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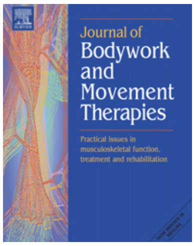

ORIGINAL RESEARCH

Interrelationships between dental occlusion and plantar arch

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Temporomandibular joint disorders;
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Summary *Objective:* The aim of this study was to evaluate the influence of different jaw relationships on the plantar arch during gait.
Methods: 168 subjects, participating in this study, were distributed into two groups: a control (32 males and 52 females, ranging from 18 to 36 years of age) and a Temporomandibular joint disorders group (28 males and 56 females, ranging from 19 to 42 years of age). Five baropodometric variables were evaluated using a baropodometric platform: the mean load pressure on the plantar surface, the total surface of feet, forefoot *vs* rearfoot loading, forefoot *vs* rearfoot surface, and the percentage of body weight on each limb. The tests were performed in three dental occlusion conditions: mandibular rest position (REST); voluntary teeth clenching (VTC); and cotton rolls placed between the upper and the lower dental arches without clenching (CR). The variables were analyzed through repeated measures ANOVA. The Mann–Whitney test was used to compare the postural parameters of the two groups. The level of significance was $p < 0.05$.
Results: As to the intra-group analysis of TMD group, all posturographic parameters in both lower limbs showed a significant difference between REST *vs* CR ($P < 0.001$) and between VTC *vs* CR ($p < 0.001$), except for the percentage of body weight on each limb. The control group showed a significant difference between REST *vs* VTC, REST *vs* CR and VTC *vs* CR ($p < 0.001$) in the mean load pressure on the plantar arch, forefoot surface, rearfoot surface and total surface of feet.

The mean load pressure on the plantar arch in VTC, and the forefoot and total surfaces of feet in CR ($p < 0.05$) were significantly higher in the TMD group in both limbs.

The results of this study indicate that there are differences in the plantar arch between the TMD group and control group and that, in each group, the condition of voluntary tooth clenching determines a load reduction and an increase in surface on both feet, while the inverse situation occurs with cotton rolls. The results also suggest that a change in the load distribution between forefoot and backfoot when cotton rolls were placed between the dental arches can be considered as a possible indicator of a pathological condition of the stomatognathic system (SS) which could

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influence posture. Therefore the use of posture monitoring systems during the treatment of stomatognathic system is justified.

Introduction

Temporomandibular joint disorders (TMD) are a group of diseases affecting masticatory muscles, temporomandibular joint, and surrounding structures (Okeson, 1993). Patients with TMD showed a significantly smaller loading surface in the foot and a consequent increase of load pressure, than control subjects during walking, after insertion of cotton rolls between the upper and the lower dental arches (Tecco et al., 2008). Subsequently the same researchers showed that in healthy subjects without TMD symptoms, there are detectable interrelationships between occlusion and locomotion (Tecco et al., 2010).

Both static and dynamic postural stability are the result of many types of sensory information emanating from the visual, vestibular and proprioceptive systems and from the plantar surface of the foot.

The vestibular and the visual systems signal changes in head and eye position with respect to the external world; the somatosensory system signals motion of the joints as well as changes in the muscle state, while the plantar surface signals contact between the feet and the ground.

The stomatognathic system (maxilla and mandible, dental arches, salivary glands, nervous and vascular supplies, temporomandibular joint and masticatory muscles) may influence muscular function in other parts of the body (Ishijima et al., 1998), range of movement in the hip (Fernández-de-las-Peñas et al., 2006), balance control (Bracco et al., 2004), gaze stabilization quality (Gangloff et al., 2000), ocular convergence, and fusional reserves (Cuccia and Caradonna, 2008).

A close correlation has been recognized between trigeminal input and the activities of the neck muscles (trigemino-cervical reflex) (Alstermark et al., 1992; Abrahams et al., 1993): the activities of the muscle spindles and mechanoreceptors of the periodontal ligament all influence the activities of the motor neuron pool of the sternocleidomastoid muscles through the central ramus of the mesencephalic trigeminal neurons. This contributes to the prevention of excessive head movements and body sway (Manni et al., 1975), and plays an effective role in the enhancement of sports performance (Ishijima et al., 1998). The loss of the occlusal support and instability of mandibular position might influence weight distribution at the feet during clenching, and cause deterioration of quickness (Yoshino et al., 2003).

