Assessment of Atlanto-Axial and Mandibular Rotation by Cone Beam Computed Tomography

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Abstract: The cranial portion of the vertebral segment together with the atlanto-occipital joint represents a very complex area. Since this system could be influenced by different atlas and mandibular position, the aim of this work was to assess atlanto-axial and mandibular rotation. Scanora 3-dimensional cone bean computed tomography images from 205 patients without signs or symptoms of temporomandibular disorder were evaluated. Using a digitalized images analyzer, the axial rotations of atlas and mandible rotation were calculated, measuring the angle with respect to the frontal plane. The same direction for the axial rotation of the mandible and for the atlanto-axial rotation (consistent group) was observed in 80.98% of the patients; opposite directions (inconsistent group) were observed in 19.02%. Among the consistent group, the left rotation was observed in 71.08% of the patients and the right rotation in 28.92%. Absolute values showed a more marked rotation for atlas than mandible and higher values for the left rotation were reported for both.

Taking together these data represents important starting points for the knowledge of atlas and mandible relationship and its functional and clinical implication.

Key Words: Atlas, CBCT, mandible

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In general, it is well known that asymmetry can cause postural dysfunction, whereas a symmetric alignment corresponds to a correct postural balance and to coordinated and tonic activities of the muscles. Several anatomical conditions are required for a correct postural position, among which the alignment of bone structures, the symmetric weight distribution, the symmetric stress at the joints, the absence of vascular and nerve compression, and an appropriate and symmetric muscular trophism.[1]

The region of cervical vertebrae, in particular C1-C2, represents a crucial segment from a postural, neurological, and vascular point of view, and the suboccipital muscles play a pivotal role in C1-C2 and atlanto-occipital stabilization. Atlanto-axial rotation, in fact, besides its role in alignment of C2 and other cervical vertebrae,[2] influences also the weight distribution at joint level, leading to a compensatory contraction of antagonist muscles that can generate a chronic stress of joint and muscles.[1]

From a neurological point of view, several evidences about the strong association between the dura and suboccipital muscles, as well as the dura and the nuchal ligament, were present in the literature;[3–5] in particular, headache might be associated with a functional alteration of suboccipital muscles.[6,7]

Furthermore, vertebral arteries represent important structures that should be considered. These arteries, in fact, run into a canal bone constituted from the overlapping of the transverse foramina of the cervical vertebrae and adopt a serpentine course in relationship to the cranio-vertebral region;[8] at the C1-C2 level these arteries present a tortuous course with loops that could be accentuated if C1-C2 vertebrae are rotated,[8–11] while the suboccipital muscles protect the vertebral arteries in the tract between C1 and the occipital bone.[12] An uncommon consequence of the relationship between C1-C2 vertebrae and the vertebral artery is that atlanto-axial rotation could reduce vertebral blood flow in the brain.[13] Indeed, during head rotation to the right side, 2 patients of left vertebral artery transient total occlusion at the atlanto-axial joint were reported.[14]

Cervical vertebrae and mandible are also strictly related. Some evidences suggest a strong correlation between their relative position and orientation; in particular, it is known that temporomandibular joint dysfunction can cause postural alteration with incorrect coordination of axial muscles.[15,16]

On the basis of these evidences, the cranial portion of the vertebral segment together with the atlanto-occipital joint represents a very complex area, in which several muscles, mainly suboccipital muscle, are involved in maintaining vertebral and head position. Since this system could be influenced not only by an alteration of the anatomical structures, but also by a different atlas and mandibular position, the aim of this work was to analyze the relationship between atlanto-axial and mandibular rotation.

METHODS

Scanora 3-dimensional cone bean computed tomography (CBCT, Soredex Oy, Tuusula, Finland; scan time 18–34 seconds, effective exposure time 2.4–6 seconds, fixed anode tube, focal spot 0.5 mm, target angle 15°, 60–90 kV, 4–10 mA) was used in this study. Cone bean computed tomography images were obtained for diagnostic reasons independent of this study from the Dental Clinic in Pistoia. In particular, we used CBCT before oral surgery (ie, implant placement, third molar teeth extraction).

Each individual examination has complied with all 17 basic principles set out in paragraph 3.3 of the "European Commission Radiation, Protection n° 172, Cone Beam CT for dental and maxillofacial radiology, evidence-based guidelines, Directorate-

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General for Energy Directorate D — Nuclear Energy Unit D4 — Radiation protection 2012." For each patient, it has been evaluated the dimensional accuracy of the volume used and, according to paragraph 4.1.1 of the same document, the volume of choice used for the presurgical and preimplant diagnostic investigation has been the large field of view (7.5 cm × 14.5 cm), which is ideal when the complete dentition (or also both temporomandibular joints and upper cervical spine) must be examined. The extension in the horizontal plane of this volume allows obtaining, both for the lower jaw and the upper one, all the required information to perform treatments on the maxillofacial district with an adequate safety, avoiding risks of retakes or examination repetitions due to insufficient or missing information. This one is the minimum volume that allows understanding all the anatomical details of the upper jaw and the lower one, and for the cylindrical geometry of the scan volume, the perimeter is convex up to include also the front of the C1 vertebral body.

