Cervical spinal pain in chronic craniomandibular pain patients. Recognition, prevalence and risk indicators

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Chapter 2

Kinematics of the human mandible for different head postures


Chapter 2

Abstract

The influence of head posture on movement paths of the incisal point (IP) and of the mandibular condyles during free open-close movements was studied. Ten persons, without craniomandibular or cervical spinal pain, participated in the study. Open close mandibular movements were recorded with the head in five postures, i.e., natural head posture, forward head posture, military posture, and lateroflexion to the right and to the left side, using the Oral Kinesiologic Analysis System (OKAS-3D). In military posture, the opening movement path of the incisal point shifted anteriorly relative to the path with the head in the natural head posture. In a forward head posture, the movement path shifted posteriorly, whereas during lateroflexion, it deviated to the side the head had moved to. Moreover, the intra-articular distance in the temporomandibular joint during closing was smaller with the head in military posture and greater in forward head posture, as compared to the natural head posture. During lateroflexion, the intra-articular distance on the ipsilateral side was smaller. The influence of head posture upon the kinematics of the mandible is probably a manifestation of differences in mandibular loading in the different head postures.
Introduction

Already for decades, the kinematics of the human mandible have been the topic of investigation (Uhlrich, 1959; Gibbs et al., 1971; Goodson and Johansen, 1975; Gibbs and Lundeen, 1982). Until recently, with most of the available mandibular movement recording instruments it was only possible to study the movements of a single point of the mandible, usually the lower incisal point. The movement paths of this point during free open-close and laterotrusive movements as well as during chewing are well documented (Posselt, 1952). More recently, six degrees of freedom jaw movement recording systems have become available. They make it possible to reconstruct the movement paths of any point of the lower jaw with respect to the upper jaw (Gibbs et al., 1971; Merlini and Palla, 1988; Pröschel et al., 1993; Yatabe et al., 1995). This offers the possibility to study the movements of the condyle within the temporomandibular joint as well. One of the interesting suggestions which has come up from these condylar movement studies was that during free open-close movements, the kinematic centre of the condyle/disc complex would move closer to the articular eminence during opening than during closing. Yatabe et al. (1997) concluded that during opening, the condyle-disc complex moves along the articular eminence, whereas during closing there is a small distance between the condyle-disc complex and the articular eminence: the intra-articular distance. This intra-articular distance appears to be dependent upon the mechanical load imposed upon the mandible during closure (Naeije and Lobbezoo, 1997; Huddleston Slater et al., 2000). A small mechanical resistance counteracting mandibular closure makes the intra-articular distance smaller, indicating that the condyle-disc complex is then also slightly pressed against the articular eminence.

Since it is likely that different head postures also alter the mechanical loading upon the mandible, the kinematics of the mandible may be different in different head postures. Despite speculations about it, the influence of head posture upon the kinematics of the human mandible has not been extensively investigated. With the head in an extended posture, the movement paths of the lower incisal point are suggested to run posteriorly to the path with the head in the so-called natural head posture. With the head in a flexed posture, as during eating, the opposite would occur
(Okeson, 1993). However, there is not much experimental evidence that supports these suggestions. The influence of head posture upon the kinematics of the temporomandibular condyle within the joint has not been speculated upon so far and has also not been investigated yet. Therefore, the aim of this study was to determine the influence of head posture on the kinematics of the human mandible. To that end, mandibular movement recordings were made with the head in five postures, i.e., natural head posture, forward head posture, military posture, and lateroflexion of the head to the right side and to the left side. The movement tracings of the lower incisal point and of the mandibular condyle kinematic centre were analysed.

Materials and methods

Participants
Ten persons, 4 men and 6 women, with a mean age of 24 years (SD = 3.1; range = 20-32), without a history of craniomandibular or cervical spinal pain, participated in the study, after giving informed consent. Clinical examination revealed no pain during active movements or during dynamic/static tests of the masticatory system and neck. All participants had an Angle Class 1 molar relationship, uninterrupted dental arches until second molars and no sounds in the temporomandibular joints.

Recording system
The Oral Kinesiologic Analysis System (OKAS-3D) was used to record mandibular movements (Naeije et al., 1995). OKAS-3D is an opto-electronic system capable of recording mandibular movements with six degrees of freedom at a sampling frequency of 300 Hz. Lightweight frames (12 g) were attached to the upper and lower incisors and canines by means of individually adapted clutches. On each frame, three pairs of photocells were located. Two cathode ray tubes (CRT) displays, oriented perpendicular to each other, tracked the movements of these photocells (Figure 1). Offline, the movement path of any mandibular point relative to the maxilla can then be calculated by means of the formulas of the rigid body mathematics. The x-y plane of
the OKAS co-ordinate system runs parallel to the occlusal plane and its x-z plane runs perpendicular to the x-y plane.

