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Postural changes in orthodontic patients treated with clear aligners: A rasterstereographic study.

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INTRODUCTION

Correlations between dental occlusion and body posture has been discussed and described in the last decades[8, 19, 30]. According to Kandel et al[18], the term “posture” indicates the position of the human body and its orientation in space. Posture involves the activation and the deactivation of muscles, under the control of central nervous system, and with a mechanism of postural adjustments. Through mechanism of feed-back and feed-forward, postural adjustments represent a critical role in postural control. Despite the growing interest in the field there is still a lack of general consensus regarding possible correlation between malocclusions and body, head and/or neck posture[10, 11]. As regards the influence of dental occlusion abnormalities on remote musculoskeletal districts, it was hypothesised that jaw posture may influence distal muscles and cause postural adaptations at the spine cord level. Radiologic investigation is still considered the gold standard for analyzing spine modifications: however the biological costs of this kind of analysis is an important limitation in both clinical and research settings. Non-invasive methods for posture analysis have been introduced, such as posturographic platforms[28] and rasterstereography[3, 4, 36]. Posturographic platforms failed to detect an association between body posture and dental occlusion or, when detected, these were notably small and with poor clinical relevance[25].

Rasterstereography is an investigation method developed by Drerup and Hierholzer[6] allowing the tridimensional reconstruction of the thoracic and lumbar spine starting from the back surface analysis.

Several studies concerning the relationship between the characteristics of the body posture determined by rasterstereographic procedures and certain cephalometric parameters have been published in recent years. Results showed a strong association between cephalometric vertical parameters and body posture parameters[21-24].

In our knowledge there is a lack of studies conducted to test the effects of orthodontic appliances on the rasterstereographic parameters during treatment. In the last decades an increasing number of patients expressed the desire for an aesthetic and comfortable orthodontic alternatives to fixed appliances. To answer this request clear aligners treatment (CAT) was introduced[31, 32]. Recent studies demonstrated that CAT is able to achieve predicted tooth positions with high accuracy[12] and that CAT can obtain clinical results that are comparable to those obtained with fixed appliances[13].

On the basis of these premises, the present study was conducted to answer the following clinical/research question:

1) Does the orthodontic treatment with Invisalign® (Align Technology, San José, CA, USA) aligners produce posture changes during treatment?

The null hypothesis of the study is that no posture changes, evaluated by rasterstereography, in orthodontic patients treated with Invisalign® (Align Technology, San José, CA, USA) could be observed. Considering that aligners produce an alteration of the vertical height due to the occlusal coverage of both dental arches, and that a stimulation of periodontal receptors causes an inhibition of the jaw closing muscles[7], changes in mandibular posture could be hypothesized during aligners treatments.

MATERIALS AND METHODS

The sample consisted of 15 patients (9 females and 6 males) with a mean age of 21,8 years. The patients were recruited at the Orthodontics Department of the Dental School of University of Turin, after a first analysis of all essential diagnostic data (anamnesis, photos, gypsum casts of the dental arches, ortopantomography, skull radiograph, cephalometric analysis). Control Group consisted in 15 patients (8 females and 7 males) with a mean age of 23,67 years.

Inclusion criteria were: patients with class I malocclusions, crowding < 8 mm, with permanent dentition, after the growth spurt, with all the teeth, with the exception of third molars.

Exclusion criteria were motor or neurological problems, internal diseases, orthopedic illness or trauma, orthodontic treatment (ongoing or preceding), extraction cases.

Participants were randomly assigned to one of the two groups:

1. *Study group:* orthodontic treatment was provided with Invisalign aligners (Align Technology, San José, CA, USA). The treatment plan of each patient was designed by the same operator. Treatment was conducted by post-graduate students under the supervision of an expert operator. All patients were provided with a precise sequence of aligners, to be replaced every two weeks, according to the standard treatment protocol[29]. Every month each patient was monitored to perform routine controls. Every patient was instructed to wear the aligners for 21 hours per day as recommended by the producer.
2. *Control group:* These patients were untreated during the study period and were analyzed at the same timepoints of Study Group. They were enrolled in a control program consisting in monthly appointments to perform routine evaluations. Their orthodontic treatments were planned to start after 6 months from the beginning of the study

Rasterstereography. To measure spinal shape on the sagittal plane, a non-invasive technique called rasterstereography (Formetric 4D®, Diers International GmbH, Schlangenbad, Germany) was used. The good correlation between this optical analysis and rx findings was demonstrated in the past[18, 19].

