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THE POSSIBILITIES OF MOVEMENT IN THE CRANIOVERTEBRAL JOINTS

By

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During the last hundred years the mechanics of the cranio-vertebral joints have received only little attention. Our present knowledge of the anatomy and mechanics of these joints is based almost entirely on investigations dating back to the middle of the last century (*Weber & Weber* 1836, *Sappey* 1853, *Henle*, 1856, *Henke* 1858). Though a few papers on certain details have since been published (*Fick* 1904–1911, *Hultkrantz* 1912, *Hecker* 1923, *Virchov* 1928, *Bakke* 1931, *Poirier & Charpy* 1931) no unanimity of opinion has been achieved on the mechanics of these joints. Misinterpretation of roentgenograms of the cranio-vertebral joints during the last few years has also helped to confuse opinions. On the other hand, roentgenograms have been seen which could not be explained by our present conception of the anatomy and mechanics of the joints (*Jacobson & Adler* 1953).

The cranio-vertebral joints have been divided functionally and anatomically into two composite joints, the occipito-atloid joint consisting of two separate joints and the atlo-axoid joint consisting of four separate joints.

There is general agreement that the *occipito-atloid joint* permits ante-retroflexion or bending and lateroflexion or tilting and that rotation about a longitudinal axis or turning is prevented because of the shape of the occipito-atloid joint. The two axes of movement, the transverse axis and the sagittal axis, cross one another at right angles in different planes. This implies that the joint has the same possibilities of movement as a fusiform body in an annular tube (Fig. 1). Such movements cannot be directed by ligaments and are consequently a function of the shape of the joint (Fig. 2).

The *atlo-axoid joint* has been described by *Weber & Weber* as uni-

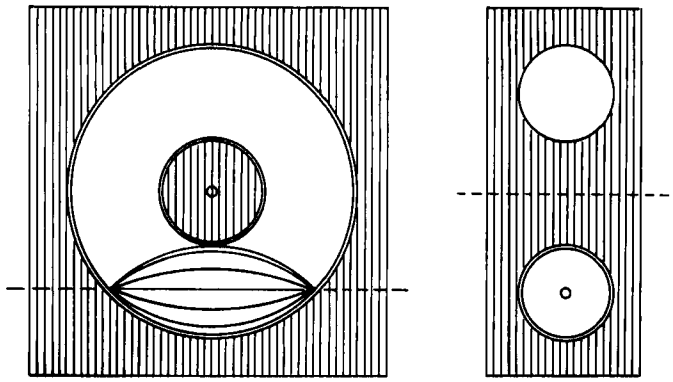


Fig. 1.
The occipito-atloid joint has the same type of movement as is possible for a fusiform body in an annular tube, i.e. along the longest contour-line and around the longitudinal axis of the fusiform body.

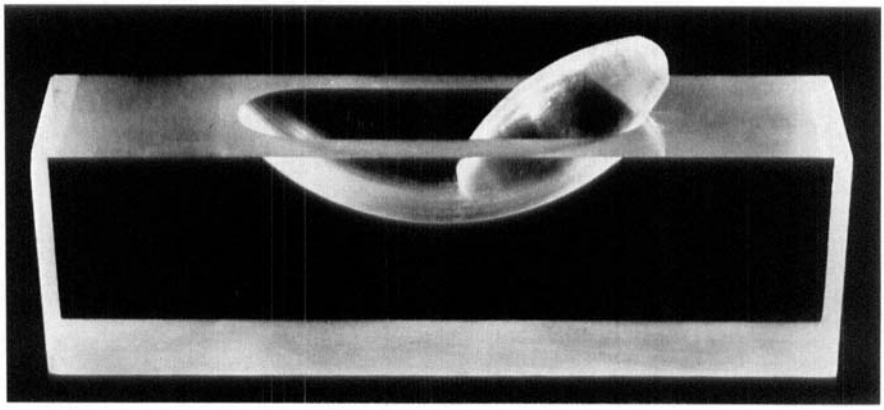


Fig. 2.
Model, illustrating how a part of an annular tube holds the fusiform body and controls its movements.