**Experimental procedure**

Before the experiment started, the co-ordinates of the lower incisal point and of the lateral pole of both condyles were recorded using a specially developed pointer. To determine the location of the condylar kinematic centre, several 20-second recordings of free maximal open-close and protrusive-retrusive movements were obtained. Subsequently, 20-second recordings of free maximal open-close movements in five different head postures were made. First, recordings were made with the head in its natural head posture (NHP). In NHP, the participant was sitting upright, without head restraints, and looking into the pupils of his eyes in a mirror placed in front of him (Figure 1; Solow and Tallgren, 1971). Second, recordings with the head in the military posture (MP; Juhl et al., 1962) were made. To that end, the participant moved his head 10 degrees backward with respect to NHP, while looking into his eyes and keeping the Frankfort plane horizontally. The angle between the line through the trigus of the left ear and the seventh cervical spinal process with the horizontal plane was measured using a goniometer. One goniometer arm was kept horizontally using a fluid level.
device. In order to maintain MP during the experiment, a small extensible bar was placed between the person's forehead and the mirror (Figure 1). Third, recordings were made with the head in the forward head posture (FHP) (Griegel-Morris et al., 1992). The participant moved his head 20 degrees forward in regard to NHP, while looking into his eyes and keeping the Frankfort plane horizontally. FHP was similarly maintained as described for MP. Finally, recordings with the head held in 20 degrees of lateroflexion (LF) to the right and to the left were made. This was achieved by placing another goniometer on the participant's forehead. The participant could control the amount of lateroflexion by looking at the goniometer in the mirror. In each head posture, 20-second recordings were made while performing open-close movements to and from the intercuspal position.

**Data Analysis**

For each participant, the location of the right and left condylar kinematic centre was determined according to the software procedure described by Yatabe et al. (1995). The kinematic centre was chosen as reference point for tracking condylar movements, since it is the only condylar point, which translates along the articular eminence. For each head posture, the 3D-movement paths of the kinematic centres and of the incisal point (IP) were constructed.

To quantify the influence of head posture on the movement path of the incisal point, the mean y co-ordinate for the head held in MP and FHP, and the mean x co-ordinate for the head held in lateroflexion to the right and to the left, were compared with their corresponding values with the head held in NHP. Comparisons were made at the z co-ordinate of the opening movement path of 2.5 cm. The value of 2.5 cm for the z co-ordinate was chosen, because this was the smallest maximum mouth opening recorded during movements with the head in MP. Figure 2 shows typical examples of incisal point movement paths.

To study the influence of head posture upon the kinematics of the condyle within the temporomandibular joint, the average distance (intra-articular distance) between the opening and closing kinematic tracings was calculated for the movement recordings in the different head postures, as suggested by Visscher et al. (1998) and Huddleston Slater et al. (2000). The opening movement path of the kinematic centre
was divided into 100 horizontal increments of equal length. At each increment, the vertical distance between the opening and closing movement path was determined. The intra-articular distance during the closing phase of an open-close movement is defined as the mean value of these one hundred vertical distances.

ANOVA, followed by post-hoc paired t-tests, was used to test the null-hypothesis that head posture does not influence the mandibular movement path. When ANOVA showed no difference between the right and the left kinematic centre tracings, their pooled data were used in the further analysis. Statistical analysis was performed with significance set at the 0.05 probability level.
**Chapter 2**

**Results**

**Incisal point**

Figure 2 shows an example of the opening movement path of an incisal point with the head held in the forward head posture, natural head posture, and military posture (Figure 2a), and in natural head posture and lateroflexion to the right side, and to the left side (Figure 2b).

**Figure 2.** Example of an open movement path of the incisal point with the head held in forward head posture (FHP), natural head posture (NHP) and military posture (MP; Figure 2a) and in NHP and lateroflexion to the right (LF, right) and to the left (LF, left; Figure 2b). ICP = intercuspal position.

Head posture significantly influenced the opening movement path of the incisal point, both in the sagittal plane (Table 1, p=0.000) and in the frontal plane (Table 2, p=0.008), at a mouth opening of 2.5 cm.

**Table 1.** ANOVA: effect of head posture (forward head posture, military posture and natural head posture) and gender on the y co-ordinate (antero-posterior co-ordinate) of the opening movement path of the incisal point, at a mouth opening of 2.5 cm. (N=10).

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head posture</td>
<td>2</td>
<td>62.37</td>
<td>0.000</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>0.23</td>
<td>0.645</td>
</tr>
</tbody>
</table>
Table 2. ANOVA: effect of head posture (NHP, lateroflexion to the right and to the left) and gender on the x co-ordinate (left-right co-ordinate) of the opening movement path of the incisal point, at a mouth opening of 2.5 cm. (N=10)

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head posture</td>
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<tr>
<td>Gender</td>
<td>1</td>
<td>0.43</td>
<td>0.532</td>
</tr>
</tbody>
</table>

With respect to the path in the natural head posture, the movement path was shifted anteriorly when the head was held in military posture and posteriorly with the head in forward posture (Figure 3). During lateroflexion, the opening movement path deviated to the side the head had moved to in comparison to the path with the head in NHP.

