Neuroscience Letters 450 (2009) 221–224

Contents lists available at ScienceDirect

Neuroscience Letters

journal homepage: www.elsevier.com/locate/neulet

# Dental occlusion and postural control in adults

Corinne Tardieu[a], Michel Dumitrescu[b], Anne Giraudeau[a], Jean-Luc Blanc[b], François Cheynet[c], Liliane Borel[b,*]

[a] Faculté d'Odontologie, Université de la Méditerranée, 27, Boulevard Jean Moulin, 13385 Marseille Cedex 5, France
[b] Laboratoire de Neurosciences Intégratives et Adaptatives, UMR 6149, Université de Provence/CNRS, Pôle 3C, Case B, 3, Place Victor Hugo, 13331 Marseille Cedex 3, France
[c] Service de Chirurgie Maxillo-faciale, Stomatologie, Hôpital de la Timone, 163 rue Saint Pierre, 13385 Marseille Cedex 5, France

ARTICLE INFO

*Article history:*
Received 29 July 2008
Received in revised form 1 December 2008
Accepted 2 December 2008

*Keywords:*
Occlusion status
Crossbite
Balance control
Head stabilization
Motion analysis
Static and dynamic posturography

ABSTRACT

We studied the influence of a dental occlusion perturbation on postural control. The tests were performed in three dental occlusion conditions: (Rest Position: no dental contact, Maximal Intercuspal Occlusion: maximal dental contact, and Thwarted Laterality Occlusion: simulation of a dental malocclusion) and four postural conditions: static (stable platform) and dynamic (unstable platform), with eyes open and eyes closed. A decay of postural control was noted between the Rest Position and Thwarted Laterality Occlusion conditions with regard to average speed and power indexes in dynamic conditions and with eyes closed. However, the head position and stabilization were not different from those in the other experimental conditions, which means that the same functional goal was reached with an increase in the total energetic cost. This work shows that dental occlusion differently affects postural control, depending on the static or dynamic conditions. Indeed, dental occlusion impaired postural control only in dynamic postural conditions and in absence of visual cues. The sensory information linked to the dental occlusion comes into effect only during difficult postural tasks and its importance grows as the other sensory cues become scarce.



Postural control is usually described as being based on the visual, proprioceptive, and vestibular systems. Hence, mandible position could have an impact on postural control since it affects the head position. Mandibular proprioception, assisted by the trigeminal nerve and provided by the masticatory muscles and the periodontal ligament [22], contributes to head postural control *via* the sterno-cleido-mastoidian muscle [14].

Several studies have focused on the relation between dental occlusion proprioceptive information and upright stance some of them reporting postural control is influenced by dental occlusion. The laterotrusive occlusal position and the lack of balance between the antagonist left and right masticatory muscles may cause a deviation of the cervical spine [23]. This human modeling study was supported by results on the rat [5]. These authors reported vertebrae alignment changed after dental occlusion modification. Also, changes in the mandibular position could influence gait stabilization [8] and postural stability [3]. Starting from observations of increases of the spinal curve, it was shown that a cervical hyper lordosis is often linked to a class II angle malocclusion and that a scoliosis and a torticolis augment the risk of anterior crossbite [13]. This reciprocal link between postural deficits and dental malocclusion suggests that mandibular position or dental occlusion may influence static and dynamic posture and even cause postural pathologies.

However, other studies reported that dental malocclusion or temporo-mandibular disorders have no influence on postural control [7]. Finally, as shown by a systematic review [11], contradictory results are still reported concerning the influence of dental occlusion on posture. We hypothesized that such contradictions could originate in the nature of the postural task (static versus dynamic) and the sensory cues available to stabilize body in space (light versus darkness).

The present study focused on the influence of dental occlusion on postural control in young, healthy adults. The main issue was to specify the weight of dental occlusion on postural control according to the task difficulty (static and dynamic upright stance) and to the presence or absence of visual cues (eyes open, eyes closed).