The Formetric 4D® (DIERS, International GmbH, Schlangenbad, Germany) is a largely used rasterstereographic system with excellent reliability[14, 27]. This kind of examination is based on photogrammetry technique, through a single shot of 0.04 s, which can perform accurate and reliable monitoring of body posture without ionizing radiations. It was developed from anatomical and biomechanical models, in order to obtain defined mathematical algorithms and a reconstruction of column curves and anatomical points.[6, 9]. The machine projected a multiple light sections on patient's back from different directions and thus records the back shape information (Figure 1 and Figure 2). Rasterstereography showed a very high reliability for both linear and angular data[5].

This study analyzes the patients (study group and control group) in relaxed standing posture into three different situations: in a relaxed mandible position without nothing between dental arches, in habitual position during maximum voluntary clenching (MVC) and with Invisalign® (Align Technology, San José, CA, USA) in situ for the study group. A two dimensional sagittal profile of patient back was then obtained by mathematical modeling and several measurements were taken and named as follow: the kyphotic angle (KA), spanned by the tangent lines in cervicothoracic inflection point (ICT) and thoracolumbar inflection point (ITL); the lordotic angle, spanned by tangents in ITL and lombo-sacral inflection point (ILS) ; the upper thoracic inclination, spanned by plumb line and ICT tangent; pelvic inclination, spanned by the vertical and tangent ILS (Figure 3[23]).

Every patient was analyzed at T0 (Baseline), at T1 (after 1 month), at T2 (after 3 months) and at T3 (after 6 months).

STATISTICAL ANALYSIS

The normality assumption of the data was evaluated with the Shapiro-Wilk test; homoscedasticity and autocorrelation of the variables were assessed using the Breusch-Pagan and Durbin-Watson tests.

The ANOVA test was performed to estimate the differences between variables levels (2*groups, 4*follow-up). The Control group values were used as reference in intra- and inter-group analyses. Stratification was performed for every considered test. Differences between groups during the follow-up period were also estimated [Case $_{(t3 - t0)}$ vs Control $_{(t3-t0)}$]. For every dependent variable no differences between age and sex were found. For multiple comparisons, the Tukey test at 95% family-wise confidence level was used. The level of significance was set at $p < 0.05$. Values were shown as mean ± SD. Statistical analyses were conducted using the R statistical package (version 3.0.3, R Core Team, Foundation for Statistical Computing, Wien, Austria).

RESULTS

Table 1 shows means and standard deviations of the investigated postural parameters for both study and control groups during relaxed mandible position, during MVC and during Invisalign® wearing (in the study group only). Rasterstereography recordings were performed at t0 (Baseline), at t1 (after 1 month), at t2 (after 3 months) and at t3 (after 6 months).

Intragroup analysis in control group revealed no significative differences.

The Tukey multiple comparison of means (Table 2) showed significant differences after 3 months of treatment with aligners for the Pelvic Inclination during relaxed mandibular position and MVC position. After 6 months three out of four parameters showed differences during relaxed mandibular position and MVC: Kyphosis Angle, Upper Toracic Inclination and Pelvic Inclination.

Tukey multiple comparisons of means (Study (t3 vs t0) vs Control (t3-t0)) showed significant differences between initial and 6 months timepoints. Differences in relaxed mandibular position and intercuspal position were registered for Kyphosis Angle, Upper Toracic Inclination and Pelvic Inclination, while Lordotic Angle showed no significant differences at every timepoint (Table 3).

DISCUSSION

The possible interaction between malocclusion and body posture has been discussed extensively in the past. Despite the large number of studies published on the topic, a general consensus is still lacking[17, 33]. The reason is mainly related to the controversial results reported in the existing literature[34, 35].

