3D ANALYSIS OF JAW KINEMATICS DURING MOUTH OPENING IN HEALTHY SUBJECTS AND PATIENTS WITH TEMPOROMANDIBULAR DISORDERS

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Abstract: Mandible kinematics was assessed in a group of 13 adult women with severe temporomandibular disorders (TMD) and a group of 13 healthy women, matched by age, performing free maximum mouth opening (MMO) and closing. By means of an optoelectronic motion analyzer and a biomechanical model of analysis, 3D displacements and velocities were calculated for the interincisal point and the two condylar reference points, as well as the three Cardan angles of the mandible. Also, the splitting of condylar movement in its rotational and translational components was evaluated in each 10% step of both opening and closing mandibular motion. TMD patients showed significantly reduced maximum mouth aperture together with smaller opening and closing mean velocities. However, their mandibular movement had the same degree of symmetry as the control group. Also, the pattern of condylar roto-translational components during mouth opening and closing was very similar between the healthy and TMD groups, with nearly overlapped parabola-shaped trends. The outcomes showed that in severe TMD patients the biomechanical pattern of mouth opening/closing does not differ from the physiologic condition, but is reduced in range of motion and speed: the pain reflex hampers the movement, whereas the muscular recruitment seems to adapt to the pathologic condition. The findings suggest that the proposed method could be a useful tool to evaluate the neuromuscular coordination during the performance of dynamic masticatory activities, to diagnose functionally altered stomatognathic conditions and to monitor the effectiveness of the relevant treatments.

Keywords: Human temporomandibular joint, 3D motion analysis, TMD desease.

Introduction

The main cause of pain of non-dental origin in the orofacial region is temporomandibular disorder (TMD), a collection of dysfunctions and pain in the masticatory muscles, temporomandibular joints (TMJs) and associated structures, that often coexist with headaches, neck and shoulder pain. Approximately 5-9% of the adult population is affected, with higher prevalence in women at reproductive ages [1,2].

The current gold standard to identify the presence or absence of TMD still remains mainly based on clinical examination supplemented, when deemed appropriate, with imaging [3]. However, no current imaging systems can provide a complete three-dimensional (3D) evaluation of TMJ motion, whereas mandibular movement changes are often perceptible in the presence of TMJ disorders [4]. Conventional radiographic images lack the third dimension; both spiral and helical computed tomography (CT) and magnetic resonance imaging (MRI) can be used to reconstruct 3D joint morphology, but lack the necessary dynamic information, the former ones being also invasive. Current ultrafast MR imaging shows the 3D morphology of the TMJ as continuous, high-resolution, moving images without exposing the subject to radiation; however, this technology distinguishes poorly between teeth and bone, because of low contrast between these two hard tissues. Furthermore, the patient must lie down during MRI imaging, altering normal jaw movements.

The recording of the six degrees of freedom of free jaw movements can be carried out with non-invasive 3D motion analyzers, which allow the recordings to be done while the patient sits upright in a chair. In particular, they permit to study the relative contribution of rotation and translation components of the TMJ condyle-disc assembly [5,6,7]. Indeed the amount of mandibular condylar motion has been suggested to be a good index to assess TMJ conditions [8].

The aim of the current investigation was to quantitatively compare the three-dimensional jaw kinematics of healthy subjects and patients with severe TMD performing non-assisted maximum mouth opening (MMO).

Materials and methods

Subjects and data collection – Thirteen female patients with chronic, bilateral, severe TMD (21–30 years old), and 13 volunteer healthy women (18–34 years old) matched by age were analyzed in this study. To be recruited in the pathologic group, patients had to present a long-lasting severe TMD according to the Research Diagnostic Criteria for TMD [9] and ProTMDmulti protocol [10], and they should not had started treatment yet. The inclusion criteria to be recruited in the control group (CTRL) were: a sound, complete, permanent dentition with bilateral canine and molar Angle Class I jaw relationships; anterior teeth with vertical and horizontal overlap between 0 and 3 mm; maxillary and mandibular interincisal lines without lateral deviations larger than 2 mm; no cast restorations or cuspal coverages, no anterior or lateral reverse occlusion; no previous history of craniofacial trauma or congenital anomalies; no TMJ or craniocervical disorders.