Ten young healthy subjects were included, six men and four women, aged from 25 to 28 years (mean: $21 \pm 0.73$). They were selected after evaluation of their plaster dental cast and questionnaire assessment. The selecting criteria were bilateral angle I of molars and canines; absence of anterior and lateral crossbite; absence of oral pathology (malocclusion or articular disorders), orofacial pain, temporary restorative dental treatment or periodontal healing tissues; and absence of neuropathology, postural and gait disorders or vestibular disorders. The subjects gave their written

* Corresponding author. Tel.: +33 4 88 57 68 38; fax: +33 4 88 57 68 18.
*E-mail address:* liliane.borel@univ-provence.fr (L. Borel).

0304-3940/$ – see front matter 
doi:10.1016/j.neulet.2008.12.005

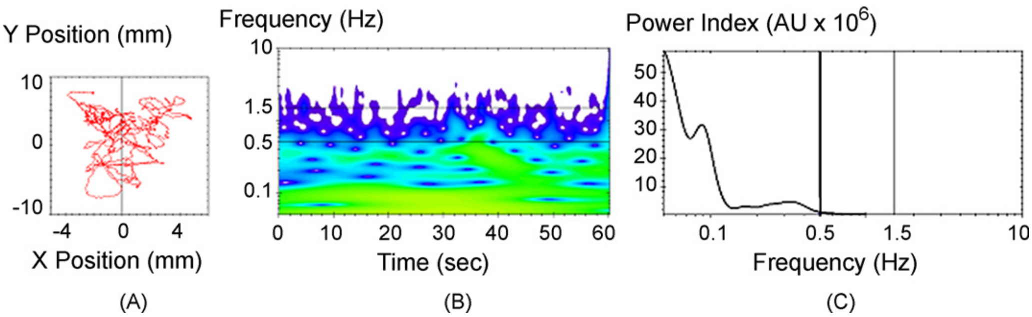


**Fig. 1.** Posturographic recording analysis. A: Stabilogram, B: three-dimensional chart obtained by wavelet analysis, C: posturographic signal power versus frequency plot. This example illustrates the recordings from a test in static eyes open condition, and in dental rest position condition (no dental contact).

consent to participate in the study. The experimental protocols were approved by the local Ethics Committee and followed the recommendations of the Declaration of Helsinki.

From the 10 subjects, angle I was obtained using an orthodontic treatment for six of them. For the other four, angle I was natural. For each subject, 12 recordings were performed using three dental occlusion conditions and four postural conditions.

The dental occlusion conditions were the following: Maximal Intercuspal Occlusion (IO), i.e., when the maximum number of teeth is in contact with the mouth closed; Rest Position (RP), i.e., when there is no dental contact while the mouth is slightly open after swallowing; Thwarted Laterality Occlusion (TLO) was considered as being the opposite of the spontaneous one for each subject. Subjects were required to bite a hard wax (Moyco) up to dento-dental contact. The wax allows for constant dental positioning during the test [16].

The postural recordings were performed using the Multitest Equilibre apparatus (Framiral, Cannes, France), which is a static and dynamic posturography platform. The postural conditions were chosen so as to implicate different sensory information and different levels of task difficulty: (i) stable platform eyes open (Static EO); (ii) stable platform eyes closed (Static EC); (iii) unstable platform eyes open (Dynamic EO); unstable platform eyes closed (Dynamic EC).

The tests were recorded during 60 s, with the subject standing barefoot, without voluntary gestures, hands in natural position (i.e., along the body vertical axis), and the gaze fixed on a real target (EO condition) or on a virtual one (EC condition).

The three dental occlusion conditions (RP, IO and TLO) and the four postural conditions (static EO, static EC, dynamic EO, dynamic EC) were randomly attributed. A resting period of 1 min was observed between each recording to avoid muscular fatigue effects. Each subject performed three experimental sessions including one type of dental occlusion and four postural conditions. Consequently, each subject was tested once for each postural and occlusal condition. Between the sessions, a rest period of 5 min was observed. This randomized order of experimental conditions was intended to dissociate the dental occlusion effect from the session repeating effect, which may lead to habituation.

