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The mechanism in the temporomandibular joint.[1]

By

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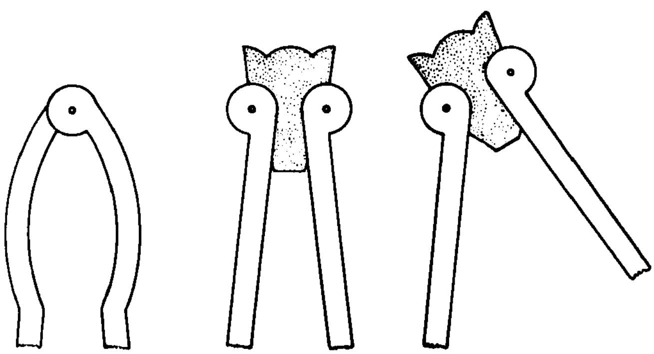
Introduction.

It is generally assumed that an articular disc serves the purpose of levelling incongruities between the joint surfaces. Having studied various conditions of joint mechanisms for many years the writer has, however, arrived at the opinion that the function of an articular disc is probably to form the anatomical basis for a special joint mechanism. Thus, a biconcave articular disc provides to two joint sockets and both ends of the bones meeting in the joint can then assume the form of a joint head. This implies that there can be at least one axis of movement on either side of the disc. If we want to liken a ginglymus joint without a disc to a "uniaxial" nutcracker (fig. 1 a), then a ginglymus joint which is complicated by a disc may be comparable to a "biaxial" nutcracker (fig. 1 b).



a. b. c.

Fig. 1.

[1] Submitted for publication, January 1953.

In the biaxial nutcracker the two shafts can be made to perform the same movements as in the uniaxial variety. The only difference is that in the latter the shafts have a common axis of movement, while in the former each shaft has its own axis of movement. In addition, however, in the biaxial nutcracker another movement can be performed which cannot be imitated in the uniaxial nutcracker. Thus, having the possibility to turn the middle part of the biaxial nutcracker, *i. e.* the nutcracker's "disc", about one of the axes of movement one can bring the other axis of movement to alter its place and position (fig. 1 c).

The lowering and raising of the mandible.

When the mandible is lowered and raised it can be compared to a biaxial nutcracker, one shaft of which is bent at an angle corresponding to the angulus mandibulae (cf. fig. 2). On that account such a biaxial nutcracker put in different positions will be reproduced together with the schematic drawings, which are shown in this paper in order to demonstrate the author's opinion of the joint mechanism when the mandible is lowered and raised.

It is a generally accepted fact that a lowering and raising of the mandible can be effected through a pure ginglymus movement in the lower division of the temporomandibular joint. When the movement in question takes place passively in the cadaver, it mostly occurs in this division of the joint. The joint head is then represented by the capitulum mandibulae and the joint socket by the under surface of the disc. The axis of movement, about which the ginglymus motion takes place, is generally considered to pass transversally and approximately through the centre of the joint head. This ginglymus motion may be called *capitulum rotation* to distinguish it from another ginglymus motion which will be discussed below. When the capitulum rotates in such a way that its upper pole is turned ventrally, *i. e.* in the direction of the arrow in fig. 2 a, it is said to *rotate forwards* (*forward rotation*). The mandible is then lowered. A raising of the mandible is effected when the capitulum *rotates backwards* (*backward rotation*), *i. e.* in the direction of the arrow in fig. 2 b.

In the living individual the articular mechanism is more complicated, as the disc alters its position during the different phases of the capitulum rotation. When the capitulum rotates forwards,

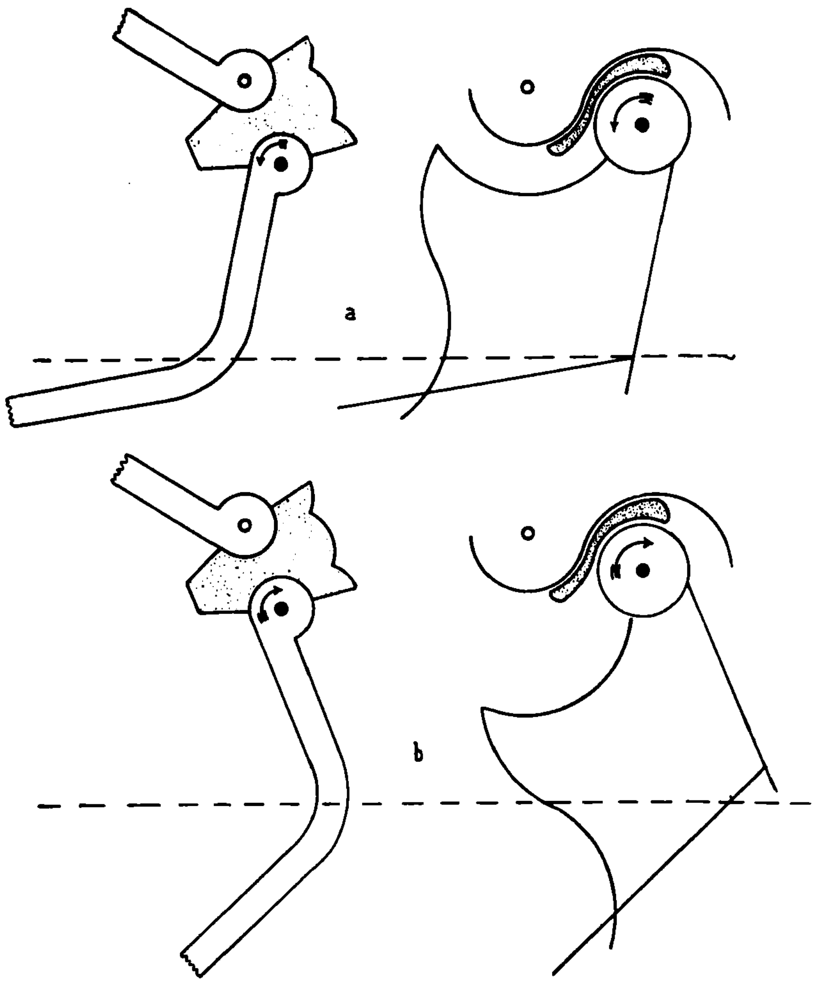


Fig. 2.

the disc and, also, the underlying capitulum begin sooner or later to be displaced downwards and forwards along the posterior and under surface of the tuberculum articulare. When the capitulum rotates backwards, the disc describes the opposite movement and is displaced backwards and upwards.