Mandibular kinematics of five consecutive MMO was recorded using an optoelectronic infrared three-dimensional motion analyzer (SMART-DX system, BTS S.p.a., Garbagnate Milanese, Italy), with a 500 Hz sampling rate. Six passive markers (diameter 5 mm) were used: three head passive markers were positioned by means of biadhesive tape on the nasion and the left and right frontotemporale landmarks, defining a cranial reference plane. These three markers were insensitive to skin motion artefacts during jaw movement. The other three were positioned on the three corners of an equilateral triangular stainless steel extra oral device (side 40 mm; weight 2 g); this tool was fixed on the mandibular anterior gingiva just out of dental contact using a surgical adhesive (Stomahesive; Convetec Inc, Deeside, United Kingdom), and provided a mandibular reference system. In a single reference frame, a further passive mandibular marker (diameter: 3 mm) was located on the midline incisor edge (inter-incisor point, IP); it identified a dental (occlusal) landmark, relative to the extraoral system [5]. Similarly, two condylar reference points (CRPs) were firstly individuated by palpation and secondly detected by means of a marked pointer while the subject was keeping her mouth closed in intercuspal position (Figure 1).

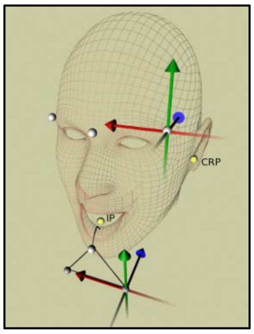

Figure 1: Global view of the marker set and the two reference systems.

All procedures were non-invasive and did not provoke pain or discomfort to the subjects, who were free to stop their examination in any moment. The study protocol was approved by the local Ethical Committee (HCRP-14332/2011).

Kinematic analysis – The extraoral mandibular markers individuated the plane of mandibular motion [5]. The relative motion between the head reference system and the mandibular one was computed by means of mapping operators, which allow analyzing mandibular pathway relative to the head. Subsequently, the displacements of the dental and condylar points were reported in the global reference system (head system), with their paths being evaluated in the horizontal, frontal, and sagittal planes. The data were mathematically smoothed using a second-order Butterworth low-pass filter (cut-off frequency of 8 Hz). In each motion frame, the rotational angles made by the extraoral device (i.e. the mandible) around the three global axes were calculated using Cardan angles. The sagittal mandibular movement during mouth opening and closing was further divided into its rotation and translation components; in each frame of motion, the relative percentage contribution of the two components to the total movement was calculated. In order to compare different patients, the mandibular movement was normalized on MMO distance (sagittal projection): mouth opening and closing were sampled in 10% steps, and in each step the rotation and translation components of the condyle were further considered [7].

Statistical calculations – Descriptive statistics of subjects' age and kinematic parameters (3D angles, displacements and velocities) were calculated separately for CTRL and TMD groups. The normal distribution of data was checked with the Kolmogorov-Smirnov test. All the parameters were compared between CTRL and TMD groups by means of Student's t-test for independent samples. The significance level was set at 5% for all statistical analyses ($p>0.05$, NS, non-significant).

Results

TMD women showed reduced MMO at the IP, together with a limited sagittal angle of mandible rotation. Also, mandibular movement during both mouth opening and closing was significantly slower in TMD group. Peak-to-peak lateral deviation of the IP was almost the same in the two groups (Table 1).

Table 1: Main kinematic parameters, mean±SD.

Measure [unit]	CTRL	TMD	p
MMO [mm]	48.8±4.0	37.2±13.6	.011
Sagittal angle [°]	34.3±3.5	24.9±10.4	.008
Peak-to-peak lateral deviation [mm]	2.9±1.1	3.3±2.1	NS
IP opening mean velocity [mm/s]	68.6±21.6	44.1±24.8	.013
IP closing mean velocity [mm/s]	71.5±18.7	46.3±22.0	.004

During mouth opening and closing, standardized as a percentage of MMO distance (Figure 2), the relative contribution of condylar translation (gliding component) was almost always similar in healthy and TMD women, with differences ranging between 0 and 7% ($p>0.05$ for all steps). The rotation component was prevalent during all the movement of mouth opening and closing, in particular near MMO.

Figure 2: Translation component of the condylar movement in mouth opening and closing, mean±SD.

At the maximum displacement of the interincisal point, the overall percentage of mandibular movement explained by pure condylar translation was very similar between CTRL (mean, 23%; SD, 4%) and TMD groups (mean, 23%; SD, 6%). The mean value of condylar path length was slightly reduced in patients (CTRL, 15.5±3.4 mm; TMD, 12.2±5.8 mm; $p>0.05$).