Therefore, mandibular deviation and atlanto-axial rotation were evaluated in those CBCT images in which the 2 bony structures were visible. The atlanto-axial and the mandibular rotations were measured in 205 patients. The patient had no signs or symptoms of temporomandibular disorder. The informed consent regarding the medical examinations was previously acquired in the case history forms of the patients.

To reduce mistakes, each patient assumed the position of maximal dental occlusion (this is a repeatable position) and their head was aligned using a red-light landmark.[17] All the radiological procedure and analysis were made by the same operator with the same apparatus.

The machine generates light landmarks (beams) onto 3 axes achieving the correct head placement: vertical axis passing through the Nasion; horizontal axis in correspondence with the infraorbital margin of the maxillary bone; a second lower horizontal axis passing through the chin's lower margin; frontal axis identifying the plane projected in correspondence to the upper mandibular branch. Using a digitalized images analyzer, the axial rotation was calculated, measuring the angle with respect to the frontal plane. For the mandibular rotation, the angle between the frontal plane and the line tangent to the posterior margin of the ramus of the mandible was measured (Fig. 1A). For the atlanto-axial rotation, the angle between the frontal plane and the line tangent to the anterior margin of the transverse foramina of the atlas was measured (Fig. 1B).

Conventionally, the right rotation was considered as negative and the left one as positive (Fig. 2A, B). The patients were classified into 2 groups: consistent group, with the same direction for the axial rotation of the mandible and for the atlanto-axial rotation (both positive or negative); inconsistent group, with opposite direction for the axial rotation of the mandible and for the atlanto-axial rotation (1 positive and 1 negative) (Fig. 2C, D).

The data were presented by mean ± SE. Appropriate analyses of variance (ANOVA test) corrected by the Bonferroni test were performed using statistical analysis software. $P < 0.05$ was considered to be significant.

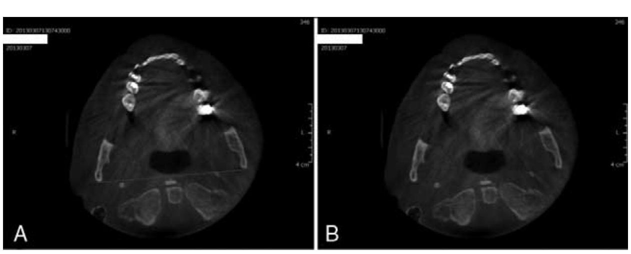

FIGURE 1. (A) Deviation between the frontal plane and the line tangent to the posterior margin of the ramus of the mandible (line). (B) Deviation between the frontal plane and the line tangent to the anterior margin of the intervertebral foramina of the atlas (line).

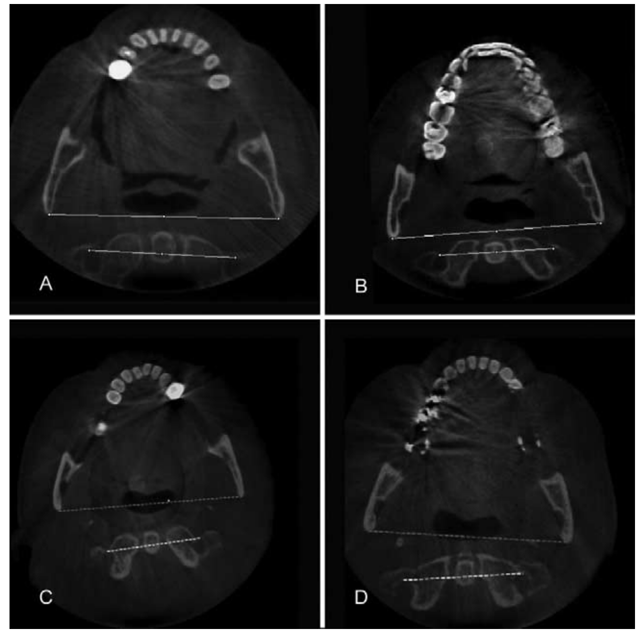

FIGURE 2. (A) Atlanto-axial and mandibular right rotation. (B) Atlanto-axial and mandibular left rotation. (C) Consistent group: atlas and mandible have same direction of rotation. (D) Inconsistent group: atlas and mandible had opposite direction of rotation.