This change in the position of the disc during the forward rotation of the capitulum has usually been interpreted as a consequence of the displacement of the axis of movement, originally passing through the centre of the capitulum mandibulae, to the

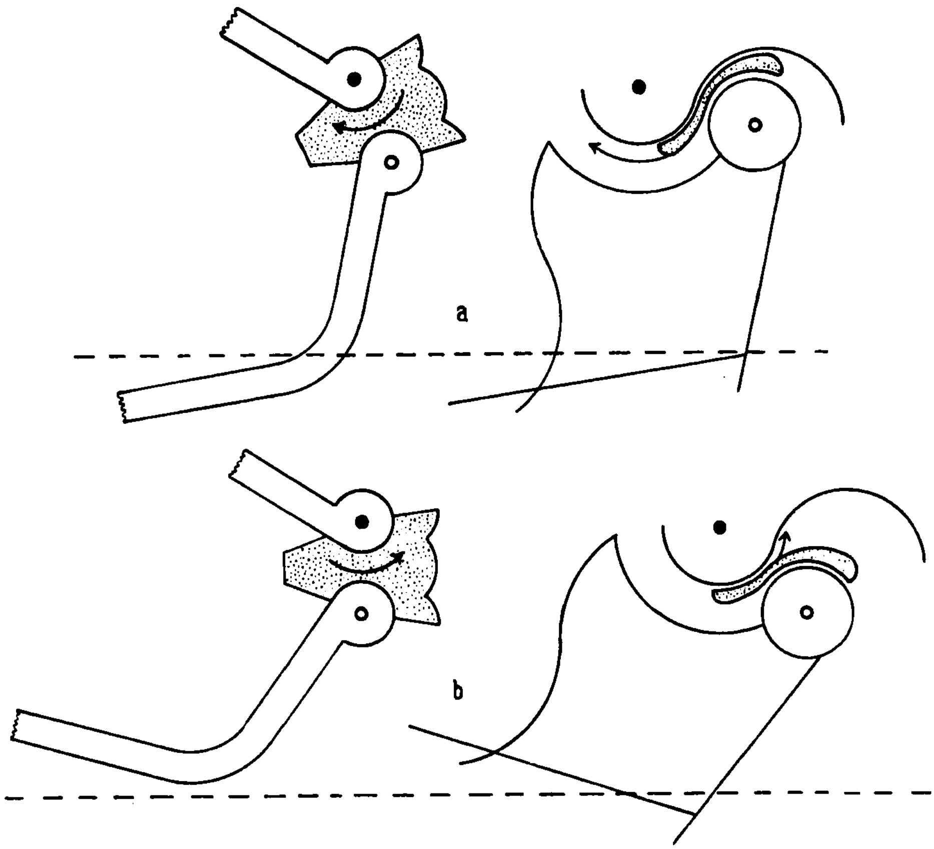


Fig. 3.

region of the foramen mandibulare. According to the same interpretation, the disc gradually resumes its original position during the backward rotation of the capitulum. In order to be acceptable, this interpretation, however, must be based on the assumption that the disc in its displacement downwards-forwards describes a curve, with caudally-directed concavity, about the axis of movement which gradually moves from the capitulum mandibulae to the region of the foramen mandibulare. This assumption is incorrect. It is true that the disc describes a curve, but with a cranially-directed concavity around a centre which lies above the disc in the tuberculum articulare or even higher.

For this reason it seems more justifiable to consider the displacement of the disc as the result of a pure ginglymus movement about a transversally situated axis of movement in the centre of the approximate circle of which the curved contour of the tuberculum articulare in the sagittal plane forms a part. The tuberculum articulare thus constitutes a joint head, which in this case may be considered as fixed, while the upper surface of the disc represents a joint socket that may be moved around the head of the joint. The ginglymus movement in the upper division of the temporomandibular joint may be called *tuberculum rotation* as distinguished from the capitulum rotation in the lower division of the temporomandibular joint. We postulate that the disc *rotates forwards* (*forward rotation of the disc*) when it is displaced downwards and forwards, and that the disc *rotates backwards* (*backward rotation of the disc*) when it is displaced backwards and upwards.

An analysis of the purely theoretical effect on the mandible of the tuberculum rotation alone (*i. e.* without simultaneous capitulum rotation of any sort) shows that during the forward rotation of the disc from the position in fig. 3 a to the position in fig. 3 b the mandible as a whole is brought farther forwards and at the same time it is raised. Of course, the movement mentioned cannot take place in practice as the maxilla with its teeth prevents the raising of the mandible. A backward rotation of the disc from the position in fig. 3 b to the position in fig. 3 a would result in a replacement and lowering of the mandible to its initial position. The raising and lowering of the mandible caused by the tuberculum rotation is really due to the fact that the capitulum mandibulae does not only move downwards-forwards and backwards-upwards during the tuberculum rotation, but also turns somewhat in space (cf. fig. 3).