On the other hand, only few studies have investigated the effect of occlusal conditions on the plantar arch during gait.

Gait is a complex motor skill, frequently used to evaluate general motor function. Gait requires the integration of mechanisms of locomotion with those of balance, motor control, and musculoskeletal functions, in order to keep the projection of the centre of gravity of the subject over the base-of-support (Öberg et al., 1993).

A functional correlation between temporal and masseter EMG activity, interdental occlusal plane, and the plantar arch have been reported. The authors hypothesized the existence of connections between the afferent proprioceptive impulse of the muscles governing the configuration of the plantar arch and the trigeminal motor nucleus that innervates the masticatory muscles (Valentino et al., 1991).

It has been reported that mandibular position affects gait stability (Ferrario et al., 1996), and that wearing complete dentures influences gait by improving the stability of edentulous patients under both static and dynamic conditions (Fujimoto et al., 2001; Okubo et al., 2010).

The aim of the present study was twofold: to identify the effects of TMD on plantar pressure and surface compared to a healthy control group during gait, and to verify if different jaws relationships may modify the plantar arch in the same sample.

Material and methods

The Ethics Committee of the University of Palermo approved the protocol. Written informed consent was obtained from each subject after a full explanation of the experiment.

Subjects

Inclusion criteria for both groups were as follows: age beween18 years and 40 years, absence of any kind of removable prosthetic restoration, presence of a bilateral molar support, absence of periodontal disease, neuropathology, postural and gait disorders, vestibular dysfunction, oculomotor abnormalities and other diseases that could affect balance, negative history of macro trauma in the head region or in the vertex.

The Temporomandibular group was selected from 2 February 2007 to 1 December 2009 from among those referred to the Department of Orthodontics, University of Palermo, Italy. The control group consisted of randomly recruited university students who agreed to participate in the study. They were selected after evaluation of their plaster dental cast and questionnaire assessment.

The presence of TMD in these subjects was confirmed using a clinical examination conducted to measure any signs and symptoms according to the American Academy of Orofacial Pain:

- Painful symptomatology (spontaneous or upon digital palpation) in the masticatory muscles or in the TMJ
- Internal sounds detectable by manual palpation of lateral and/or posterior poles of the TMJ
- Inharmonious or constrained mandibular movements.

The same examination was performed on the control group. There were no signs or symptoms of TMD during history and clinical examination.

The study sample includes 168 patients: 84 (28 males and 56 females) with TMD (TMD group) and 84 healthy subjects (32 males and 52 females, control group).

Table 1 shows the variables considered for the two groups (age, height, weight, age and shoe size).

Measurements

In the present study, a quantitative method was adopted to analyze walking at a natural pace. A baropodometric platform was used to measure the distribution of pressure and load on the plantar surface during locomotory activities (dynamical analysis) by the same examiner, aiming at minimizing possible methodological problems.

For the present study an Electronic Modular Baropodometer (Diagnostic Support S.r.l. Via Dora 1 — 00198 Roma, Italy) was used. The baropodometer consisted of a platform (720 × 75 cm), with a recording surface (120 × 40 cm) in the middle. This platform was characterized by load cells with an internal circuit that changed electrical resistance upon the application of foot pressure. The resolution was of one sensor per cm^2. The platform interfaced with a computed workstation and dedicated software for data storage and subsequent analysis (Milletrix, Diagnostic Support).

The software separated each foot in two regions: forefoot (FF) and rearfoot (RF). For postural evaluation, we selected seven parameters for each occlusal condition on the right and left foot: the mean load pressure on the plantar surface (ML, measured as g/cm^2), the total surface of feet (TS, measured as cm^2), FF *vs* RF loadings (L), FF *vs* RF surfaces (S), and the percentage of body weight placed on each limb (L, measured as %).

The dynamic baropodometric variables of subjects were tested under three experimental conditions: (a) habitual occlusion after swallowing without clenching (mandibular rest position, REST); (b) voluntary teeth clenching (VTC); (c) occlusion by cotton rolls (diameter 1 cm, length 3.7 cm) placed bilaterally between the upper and the lower dental arches without clenching (CR).