Our study demonstrated the existence of a postural effect of the Invisalign® appliance with better results in terms of a positive correspondence between body posture, spine position and occlusal contacts. Comparing treated patients with untreated controls, significant differences were revealed after 6 months of treatment, while no differences were found after 1 month and after 3 months of treatment. Since the treated malocclusion was a class I malocclusion with crowding, after 6 months of treatment the malocclusion was almost corrected, resulting in a more stable intercuspal position. Hellmann et al[15] demonstrated that biting, even if do not change the basic control of postural control strategy, affects neuromuscular co-contraction patterns, resulting in increased kinematic precision. Therefore submaximal biting occurring during normal functions could led to more precise kinematic effects and thus to a more balanced posture resulting from decreased Kyphosis Angle, Upper Toracic Inclination and Pelvic Inclination. Results of the present study were in accordance with those previously highlighted by Lippold et al[22]. However our results contradicted the statements made by Michelotti et al[26], confirming an existing correlation between dental occlusion and posture, but limited only to the cranio-cervical portion of the vertebral column. The available literature reviews[1, 2, 25] suggested that there is a need to improve the methodological quality of the investigations as well as to address more specific clinical questions.

Postural control is no longer considered simply a summation of static reflexes but, rather, a complex skill based on the interaction of dynamic sensorimotor processes[16]. The two main functional goals of postural behaviour are postural orientation and postural equilibrium[16]. Sensory information from somatosensory, vestibular and visual systems is integrated, and the relative weights placed on each of these inputs are dependent on the goals of the movement task and the environmental context. Equilibrium in this context is not a specific position, but rather a dynamic process dealing with the manifold problems of redundancy determined by, e.g. the size of the base of support, the presence of internal and external forces, the availability of sensory information, intermuscular and intramuscular synergy, and coordination of several joints with several degrees of freedom[16]. Consequently, there is no agreement on the general principles of motor control[15,20]. On the basis of these observation could be hypothised that the lack of a general consensus about possible relationships between dental parameters and postural control is related to the static analysis of the entire system. Our preliminary results seem to indicate that orthodontic appliances able to disclose the jaws, improving intercuspation can affect the biting efficiency during function, thus resulting in more controlled neuromuscular co-contractions patterns[15] probably producing a more balanced posture.

As already stated by Korbmacher et al[19] and confirmed later by Lippold et al[22], there is a lack of high quality studies on the relationship of the jaw position to the body posture regarding spine sections below the cervical spine. Rasterstereography is a non-invasive and reliable method to analyse postural parameters in a research setting. Furtheremore, with respect to a stabilometric platform, this method of body posture analysis, carries out a complete 3D analysis about the location of the body in the space instead of evaluating only the projection of the centre of gravity.

CONCLUSIONS

This study demonstrated modifications, after 6 months of orthodontic treatment with clear aligners, of Kyphosis Angle, Upper Toracic Inclination and Pelvic Inclination. Occlusal coverage caused by clear aligners treatment could influence body posture not only for upper spine sections, but also lower spine sections.

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Table 1a

		Case Group (Mean ± SD)			
Test	Follow-up	Kyphosis Angle	Upper Toracic Inclination	Lordotic Angle	Pelvic Inclination
Relax	baseline	46.58 ± 8.29	40.46 ± 8.38	37.70 ± 8.34	20.33 ± 6.44
	1 month	45.43 ± 7.86	39.91 ± 7.84	38.79 ± 8.10	21.01 ± 5.67
	3 months	46.21 ± 9.11	40.11 ± 8.69	38.05 ± 7.86	21.45 ± 4.94
	6 months	43.41 ± 7.59	37.62 ± 9.00	38.17 ± 8.39	22.69 ± 4.25
Clench	baseline	46.35 ± 7.27	40.27 ± 7.14	38.32 ± 8.44	20.57 ± 6.55
	1 month	46.33 ± 8.61	40.53 ± 7.84	39.76 ± 7.05	21.79 ± 5.60
	3 months	46.32 ± 10.95	39.55 ± 10.88	38.97 ± 8.73	22.11 ± 4.25
	6 months	44.17 ± 10.07	37.12 ± 10.69	38.72 ± 8.14	23.32 ± 4.53
Aligner	baseline	44.15 ± 8.75	37.75 ± 9.79	36.64 ± 9.22	20.47 ± 6.24
	1 month	45.19 ± 9.75	38.21 ± 10.22	39.51 ± 7.47	21.71 ± 6.54
	3 months	45.77 ± 9.04	39.65 ± 9.06	37.87 ± 7.71	22.55 ± 4.83
	6 months	45.53 ± 10.19	38.23 ± 11.11	38.10 ± 8.31	23.29 ± 4.66