In reality the tuberculum rotation takes place simultaneously with the capitulum rotation. It can then be established that the phases in the two movements, which are in direct combination, have just the opposite effect on the lowering and raising of the mandible. Thus, when the capitulum rotates forwards (fig. 4 a), the mandible is lowered, while the simultaneous forward rotation of the disc tends to raise the mandible. When the capitulum rotates backwards (fig. 4 b), the mandible is raised, while the simultaneous backward rotation of the disc tends to lower the mandible.

Thus, the forward rotation of the disc does not directly aid the actual lowering of the mandible but rather counteracts it. Indirectly, however, the forward rotation of the disc may assist

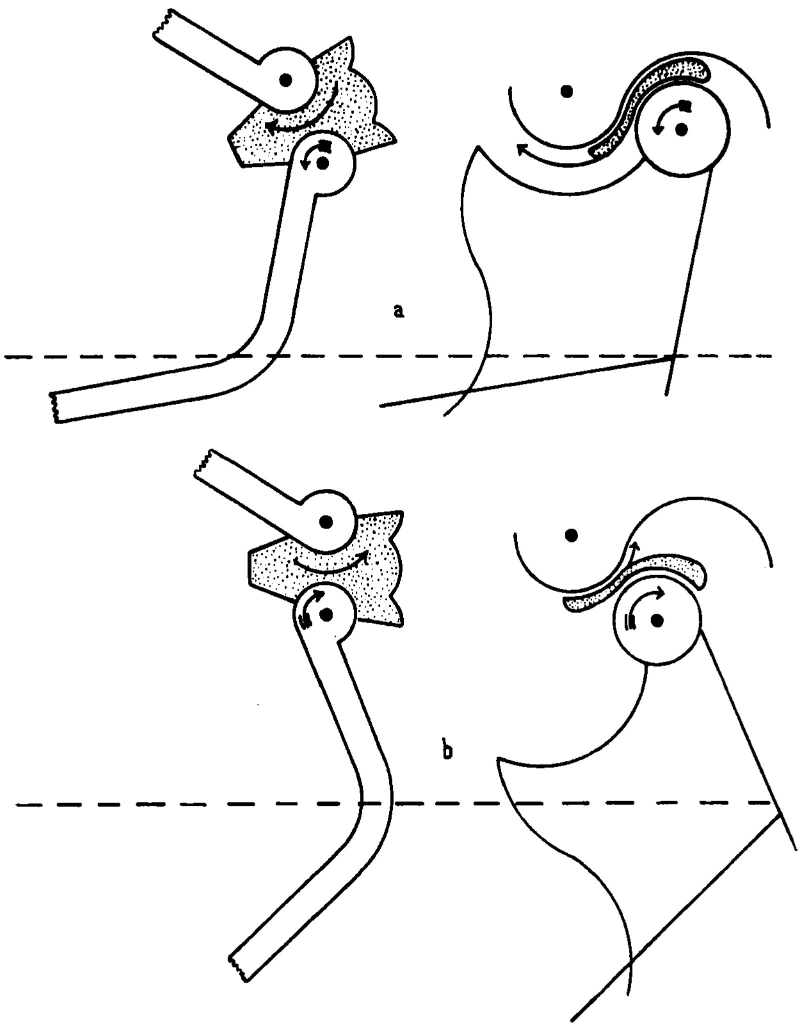
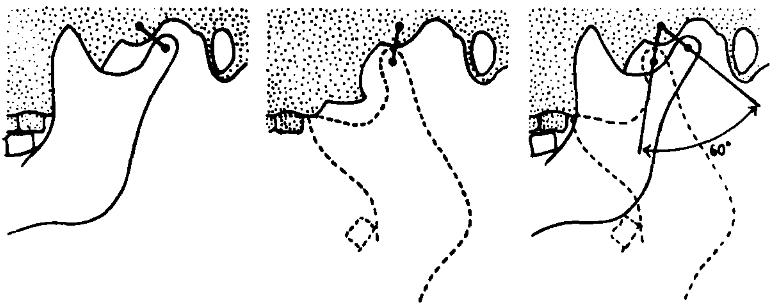


Fig. 4.

the lowering of the mandible by changing the position of the capitulum in a caudal direction. There is another way in which the forward rotation of the disc may assist the lowering of the mandible. Thus, as long as the capitulum is in a posterior position, an extreme lowering of the mandible is prevented by the soft parts of the neck. This is not the case when the capitulum has been placed farther forwards by the forward rotation of the disc.

In order to demonstrate how to compute the tuberculum rota-

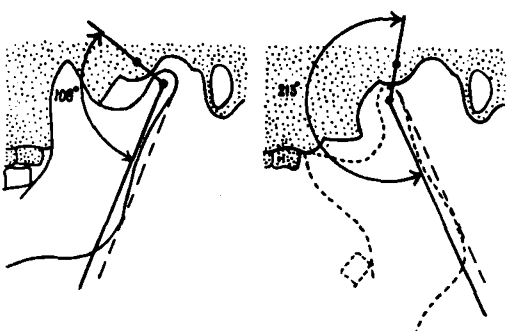


a. b. c.

Fig. 5.

tion as well as the capitulum rotation that have occurred in a certain case, the following example is given.

Fig. 5 a shows a schematic drawing of a temporomandibular joint with the mandible in centric occlusion. In fig. 5 b the mandible has been lowered in the way mentioned above (cf. fig. 4), *i. e.* by tuberculum rotation in combination with capitulum rotation. In both figures the tuberculum centre has been connected with the capitulum centre by a line, which may be called *the centre line.* The angle between the centre lines in fig. 5 a and fig. 5 b, when the figures have been placed upon each other as in fig. 5 c, indicates the magnitude of the tuberculum rotation. Thus, in this purely theoretical case the tuberculum rotation is 60°.



a. b.