axial and capable of movement round a longitudinal axis, i.e. turning. *Hultkrantz,* however, found this joint also capable of bending, i.e. movement round a transverse axis. During the last few decades erroneous interpretation of roentgenograms has led to the belief that this joint allows tilting or lateroflexion by translation of the atlas. But such movement is prevented by the fact that the atlas is fixed to the dens epistrophei like a wheel to its axle-shaft (*Fick, Hecker*). Unlike the axes of the occipito-atloid joint, the axes of the atlo-axoid joint are not

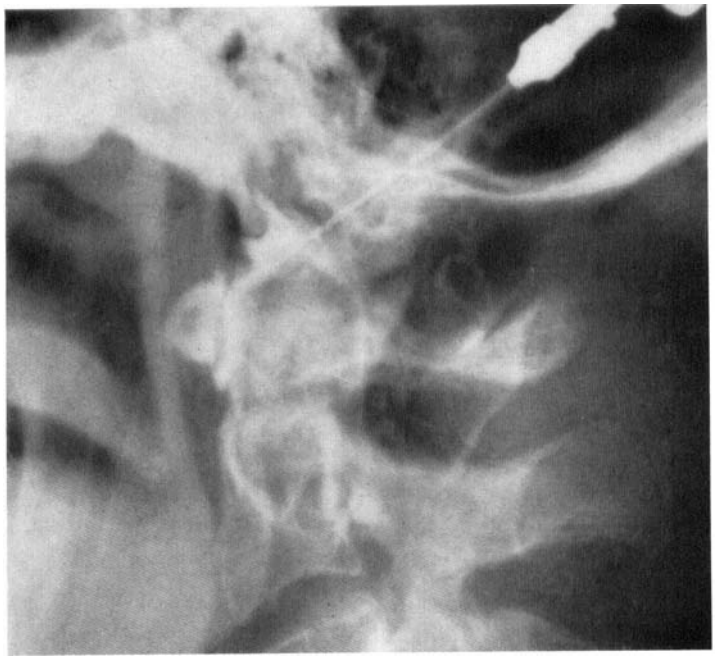


Fig. 3.
Contrast-filling of the bursa between the anterior margin of the foramen occipitale magnum and caput dentis. On anteflexion there is contact between the mentioned osseous parts and the bursa is easily located with the point of the injection needle.

fixed. The transverse axis moves ventrally on anteflexion and dorsally on retroflexion, and much suggests that the longitudinal axis of the turning movements deviates from the longitudinal axis of the body on rotation, because the movements in the intervertebral joints between the atlas and epistropheus are most likely not symmetrical bilaterally. For most purposes it may be sufficient to say that both axes of the atlo-axoid joint pass through the centre of the annulus osteofibrosus.

Limitation of the range of movement of the cranio-vertebral joints is almost entirely ascribed to the intraspinal ligament of these joints. An exception, however, is anteflexion of the occipito-atloid joint, whose movement is not directly limited by any ligament. On anteflexion the ligament becomes slack until the anterior edge of the occipital foramen magnum comes into contact with the caput dentis. But it appears strange that such contact should occur without any known form of joint. Immediately adjacent, i.e. anteriorly and laterally, to the ligamentum apicis dentis, however, a bursa is regularly found, and some-

times it is so well developed that it gives the impression of an extra ligament. In an attempt to investigate the extent of this bursa contrast medium (umbradil) was injected at the anterior edge of the foramen occipitale magnum of two cadavers. A contrast filling was obtained of a bursa between the anterior margin of the foramen occipitale magnum and caput dentis. It was found to communicate with the odontoid joints (Fig. 3). This bursa was called bursa apicis dentis because small bursa-like formations or recesses in the region of the caput dentis with similar names probably consist of recesses in this bursa and are therefore of no relevant interest.