Figure 3. Mean difference and standard deviation in distance between opening movement paths of the incisal point with the head in military posture and forward head posture (y co-ordinate, Figure 3a) and in lateroflexion to the right and left side (x co-ordinate, Figure 3b), in respect to natural head posture (paired t-test, N=10; **p<0.01, ***p<0.001).
**Condylar kinematic centre**

Figure 4 shows an example of the sagittal movement paths of the condylar kinematic centre with the head held in natural head posture, forward head posture, military posture, and in lateroflexion. For lateroflexion, the side the head moved to (ipsilateral side) was distinguished from the other, contralateral side.

![Diagram showing sagittal movement paths of the condylar kinematic centre](image)

**Figure 4.** Example of 20-second recordings of open-close movements of the kinematic centre of the mandibular condyle with the head held in natural head posture, military posture, forward head posture and lateroflexion.

The intra-articular distance within the temporomandibular joint during closure was significantly influenced by head posture (Table 3, p=0.000). Since no effects of the condylar side were found, the pooled data were used in the further analysis.
Table 3. ANOVA: effect of head posture (NHP, MP, FHP, Lateroflexion to the right and to the left), left or right condyle, and gender on the mean intra-articular distance of the temporomandibular joint. (N=10)

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head posture</td>
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<td>25.31</td>
<td>0.000</td>
</tr>
<tr>
<td>Left/right</td>
<td>1</td>
<td>0.00</td>
<td>0.967</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>0.61</td>
<td>0.458</td>
</tr>
</tbody>
</table>

In comparison to the value with the head in natural head posture, the intra-articular distance during closure was smaller when the head was held in military posture and in lateroflexion to the ipsilateral side (Figure 5). No change was found for the contralateral side. With the head held in forward head posture, the intra-articular distance was larger.

Figure 5. Mean intra-articular distance and standard deviation of the temporomandibular joint with the head held in natural head posture (NHP), military posture (MP), forward head posture (FHP), and lateroflexion (LF, ipsilateral and contralateral side) (paired t-test; N=10; ** p<0.01, *** p<0.001, NS=not significant)
Discussion

This study has shown that head posture influences the kinematics of the human mandible. This influence is apparent both in the movement paths of the lower incisal point and in those of the condyles within the temporomandibular joint. According to this study, the opening movement path of the incisal point with the head held in a military posture is shifted anteriorly relative to its path in a natural head posture. In a forward head posture its path is shifted posteriorly. During lateroflexion, the movement path of the incisal point deviates to the side the head has moved to. The suggestion that movements of the incisal point depend upon head posture, has been made before (Okeson, 1993), but needed further experimental verification. Until now, only the effects of head posture on the movements from rest position to maximal occlusion have been studied quantitatively. Goldstein et al. (1984) showed, that head posture influences the rest position of the mandible. In addition, our study has shown that head posture also influenced its position 2.5-cm away from occlusion.

To our knowledge, it was shown for the first time that head posture also influences the movements of the condyle within the temporomandibular joint. Yatabe et al. (1995: 1997) showed that the condyle-disk complex has closer contact with the articular eminence during opening than during closing, which indicates that, during closing, there is a small intra-articular distance in the temporomandibular joint. This intra-articular distance during closure is smaller when, during closing, the mandible is loaded by applying a small, downward directed force on the chin (Naeije and Lobbezoo, 1997; Huddleston Slater et al., 2000). That the intra-articular distance is also smaller with the head in military posture and in the ipsilateral joint during lateroflexion, and larger with the head in a forward posture, may be regarded as a consequence of differences in mechanical loads put on the mandible in the various head postures. The intra-articular distance is also influenced by experimental factors such as the accuracy with which the location of the condylar kinematic centre is determined and the noise in the condylar movement tracings. For the OKAS-3D recording device, the noise in the co-ordinates in the condylar region is about 0.27 mm (Naeije et al., 1995). Due to these experimental factors, the intra-articular distance still has a value of at least 0.20-mm in case the opening and closing condylar tracings
overlap (Huddleston Slater et al., 2000). This indicates that, in particular in the military condition, the opening and closing condylar tracings coincide (Figure 4).

The influence of head posture upon the kinematics of the mandible is probably related to stretching and/or elongation of the opening and closing muscles of the mandible and of other soft tissues that are attached to the mandible, and to the varying influence of the force of gravity upon the mandible. This study has shown that head posture influences intra-articular distance in the temporomandibular joint. However, it should be realised that, in absolute terms, these changes are relatively small (maximum decrease in intra-articular distance is about 0.19 mm). Therefore, it remains uncertain whether abnormal head posture is related to the development of craniomandibular pain. On the other hand, these results do suggest that in studies to the delicate movements of the mandible, it is important to standardise head posture.