Fig. 6.

To be able to compute the capitulum rotation in the same case one will have to draw yet another line, called *the ramus line,* from

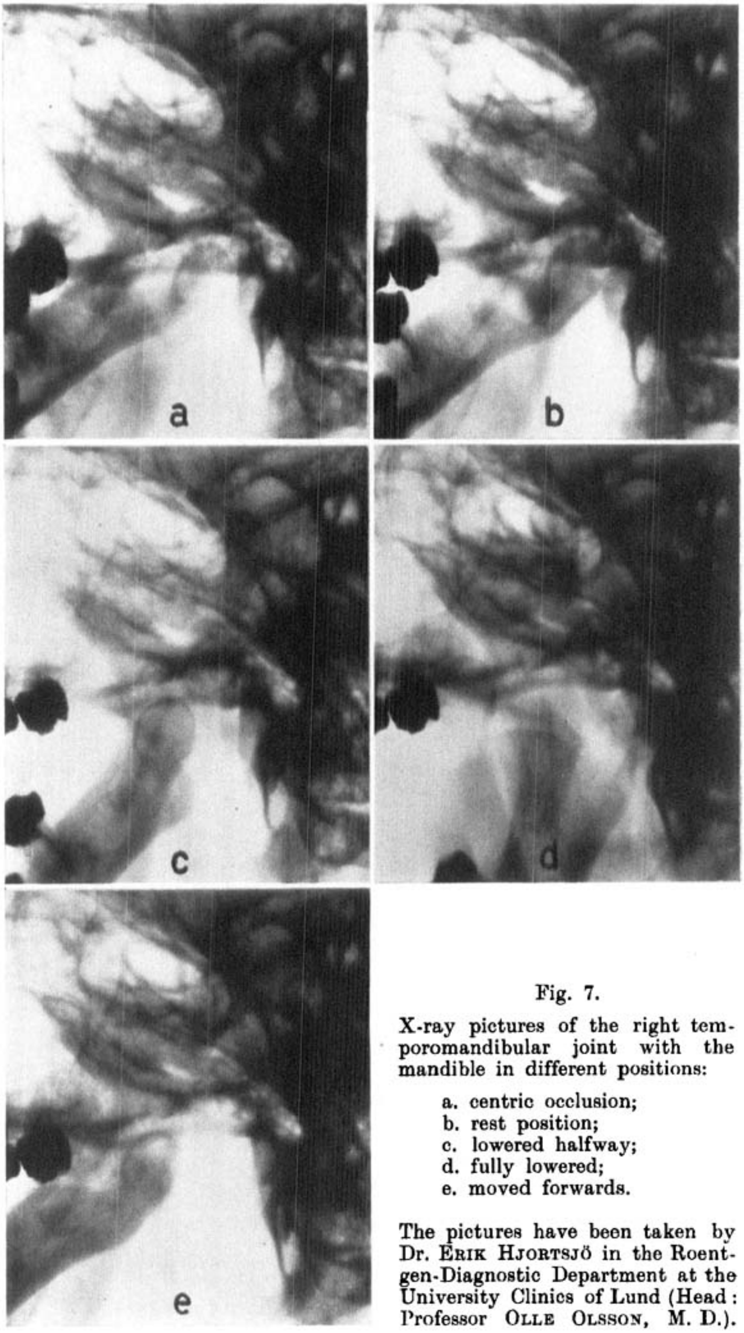


Fig. 7.

X-ray pictures of the right temporomandibular joint with the mandible in different positions:

a. centric occlusion;
b. rest position;
c. lowered halfway;
d. fully lowered;
e. moved forwards.

The pictures have been taken by Dr. ERIK HJORTSJÖ in the Roentgen-Diagnostic Department at the University Clinics of Lund (Head: Professor OLLE OLSSON, M. D.).

the capitulum centre towards the angulus region, parallel with a line, which touches the posterior contour of the capitulum and the angulus mandibulae. The angle between the centre line and the ramus line is then read off. In fig. 6 a, where the mandible is in centric occlusion, the actual angle is 108°. In fig. 6 b, where the mandible has been lowered, the same angle amounts to 213°. The difference between the angles, thus in this case 105°, indicates the magnitude of the capitulum rotation.

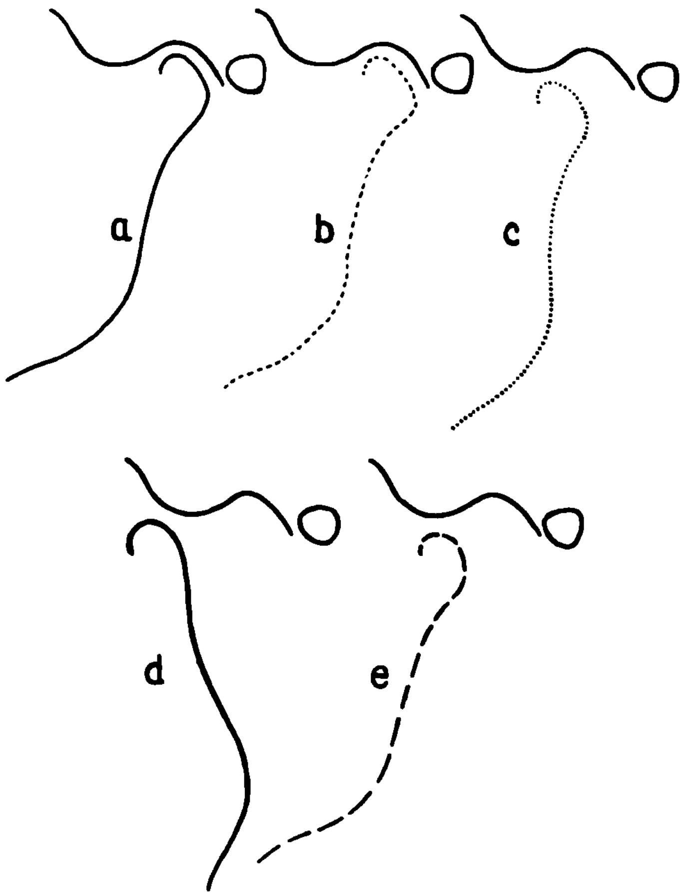


Fig. 8.