In order to assess for method error, a pilot study was performed on a sample of 12 subjects randomly selected in the department. An examiner placed the subject on the platform and performed all the measurements (REST, VTC and CR) following the same protocol of the sample study. Then, the subject was asked to step down the platform and to take several steps. After 2 min, the subject stepped back up on the platform and the recording in REST, VTC and CR was performed again. The method error (ME) for all these measurements was assessed by means of the formula $\mathrm{ME}=\sqrt{(\sum d^2/2n)}$ where d is the difference between the two measurements and n is the number of recordings. Systematic differences between replicated measurements were tested with paired Student's t-test setting the alpha error at 0.1.

Test procedure

The baropodometric examinations were performed in the department of Orthodontics and Gnathology, University of Palermo. The examiner taking stabilometric measurements was blind about the TMD/control group status of the subjects. Each subject received instructions about the procedures to become familiar with the testing protocol and was instructed to swallow two to three times and to relax his/her trunk, upper and lower limbs before beginning the examination.

The subject was asked to take several steps on the platform in order to calibrate the system. With the objective of diminishing variability of the data, the subjects walked without shoes to and fro for three times (for a total of six deambulations) onto the platform during the recording: the software provided to measure the mean values of these three parameters (Figure 1).

For all three tests the subjects were asked to walk along the platform in as stable a manner as possible, maintaining a natural head and body posture with both arms hanging freely beside the trunk while looking to the horizon, according to the protocol supplied by the manufacturer. A resting period of 1min was observed between each recording in REST, VTC and CR. All subjects were asked to avoid alcohol and heavy exercise during the 24 h before the clinical recording.

The order of testing was similar for all subjects.

Table 1 Subject demographics (n = 84).

TMD group	Male = 28		Females = 56		
	Mean	St. dev	Min.	Max	
Age (years)	28.9	10.3	19	42	NS
Height (cm)	165.3	9.3	145	189	NS
Weight (Kg)	60.8	13.3	40	98	NS
Shoe size	36.3	8.3	35	43	NS
Control group	Male = 32		Females = 52		
	Mean	St. dev	Min.	Max	NS
Age (years)	27.1	9.2	18	36	NS
Height (cm)	167.1	9.6	152	194	NS
Weight (Kg)	62.1	12.4	43	87	NS
Shoe size	37.3	9.4	36	45	NS

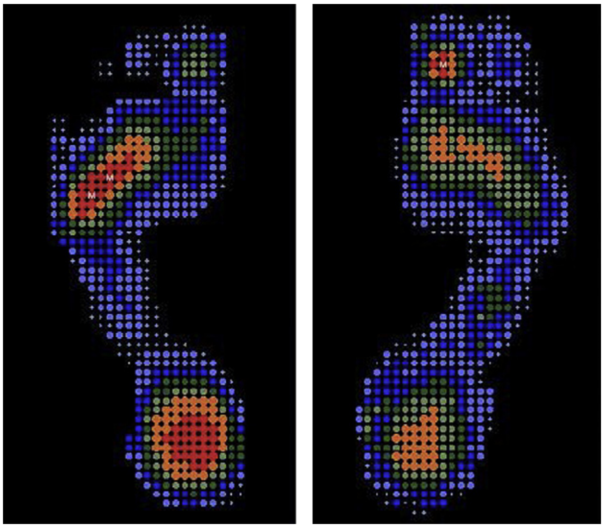

Figure 1 The plantar profile from a baropodometric record. The baropodometric imprints also show the pressure distribution on the foot plantar surface, by means of a color scale (dark peak, maximum pressure of the foot plant).

Data analysis

Descriptive statistics (mean and SD) were computed for all variables.

The differences in age average, foot measurements, weight and height between the control group and the group with TMD was analyzed through Student's *t*-test.

The analysis of variance for repeated measures (ANOVA) test with the Student-Newman—Keuls Multiple Comparisons post-test were used in order to verify whether eventual postural variations in the different mandibular positions were statistically significant. The Mann—Whitney test was used to compare the postural parameters of the two groups.

Data were analyzed using Primer of Biostatistics for Windows (version 4.02, McGraw-Hill Companies, New York). Statistical significance was set at 5 percent error level ($p < 0.05$).

Results

The mean method error was 5.5% for the ML, 8.8% for TS, 15.5 for the FFL *vs* RFL, 18.8 for the FFS *vs* RFS and 28.2 for L.

