingly, even results from the final multivariate regression models obtained under RP condition were very similar to those obtained under corresponding ICP condition (Table 3). Therefore, even in the case of dental malocclusion, occlusion state *per se* had no effect on the posturographic parameters. This evidence is consistent with previous investigations using comparable study designs that include subjects with normal occlusions[6,10] as well as with malocclusions.[14] In contrast, some previous investigations[4,5,7] have reported a change in posturographic parameters among different mandible positions through static or dynamic posturography. However, it should be noted that although statistically significant, these differences were small and likely not clinically meaningful, particularly considering the high standard deviations recorded.[2] Therefore, the present evidence demonstrates that activation of the proprioception of the periodontal ligament through ICP has no immediate effects on body posture.

Malocclusal traits

Whereas the occlusion state did not correlate with postural stability in the present study (Table 2), a few correlations were observed for malocclusal traits (Table 3). In particular, overbite and dentition phase primarily showed significant associations with antero-posterior and right-left body load differences. Note that dynamic posturographic parameters, namely sway area and velocity, did not show any significant correlation with malocclusal traits (Table 3). Moreover, malocclusal traits such as decreased overbite correlated with a more balanced load distribution (Table 3). However, the clinical meaning of such correlations is likely to be poor, at least for young subjects with no temporomandibular disorders. This was indicated by the low R^2 obtained for each regression model that ranged from 0.03 (sway area in both occlusion states) to 0.09 (antero-posterior load difference under ICP condition). Thus, even though malocclusal traits were significantly associated with postural stability, they only accounted for 3% to 9% of total variability of the corresponding recorded posturographic parameters. Hence, these correlations appear to have biological rather than clinical implications when referring to body posture,[2,24] at least when posture is recorded using the methods reported here.

Previous studies have shown no significant correlations between body sway recorded through static posturography[10] or leg length inequality[11] and unilateral crossbite in young subjects. Similarly, another study[20] on the correlation between fleche lombaire and trunk inclination in craniofacial morphology reported no significant associations with class II and III malocclusions. In contrast, weak correlations between malocclusion and body posture were observed in more severe skeletal-based malocclusions in class II children[12] and adults.[13] Note that according to the conclusions of the only longitudinal study on this topic, which included a one-year follow-up, postural changes observed were without orthopedic consequence.[13]

In the present study, having a permanent dentition over a mixed dentition showed a significant and negative correlation with antero-posterior load difference under both recording conditions (Table 3). Therefore, permanent dentition is associated with a more balanced antero-posterior load distribution, although clinical meaning is likely negligible. In contrast, a previous study[8] reported large differences in postural stability of subjects having either primary or permanent dentition. However, the groups compared in that study were also greatly unmatched with respect to age (2 to 5 years old versus 16 to 25 years old), making it necessary to interpret the study's conclusions cautiously.

Considering that malocclusal traits are usually present in combination each other,[17,18] a further multivariate analysis (results not shown) was run to evaluate any possible additive effects of such traits on postural stability. However, no significant association was observed. A possible explanation for the low degree of correlation between some malocclusal traits and postural load imbalance (namely, antero-posterior and right-left) may arise from the contention that the stomatognathic system can induce modifications that would likely be limited to the cervical region.[27] Thus, an altered head and neck posture might be responsible for small load imbalances observed here.

We found few correlations between malocclusal traits and body posture recorded through static posturography. These correlations may have poor clinical implications, especially considering the mean error measurement of the static posturography for the antero-posterior and right-left load differences. Nevertheless, further evidence as to whether correlations between the stomatognathic system in general and body posture exist might be yielded through the use of more complex and dynamic posturographic tests. Moreover, future studies capable of establishing a possible correlation between dental malocclusion and body posture are warranted, especially if conducted on older subjects, seeking an orthodontic treatment due to major malocclusal problems or subjects that show combinatory effects with other dysfunctions in the stomatognathic system, such as temporomandibular disorders.

CONCLUSIONS

Orthodontic treatments in young subjects who are negative for temporomandibular disorders should not include the prevention or treatment of postural imbalances among their indications. Moreover, static posturography aimed at monitoring potential body postural effects triggered by dental malocclusion appears to have low relevance.

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