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## HINGE OPENING AXIS OF THE MANDIBLE<sup>1</sup>

by

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The question whether the mandible carries out a hinge-movement (capitulum rotation<sup>6</sup> only) or whether during mouth opening the condyles shift forward (tuberculum rotation<sup>6</sup>) from the very beginning, has been — and still is — widely discussed. It has been stressed<sup>9</sup> that this discussion is mainly due to lack of precision of the problem.

It has been shown that in human beings the mandible can carry out an opening movement to a distance of up to 20 mm between the incisors without any forward gliding of the condyles<sup>9</sup>. Unlike the habitual, "natural" opening of the mouth, such a hinge movement is remarkably constant (movement path of an anterior reference point is reproducible) and although it is most readily produced passively, it can, with a certain amount of practice, also be reproduced actively<sup>9</sup>.

Some authors<sup>1, 4, 5, 8</sup> have recorded a stationary axis of the hinge opening movement, which they consider of great practical importance for bite registration<sup>9</sup>.

*McCullum*<sup>8</sup> used roentgenography of the mandibular joint with cassettes in the sagittal plane of two cadavers and considered that the shadows of the lead indicators fixed in the cheeks at a site corresponding to the kinematically found axis fell within the outlines of the condyles.

*Beyron*<sup>1</sup> studied 10 cases tomographically in which the hinge axis had been determined by means of kinematic facebow and the sites of the condyles marked with metal indicators on either side of the face. Films were taken in the retruded position with

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<sup>1</sup> Received for publication December 1955.

normal height of bite and a posterior opening of about 10 mm. *Beyron* found that the axial point of each condyle was located in a region round the indicator, i.e. within the outline of the condyle, but not in any regular relationship to any definite part of the latter. In one of the 5 cases illustrated the axis was close to the periphery of the outline of the condyle.

## WRITER'S INVESTIGATION

### AIM OF THE INVESTIGATION

It is apparent from the above that as yet no attempts have been made to determine the relationship between the outline of the condyles with the mouth open to the extent to which it has been demonstrated<sup>9</sup> possible without anterior gliding of the condyles. In addition, there is still divergence of opinion concerning the accuracy of determination of the site of the axis by means of a kinematic facebow<sup>7</sup>. It was therefore thought worth while elucidating these problems by means of different methods, mainly by profile roentgenograms.

### MATERIAL AND METHODS

Profile roentgenograms were taken of 17 male volunteers (undergraduates) aged 20—29 and with all or practically all of their teeth present<sup>9</sup>. Roentgenograms were made of the mandible in the (1) retruded contact position, (2) retruded position with a posterior bite opening of about 20 mm, and (3) with maximal opening. Position 2 was fixed after graphic registration by means of a method previously described<sup>9</sup>.

For registration with the gnato-tesiometer<sup>10</sup> (see below) a further 2 subjects were used, namely a woman aged 20 and a man aged 38, both satisfying the same requirements as to their teeth<sup>9</sup> as the students.

#### *Tracing of the profile roentgenograms*

The roentgenographic outline of the most important parts of the skull with the mandible in the retruded contact position is traced onto transparent paper. Tracing of the outline of the

