Introduction: The temporomandibular joint (TMJ) kinematics was measured on 5 healthy subjects (mean age 24) with no TMJ disorder. Our first goal was to obtain mean angular and translational values for specific movements of the TMJ on normal subjects. In order to get a better description of the TMJ kinematics, the behaviour of the mean helical axis was also computed. Second objective was to test the system for future clinical applications such as optimal surgical planning.

Material and methods: Cycles of normal and maximum open/close movements, together with protrusion and laterotrusion movements were recorded for each subject. An electromagnetic system (Fastrak, Polhemus&Co) was used to measure the motion of the mandible relative to the skull with one sensor rigidly fixed to each part of the joint: One sensor was firmly taped on the forehead and the other was screwed on a resin holder precisely fitting the lower incisors. The small dimensions of the sensors (about 1x1x1.5 cm³) and their low weight allowed a fixation that did not perturb the subject during the recorded movements. The 6 degrees of freedom of each sensor were recorded at 20-Hz relative to a source placed near the subject. Digitisation of anatomical landmarks allowed a proper determination of reproducible anatomical coordinate systems attached to the corresponding sensor. For the skull, the transverse plane was defined as the one passing through the two Svenson’s points and the two infra-orbital points. The sagittal plane was constructed perpendicular to it and passing through the nasion point. Finally the frontal plane was constructed perpendicular to the two others and passing through the mid-point of the intercondylar line, which was assumed to be the origin of the skull reference system. For the mandible, the transverse plane was defined as the plane passing through the tip of the two canines and of the vestibular cusp of the two first molars. The sagittal plane was constructed perpendicular to it and passing through the inter-incisal point. The frontal plane was constructed perpendicular to the two others. As for the skull reference system, the origin was set at the mid-point of the intercondylar line, so that the origin of both skull and mandible reference systems did coincide at maximum intercuspation. The centre of each condyle was assumed to lie 15 mm below the skin and along a line connecting the two Svenson’s points. Angular data (smoothed using a 4th order Butterworth filter at 8 Hz) were expressed using the Grood and Suntay (1983) joint coordinates system as illustrated in Figure 1 for a maximum open/close movement. We have also reconstructed the three-dimensional (3D) trajectory of anatomical landmarks (centre of the condyles, inter-incisal point) during the recorded movements. Finally, in order to relate their position to anatomical structures of the skull, specific data points such as the intersect of the mean helical axis with the sagittal plane were projected on a standard teleradiography of the subject (Figure 2). As already pointed out by Gallo et al (1997), the helical axis yields more information on whole mandibular movements than simply the movements of the condylar points.

Figure 1: Typical angular curves for a single open/close movement (at maximum amplitude). Blue: opening. Red: inclination. Green: axial rotation.
<table>
<thead>
<tr>
<th></th>
<th>Opening (normal)</th>
<th>Opening (maximum)</th>
<th>Laterotrusion (rotation)</th>
<th>Protrusion (translation)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>15.9°</td>
<td>35.2°</td>
<td>11.0°</td>
<td>1.1 cm</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>4.0°</td>
<td>4.2°</td>
<td>3.7°</td>
<td>0.1 cm</td>
</tr>
</tbody>
</table>

*Table 1: Mean amplitudes of the recorded movements of the TMJ, together with the corresponding standard deviations (SD). See text for details.*

**Results:** We measured a mean amplitude for the maximum open/close movement of the TMJ of 35° with a standard deviation (SD) of 4°. The corresponding values for a normal open/close movement were found to be 16° and 4° respectively. The other angular components (inclination and axial rotation of the mandible) were very small, indicating a correct alignment of our anatomically defined reference systems (Figure 1). During the laterotrusion movement, the amplitude of the axial rotation in the transverse plane measured 11° in average with a SD of 3.7°. Finally during protrusion movement, the mandible anterior translation was 1 cm in average with a SD of 0.1 cm. These values are summarized in Table 1. The trajectories of the inter-incisal point and of the mid-point of the intercondylar line correspond to what already observed in the literature. During the open/close movement, the intersect of the mean helical axis with the sagittal plane was found to move in a region situated between 0 and 4 cm below and between 0 and 4 cm behind the mid-point of the intercondylar line as illustrated in Figure 2. However one must notice that the helical axis calculation is very sensitive to every small displacement between the sensor and the bone. This explains why we observed that the mean helical axis pathways varied noticeably between individuals.

![Figure 2: Standard lateral teleradiography of one of the subjects. The projection on the sagittal plane of the skull of the trajectory of the inter-incisor landmark (yellow) and of the mid-point of the intercondylar line (red) are superimposed. The green line corresponds to the intersection of the mean helical axis with this plane.](image)

**Conclusion:** Our measurement set-up allowed us to measure the full kinematics of the TMJ for specific movements. All the measured angular and translational values appeared to be consistent between the different subjects except for the mean helical axis parameters, which varied significantly from one individual to the other. The system proved to be easy to use in a clinical environment. The only time-consuming requirement is the realisation of a resin sensor-holder specific to each patient.

**References**