The stabilometric data were sampled at 50 Hz. The recordings were processed using the PosturoPro software to analyze the postural sway of the subject in the different experimental conditions. The parameters were the body sway area (the projection of the center of foot pressure displacement, mm$^2$) (Fig. 1A), the average speed of the center of foot pressure (mm/s), and the power of the recorded signal in three frequency bandwidths (0.05–0.5 Hz, 0.5–1.5 Hz, and 1.5–10 Hz) (arbitrary units: AU) (Fig. 1C). The PosturoPro software performs a wavelet analysis, yielding a three-dimensional time-resolved and frequency-resolved chart of the instant power of the recording (Fig. 1B). This chart is elaborated using the time stack (i.e., one point at each sampling instant giving a total number of 3000), and the frequency stack (in our case the 352 frequencies used for wavelet decomposition of the recording). The color is given by the value of the power matrix at a given time for a given frequency, suitability coded ("hot" colors for high power values and "cold" colors for low power values). Wavelet analysis also served to compute the mean power for all 352 frequencies over the whole recording time. For a quick evaluation, the mean power curve is then divided into three spectral regions: the first region spans from 0.05 to 0.5 Hz, the second from 0.5 to 1.5 Hz and the third from 1.5 to 10 Hz. Subsequently, a mean level is computed for each spectral region, and is referred to as the power index.

The head position and its stabilization were recorded using a movement analysis system (Codamotion, Charnwood Dynamics, UK). Three active markers were placed in forehead and infraorbital positions to provide for correct analysis in all three space coordinates.

For each subject, the motion recordings were performed simultaneously with the postural ones (60 s), using a sampling frequency of 100 Hz. The angular displacement of the head measured in the XoY, XoZ, and YoZ planes was computed from the position of each active marker by the following formulas:

$$\text{XoZ plane} \quad \alpha(t) = \arctan\left(\frac{x(t) - x_v(t)}{z(t) - z_v(t)}\right)$$

$$\text{YoZ plane} \quad \beta(t) = \arctan\left(\frac{y(t) - y_v(t)}{z(t) - z_v(t)}\right)$$

$$\text{XoY plane} \quad \gamma(t) = \arctan\left(\frac{x(t) - x_v(t)}{y(t) - y_v(t)}\right)$$

where $x(t)$, $y(t)$, and $z(t)$ are the coordinates of the forehead marker at instant $t$ and $x_v(t)$, $y_v(t)$, and $z_v(t)$ are the coordinates of the median of the segment defined by the two infraorbital markers.

Using these values, the head position was defined as the average of each angle, and the head stabilization was defined as the standard deviation of each angle.

Statistical analyses were carried out using repeated-measures analysis of variance (ANOVA) with dental occlusion conditions (RP, IO, TLO) and postural conditions (Static EO, Static EC, Dynamic EO, Dynamic EC) as within-subjects factors. A separate ANOVA was performed with the sessions and postural conditions in order to assess the session-repeating effect (habituation) over time. Results were considered statistically significant for $P < 0.05$.

*Habituation*: our results showed that repeating sessions induced habituation, i.e., the postural parameters progressively decreased over time. This was the case with the powers of the stabilometric recordings computed using the wavelet analysis for the 0.05–0.5 Hz [$F(2, 18) = 6.39$; $P = 0.008$] and the 1.5–10 Hz [$F(2, 18) = 7.26$; $P = 0.005$] frequency bandwidths. Similarly, the average speed of the center of foot pressure decreased [$F(2, 18) = 10.46$; $P = 0.001$], as did the sway area [$F(2, 18) = 3.81$; $P = 0.04$]. Note that