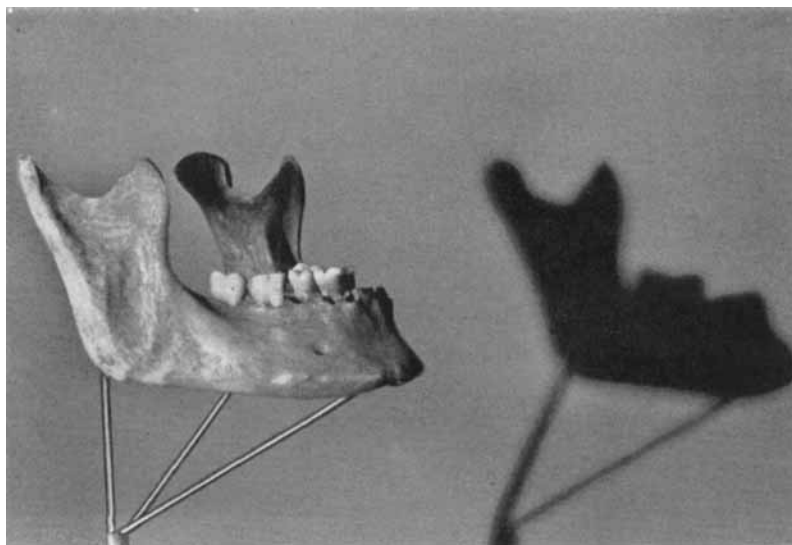


Fig. 1. Mandible on rotatable frame for checking of tracing of profile roentgenograms. The entire apparatus is shown in Fig. 2.

mandible is attended by the following difficulties: (1) the upper outline of the condyles is, as a rule, discernible only when the mouth is fairly wide open or in the protruded position. It is usual to trace the entire outline of the mandible with the mouth wide open and transfer it to the position of the mandible with the mouth closed. This can be done accurately because the outline of the entire mandible except the condyles is distinct in both roentgenograms. (2) Fairly often double contours occur especially in the region of the ramus. As the roentgen rays are not exactly parallel, the distance between the contours will vary with the distance between the rami and with any asymmetric position of the jaw. The latter disadvantage (2) can be eliminated by drawing a line intermediate the double contours.

The accuracy of the measurements of parts capable of giving double contours has been analysed by Björk<sup>2</sup>. He found that reference points intermediate double contours gave the least measuring error. According to Björk, the standard deviation on roentgen measurement from the point 'articulare'<sup>2</sup> to other reference points is between 0.3 and 0.8 mm, whereby it should be

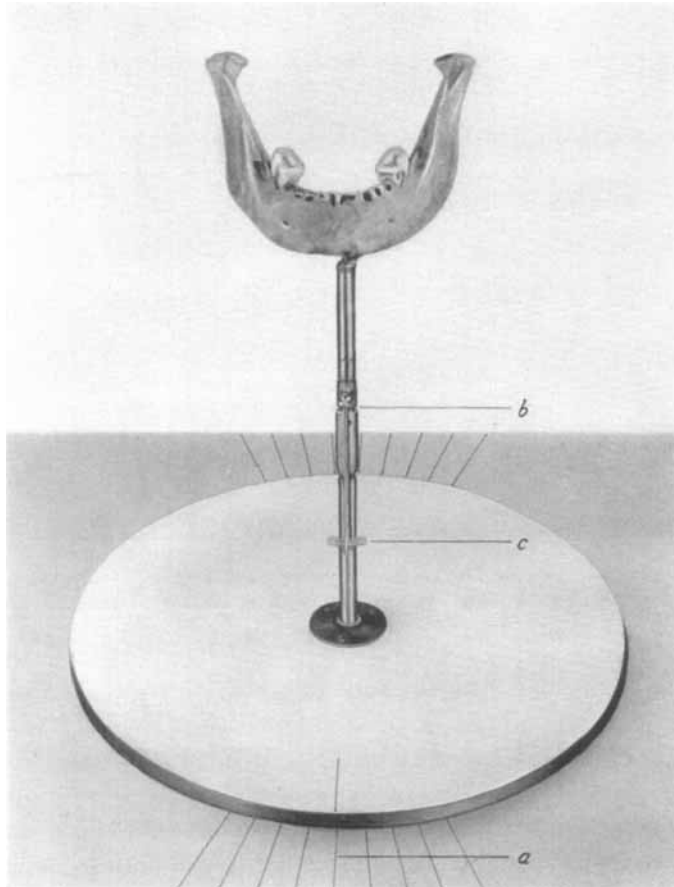


Fig. 2. Apparatus for checking of tracings from roentgenograms. The degree of rotation around the vertical axle can be read from the scale (a) on the foot. Rotation around the sagittal axle (b) can be read from the frontal scale at (c).

observed that these errors appear as a summation of the marking of two points i.e. one point besides the 'articulare' point. As far as the contour of the angulus is concerned, the midpoint was likewise found to be much more accurate than either contour point.