The joint mechanism described above, when the mandible is lowered and raised, is beautifully demonstrated by the X-ray pictures of the right temporomandibular joint (female 27 years of age) in fig. 7 a—d and the contour drawings in fig. 8 a—d made from these X-ray pictures, in spite of the fact that it was impossible to take the pictures straight from the side. Thus, in order to get the temporomandibular joint projected free from the

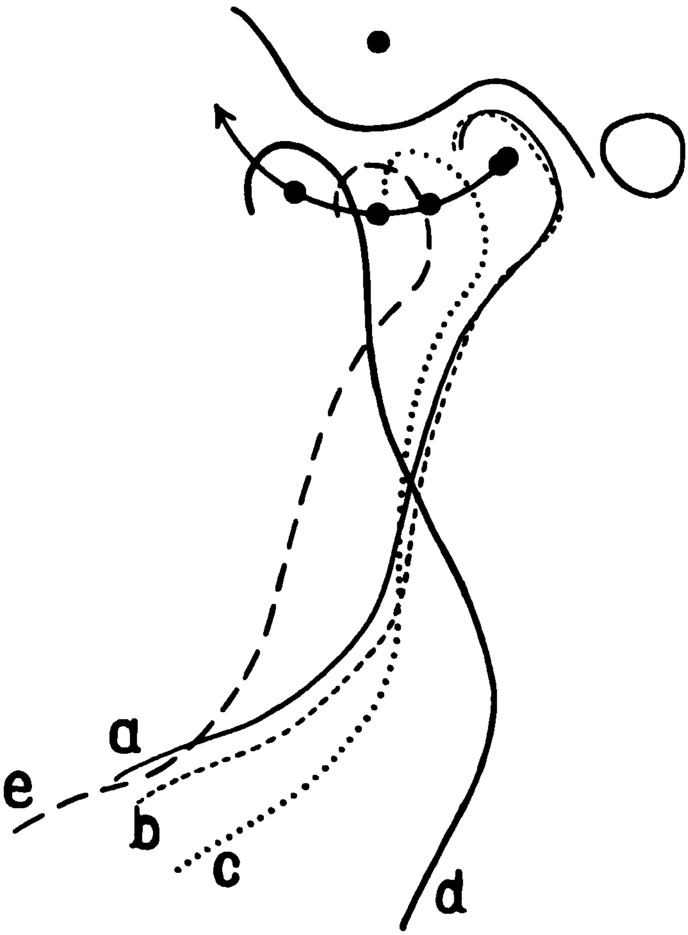


Fig. 9.

skull base, it was necessary to take the pictures from the left side, somewhat from above and very little from behind. The direction of the central ray was about 20° to the transverse plane and about 5—10° to the frontal plane. In figs. 7 a and 8 a the mandible is in centric occlusion, in figs. 7 b and 8 b in the rest position. In figs. 7 c and 8 c the mandible has been lowered halfway and in figs. 7 d and 8 d fully lowered. The fact that it has not been possible to reproduce the joint straight from the side has caused *i. a.* difficulties in determining the capitulum centre, especially as the capitulum contour changes its shape when the capitulum is placed in different positions. Because of this, the magnitude of the capitulum and the tuberculum rotations has not been determined in this case.[1] In fig. 9, however, where the contour drawings have been placed upon each other, one can establish that the approximate capitulum centre describes a beautiful arc about the approximate tuberculum centre when the mandible is lowered. Furthermore, some tuberculum rotation (combined with capitulum rotation) seems to have occurred as early as at the transition from centric occlusion to the rest position.

The forward and backward movement of the mandible.

From the foregoing discussion it may be evident that there can be no difference in principle between the lowering and raising of the mandible and its forward and backward movement.

Thus, in the forward movement of the mandible exactly the same movements take place in the temporomandibular joint as when the mandible is lowered. The disc rotates forwards, thereby moving the mandible forwards. At the same time the capitulum rotates forwards lowering the mandible to the same degree as the forward rotation of the disc tends to raise it and sufficiently to eliminate overlap.

Analogously, in the backward movement of the mandible the same movements take place as in the raising of the mandible. The disc rotates backwards, thereby moving the mandible backwards. Simultaneously the capitulum rotates backwards in order to raise the mandible from the lowering caused by the overlapping, and, furthermore, to raise the mandible to the same degree as the backward rotation of the disc tends to lower it.

[1] At the X-ray department of the Dental College of Malmö, Prof. A. Sonesson has worked out a technique by use of which it is possible to get good X-ray pictures of the temporomandibular joint straight from the side. On a rather large X-ray material obtained in this way, which is being collected at present, Prof. Sonesson, the author, and co-workers will calculate the number of degrees of the tuberculum and the capitulum rotations in order to find the means.

In figs. 7 e, 8 e, and 9 e the temporomandibular joint is shown when the mandible has moved forwards. From these figures it is evident that the tuberculum rotation in connection with the forward movement is greater than that tuberculum rotation which has occurred when the mandible has been lowered halfway. It is, however, smaller than that tuberculum rotation which has occurred when the mandible has been fully lowered.