RESULTS

The results obtained from this study showed that all the patients presented atlanto-axial and mandibular rotation and that the 2 anatomical structures were not perfectly aligned with the frontal plane. In particular, 166 patients (80.98%) had same direction for the axial rotation of the mandible and for the atlanto-axial rotation (consistent group), whereas 39 patients (19.02%) had opposite direction (inconsistent group) (Fig. 3A). Within the consistent

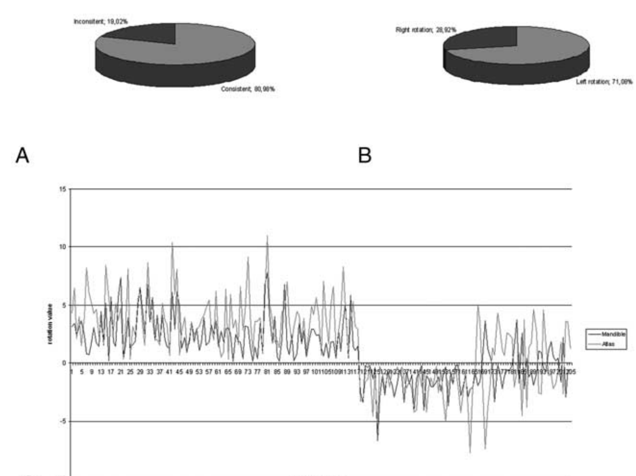

FIGURE 3. (A) Percentage of patients as consistent group and inconsistent group. (B) Within the consistent group, percentage of patients with left and right rotation. (C) Values of atlanto-axial and mandibular rotation in relation with each patient.

TABLE 1. Quantitative Analysis of Atlas and Mandibular Rotation

	Consistent		Inconsistent	
	Left	Right	Left	Right
Mandible	2.56 ± 0.163	-1.75 ± 0.187	1.12 ± 0.279	-1.24 ± 0.183
Atlas	$3.85 \pm 0.204^{*}$	$-2.07 \pm 0.237^{\dagger}$	2.52 ± 0.285	-2.56 ± 0.43

$^{*}P < 0.05$ versus mandible left rotation.
$^{\dagger}P < 0.05$ versus atlas left rotation.

group, 118 patients (71.08%) had left rotation and 48 patients (28.92%) have a right rotation (Fig. 3B); in addition, the values of left rotations were higher than the ones recorded for right rotations for both mandible and atlas measurements. Moreover, although there were substantial differences between the atlanto-axial and mandibular rotations in the same patient, a reciprocal constant proportion was found: the atlas had a more marked rotation rather than the mandible, like the action of an "adaptive multiplier flywheel."

A smaller percentage of patients (19.02%) had opposite direction of rotation (inconsistent group) and, in these patients, the values of the mandible rotations were about a half the atlanto-axial rotation (Fig. 3C); in addition, the values of left rotations were slightly higher than the value recorded for right rotations for both mandible and atlas measurements.

Taking into account all the patients, 61 patients (29.76%) had a higher absolute value of the mandible rotation, whereas 142 patients (69.27%) had a higher absolute value of the atlanto-axial rotation; only 2 patients (0.97%) had the same value for both.

The mean value of the results obtained is reported in Table 1.

DISCUSSION

Cervical vertebrae and mandible are functionally and anatomically related; in particular, it was found that length of the mandible showed strong correlation with the atlas length.[15]

Some authors found that cervical vertebral morphology, and in particular atlas morphology, is related to craniofacial morphology, head posture,[18] and length and growth direction of jaws.[19,20] Moreover, correlations between head posture and the intervertebral space were found,[19,21] and a correlation between the inclination of cervical column and the facial profile, the direction of mandibular growth, the mandibular length, and the airway adequacy was reported.[19,22–24]

On the contrary, other studies analyzed the correlation between jaw position and body posture, but they did not show any significant relationship.[25,26]

The majority of studies evaluated correlations between cervical vertebrae and mandible from a lateral point of view (for example considering the possibility of the relationship between head posture and the sagittal craniofacial morphology). In the present study, these districts were evaluated from a frontal point of view, by means of axial rotation of atlas and mandible.

Regarding atlanto-axial and mandibular rotation, Nisayif and Al-Sahaf[27] reported that atlas dorsal arch and atlas lengths showed a significant correlation with mandibular rotation; in particular, a higher dorsal arch and a longer atlas were related to a major horizontal (anterior) rotation of the mandible.

The results of this study showed that the mandibular and atlanto-axial rotation is a very common aspect; in particular, we found that in 80.98% of the patients, the rotation of the 2 structures was in the same sense. Furthermore, the 19.02% prevalence of the inconsistent group suggests that some factors could influence the atlanto-axial rotation on the opposite side toward the mandible.

This is an important finding, indeed an improved understanding of the relationship between atlanto-axial and mandible rotation could be helpful in investigating if the cervical part of the column could cause problems of the masticatory district.

In addition, an improved understanding of the coordinating mechanisms, which contribute to a normal development of head and neck, is very important for the diagnosis and the treatment of morphological and functional disturbances in the craniofacial region.[19]

These data represent a fundamental starting point for further analysis about chewing and swallowing, for a better characterization of the relationship between atlas and mandible, and for understanding the importance of this relationship from a functional and clinical point of view. In the future, it could be useful to investigate the relationship between atlanto-axial and mandible rotation toward masticatory district dysfunctions, like temporomandibular disorders; furthermore, the relation between neck muscle spasms and changing in atlas and mandibular deviation should be assessed.

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