Anteflexion in the occipito-atloid joint is thus limited by skeletal contact between the anterior margin of the foramen occipitale magnum and the caput dentis. As is well known, the range of retroflexion is limited by the tectorial membrane. As a rule limitation of the range of lateroflexion in this joint is ascribed to the unilateral effect of the alar ligaments (*Henke, Fick*). A unilateral effect of an alar ligament, however, produces a rotation of the epistropheus and lateroflexion is therefore not prevented until the contralateral alar ligament is thrown into function and prevents further rotation. Lateroflexion in the occipito-atloid joint is therefore accompanied by a rotation in the atlo-axoid joint (Fig. 4).

As to the alar ligaments, they are generally described as tense, tight ligaments. But when the head is in midposition they are slack and exert an inhibiting effect only when the head is in certain extreme positions. At autopsy of some 30 cases the writer never found the alar ligaments to be stretched when the head was in midposition. In 5 cases detailed attention was directed to anatomic preparations. When not being examined these preparations were kept at about —20° C. When thawed for the third or fourth time, however, the alar ligaments were so thight that it was not possible to place the head in midposition and maintain it there without special measures. The preparations then showed the same properties which *Henke* described as physiologic. There is therefore reason to assume that *Henke* did not consider post-mortem changes, in this case probably dehydration.

In this connection it might be mentioned that the literature describes the occurrence of an accessory ligament spanning the spinal canal in the cranially open angle subtended by the alar ligaments—the occipito-occipital ligament or Lauth's ligament. After removal of the tectorial membrane, which fixes the cranium vertically, a certain degree of vertical translation of the cranium is possible—on the average 2.7 mm