Judging from these results, the mandibular outlines of particular interest, namely those of the condyles, ramus and mandibular base can be traced with such a high degree of accuracy

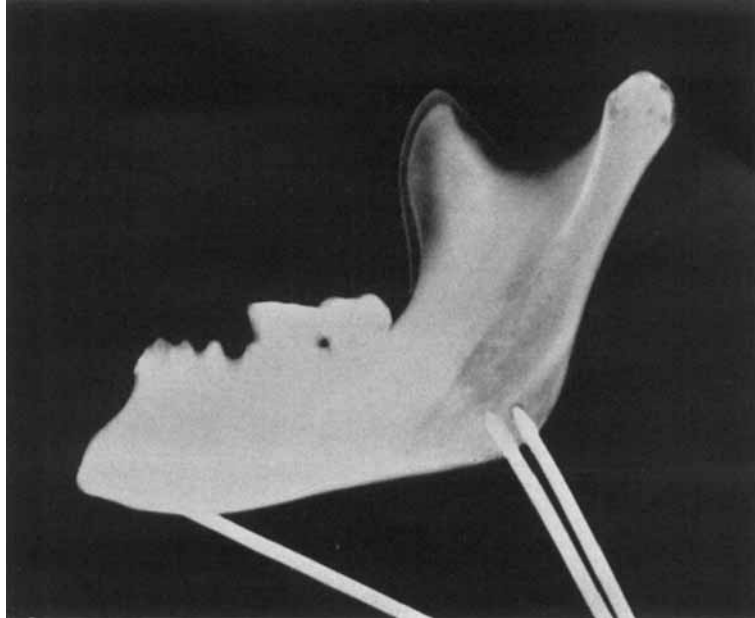


Fig. 3. Roentgenogram of the mandible in unrotated position.

that forward-downward gliding of the condyles, for example, and small deviations of such a shift can be judged with satisfactory accuracy<sup>9</sup>.

In order further to assess the accuracy of the tracing method, which is of great importance if the axes are to be constructed on the basis of such tracings, the following experiments were carried out: —

A mandible was mounted in a graduated frame permitting rotation round a vertical axle and round a sagittal axle. The vertical axle (*Fig. 1* bottom) was a centimeter or so behind the intercondylar axis. The occlusal plane was horizontal. The shadow of the mandible appears also in *Fig. 1*. The sagittal axle crossed the vertical axle 14 cm below the mandibular base.

Profile roentgenograms were taken first without rotation then with 2.5° and 5° rotation round the vertical axis and finally round the sagittal axis.

The experimental apparatus (*Fig. 2*) was arranged so that the central ray passed through both condyles.

