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Evaluation of the correlation between dental occlusion and posture using a force platform

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OBJECTIVES: Force platforms are widely used to evaluate the relationship between posture and dental occlusion. This study evaluated whether force platforms are able to detect eventual postural modifications resulting from dental occlusion.

METHOD: A total of 44 healthy volunteers who were given no information on the aim of the study underwent six postural stabilometric exams under different mandibular and visual conditions. Four parameters were considered: sway area, sway velocity, X axis displacement of the center of the foot pressure and Y axis displacement of the center of the foot pressure.

RESULTS: An analysis of variance (ANOVA) revealed the relative influence of each factor; specifically, the ocular afference significantly influenced the sway area and sway velocity parameters, and the mandibular position had only a weak influence on the sway area parameter.

CONCLUSIONS: Vision was shown to influence body posture, and a weak correlation was observed between mandibular position and body posture in healthy subjects. However, the force platform is most likely not able to clearly detect this relationship. Gnathologists must use caution when using force platform analysis to modify a therapeutic plan. The sway area seems to be the most sensitive parameter for evaluating the effect of occlusion on body posture.

KEYWORDS: Posture; Dental Occlusion; Occlusal Splint; Mandible.

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INTRODUCTION

The human posture represents the position of the body and the spatial relationships between its anatomical segments that maintain balance under dynamic and static conditions (anti-gravity function of the muscles) according to the requirements of the environment and the motor goals.

A dedicated ''Tonic Postural System'' regulates and adjusts postural balance based on visual, vestibular and somatosensory inputs (1), as well as (in some cases) respiration and mood states. In particular, the head and neck position can modify the postural pattern of each individual (2).

In fact, the erect position of the head is maintained by a balanced tension between the craniocervical bones, myofacial structures and dental occlusion, and many neuroanatomical connections have been documented between the oral and cervical areas (3-6).

Based on the available literature, it seems that in this system, the mandible represents a sort of balancing pole that is capable of affecting posture and of being influenced by the posture itself (7).

In the majority of studies involving the hypothetical influence of dental occlusion on posture, as well as in clinical practice, the force platform is the principal instrument used to analyze these correlations, although the results are still contradictory (8). Many authors (9) do not consider the force plate to be a reliable instrument, although there are a few studies demonstrating the scientific reliability of the results obtained using the force plate and its clinical implications (8).

Before using the force plate for the analysis of the correlation between dental occlusion and posture, the following factors should be confirmed:

- The accuracy and precision of the test.
- The reliability of the test.
- Whether the force platform and its parameters are able to demonstrate an influence of dental occlusion on posture.

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Only after having confirmed these elements is it possible to verify the existence and degree of the correlation between dental occlusion and posture.

The accuracy and precision of the instrument are guaranteed by the manufacturer and by the maintenance and calibration of the device.

Some authors (10-12) have studied the reliability of the force plate exam, concentrating on the intrasession variability, and they have obtained excellent results. Other authors have attempted to confirm whether there is also good intersession reliability (13).

In this study, we sought to evaluate whether the force plate is capable of demonstrating a relationship between dental occlusion and posture in healthy subjects.

MATERIALS AND METHODS

Forty-four healthy volunteer subjects, including 30 males and 14 females (ages 17-35 years, mean age 23.75 ± 4.10 years), who were given no information about the aim of the study, were enrolled in the study, which was approved by the ethical committee, after signing an informed consent form.

Based on a clinical and anamnestic analysis, subjects were included in the study if they met the following inclusion criteria:

- Good general health according to the medical history.
- Absence of trauma or surgery, which can influence posture.
- Absence of visual or vestibular problems.
- Absence of any other disorder capable of influencing posture.
- Absence of evident postural problems.
- Presence of at least 28 teeth.
- Dental overjet between 1 and 4 mm.
- Absence of any type of crossbite, open bite or deep bite.
- Absence of cast restoration and extensive occlusal restoration.
- Absence of craniomandibular disorders.

The single-blind experimental protocol was carried out by performing posturographic and stabilometric analysis with a force platform, Postural Health Station (DL Medica SpA, Milano, Italy) (Figure 1). This platform is characterized by load cells with an internal circuit that changes electrical resistance when a force is applied.

The participants underwent a force plate exam; each recording had a duration of 51.2 sec (in accordance with the guidelines of the French Posturology Association) and was performed under the following conditions: mandibular rest position, with eyes opened and closed; mandibular position of centric occlusion, with eyes opened and closed; and mandibular position, with cotton rolls and eyes opened and closed.

To obtain the ''cotton rolls'' mandibular position, cotton rolls that were 8 mm thick and 37 mm long were positioned between the mandibular teeth distal to the canines.

Quiet conditions were maintained during the exam, and disturbing elements were eliminated to avoid any influence on posture.

A force plate was placed 150 cm from a wall such that the subjects were positioned perpendicular to the wall.