There was no systematic error for duplicate baropodometric measurements (Student's *t*-test; $p > 0.1$).

No statistical differences were found for age, height, weight and foot measure between the two groups (Table 1).

A detailed analysis showed that dental occlusion modifies the postural conditions and that the condition of VTC determines a significant load reduction and a significant increase in surface on both feet, while the inverse situation occurs in CR, thus indicating that the plantar surface of the foot was differently affected by the dental occlusion. For the intra-group analysis of TMD group, all posturographic parameters in both lower limbs, showed significant differences between REST *vs* CR ($P < 0.001$) and between VTC *vs* CR ($p < 0.001$), except L (Table 2). The control group showed significant differences between REST *vs* VTC, REST *vs* CR and VTC *vs* CR ($p < 0.001$) in the ML, FFS, RFS, TS, while there were no significant interactive effects between mandibular positions and distribution of load on the foot (FFL and RFL, $P > 0.05$), and between feet ($L < 0.05$) (Table 3). No significant differences were observed between the two groups in the right and the left limbs in all occlusal conditions, except in the TMD group, where significantly higher values of ML in VTC, and TS and FFS in CR took place (Tables 4 and 5).

Discussion

The present study has shown that there are differences in the plantar arch between the TMD group and control group and that, in each group, the condition of voluntary tooth clenching determines a load reduction and an increase in surface contact on both feet, while the inverse situation occurs with cotton rolls. The results also suggest that a change in the load distribution between forefoot and backfoot, when cotton rolls were placed between the dental arches, can be considered as a possible indicator of a pathological condition of the stomatognathic system which could influence the posture.

Sensory information issuing from proprioceptors of muscles and articulations and from the plantar surface of the foot are important for postural control.

A role of such functional sensory information could be to inform the central nervous system about ground reaction forces when the body sways while standing on a stable support.

Posture analysis deriving from baropodometrical digital techniques offers various advantages:

- It is free from any influence deriving from contact between patient and examiner
- It allows the investigation of plantar arch, postural and locomotor biomechanics
- The entire sample may be uniformly analyzed through a standardization of procedures.

The foot, from a postural point of view, may cause postural imbalance, or may be an adaptive response to pathological alterations in other parts of the body (especially stomatognathic and oculomotor systems) (Bricot, 1998).

Rothbart (2008) showed a positive correlation among foot pronation, innominate rotation and vertical facial dimension, theorizing an ascending foot-cranial model to explain these findings. Rothbart has demonstrated that pronation creates problems in the knees (Rothbart and Estabrook, 1988).

Such relationship may be reciprocal.

Chaitow (2005) has noted a link between temporomandibular joint disorders, together with pedal disorders, as well as sinusitis, headaches, facial pain, hypertension, shoulder/arm syndrome.

Dysfunctions in the stomatognathic system (eg, asymmetrical loss of an occlusal supporting zone, occlusal interferences) were linked to changes in the distribution of the

Table 2 Mean values (S.D.) for the baropodometric parameters of 84 subjects with TMD.

Right plantar surface (mean values)	REST		VTC		*CR*		**F**	**P**	**SNK Post test**
	Mean	D.S.	Mean	D.S.	*MEAN*	*D.S.*			
ML(g/cm^2)	642.338	178.46	614.54	148.6014	779.9471	186.206	22.33	0.000	VTC/*CR* REST/*CR*
FFS (cm^2)	52.5599	11.95	54.0774	10.47339	46.19118	8.97327	13.16	0.000	VTC/*CR* REST/*CR*
FFL (%)	50.531	2.64	50.394	2.071165	49.35294	2.85331	7.75	0.005	VTC/*CR* REST/*CR*
RFS (cm^2)	47.1862	9.6	48.7537	8.410715	43.26412	7.92672	8.94	0.000	VTC/*CR* REST/*CR*
RFL (%)	47.569	2.58	47.7893	2.033693	48.61765	2.80206	4.15	0.017	VTC/*CR* REST/*CR*
L (%)	50.85	2.84	50.8167	3.003726	51.46471	3.28499	N.S.		
TS (cm^2)	99.7461	21.25	102.83	18.66224	89.45706	16.3208	11.52	0.000	VTC/*CR* REST/*CR*
Left plantar surface (mean values)									
ML(g/cm^2)	650.521	179.984	636.461	159.7988	791.541	169.7432	N.S.		
FFS (cm^2)	51.5093	11.9369	52.4265	11.20759	44.1035	8.753276	15.23	0.000	VTC/*CR* REST/*CR*
FFL (%)	50.7167	2.75309	50.3217	2.535458	48.9941	3.76704	7.29	0.000	VTC/*CR* REST/*CR*
RFS (cm^2)	46.9169	9.2658	47.6523	8.904446	42.3912	7.346517	9.34	0.000	VTC/*CR* REST/*CR*
RFL (%)	47.3464	2.79291	47.7639	2.462033	48.8647	3.53464	5.90	0.003	VTC/*CR* REST/*CR*
L (%)	49.15	2.8437	49.1602	3.014475	48.5353	3.284993	N.S.		
TS (cm^2)	98.4276	20.8187	100.08	19.82342	86.4959	15.59077	12.96	0.000	VTC/*CR* REST/*CR*