The lateral movement of the mandible.

Before analysing the joint mechanism of the temporomandibular joint when the mandible is moved laterally, some abbreviations will be introduced:

Tub^W and Cap^W	=	tuberculum and capitulum on the working side;
Tub^B and Cap^B	=	tuberculum and capitulum on the balancing side;
$TubC^W$ and $CapC^W$	=	centre of tuberculum and capitulum on the working side;
$TubC^B$ and $CapC^B$	=	centre of tuberculum and capitulum on the balancing side.

When the mandible is lowered and raised, and moved forwards and backwards the joint mechanism at any moment is exactly the same in both temporomandibular joints. In the lateral movement of the mandible the effect of the motion will, of course, be of different character on the balancing and working side. Furthermore in order to understand the joint mechanism, it must be realized that the capitulum on the one side cannot perform any movement at all without causing the capitulum on the other side to move to a greater or smaller degree. On the other hand, a unilateral movement of the disc does seem possible.

During the lateral movement of the mandible, a movement in the joint of the balancing side occurs which is very similar to the movement performed bilaterally in the joint in the forward movement of the mandible. Owing to a common tuberculum rotation about the transverse axis of movement through $TubC^B$, the disc of the balancing side rotates forwards. Thereby, Cap^B is brought underneath Tub^B, but Cap^B will also be carried somewhat medially, a fact which will be discussed below. At the same time as Cap^B changes its position owing to the forward rotation of the disc, Cap^B itself performs a forward rotation about its transverse axis of movement through $CapC^B$. It does so in order to lower the mandible just as much as the mandible would have been raised during the forward rotation of the disc, and sufficiently to eliminate overlap. However, the transverse axis of movement through $CapC^B$ also passes through $CapC^W$. Thus, when Cap^B rotates forwards as mentioned, Cap^W must also rotate forwards.

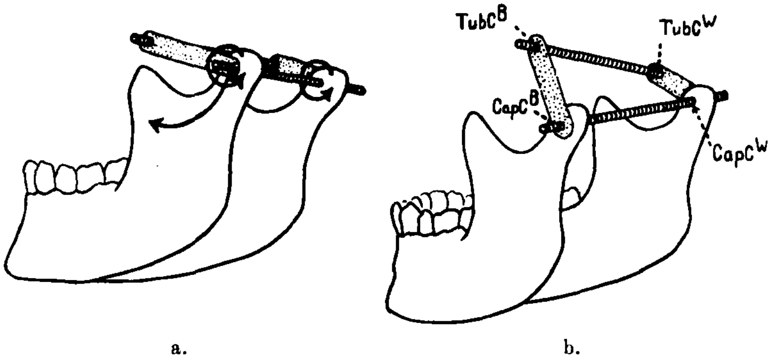
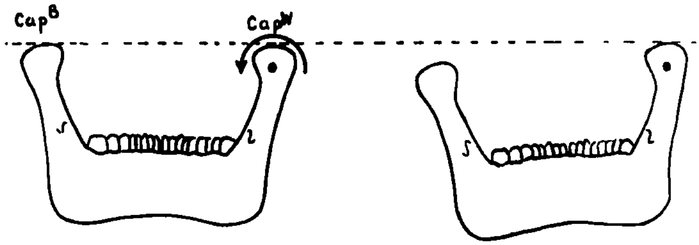


Fig. 10.

No tuberculum rotation on the working side seems to occur, at least not in the typical case. Because of this, Cap^W will retain its posterior position while Cap^B, owing to the tuberculum rotation on the balancing side, is carried downwards-forwards-medially as mentioned above. However, this forces the transverse axis of movement through $CapC^B$ and $CapC^W$ to change its position in space as the tuberculum rotation on the balancing side gradually proceeds. At the end stage of the lateral movement of the mandible, this axis of movement will thus be directed from $CapC^B$ somewhat obliquely upwards-backwards to $CapC^W$. In reality, when moving in space from the position in fig. 10 a to the position in fig. 10 b, the transverse axis of movement produces a surface which forms a part of the curved surface of a cone.

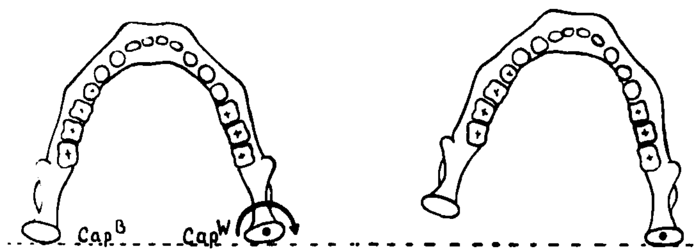
If Cap^W performs certain simultaneous movements, Cap^B is able to move downwards-forwards-medially as described, while Cap^W remains stationary in a posterior position. On the same assumption the change in position in space of the transverse axis of movement through $CapC^B$ and $CapC^W$ is possible. Thus, Cap^W rotates about a sagittal axis of movement passing through the centre of the approximate circle of which the curved upper contour of the capitulum in the frontal plane forms a part. It



a. b.

Fig. 11.

then rotates in such a way that its lateral part is raised while its medial part is lowered. This rotation also causes a change in the position of Cap^B from the position in fig. 11 a to the position in fig. 11 b. In other words, Cap^B is lowered a distance corresponding to the height of the tuberculum articulare. Simultaneously with this rotation about a sagittal axis of movement, Cap^W also rotates about a vertical axis of movement through $CapC^W$. In this rotation the medial part of Cap^W is moved forwards, while its lateral part is brought backwards. Greater or smaller parts of this rotation may possibly be performed between the disc and the cranium. This rotation causes a change in the position of Cap^B from that in fig. 12 a to that in fig. 12 b. Thus, Cap^B as a whole is brought forwards but also somewhat medially. This has been stated above, but without proof being offered. Mention has also been made of the fact that Cap^W



a. b.