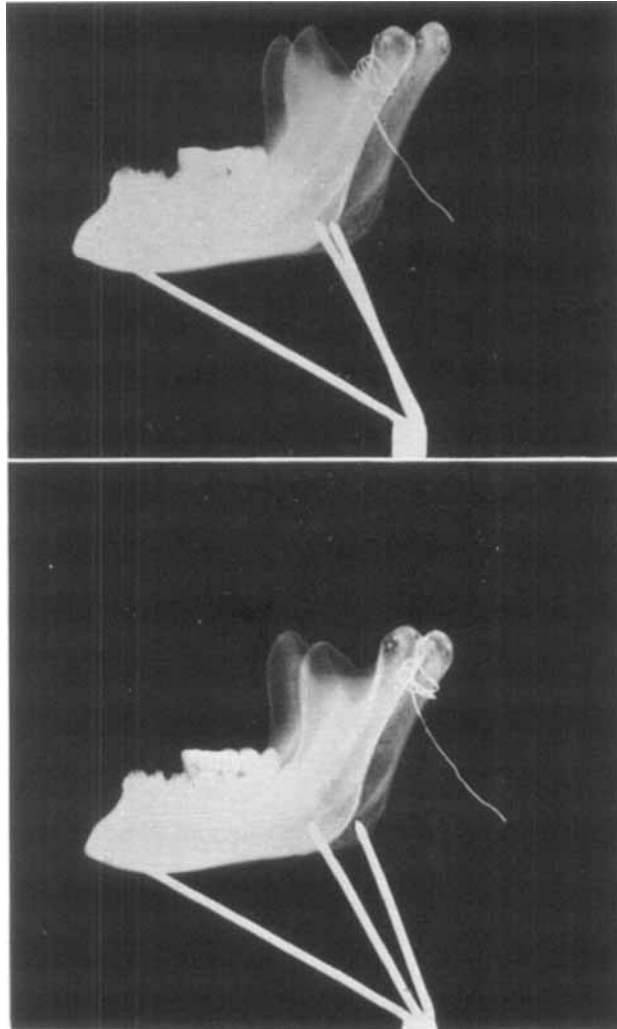


Fig. 4. Roentgenograms of the mandible at 5° left rotation round the vertical axis (top) and right rotation (bottom).

Tracings were made of the roentgenograms of the model in unrotated (*Fig. 3*) and in rotated (*Fig. 4*) position, the outlines of both sides as well as the mid-outline being traced (*Fig. 5*). The tracing of the unrotated model fitted exactly into the mid-outline, both at 2.5° and 5° rotation in either direction. Rotation

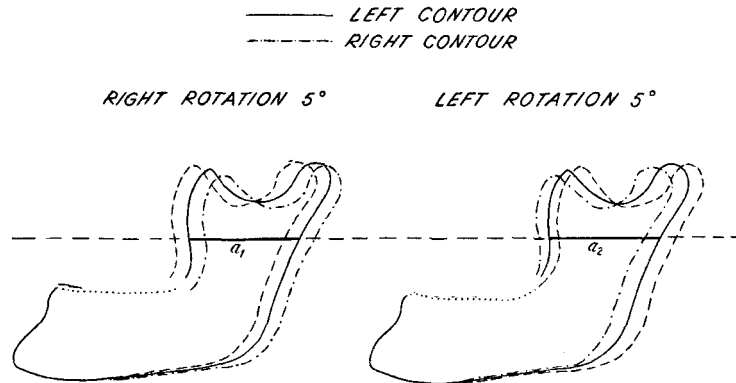


Fig. 5. Tracing of the two profile roentgenograms shown in Fig 4. It is difficult to show in the reproduction that the tracing of the roentgenogram in Fig. 3 coincides exactly with the mean outline. Two parts,  $a_1$  and  $a_2$ , of a horizontal line through the ramus were found to be the same length in each tracing.

of 5° round a vertical axle resulted in a maximum distance of 12 mm between the previously determined points in the region of the angulus. This is more than was ever seen in the roentgenograms of the mandible which, theoretically, should be symmetric (like the retruded position, centric occlusion and mandibular positions with varying degrees of protrusion).

#### *Reproduction of the posterior hinge movement with cardboard pattern*

If the mandible rotates around a frontal axis passing through both condyles, any given point on the mandible must rotate concentrically round the axis. This was checked by the following experiment. Cardboard patterns were made from roentgen tracings of the jaw with the mouth wide open. By means of concentric circles<sup>6</sup> marked on celluloid and placed 1 mm apart the approximate centre of the upper and lower contours of the condyles on the tracings was determined. The centre point was transferred to the cardboard pattern, which was then placed so as to coincide with the contour of the mandible in retruded contact position. By rotation of the cardboard model round a pivot at the site of the centre found, the contours of the cardboard should coincide with the contours of the mandible drawn from