Figure 1 - Force platform (DL Medica Spa Milano).

The subjects were required to remain as stable as possible, relaxed, with their arms hanging free beside their trunk, and facing the wall without concentrating on a precise point.

Moreover, all of the subjects were asked to avoid alcohol, sports and conservative therapies during the 24 h before the clinical recordings.

The placement of the subjects on the force plate was standardized; specifically, a hand was placed under the foot of the subject, lifting the foot until it met the following criteria using the markers painted on the surface of the platform (Figure 1):

- Foot angle of 30° following the principal red line.
- Calcaneal tendon positioned along the length of the foot, expressed in French points and centered on the principal red line.
- Malleolus positioned corresponding to the angled red line.
- Second toe root projection corresponding to the principal red line.
- Foot outline corresponding to the areas drawn on the surface of the platform.

Based on the results obtained, four parameters were evaluated: sway area; sway velocity; COP X (position of the center of the foot pressure on the X axis compared with the theoretical ideal position); and COP Y (position of the center of foot pressure on the Y axis compared with the theoretical position)

The statistical analysis of the data was performed using the software Minitab 15 (Minitab Inc. State College, Pennsylvania, USA).

An analysis of variance (ANOVA) with statistical significance indicated by a p-value<0.1 was performed to evaluate the influence of each of the considered factors (visual condition and mandibular position) on the posture of healthy subjects.

Table 1 - Mean and standard deviation of the results.

Parameter	Conditions	Mean	Standard dev.
Sway area	Rest eyes open	94.30	43.50
	Rest eyes closed	143.70	94.10
	Centric eyes open	108.00	63.00
	Centric eyes closed	172.00	130.00
	Cotton eyes open	109.70	80.60
	Cotton eyes closed	178.00	144.00
Sway velocity	Rest eyes open	5.74	1.33
	Rest eyes closed	8.20	2.39
	Centric eyes open	5.77	1.36
	Centric eyes closed	8.14	2.63
	Cotton eyes open	5.78	1.53
	Cotton eyes closed	7.97	2.49
Cop x	Rest eyes open	1.40	7.62
	Rest eyes closed	2.20	7.51
	Centric eyes open	1.06	8.02
	Centric eyes closed	1.84	8.51
	Cotton eyes open	2.02	7.51
	Cotton eyes closed	2.06	6.81
Cop y	Rest eyes open	-8.12	9.96
	Rest eyes closed	-6.60	10.50
	Centric eyes open	-7.00	12.20
	Centric eyes closed	-9.20	11.30
	Cotton eyes open	-8.00	11.60
	Cotton eyes closed	-9.80	11.20

■ RESULTS

A preliminary analysis of the results showed that the values of the postural parameters tended to increase when the subjects' eyes were closed. Results in Table 1.

SWAY AREA: The mean values of the sway area obtained when the eyes were closed were between 143 and 178 mm^2, which is more than 60 mm^2 larger than the values obtained with the eyes open (mean values between 94 and 110 mm^2), demonstrating that the area increased by approximately 39% when the eyes were closed. The variations between the areas recorded in different mandibular position were lower under the same visual conditions (15-30 mm^2). The lowest areas were recorded in mandibular resting position. The mandibular position was able to increase the sway area by approximately 16%.

SWAY VELOCITY: The mean values of the sway velocity when the eyes were closed were between 7.97 and 8.20 mm/s, which is approximately 2.21-2.42 mm/s greater than the velocity obtained when the eyes were open (mean values between 5.74 and 5.78 mm/s), demonstrating that the sway velocity increased by approximately 29% when the eyes were closed.

In different mandibular positions under the same visual condition, there were variations of 0.04 mm when the eyes were open and 0.21 when the eyes were closed; thus, the mandibular position was able to increase the sway area by approximately 0.7-2.5%.

The position of the center of the foot pressure on the X and Y axis is affected by wide variations.

An ANOVA revealed that the sway area and sway velocity parameters were significantly influenced by vision ($p<0.001$).

In contrast, the p-values for the COP X and COP Y parameters were particularly high, with values of $p=0.26$ for the Y axis and $p=0.79$ for the X axis.

The mandibular position significantly influenced only the sway area ($p=0.065$) without significantly affecting the other parameters ($p>0.14$).

Table 2 - ANOVA results.

Parameter	Influence	*p*-value
Sway area	Vision	0.000
	Mandibular pos.	0.065
Sway velocity	Vision	0.000
	Mandibular pos.	0.905
Cop x	Vision	0.794
	Mandibular pos.	0.931
Cop y	Vision	0.260
	Mandibular pos.	0.146

p-values of the ANOVA show the statistical relevance of the influence of vision and mandibular postitions on the postural parameters.

■ DISCUSSION

The results of the ANOVA in this study confirm the existence of an important and clear correlation between vision and postural control (14).