Fig. 12.

finally rotates forwards about the transverse axis of movement through the centres of the two capitula lowering the mandible to the same degree as the forward rotation of the disc on the balancing side would have raised it. Furthermore, Cap^W rotates forwards far enough to eliminate overlap.

To be able to perform these movements, the temporomandibular joint on the working side acts as a triaxial ball joint. The anatomical shape of the temporomandibular joint does in fact permit such a mechanism.

However, it is an interesting fact to establish that in reality the three axes of movement on the working side are also used by the temporomandibular joint on the balancing side, when Cap^B is brought downwards-forwards-medially through the aid of its own joint mechanism.

It is possible that the disc of the balancing side is displaced somewhat medially during the above-mentioned displacement of Cap^B in a medial direction. This would not be due only to the rotation of the disc about the transverse axis of movement through $TubC^B$, but also to a translation in a medial direction along this axis. Consequently, the movement between the tuberculum and the disc will then be performed as a typical screw joint movement (1 axis of movement with 2 degrees of freedom).

It is, however, not necessary to resort to the screw joint mechanism in order to explain such a medial displacement of the disc on the balancing side. Even a common ginglymus mechanism causes a medial displacement of the disc if a somewhat oblique axis of movement, extending from $TubC^B$ to $CapC^W$, is used for the tuberculum rotation instead of the transverse axis mentioned above through $TubC^B$ and $TubC^W$. This oblique axis constitutes the longitudinal axis of that cone whose curved surface is produced as mentioned above by the transverse axis of movement from $CapC^B$ to $CapC^W$, when the latter axis moves in space from the position in fig. 10 a to that in fig. 10 b. This assumption of a somewhat oblique axis of movement instead of an exactly transverse axis during the tuberculum rotation on the balancing side is quite compatible with the other mechanisms of movement discussed above.

This and previous papers by the present author (1951, 1952, 1953) on the temporomandibular joint mechanism should not be considered as providing the final answer to the problem of what really occurs in the joints on movement of the mandible. They constitute only the theoretical basis for the investigations of the author on the anatomy and mechanism of the temporo-mandibular joint.

Summary.

The author advances the opinion that the actual function of an articular disc is to provide the anatomical basis for a special joint mechanism. A biconcave disc provides two joint sockets and both ends of the bones meeting in the joint can then assume the form of a joint head. From this conception the author draws a comparison between the joint mechanism during the lowering and raising of the mandible and the mechanism in a biaxial nutcracker. When the mandible is lowered, the disc rotates downwards and forwards about a transverse axis of movement through the tuberculum articulare (tuberculum rotation). Thereby the capitulum mandibulae is carried downwards and forwards underneath the tuberculum articulare. At the same time the capitulum mandibulae itself rotates about a transverse axis of movement through the capitulum mandibulae (capitulum rotation), causing the mandible to descend. No difference in principle exists between the movements when the mandible is lowered and when it is moved forwards. It is only the degree of the tuberculum and the capitulum rotations which is different in the two types of movement.

The author also presents an analysis of the lateral movement of the mandible and considers that on the balancing side a movement occurs similar to that taking place during the forward movement of the mandible. During the forward rotation of the disc on the balancing side, the capitulum mandibulae of this side moves downwards and forwards but also slightly medially. Simultaneously with this change in position, the capitulum mandibulae rotates about its transverse axis of movement. The capitulum mandibulae of the working side is forced to perform the same rotation. On the working side no forward rotation of the disc seems to occur, for which reason the capitulum mandibulae on this side remains in a posterior position. In addition to the above-mentioned rotation about the transverse axis of movement the capitulum mandibulae on the working side rotates about a sagittal axis of movement in order to permit a lowering of the capitulum mandibulae on the balancing side underneath

the tuberculum articulare. Finally, the capitulum mandibulae on the working side also rotates about a vertical axis of movement, allowing the capitulum mandibulae on the balancing side to move forwards-medially. In other words, in order to perform these movements the temporomandibular joint on the working side functions as a ball joint that allows motion about three axes.

Résumé.

L'auteur expose l'opinion que la propre fonction d'un fibrocartilage interarticulaire est de fournir la base anatomique pour un mécanisme articulaire spécial. Un fibrocartilage biconcave fournit deux cavités glenoïdes, et ainsi les bouts des deux os qui se rencontrent dans la jointure peuvent prendre la forme d'une tête articulaire. Partant de cette conception, l'auteur établit une comparaison entre le mécanisme articulaire pendant l'abaissement et l'élévation de la mandibule et le mécanisme d'un casse-noisette biaxial. Lorsque la mandibule est abaissée, le fibrocartilage fait un mouvement rotatoire en bas et en avant autour d'un axe transversal à travers le tuberculum articulare (rotation tuberculaire). Par ça le capitulum mandibulae est conduit en bas et en avant sous le tuberculum articulare. Au même temps, le capitulum mandibulae lui-même fait un mouvement rotatoire autour d'un axe transversal à travers le capitulum mandibulae (rotation capitulaire), en faisant descendre la mandibule. En principe, il n'y a pas de différence entre les mouvements lorsque la mandibule descend et lorsqu'elle avance. Ce n'est que le degré de rotation tuberculaire et de rotation capitulaire qui diffère dans les deux types de mouvement.