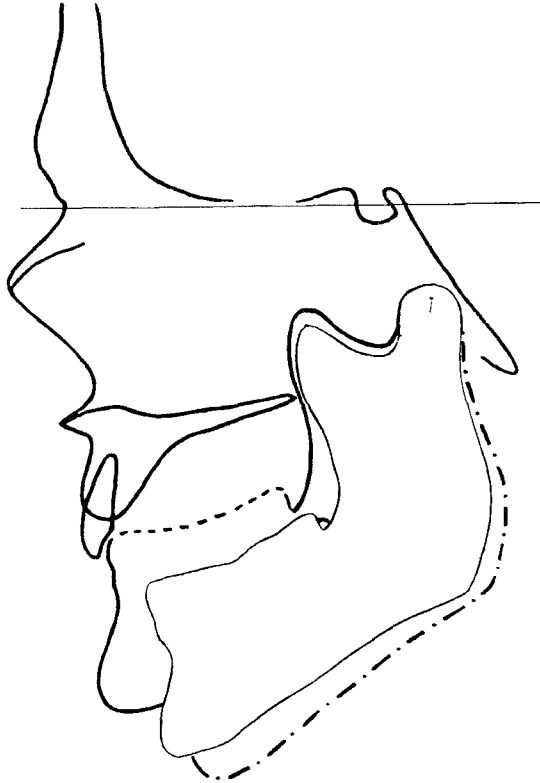


Fig. 6a.

Fig. 6. Experiment with rotation of a cardboard pattern around the hinge axis found. *Fig. 6a* shows rotation in part, *Fig. 6b*, complete rotation of the cardboard pattern. The .-.-.-line corresponds to a posterior bite opening of about 20 mm.

the roentgenogram of the jaw in the retruded open position registered. This was found to be so (*Figs. 6 a and b*).

*Experimental series (1). Geometrical construction of the hinge axis from profile roentgenograms*

The outlines of the mandible in the retruded contact and retruded open position besides the most important outlines of the skull were traced on one and the same paper. According to the above line of thought, on rotation round a stationary intercondylar axis a point on the anterior part of the mandible and

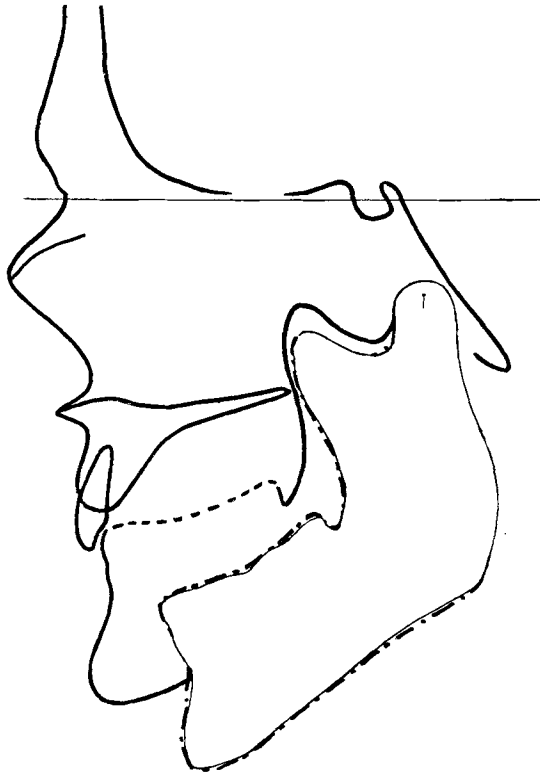


Fig. 6b.

a point on the mandibular base should move concentrically round the axial point. If the positions of the two points on the mandible be connected by a straight line, it will form a chord to the concentric paths of the two points. As a point on the anterior part of the mandible an indicator point was selected as shown in a previous paper<sup>9</sup>. As a point on the mandibular base a point can be marked, e.g. on the angulus, which is then transferred to the film of the mandible with the mouth open by allowing only the contours of the lower jaw to coincide in these films. However, it is probably easier to mark the points of intersection on the mandibular base with a compass.

If midpoint perpendiculars are drawn to the chords, their extension must meet the axis of movement and then they must bisect one another at the axial point. In *Fig. 7* the midpoint