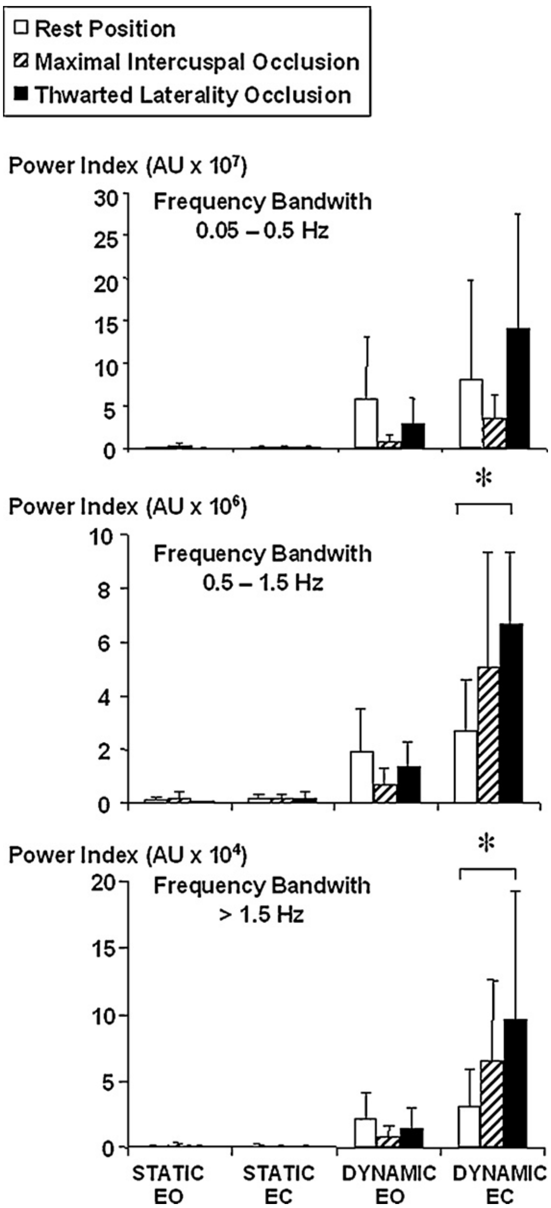


**Fig. 2.** Effect of dental occlusion on postural control. Stabilometric signal power in the three frequency bandwidths compared for each postural condition (Static Eyes Open, Static Eyes Closed, Dynamic Eyes Open, Dynamic Eyes Closed) and for each dental occlusion condition (Rest Position, Maximal Intercuspal Occlusion, Thwarted Laterality Occlusion). Vertical bars represent the confidence intervals. *$P < 0.05$.

this habituation appeared only for the dynamic conditions and that it started from the second session.

No significant differences in postural parameters were found between the TLO versus the IO conditions or between the RP versus IO conditions, whatever the visual context (eyes open or eyes closed). Therefore, we focused on TLO versus RP conditions.

*Dental occlusion effect on postural sway—stabilometric signal power*: in the first frequency band spanning from 0.05 to 0.5 Hz and corresponding to the slower movements, the power index was almost the same in TLO and RP conditions (Fig. 2A).

However, in the second frequency band (0.5–1.5 Hz) the power index was significantly higher in the TLO condition than in the RP condition [$F(1, 9) = 6.99$; $P = 0.026$]. The results also showed a significant interaction of dental occlusion × postural conditions [$F(3, 27) = 8.04$; $P = 0.0005$], thus indicating that the power index was differently affected by the dental occlusion conditions according to the postural conditions. A detailed analysis showed that the dental occlusion modifies the stabilometric signal power only in dynamic conditions (unstable platform) and when there were no visual cues ($P = 0.007$) (Fig. 2B). Note that this was a very robust effect, since it appeared in spite of the habituation effect formerly described.