Table 2b

		Control Group (Mean ± SD)			
Test	Follow-up	Kyphosis Angle	Upper Toracic Inclination	Lordotic Angle	Pelvic Inclination
Relax	baseline	47.41 ± 7.17	43.49 ± 5.61	37.63 ± 8.26	17.89 ± 4.61
	1 month	48.12 ± 4.35	42.10 ± 7.02	37.53 ± 6.28	17.53 ± 4.39
	3 months	48.20 ± 6.85	43.64 ± 6.86	36.08 ± 6.12	18.02 ± 4.63
	6 months	49.24 ± 5.78	43.57 ± 6.19	37.11 ± 6.46	18.14 ± 4.47
Clench	baseline	48.19 ± 6.09	43.04 ± 6.35	37.67 ± 6.71	17.88 ± 4.98
	1 month	48.36 ± 4.79	43.56 ± 4.67	38.03 ± 5.80	18.20 ± 3.28
	3 months	49.89 ± 6.07	44.17 ± 6.67	37.10 ± 5.22	17.66 ± 4.87
	6 months	49.12 ± 6.65	44.48 ± 6.34	37.98 ± 6.31	18.06 ± 4.23

Table 2a:Tukey multiple comparisons of means (case vs control) at 95% family-wise confidence level during relax test (* p<0.05)

	Relax			
Follow-up	Kyphosis Angle	Upper Toracic Inclination	Lordotic Angle	Pelvic Inclination
baseline	-0.83 (-7.74, 6.08)	-3.03 (-9.58, 3.52)	0.07 (-7.20, 7.33)	2.44 (-2.67, 7.54)
1 month	-2.69 (-8.63, 3.25)	-2.19 (-8.80, 4.41)	1.25 (-5.30, 7.80)	3.48 (-1.10, 8.06)
3 months	-1.99 (-9.39, 5.32)	-3.54 (-10.60, 3.52)	1.97 (-4.40, 8.33)	**3.43 (0.86, 7.71) ***
6 months	**-5.84 (-11.95, -0.27) ***	**-5.95 (-13.02, -1.13) ***	1.06 (-5.71, 7.83)	**4.55 (0.62, 8.47) ***

Table 2b: Tukey multiple comparisons of means (case vs control) at 95% family-wise confidence level during clench test. (* p<0.05, ref. control group)

	Clench			
Follow-up	Kyphosis Angle	Upper Toracic Inclination	Lordotic Angle	Pelvic Inclination
baseline	-1.84 (-7.84, 4.17)	-2.77 (-3.23, 8.77)	0.65 (-7.52, 6.21)	2.69 (-7.97, 2.59)
1 month	-2.03 (-8.54, 4.48)	-3.02 (-9.02, 2.98)	1.73 (-4.07, 7.52)	3.59 (-0.68, 7.86)
3 months	-3.57 (-11.85, 4.71)	-4.62 (-12.99, 3.75)	1.87 (-4.82, 8.56)	**4.45 (0.46, 8.44) ***
6 months	**-4.95 (-12.80, -2.90) ***	**-7.36 (-15.53, -0.82) ***	0.74 (-5.84, 7.33)	**5.27 (1.27, 9.26) ***

Table 3: Tukey multiple comparisons of means (Case (t3 vs t0) vs Control (t3-t0)) at 95% family-wise confidence level. (* p<0.05)

Test	Kyphosis Angle	Upper Toracic Inclination	Lordotic Angle	Pelvic Inclination
Relax	**-5.00 (-9.40, -0.61) ***	**-2.92 (-8.01, -2.18)***	0.99 (-2.42, 4.41)	**1.59 (0.91, 4.09) ***
Clench	**-3.11 (-8.25, -2.03) ***	**-4.58 (-10.74, -1.57)***	0.09 (-4.50, 4.68)	**-2.56 (0.32, 4.73) ***