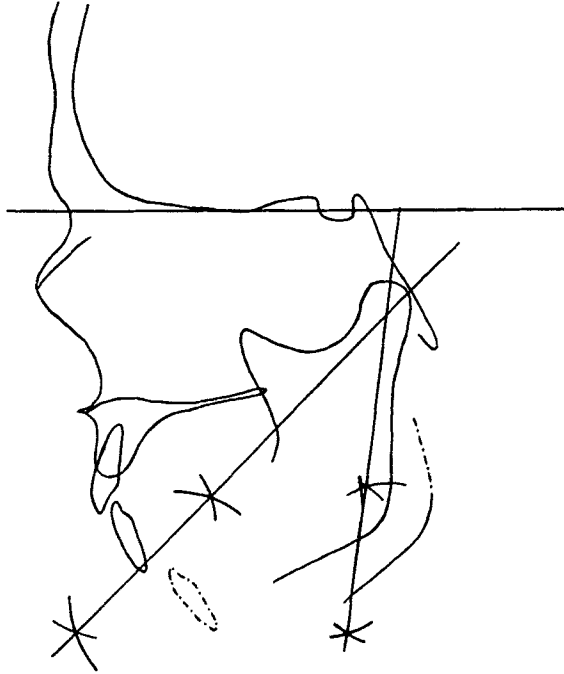


Fig. 7. Geometric construction of the axis of the hinge movement.

perpendiculars have been drawn to the chords, only the end-points of which are marked.

It should be observed that any error in the marking of the points, and in the construction or drawing of the lines, increases with the distance between the axis and the pair of points.

This construction was made for 17 subjects.

*Experimental series (2). Axial points recorded by means of a kinematic facebow and checked by profile roentgenograms*

In 2 cases the kinematic facebow was fitted to the subjects by means of removable splints. The axial points on the skin, to which the tips of the condyle pointers pointed, were marked on each side with metal indicators. A steel ball bearing 1.2 mm in diameter was fastened by adhesive tape to the left side and a small lead indicator the anterior tip of which coincided with the point of the axis was fastened in the same way to the right side.

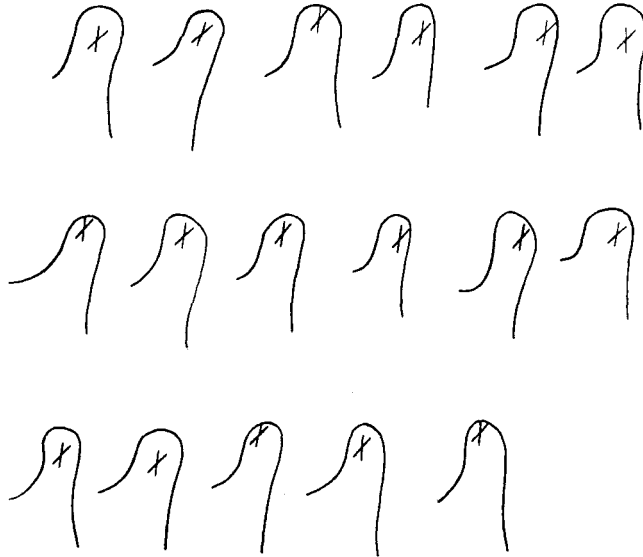


Fig. 8. Constructed axis points, 17 cases.

Profile roentgenograms were taken in the retruded contact position and in retruded open position. In one case profile roentgenograms were also taken in actively maintained retruded open position.

*Experimental series (3). Variations of the hinge axis found by means of the gnato-tesiometer*

In a specially designed apparatus<sup>10</sup> the model of the mandible in retruded closed position was fitted to the maxillary model. By means of the wax index taken in retruded positions with an average bite opening of 9 and 15 mm the degree of the shift could be determined. The experiment was carried out on 4 persons including 2 who had belonged to the material in which the registration had been made by profile roentgenograms.

RESULTS

*Fig. 8* shows the axes constructed from profile roentgenograms in relation to those determined by tracing of the condyles.

It was found that the axial points lay within the outlines of



Fig. 9. Profile roentgenograms with an opening of about 15 mm. The mandible is in passive, retruded position. Metal indicators as seen in the contours of the condyles have been fastened to the skin in the kinematic axial points.

the condyles throughout, although in some cases they were near the actual outline. A position slightly anterior to the midpoint of the condyles was recorded for two cases, in which the metal indicators had been attached to the kinematic axial points on either side of each subject.

Duplicate gnatho-tesiometric measurements<sup>10</sup> of four persons with a 9 mm and 15 mm posterior bite opening showed a standard deviation of about 0.5 mm for both degrees of opening.