REST = mandibular rest position; VTC = maximal intercuspal position; CR= cotton rolls; ML = mean load pressures; FFL = forefoot surface; RFS = backfoot surface; FFL = forefoot load; RFL = backfoot load; L = limb load, percentage of body weight placed on each ; TS = total surface.

Table 3 Mean values (S.D.) for the baropodometric parameters of 84 subjects without TMD.

Right plantar surface (mean values)	REST		VTC		*CR*		F	P	SNK Post test
	Mean	D.S.	Mean	D.S	*Mean*	*D.S.*			
ML(g/cm^2)	626.6708	101.7606	567.9917	66.67307	771.661	149.7735	74.5	0.000	VTC/*CR* REST/*CR* VTC/REST
FFS (cm^2)	50.07583	9.154053	53.22792	8.119759	42.1079	8.953978	36.5	0.000	VTC/*CR* REST/*CR* VTC/REST
FFL (%)	50.87917	2.413004	50.9375	1.981614	49.8761	5.767664	N.S.		
RFS (cm^2)	44.6225	7.788115	47.11958	5.983222	41.9732	9.873456	8.60	0.000	VTC/*CR* REST/*CR* VTC/REST
RFL (%)	47.16667	2.433224	47.30833	1.98032	47.8747	7.937654	N.S.		
L (%)	51.15833	2.996363	51.0625	2.267696	50.7673	6.297656	N.S.		
TS (cm^2)	94.69917	16.54507	100.3483	13.85999	84.0723	15.59077	24.27	0.000	VTC/*CR* REST/*CR* VTC/REST
Left plantar surface (mean values)									
ML(g/cm^2)	621.35	106.55	562.9583	72.21199	739.921	138.8735	N.S.		
FFS (cm^2)	48.2754	9.9883	52.99417	8.763289	41.0965	9.994568	28.43	0.000	VTC/*CR* REST/*CR* VTC/REST
FFL (%)	49.9333	2.59693	50.60417	2.356947	49.9654	7.794565	N.S.		
RFS (cm^2)	45.4342	6.34391	47.205	7.087694	40.9342	9.8987676	14.00	0.000	VTC/*CR* REST/*CR*
RFL (%)	48.0167	2.2738	47.49583	2.14425	48.8557	6.922234	N.S.		
L (%)	48.9875	3.04849	48.9375	2.267696	50.8983	6.987656	N.S.		
TS (cm^2)	93.7113	16.0468	100.2	15.5888	82.1563	11.99977	30.08	0.000	VTC/*CR* REST/*CR* VTC/REST

REST = mandibular rest position; VTC = maximal intercuspal position; CR= cotton rolls; ML = mean load pressures; FFL = forefoot surface; RFS = backfoot surface; FFL = forefoot load; RFL = backfoot load; L = limb load, percentage of body weight placed on each ; TS = total surface.

Table 4 Mean values (S.D.) for baropodometri parameters of subjects with and without TMD.