In the third frequency band spanning from 1.5 to 10 Hz and corresponding to the faster movements, a significant interaction was also found for dental occlusion × postural conditions [$F(3, 27) = 4.90$; $P = 0.007$]. As for the previously described interaction, its origin was the higher energetic cost during dynamic condition without visual cues in the TLO condition ($P = 0.047$) (Fig. 2C).

*Dental occlusion effect on postural sway—average speed of the center of foot pressure*: a significant interaction was found for dental occlusion × postural conditions [$F(3, 27) = 4.85$; $P = 0.008$]. Detailed analyses indicated that this effect resulted from the increase in speed of the center of foot pressure in the dynamic EC postural condition (Fig. 3).

*Dental occlusion effect on postural sway—body sway area*: this parameter was less discriminating since the variance analysis showed that the body sway areas were not significantly different from one experimental condition to another, whether dental occlusion or postural condition (Fig. 3).

*Dental occlusion effect on head orientation and stabilization*: the movement analysis data showed that neither the head position nor the head stabilization significantly differed for the various postural conditions, whatever the dental occlusion condition. Fig. 4 illustrates the head stabilization, i.e., the head angular displacement in the three spatial planes (XoY, XoZ, YoZ) in the dynamic postural condition EC, for the three dental occlusion conditions. Only dynamic postural EC is shown because it is the only condition for which the other parameters were modified.

The TLO condition, which simulates an anomaly of the dental occlusion, induces changes in the postural control parameters relative to the RP condition. This is true for the average speed parameter and for the power index, but only when the dynamic postural

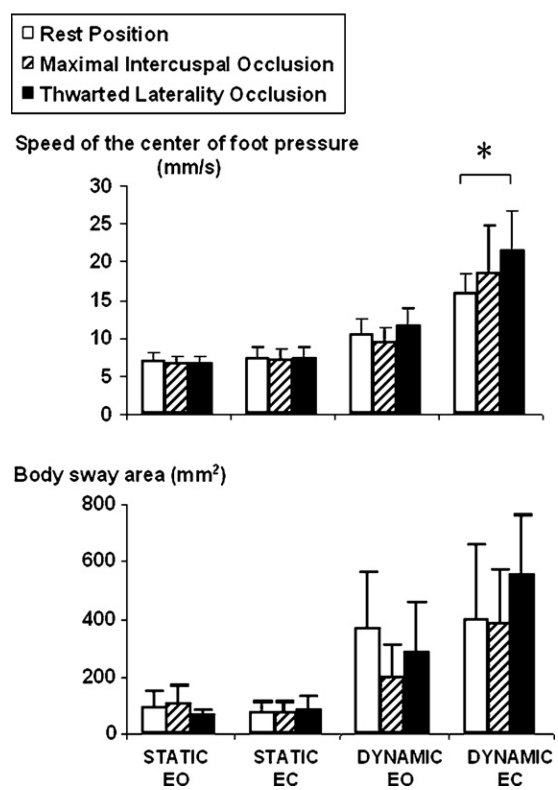


**Fig. 3.** Effect of dental occlusion on postural control. Average speed of the center of foot pressure and body sway area compared for each postural condition and for the three dental occlusion conditions. Same conventions as in Fig. 2.

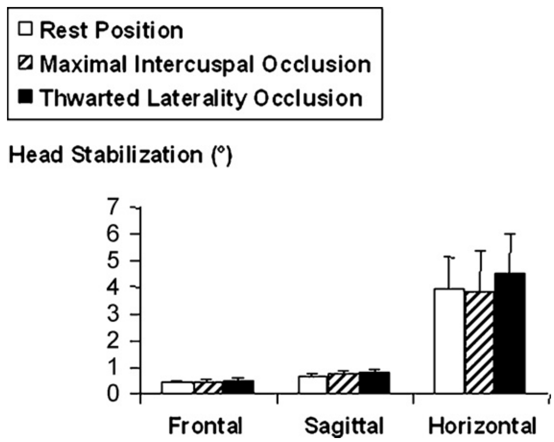


**Fig. 4.** Effect of dental occlusion on head stabilization. Head stabilization in the three spatial planes in the Dynamic Eyes Closed condition compared for the three dental occlusion conditions. Same conventions as in Fig. 2.

conditions are used, and in absence of visual cues. These parameters show that the energetic cost for balancing is higher in the TLO condition.