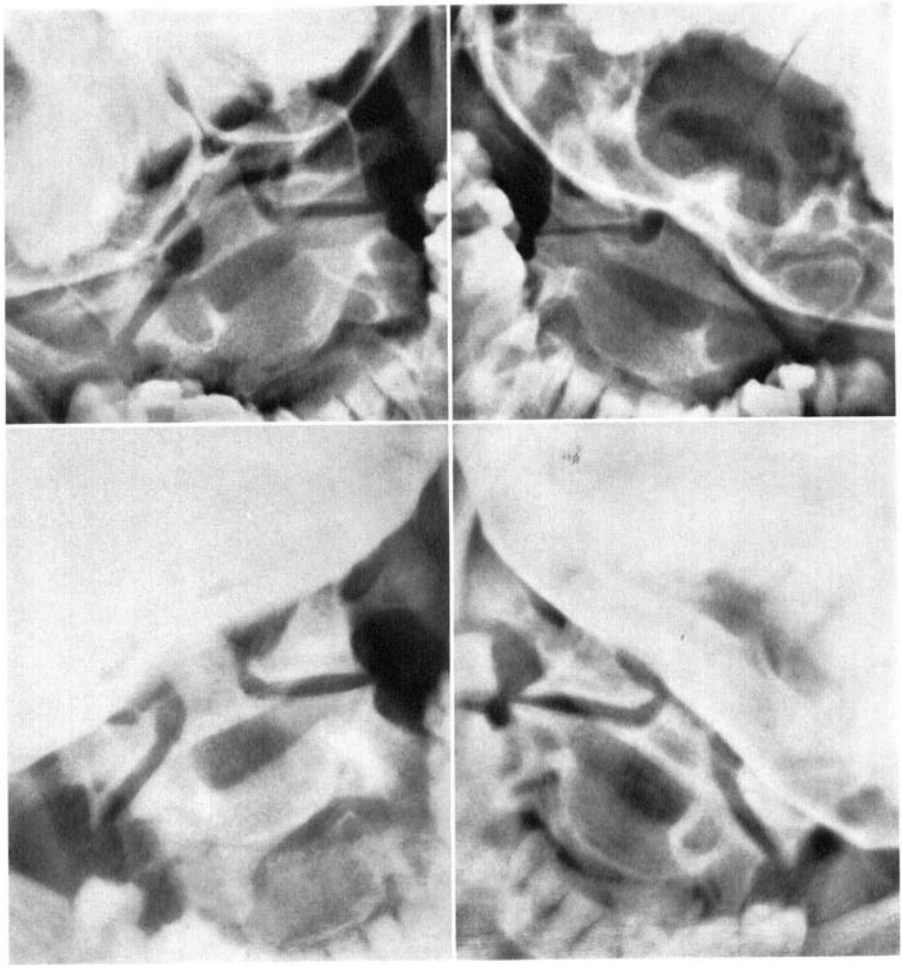
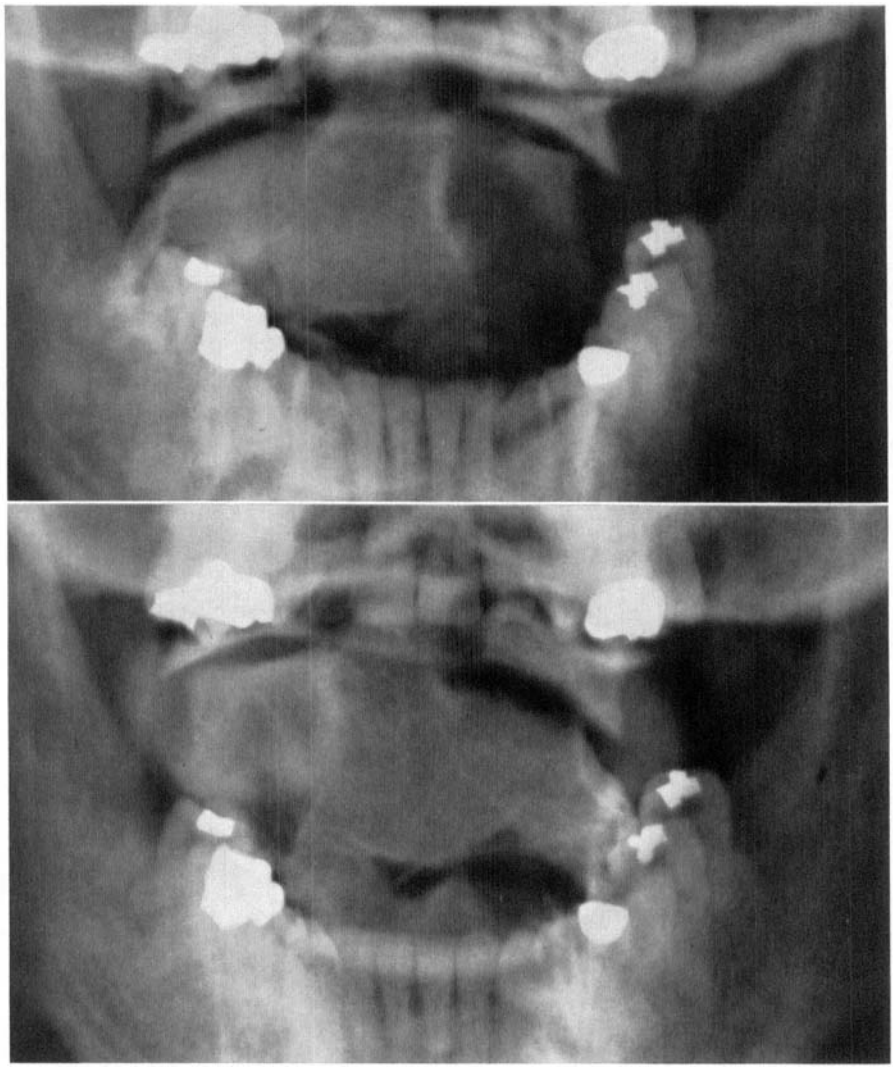


Fig. 4.
Lateroflexion in the occipito-atloid joint is associated with rotation of the anterior surface of the epistropheus in the direction of the lateroflexion. The massa lateralis of the atlas protrudes the anterior parts of the epistropheus in the direction of lateroflexion. There is, however, no translation of the atlas.