Right plantar surface (mean values)	REST					
	Subjects with TMD		*Subjects without TMD*			
	Mean	D.S.	*Mean*	*D.S.*	t	P
ML (g/cm^2)	642.338	178.46	626.6708	101.7606	N.S.	
FFS (cm^2)	52.5599	11.95	50.07583	9.154053	N.S.	
FFL (%)	50.531	2.64	50.87917	2.413004	N.S.	
RFS (cm^2)	47.1862	9.6	44.6225	7.788115	N.S.	
RFL (%)	47.569	2.58	47.16667	2.433224	N.S.	
L (%)	50.85	2.84	51.15833	2.996363	N.S.	
TS (cm^2)	99.7461	21.25	94.69917	16.54507	N.S.	
VTC						
ML (g/cm^2)	614.54	148.6014	567.9917	66.67307	2.619	0.010
FFS (cm^2)	54.0774	10.47339	53.22792	8.119759	N.S.	
FFL (%)	50.394	2.071165	50.9375	1.981614	N.S.	
RFS (cm^2)	48.7537	8.410715	47.11958	5.983222	N.S.	
RFL (%)	47.7893	2.033693	47.30833	*1.98032*	N.S.	
L (%)	50.8167	3.003726	51.0625	2.267696	N.S.	
TS (cm^2)	102.83	18.66224	100.3483	13.85999	N.S.	
CR						
ML (g/cm^2)	779.9471	186.206	771.661	149.7735	N.S	
FFS (cm^2)	46.19118	8.97327	42.1079	8.953978	2.978	0.003
FFL (%)	49.35294	2.85331	49.8761	5.767664	N.S.	
RFS (cm^2)	43.26412	7.92672	41.9732	9.873456	N.S.	
RFL (%)	48.61765	2.80206	47.8747	7.937654	N.S.	
L (%)	51.46471	3.28499	50.7673	6.297656	N.S.	
TS (cm^2)	89.45706	16.3208	84.0723	15.59077	2.185	0.030

REST = mandibular rest position; VTC = maximal intercuspal position; CR = cotton rolls; ML = mean load pressures; FFL = forefoot surface; RFS = backfoot surface; FFL = forefoot load; RFL = backfoot load; L = limb load, percentage of body weight placed on each ; TS = total surface.

weight in the feet (Yoshino et al., 2003), to changes in the upper cervical spine (C1—C3) and sacroiliac joints (Fink et al., 2003) and to postural distortions in the sagittal and frontal planes of the trunk of the body (Nicolakis et al., 2000). A positive correlation was found between craniofacial morphology and pelvic inclinations (Lippold et al., 2006).

These studies are examples of descending postural distortion patterns. That is the reason why it is very important to examine the stomatognathic system (SS) dysfunctions, in cases of resistant foot-ankle disorders.

The relationships between SS and posture can be explained by the existence of musculoskeletal and neuro-anatomical influences.

Some authors have hypothesized the existence of a functional connection between muscular groups with the same motor action (*chaînes musculaires*) (Souchard, 1993; Busquet, 1995). Myers (2001) and Stecco (2004) have described models explaining myofascial trains and sequences comprising myofascial connections crossing the entire body, linking the head to the toes and the centre to the periphery. Both these authors have postulated that these trains, or sequences, are directly involved in the organization of movement as well as muscular force transmission.

The fascial system is connected so that changes occur due to these multiple connections: an anterior cruciate ligament injury can generate changes in the masseter, anterior temporalis, posterior cervicals, upper and lower trapezius and sternocleidomastoid muscles (Tecco et al., 2006); Dvorak and Dvorak (1990), injected a hydro-saline solution into the transverse processes of C7 and using electromyography, observed muscle contraction in zones distal from the spinal metamer where the injection was made; an increase was observed in active mouth opening, and a decrease in TrP sensitivity in the masseter muscle, in response to the stretch of the hamstring muscles, assuming a functional relationship between the masticatory and hamstring muscles (Fernández-de-las-Peñas et al., 2006).

The stomatognathic system is integrated with the brainstem centers via the sensorimotor system, including body balance and coordination control systems (Yin et al., 2007).

Studies have revealed connections (in humans and in cats) between motor, mesencephalic, main and spinal nuclei of the trigeminus and vestibular and oculomotor nuclei (Pinganaud et al., 1999), dorsal and ventral horn of the cervical spinal cord (C1—C5) (Buisseret-Delmas and Buisseret, 1990), prepositus nucleus of the hypoglossus, cerebellum (Pinganaud et al., 1999), superior colliculus and many brainstem nuclei (nucleus of the solitary tract, dorsal reticular formation, cuneate nucleus) (Marfurt and Rajchert, 1991; Pompeiarto et al., 1992; Dauvergne et al., 2004). All the anatomical connections mentioned above suggest that portions of the trigeminal system strongly influence the coordination of posture.