Two subjects were examined by all three methods, and the results were found to agree with the kinematic determination of

the axis found for the entire material, viz. that the kinematic axis lies within the outline of the condyle.

Three different experimental methods — none, of course without error — gave fairly similar results. This suggests that the posterior hinge movement can be regarded as rotation around an axis passing through the condyles.

#### DISCUSSION

The degree of posterior hinge movement, as measured on the roentgenograms, corresponds to an angle of  $15^\circ$  on the average (range:  $12-18^\circ$ ). Therefore, the distance, for instance, between the two positions of the point on the mandibular base in the open and closed positions is relatively small, which makes the determination of perpendiculars less reliable.

Although the experiments here presented suggest that the mandible carries out its posterior hinge opening around an axis passing through the condyles, it does not *per se* imply that the axis can be precisely recorded by means of a kinematic hinge axis facebow.

Even recordings in the articulator<sup>3, 7</sup>, which undoubtedly can be carried out with more precision than on the patient shows that the axis-determination entails a certain error.

Finally, it should once more be stressed that a (posterior) hinge movement is a type of movement which the mandible *can* carry out, but the path of movement does not, not even in its initial phases, coincide with the habitual opening movement which, kinematically, is much more complicated.

#### SUMMARY

As a continuation of an earlier investigation in which it was shown that the mouth can be opened about 20 mm without anterior gliding of the condyles the axis of this movement was analysed especially by means of profile radiographs.

- (1) Geometric construction from profile roentgenograms,
- (2) axial points recorded by means of kinematic facebow and checked by profile roentgenographs,
- (3) experiments in the gnato-tesiometer.

Experiments carried out with these three different methods gave similar results, viz. that the (posterior) hinge opening and closing is a rotatory movement around a frontal axis passing through the condyles. This is true for an opening of about 20 mm.

The sources of error of the various methods are discussed and the results of the investigation compared with those of other investigators.

#### RÉSUMÉ

#### AXE DE ROTATION DES MOUVEMENTS D'OUVERTURE DE LA MANDIBULE

Comme suite à une étude antérieure dans laquelle on a montré que la bouche peut s'ouvrir d'environ 20 mm sans glissement antérieur des condyles, l'axe de ce mouvement a été analysé spécialement au moyen de radiographies de profil.

- (1) Construction géométrique d'après des radiographies de profil
- (2) Points axiaux enregistrés au moyen de l'arc facial cinématique et contrôlés au moyen des radiographies de profil
- (3) Expériences au moyen du "gnatho-tésiomètre".

Les expériences faites suivant ces trois méthodes ont donné des résultats concordants; elles ont montré notamment que l'ouverture et la fermeture de l'articulation postérieure est un mouvement rotatoire autour d'un axe frontal passant à travers les condyles.

Les sources d'erreur des diverses méthodes sont discutées, et les résultats de cette étude comparés à ceux d'autres chercheurs.

#### ZUSAMMENFASSUNG

#### ÜBER DIE ACHSE DER SCHARNIERÖFFNUNG DES UNTERKIEFERS

Als Fortsetzung einer früheren Arbeit des Verfassers, worin er bewies, dass der Unterkiefer eine Senkungsbewegung bis zu einer Mundöffnung von 20 mm ausführen konnte, ohne dass die Kondylen sich vorschoben, ist in der vorliegenden Arbeit die Achse dieser Bewegung untersucht worden.

- (1) Geometrische Konstruktion der Profil-Röntgenaufnahme,
- (2) Registrierung der Kondyl-Punkte mit Hilfe eines kinematischen Gesichtsbogens, kontrolliert auf der Profil-Röntgenaufnahme und

## (3) Versuch im Gnatho-Tesiometer.

Die Versuche mit diesen drei verschiedenen Methoden haben gleichartige Resultate ergeben, nämlich dass die hintere Scharnieröffnung bzw. der hintere Scharnierverschluss eine Rotationsbewegung um eine frontal stehende Achse ist, die durch die Kondylen verläuft.

Die Fehlerquellen der verschiedenen Methoden werden diskutiert, und die Untersuchungsergebnisse werden mit denen anderer Verfasser verglichen.

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