at 9 autopsies. In such studies it will be seen that the dorsal fibers of the alar ligaments, which pass the dens epistrophei, are lifted to form a fold in the cranically open angle between the alar ligaments. It is therefore possible that the occipito-occipital ligament consists of these fibers which on postmortem contraction assume the position described. If it is borne in mind that the alar ligaments enter into function as one



Right *Fig. 5.* Left

A. Rotation of the trunk to the left.
B. Rotation of the trunk to the right.

A roentgenogram similar to that shown in Fig. 4 is obtained on rotation of the trunk. The lateral parts of the atlas protrude the anterior parts of the epistropheus but no translation occurs.

single ligament with the dens epistrophei as an interposed sesamoid bone, these ligament fibers will appear as a considerable reinforcement of the alar ligaments.

In the atlo-axoid joint the tectorial membrane limits the range of anteflexion and retroflexion. This is possible because on anteflexion the tectorial membrane is tightened with the caput dentis as a hypomochleon. The tectorial membrane therefore limits also the anteflexion despite the fact that the insertions of this ligament approach one another on anteflexion. Rotation in the atlo-axoid joint leads to tightening of one of the alar ligaments with lateroflexion in the occipito-atloid joint as a consequence (Fig. 5). The contralateral alar ligament is thereby tightened and the combined movement in the two neck joints is not limited until both alar ligaments are tightened.

The range of movement of the cranio-vertebral joints was found to differ considerably from the figures given by earlier authors, as is clear from the comparison given below:

	Fick	*Poirier & Charpy*	*Werne*
Ante-retroflexion (bending)	50°	60°	23° (9–41°)
Lateroflexion (tilting)	30–40°	18–44°	8° (4–13.5°)
Rotation (turning)	60°	30–80°	47° (22–58°)

It is apparent that the cranio-vertebral joints are not functionally separate and that they should preferably be regarded as a single functional unit permitting three-dimensional movement whose main data are recapitulated in the following table:

Axes	Type of movement	Range of movement	Main movement-inhibiting factors
1) Transverse axis of the occipito-atloid joint 2) Transverse axis of the atlo-axoid joint	Ante-retro-flexion	about 23° (9–41°)	*Anteflexion* Skeletal contact for the occipito-atloid joint and membrana tectoria for the atlo-axoid joint. *Retroflexion* Membrana tectoria.
3) Sagittal axis of the occipito-atloid joint 4) Longitudinal axis of the atlo-axoid joint	Latero-flexion *and* Rotation	about 8° (4–13.5°) about 47° (22–58°)	Ligamenta alaria.

SUMMARY

Judging by an investigation of the mechanics of the cranio-vertebral joints the latter should preferably be regarded as a single unit permitting three-dimensional movement, made up of two possibilities of movement in the occipito-atloid joint (bending and tilting) and two possibilities of movement in the atlo-axoid joint (bending and turning). Tilting and turning are always combined.

RESUME

A en juger d'une enquête sur le mécanisme des articulations des vertèbres cervicales, il est établi qui celles-ci doivent être considérées comme une simple unité permettant un mouvement à trois dimensions, consistant en deux possibilités de mouvement dans l'articulation occipito-atloïdienne (flexion et inclinaison) et deux possibilitiés de mouvement dans l'articulation atloïdo-axoïdienne (flexion et rotation). L'inclinaison et la rotation sont toujours combinées.

ZUSAMMENFASSUNG

Die Untersuchung der Mechanik der cranio-vertebralen Gelenke erlaubt den Schluss, dass diese vorzugsweise als eine Einheit angesehen werden sollten, die eine dreidimensionale Bewegung gestattet, die wiederum aus zwei möglichen Bewegungen im atlanto-occipital Gelenk (Beugungs- und Kippbewegungen) und zwei möglichen Bewegungen im atlanto-epistropheus Gelenk (Beugung und Drehung) zusammengesetzt ist. Kipp- und Beugungsbewegungen sind immer kombiniert.

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