Table 5 Mean values (S.D.) for baropodometric parameters of subjects with and without TMD.

Left plantar surface (mean values)	REST					
	Subjects with TMD		Subjects without TMD			
	Mean	D.S.	*Mean*	*D.S.*	t	P
ML (g/cm^2)	650.521	179.984	621.35	106.55	N.S.	
FFS (cm^2)	51.5093	11.9369	48.2754	9.9883	N.S.	
FFL (%)	50.7167	2.75309	49.9333	2.59693	N.S.	
RFS (cm^2)	46.9169	9.2658	45.4342	6.34391	N.S.	
RFL (%)	47.3464	2.79291	48.0167	2.2738	N.S.	
L (%)	49.15	2.8437	48.9875	3.04849	N.S.	
TS (cm^2)	98.4276	20.8187	93.7113	16.0468	N.S.	
VTC						
ML (g/cm^2)	636.461	159.7988	*562.9583*	72.21199	3.844	0.000
FFS (cm^2)	52.4265	11. 20759	52.99417	8.763289	N.S.	
FFL (%)	50.3217	2.535458	50.60417	2.356947	N.S.	
RFS (cm^2)	47.6523	8.904446	47.205	7.087694	N.S.	
RFL (%)	47.7639	2.462033	47.49583	2.14425	N.S.	
L (%)	49.1602	3.014475	48.9375	2.267696	N.S.	
TS (cm^2)	100.08	19.82342	100.2	15.5888	N.S.	
CR						
ML (g/cm^2)	791.541	169.7432	*739.921*	138.8735	N.S.	
FFS (cm^2)	44.1035	8.753276	41.0965	9.994568	2.156	0.033
FFL (%)	48.9941	3.76704	49.9654	7.794565	N.S.	
RFS (cm^2)	42.3912	7.346517	40.9342	9.8987676	N.S	
RFL (%)	48.8647	3.53464	48.8557	6.922234	N.S.	
L (%)	48.5353	3.284993	50.8983	6.987656	N.S.	
TS (cm^2)	86.4959	15.59077	82.1563	11.99977	2.022	0.045

REST = mandibular rest position; VTC = maximal intercuspal position; CR= cotton rolls; ML = mean load pressures; FFL = forefoot surface; RFS = backfoot surface; FFL = forefoot load; RFL = backfoot load; L = limb load, percentage of body weight placed on each ; TS = total surface.

The periodontal receptors respond to forces applied to the teeth. There are two types of receptors in the periodontal ligament: the receptors with their cell bodies in the mesencephalic nucleus of the trigeminus located in the middle of the fulcrum-apex (mainly Ruffini-like, spindle and expanded nerve endings), and principally stimulated during clenching, whereas the receptors whose cell bodies are situated in the trigeminal ganglion are distributed throughout the entire periodontal space (Türker, 2002). Important sensory-motor functions are lost or impaired when these receptors are removed during the extraction of teeth (Trulsson, 2006).

The mesencephalic nucleus of the trigeminus, which extends itself from the dorsal portion of the spinal trigeminal nucleus to the caudal part of the superior colliculus, is a sensory nucleus with unique characteristics. The cells of this nucleus are not central neurons, but protoneurons with the function of ganglionic cells. Kandel et al. (1991) showed that this nucleus can be considered the equivalent of a sensitive peripheral ganglion. They are pseudounipolar neurons that send the axon externally to the CNS, while the other connections establish intra-axial contacts with oculomotor nuclei, cerebellum, reticular formation vestibular nuclei. This may explain the sensitivity of SS to different descending stimuli (stress, anxiety, etc.) or ascending stimuli (proprioceptive inputs from spine, feet, legs).

The functional near-infrared spectroscopy, used to determine oxygenated hemoglobin level, suggested that the activity of the premotor area significantly increased as the clenching strengthened at 20%, 50% and 80% of maximum VTC (Takeda et al., 2010).