Note that these significant differences persisted in spite of the habituation effect, which is indicated by the lower amplitude of the postural sway from session to session. Such an effect in dynamic postural conditions (EquiTest) has been reported previously [21]. In the present study, to overcome the habituation phenomena, the recordings were performed in a random order for each subject, and thus the affected recording differed for each subject.

The head position and stabilization were not affected by the TLO condition, even though the postural control characteristics differed. Thus the higher energetic cost previously described seems to be in accordance with the main goal of postural control, which is to stabilize the head in space.

No significant effect was found for the sway area parameter. This result confirms that wavelet analysis parameters have a higher sensitivity and are more discriminating than the classical ones, as shown by Dumitrescu and Lacour [6].

In static conditions, the lateral occlusal perturbation induced no change in the postural control parameters. This dental occlusion affected postural control only in difficult postural conditions. Our results highlight the importance of testing postural condition when assessing an occlusal treatment. Our results may also explain why no improvement in postural parameters was detected after temporary correction of an occlusal anomaly [17], since these tests were performed in static conditions. This may also be the case for the lack of evidence of durable efficiency of occlusal treatments [18,19].

Dental occlusion had no influence on postural control when visual cues were present. This is not surprising, since many studies have described the major role of visual cues in postural control, even when drastic sensory perturbations are present, such as in vestibular loss [1,2]. However, our results differ from those of Gangloff et al. [9] who reported significant differences between the centric relation and the intercuspal occlusion for patients tested in eyes open condition. The differences in experimental conditions may explain these contradictory results.

Finally, postural control was the same for IO and RP. These results agree with those of Bracco et al. [4] and Perinetti [20], who showed an absence of correlation between dental occlusion and postural control. All in all, these results indicate dental contacts have only a weak influence on postural control. Thus, it seems that desmodontal proprioception is not a major factor of postural stabilization. However, in the TLO condition, the proprioceptive cues from the mandibular musculo-articular system are involved, and we show here that the postural control differed from that in the RP condition. These results agree with those of Gangloff and Perrin [10] who reported impaired postural characteristics when the trigeminal muscle is unilaterally anesthetized. Thus, we hypothesize that the influence of dental occlusion on postural control depends on the presence of proprioceptive cues coming from the mandibular musculo-articular system.

Our work shows that dental occlusion differentially contributes to postural control, with no effect in static postural conditions but a worsening in dynamic conditions. Even if the weighting of proprioceptive cues linked to the dental occlusion seems to be lower than those of the other sensory cues, these results are coherent with the notion of sensory cooperation and substitution reported after impairment of other sensory systems [12,15]. The sensory information linked to the dental occlusion comes into effect only during difficult postural tasks and its importance grows as the other sensory cues become scarce.