Figures

Fig. 1. Schematic illustration of rasterstereography

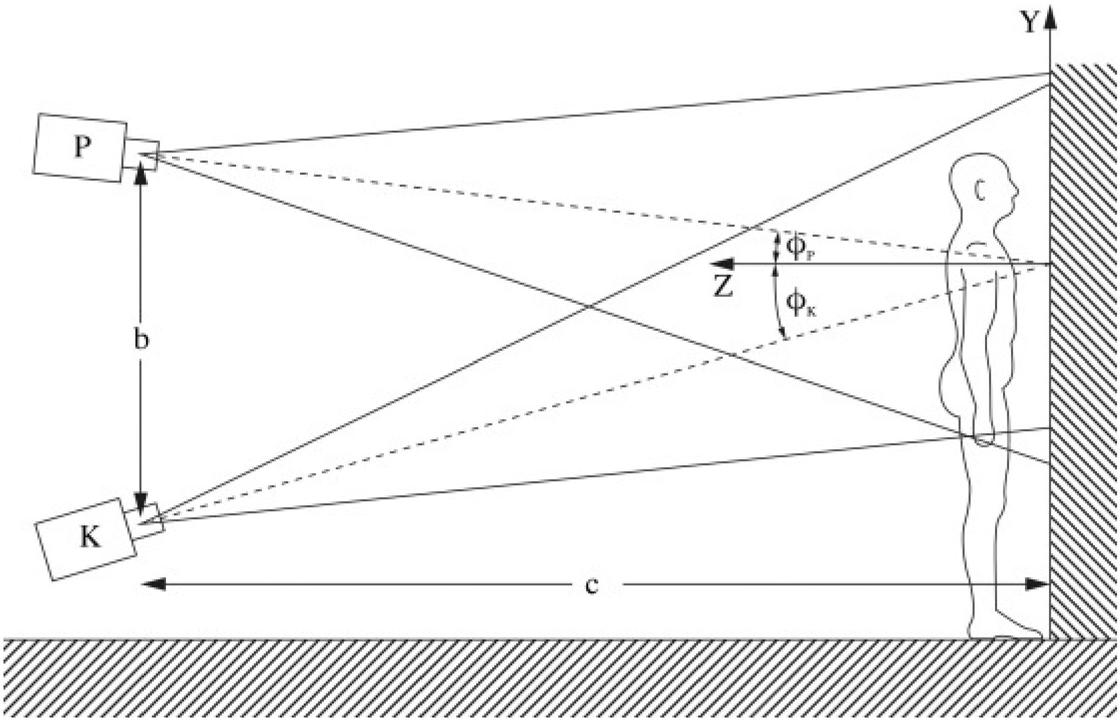

Fig. 2. Example of an analyzed patient

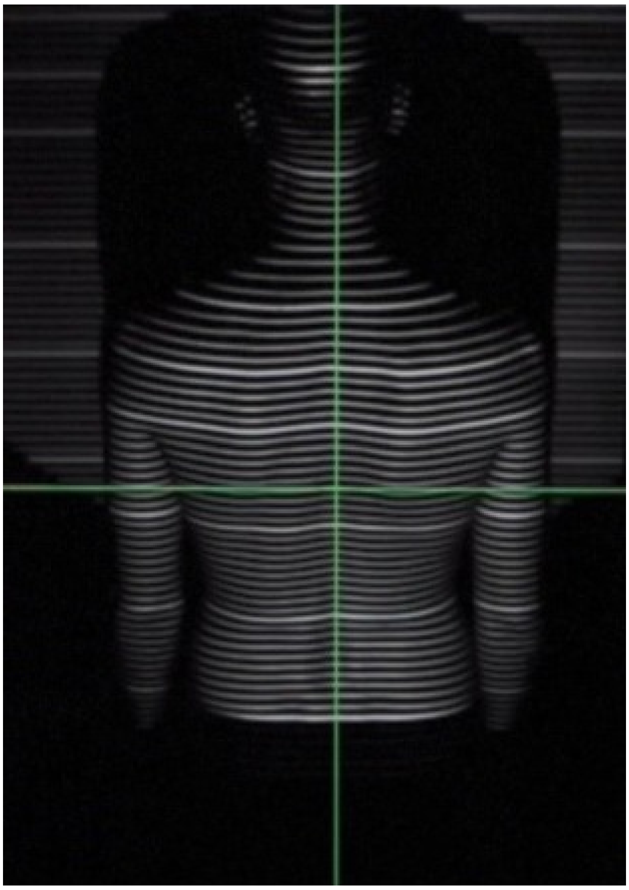

Fig. 3. Analyzed values.