Miyahara et al. (1996) showed that VTC can exert a strong influence on the motor activity of other parts of the body through actions at both a cortical and a spinal level. The spinal effect may be due to a reduction of presynaptic inhibition, whereas the cortical effect may be due to a temporal unmasking of lateral excitatory projections by afferent inputs during VTC (Schneider et al., 2000).

Probably the correlation between teeth clenching and an increase in plantar surface area with a decrease in plantar loading, can be due to facilitation of the soleus Hoffman (H-) reflex. The soleus, together with the gastrocnemius, are the main plantar flexors of the ankle.

The soleus H-reflex is modulated by influences descending from the cerebral cortex, as well as by peripheral afferent impulses deriving from the upper limbs or facial muscles (Miyahara et al., 1996).

During human walking the soleus H-reflex increases progressively during the stance phase nearly in parallel with the soleus electromyographic activity reaching its maximum amplitude late in the stance phase, when it would be helpful in lifting the body off the ground.

The same reflex is absent during the swing phase when it would oppose ankle dorsiflexion and while the tibialis anterior is active (Schneider et al., 2000).

The stance phase of walking begins when the heel of the forward limb makes contact with the ground and ends when the toe of the same limb leaves the ground, while the swing phase begins when the foot is no longer in contact with the ground and the limb is free to move. Ankle flexors and extensors are activated alternately during stance and swing phases, respectively. During the stance phase, the ankle extensors contract and ankle flexors relax to extend the ankle joint for propulsion of the body mass. On the other hand, during the swing phase the ankle flexors contract and the extensors relax (Miyahara et al., 1996; Schneider et al., 2000).

The effect of cotton rolls on body posture has been attributed to the convergence of afferents from the dental proprioceptors, the ganglion of Scarpa, and the muscular proprioceptors, on the same nuclei of the brainstem. Cotton rolls should facilitate the changes in the central pathways, determining various effects: they minimize occlusal interferences (Fischer et al., 2009), increase the vertical dimension of occlusion modifying the anteroposterior condylar position related to the glenoid fossa, creating an immediate change in the activity of the masticatory and neck muscles (Leiva et al., 2003), but also reducing proprioceptive periodontal information.

This suggests that the reduction of occlusal contacts reduce the surface and increase the load in all subjects. Tecco et al. (2010) by positioning a cotton roll on the left or on the right side of dental arches showed a lower loading surface of the ipsilateral foot than in habitual occlusion. Since the load distribution between forefoot and backfoot showed significant changes only among TMD patients when two cotton rolls were bilaterally placed between the upper and the lower dental arches, a change of these parameters could be considered as possible indicators of a pathological condition of SS which could influence the posture, with a descending action.

Studies have shown an absence of correlation between SS and posture (Fischer et al., 2009; Michelotti et al., 2006, 2007; Perinetti, 2006). Our findings, however, cannot be compared with those studies because they did not investigate patients during walking, but in static positions. In our opinion, the potential relationship between occlusion and posture has biological plausibility since in pathologic subjects (i.e., with parafunctional activities, atypical swallowing, abnormal occlusal contacts) the teeth get into contact for different time periods and with different intensity in comparison to healthy subjects, generating an imbalance of load distribution on feet during walking.

Conclusions

The success of postural treatment depends on many factors. It appears particularly important to not treat symptoms without investigating the cause of the disorder. This approach suggests that the examination should locate, and the treatment include, the primary factor. The key is to find primary conditions early in the investigation, since their correction will usually favourably influence many other dysfunctioning areas.

Since the stomatognathic system is so important in neurologic organization throughout the body, it should be evaluated whenever there is a postural deviation, such as recurrent cervical dysfunctions or fixations, unlevel head, shoulders and pelvis, aberrant gait or even abnormal foot postures.

The clinical examination, for instance a sensory receptor test that evaluate relationship between various receptors and the use of more or less complex muscular and postural monitoring systems, makes it possible to achieve a more accurate diagnosis and to begin appropriate treatment.

The findings of this study may even explain the interrelationship between stomatognathic inputs and locomotion, both in healthy subjects and in subjects with TMD symptoms. By using stimuli of different intensity and duration, further studies should ascertain how the treatment of TMD affects posture, and enables the most suitable postural parameters to be identified for evaluation and consequently to recognize the descending influences from the SS on pedal disorders.

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