## References

[1] L. Borel, F. Harlay, C. Lopez, J. Magnan, A. Chays, M. Lacour, Walking performance of vestibular-defective patients before and after unilateral vestibular neurotomy, Behav. Brain Res. 150 (2004) 191–200.
[2] L. Borel, F. Harlay, J. Magnan, A. Chays, M. Lacour, Deficits and recovery of head and trunk orientation and stabilization after unilateral vestibular loss, Brain 125 (2002) 880–894.
[3] P. Bracco, A. Deregibus, R. Piscetta, Effects of different jaw relations on postural stability in human subjects, Neurosci. Lett. 356 (2004) 228–230.
[4] P. Bracco, A. Deregibus, R. Piscetta, G. Ferrario, Observations on the correlation between posture and jaw position: a pilot study, Cranio 16 (1998) 252–257.
[5] M. D'Attilio, M.R. Filippi, B. Femminella, F. Festa, S. Tecco, The influence of an experimentally-induced malocclusion on vertebral alignement in rats: a controlled pilot study, Cranio 23 (2005) 119–129.
[6] M. Dumitrescu, M. Lacour, Nouveaux critères quantitatifs d'analyse du contrôle postural: illustration en pathologie et chez la personne âgée, in: D. Pérennou, M. Lacour (Eds.), Posture et Equilibre. Efficience du contrôle postural, Solal, Marseille, 2006, pp. 65–75.
[7] V.F. Ferrario, C. Sforza, H. Schmitz, A. Taroni, Occlusion and center of foot pressure variation: is there a relationship? J. Prosthet. Dent. 76 (1996) 302–308.
[8] M. Fujimoto, I. Hayakawa, S. Hirano, I. Watanabe, Changes in gait stability induced by alteration of mandibular position, J. Med. Dent. Sci. 48 (2001) 131–136.
[9] P. Gangloff, J.P. Louis, P.P. Perrin, Dental occlusion modifies gaze and posture stabilization in human subjects, Neurosci. Lett. 293 (2000) 203–206.
[10] P. Gangloff, P.P. Perrin, Unilateral trigeminal anesthesia modifies postural control in human subjects, Neurosci. Lett. 330 (2002) 179–182.
[11] B.A. Hanke, E. Motschall, J.C. Türp, Association between orthopedic and dental findings: what level of evidence is available? J. Orofac. Orthop. 68 (2007) 91–107.
[12] S.J. Herdman (Ed.), Vestibular rehabilitation. Contemporary Perspectives in Rehabilitation, FA Davis Company, Philadelphia, 1994, p. 392.
[13] J. Huggare, Postural disorders and dentofacial morphology, Acta Odontol. Scand. 56 (1998) 383–386.
[14] Y. Kibana, T. Ishijima, T. Hirai, Occlusal support and head posture, J. Oral Rehabil. 29 (2002) 58–63.
[15] M. Lacour, Restoration of vestibular function: basic aspects and practical advances for rehabilitation, Curr. Med. Res. Opin. 22 (2006) 1651–1659.
[16] J.P. Lucchini, J. Lavigne, M. Spirgi, J.M. Meyer, The centric relation. I. Contribution to the study of the reliability of 3 materials for interocclusal registration, SSO Schweiz Monatsschr Zahnheilkd. 85 (1975) 229–238.
[17] A. Michelotti, G. Buonocore, M. Farella, G. Pellegrino, C. Pierentili, S. Altobelli, R. Martina, Postural stability and unilateral posterior crossbite: is there a relationship? Neurosci. Lett. 392 (2006) 140–144.
[18] R.S. Milani, D. Deville de Perriere, L. Lapeyre, L. Pourreyron, Relationship between dental occlusion and posture, Cranio 18 (2000) 127–134.
[19] R.S. Milani, D. Deville de Periere, J.P. Micallef, Relationship between dental occlusion and visual focusing, Cranio 16 (1998) 109–118.
[20] G. Perinetti, Dental occlusion and body posture: no detectable correlation, Gait Posture 24 (2006) 165–168.
[21] K.S. Rosengren, K. Rajendran, J. Contakos, L.L. Chuang, M. Peterson, R. Doyle, E. McAuley, Changing control strategies during standard assessment using computerized dynamic posturography with older women, Gait Posture 25 (2007) 215–221.
[22] H. Rouviere, A. Delmas (Eds.), Anatomie humaine descriptive, topographique et fonctionnelle, Tête et cou, vol. 1, Masson, Paris, 1974, p. 608.
[23] T. Shimazaki, M. Motoyoshi, K. Hosoi, S. Namura, The effect of occlusal alteration and masticatory imbalance on the cervical spine, Eur. J. Orthod. 25 (2003) 457–463.