L'auteur présente aussi une analyse du mouvement latéral de la mandibule, et il est arrivé à l'opinion que du côté de balance il se fait un mouvement qui ressemble à cel qui se fait pendant l'abaissement et l'avancement de la mandibule. Ainsi, pendant la rotation en avant du fibrocartilage du côté de balance, le capitulum mandibulae du même côté meut en bas et en avant, mais aussi un peu dans la direction médiale. Simultanément avec ce changement de position, le capitulum mandibulae se tourne autour de son axe transversal. Le capitulum mandibulae du côté de travail est forcé à faire le même mouvement. Du côté de travail, aucune rotation du fibrocartilage ne semble avoir lieu, et par conséquent le capitulum mandibulae du côté de travail reste dans une

position postérieure. En plus de la dite rotation autour de l'axe transversal, le capitulum mandibulae du côté de travail se tourne autour d'un axe sagittal afin de permettre un abaissement du capitulum mandibulae du côté de balance sous le tuberculum articulare. Enfin, le capitulum mandibulae du côté de travail se tourne aussi autour d'un axe vertical afin de permettre un mouvement en avant et dans la direction médiale du capitulum mandibulae du côté de balance. Ainsi, afin de pouvoir faire ces mouvements, l'articulation temporo-mandibulaire du côté de travail fonctionne comme une jointure orbiculaire à trois axes.

Zusammenfassung.

Der Verf. legt die Ansicht vor, dass die wahre Aufgabe einer Gelenkscheibe darin besteht, die anatomische Voraussetzung für eine spezielle Gelenkmechanik zu bieten. Ein bikonkaver Gelenkdiskus liefert nämlich zwei Gelenkpfannen, so dass beide Knochenenden im Gelenk als Gelenkköpfe ausgebildet sein können. Ausgehend von dieser Voraussetzung macht der Verf. einen Vergleich zwischen der zusammengesetzten Mechanik beim Senken und Heben des Unterkiefers und der Mechanik eines zweiachsigen Nussknackers. Wenn der Unterkiefer gesenkt ist, rotiert der Diskus abwärts und vorwärts um eine transversale Bewegungsachse durch das Tuberculum articulare (Tuberculumrotation). Dadurch wird das Capitulum mandibulae abwärts und vorwärts unter das Tuberculum mandibulae geführt. Gleichzeitig rotiert das Capitulum mandibulae selbst um eine transversale Bewegungsachse durch das Capitulum mandibulae (Capitulumrotation), wodurch der Unterkiefer gesenkt wird. Es besteht kein prinzipieller Unterschied zwischen den Bewegungen beim Senken des Unterkiefers und bei dessen Vordrücken. Nur der Grad der Tuberculumrotation und der Capitulumrotation ist bei den beiden Typen verschieden.

Der Verf. gibt auch eine Analyse der lateralen Bewegung des Unterkiefers und ist zu der Auffassung gekommen, dass auf der Balanceseite eine Bewegung stattfindet, die stark an die Bewegung beim Vordrücken des Unterkiefers erinnert. So wird bei Vorwärtsrotation des Diskus auf der Balanceseite das Capitulum dieser Seite abwärts-vorwärts, ausserdem aber auch etwas medialwärts geführt. Gleichzeitig mit dieser Lageveränderung rotiert das Capitulum um seine transversale Bewegungsachse. Das Capitulum der Arbeitsseite wird auch zur letztgenannten Bewegung ge-

zwungen. Auf der Arbeitsseite scheint keine Vorwärtsrotation des Diskus stattzufinden, weshalb das Capitulum der Arbeitsseite in einer rückwärtigen Lage bleibt. Ausser der genannten Rotation um die transversale Bewegungsachse beschreibt das Capitulum der Arbeitsseite auch eine Rotation um eine sagittale Bewegungsachse, um eine Senkung des Capitulums der Balanceseite unter das Tuberculum articulare zu gestatten. Schliesslich rotiert das Capitulum der Arbeitsseite auch um eine vertikale Bewegungsachse, um eine vorwärts-medialwärts gerichtete Bewegung des Capitulums der Arbeitsseite zu ermöglichen. Um die genannten Bewegungen leisten zu können, wirkt das Kiefergelenk der Arbeitsseite mit anderen Worten als ein dreiachsiges Kugelgelenk.

References.

Hjortsjö, C.-H., 1951: Gesichtspunkte zur Mechanik des Kiefergelenks bei Senken und Heben sowie Vor- und Zurückdrücken des Unterkiefers. — Kungl. Fysiogr. Sällsk. i Lund Förhandl., Vol. 21, No. 10.

— 1952: Käkleden — en nötknäpparmekanism. — Svensk Tandläkare-Tidskrift, Vol. 45, No. 1.

— 1952: The temporomandibular joint — a nutcracker mechanism. — Moving picture record in the archive of the Anatomical Institute in Lund. (In co-operation with S. C. Nettelblad, Hj. Gustavsson, and T. Silfver.)

— 1952: Allmän rörelselära, fog- och ledlära. — Broman & Hjortsjö: Människans rörelseapparat. C. W. K. Gleerup, Lund.

— 1952: Huvudets leder och muskler. — Broman & Hjortsjö: Människans rörelseapparat. C. W. K. Gleerup, Lund.

— 1952: Sidoförningsrörelsen i käkleden. — Odontologisk Revy, Vol. 3, No. 3.

— 1952: Die Seitenbewegung im Kiefergelenk. — Kungl. Fysiogr. Sällsk. i Lund Förhandl., Vol. 22, No. 20.

— 1953: The lateral movement of the mandible. — Moving picture record in the archive of the Anatomical Institute in Lund. (In cooperation with S. C. Nettelblad, Hj. Gustavsson, and T. Silfver.)

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