The dynamic stabilometric parameters (area and velocity) seem to be influenced by vision, and we observed a loss of postural control when a subject closed his or her eyes, as demonstrated by an increase in the postural parameter values.

This result can be understood if we assume that the vision represents a fundamental component of the tonic postural system and that the exclusion of vision prevents the superior system from controlling the posture.

We observed that the position of the center of the foot pressure was not influenced by visual or occlusal components.

It can be supposed that the coordinates of the center of the foot pressure are dependent on the patient's positioning on the platform and are not related to the test itself and that the position of the center of the foot pressure on the X axis changes less than on the Y axis because the relationships between the anatomical body parts are more subject to anterior-posterior sway than to lateral sway.

In this study, the mandibular position significantly influenced the sway area parameter, as some authors have previously reported (7,15-17), but it did not influence the sway velocity parameter. The influence of the mandibular position on sway area appears to be weak; however, this result is not completely reliable due to the abnormal statistical distribution of its values.

In a clinical study conducted by Bracco et al. on a sample of 95 healthy subjects, posturometric and stabilometric analyses were performed with a force platform to investigate the influence of three mandibular positions on body posture. All subjects exhibited statistically significant variations of body posture with different mandibular positions according to the asymmetry index and the position of the COP on the X and Y axes (15); this result is in contrast to the results of the present study, which did not reveal an influence of the different mandibular positions on the COP values.

A study by Perinetti et al. showed no significant differences in postural parameters values between the centric occlusion mandibular position and the resting position in a sample of 26 healthy subjects. The sway area, sway velocity and length of the force platform were significantly higher when the subjects had their eyes closed versus open for both mandibular positions. There were no differences between the mandibular rest position and dental occlusion under the different visual conditions. From a theoretical viewpoint, the absolute displacement of the COP was not correlated with the visual condition or mandibular position (9). This finding is compatible with our results, with the exception that we identified a weak influence of the mandibular position on the sway area.

Finally, Sakaguchi et al. evaluated the effect of changing the mandibular position relative to the body posture and, reciprocally, changing the body posture relative to the mandibular position by using a force platform and performing a computerized analysis of dental occlusion loads in a sample of 45 asymptomatic subjects.

Statistically significant differences were found in the sway length and sway area parameters between five different mandibular positions. Furthermore, the occlusal load values revealed by the T-Scan II (Tekscan, Inc., South Boston, MA) system showed a significant difference when a heel lift was positioned under the right foot. It was concluded that changing the mandibular position affected the body posture and vice versa (7,18).

Considering these previous conclusions, it seems probable that, despite the existence of a correlation between dental occlusion and posture, our results are similar to Perinetti's findings.

Due to the presence of some significant differences between the results in the scientific literature and in accordance with the conclusion of Perinetti in his review article (19), the most reasonable interpretation of our results is that the force platform and its most widely used parameters, although commonly used in gnathopostural clinical practice, do not constitute the most ideal method for the analysis of the correlation between dental occlusion and posture because of the lack of sensitivity of the method, especially in healthy subjects.

We can suppose that, because of the increased compliance among young, healthy subjects (especially those without craniomandibular disorders and without occlusal problems), the influence of dental occlusion on posture was not clearly observed in the lower legs, and the use of a force plate makes this difference even more difficult to detect. The sway area was the only parameter that demonstrated a weak ability to detect an influence of dental occlusion on posture.

The force plate is commonly used by clinicians to analyze posture in healthy, pathological and elderly individuals and athletes undergoing postural changes. It is also frequently used by specialists of a variety of disciplines who are interested in posture (e.g., physiatrists, physiotherapists, orthopedists, neurologists, and sports doctors). However, the utility of this instrument for verifying the relationship between occlusion and posture in healthy subjects appears to be less reliable.

Based on the results of this study, gnathologists should be careful in using force platform analysis to modify their therapeutic plans, especially in young patients and those without TMJ disorders, due to its low sensitivity for revealing occlusion-related postural alterations. Thus, the force platform does not seem to be the ideal instrument for use in gnathoposturology.

In fact, despite the results of this study, a correlation between dental occlusion and body posture is suggested by gnathopostural results obtained in clinical practice (20-22), by clinical studies that have been conducted without the use of a force platform (23,24) and especially by the important finding of the existence of a reciprocal relationship between dental occlusion and body posture described by Sakaguchi et al. based on results obtained using a computerized intraoral instrument (7,25). Contrary to the conclusions of other studies (9), the clinical influence of this relationship could be important in gnathopostural approaches to treating painful trunk muscle symptomatology.

Future studies should focus on the development of new experimental protocols based, for example, on 3D analysis to clearly verify the correlation between dental occlusion and posture. These studies should evaluate the importance of this correlation for and its influence on each anatomical segment of the body.

AUTHOR CONTRIBUTIONS

Baldini A, Nota A, and Tripodi D participated in the execution of the experiment. Longoni S conducted the statistical analysis. Cozza P coordinated the study.

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