Discussion

In the current study, we examined whether subjects with TMD of severe degree who had not started treatment presented any changes in their mandibular kinematics with respect to a control group. TMD signs and symptoms were classified according to the RDC/TMD criteria [9], whose reliability had been demonstrated in a multicentre international study [11].

TMD patients showed reduced maximum mouth aperture as well as smaller opening and closing mean velocities. However, their mandibular movement had the same degree of asymmetry (negligible) as the control group.

Also, the pattern of mouth opening and closing determined more by condylar rotation than translation, which is characteristic of subjects with a healthy stomatognathic system [7], was observed in both the CTRL and TMD groups, with nearly overlapped parabola-shaped trends. Anatomically, the decrease of the condylar gliding component near MMO could be due to the progressive passive block provoked on the head of mandible by the ligament tension, which impedes further antero–inferior translation. During mouth closing, after the first steps in which the blockage remains, the translation component progressively increases: the elastic recall of the ligaments outclasses the active blocking system [12,13].

Conclusion

The outcomes showed that in severe TMD patients the biomechanical pattern of mouth opening/closing does not differ from the physiologic condition, but is reduced in range of motion and speed: the pain reflex hampers the movement, whereas the muscular recruitment seems to adapt to the pathologic condition.

The findings suggest that the proposed method could be a useful tool to evaluate the neuromuscular coordination during the performance of dynamic masticatory activities, to detect functionally altered stomatognathic conditions and to monitor the effectiveness of the relevant treatments.

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References

[1] Al-Saleh MA, Armijo-Olivo S, Flores-Mir C, Thie NM. Electromyography in diagnosing temporomandibular disorders. Journal of American Dental Association. 2012; 143 (4): 351-62.

[2] Monaco A, Sgolastra F, Ciarrocchi I, Cattaneo R. Effects of transcutaneous electrical nervous stimulation on electromyographic and kinesiographic activity of patients with temporomandibular disorders: a placebo-controlled study. Journal of Electromyography and Kinesiology. 2012; 22 (3): 463-8.

[3] Klasser GD, Okeson JP. The clinical usefulness of surface electromyography in the diagnosis and treatment of temporo-mandibular disorders. Journal of American Dental Association. 2006; 137 (6): 763-71.

[4] Merlini L, Palla S. The relationship between condylar rotation and anterior translation in healthy and clicking temporomandibular joints. Schweiz Monatsschr Zahnmed. 1988; 98 (11): 1191-9.

[5] Ferrario VF, Sforza C, Lovecchio N, Mian F. Quantification of translational and gliding components in human temporomandibular joint during mouth opening. Archives of Oral Biology. 2005; 50 (5): 507-15.

[6] Gallo LM, Brasi M, Ernst B, Palla S. Relevance of mandibular helical axis analysis in functional and dysfunctional TMJs. Journal of Biomechanics. 2006; 39 (9): 1716-25.

[7] Mapelli A, Galante D, Lovecchio N, Sforza C, Ferrario VF. Translation and rotation movements of the mandible during mouth opening and closing. Clinical Anatomy. 2009; 22 (3): 311-8.

[8] Miyawaki S, Tanimoto Y, Inoue M, Sugawara Y, Fujiki T, Takano-Yamamoto T. Condylar motion in patients with reduced anterior disc displacement. Journal of Dental Research. 2001; 80 (5):1430-5.

[9] Dworkin SF, LeResche L. Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique. Journal of Craniomandibular Disorders, Facial & Oral Pain. 1992; 6 (4): 301-55.
[10] De Felicio CM, Melchior MO, Da Silva MA. Clinical validity of the protocol for multi-professional centers for the determination of signs and syntomps of temporomandibular disorders. Part II. Cranio. 2009; 27 (1): 62-7.
[11] John MT, Dworkin SF, Mancl LA. Reliability of clinical temporomandibular disorder diagnoses. Pain. 2005; 118 (1-2): 61-9.
[12] Lotters FJB, Zwijnenburg AJ, Megens CCEJ, Naeije M. Relationship between condylar and incisor point displacement during habitual maximum open-close movements. Journal of Oral Rehabilitation. 1996; 23 (8): 548-54.
[13] Yatabe M, Zwijnenburg A, Megens CCEJ, Naeije M. Movements of the mandibular condyle kinematic center during jaw opening and closing. Journal of Dental Research. 1997; 76 (2): 714-9.