EVALUATION OF PROTRUSIVE RECORDS IN COMPLETE DENTURE CONSTRUCTION

A clinical study carried out on edentulous males with firm, healthy mucous membrane and no history or clinical signs of temporomandibular joint dysfunction.

by

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This thesis is submitted
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P R E F A C E

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PROTRUSIVE RECORD

The Glossary of Prosthodontic Terms describes protrusive record as:

> "A registration of a forward position of the mandible with reference to the maxilla" (1).

INTRODUCTION

AIMS OF INVESTIGATION

In a complete denture construction recording eccentric jaw relations are often considered too time-consuming for any advantages to be gained.

The aims of this investigation is to assess the validity of protrusive records for adjusting the inclination of the condylar guidance of the articulator in complete denture construction, using recording procedure suitable for routine use in a busy dental practice.

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PART I

REVIEW OF RELEVANT LITERATURE

AND

PREVIOUS INVESTIGATIONS

ANATOMY OF TEMPOROMANDIBULAR JOINTS

The mandible is articulated to the skull by means of joint capsules, muscles, ligaments, and other soft tissues. See Fig. 1.

A temporomandibular joint is a complex ginglymo-arthrodial (hinge and glide) articulation.

The articulating surface of the temporal bone has a posterior concave part - the glenoid (mandibular) fossa and the convex anterior part - the articular eminence.

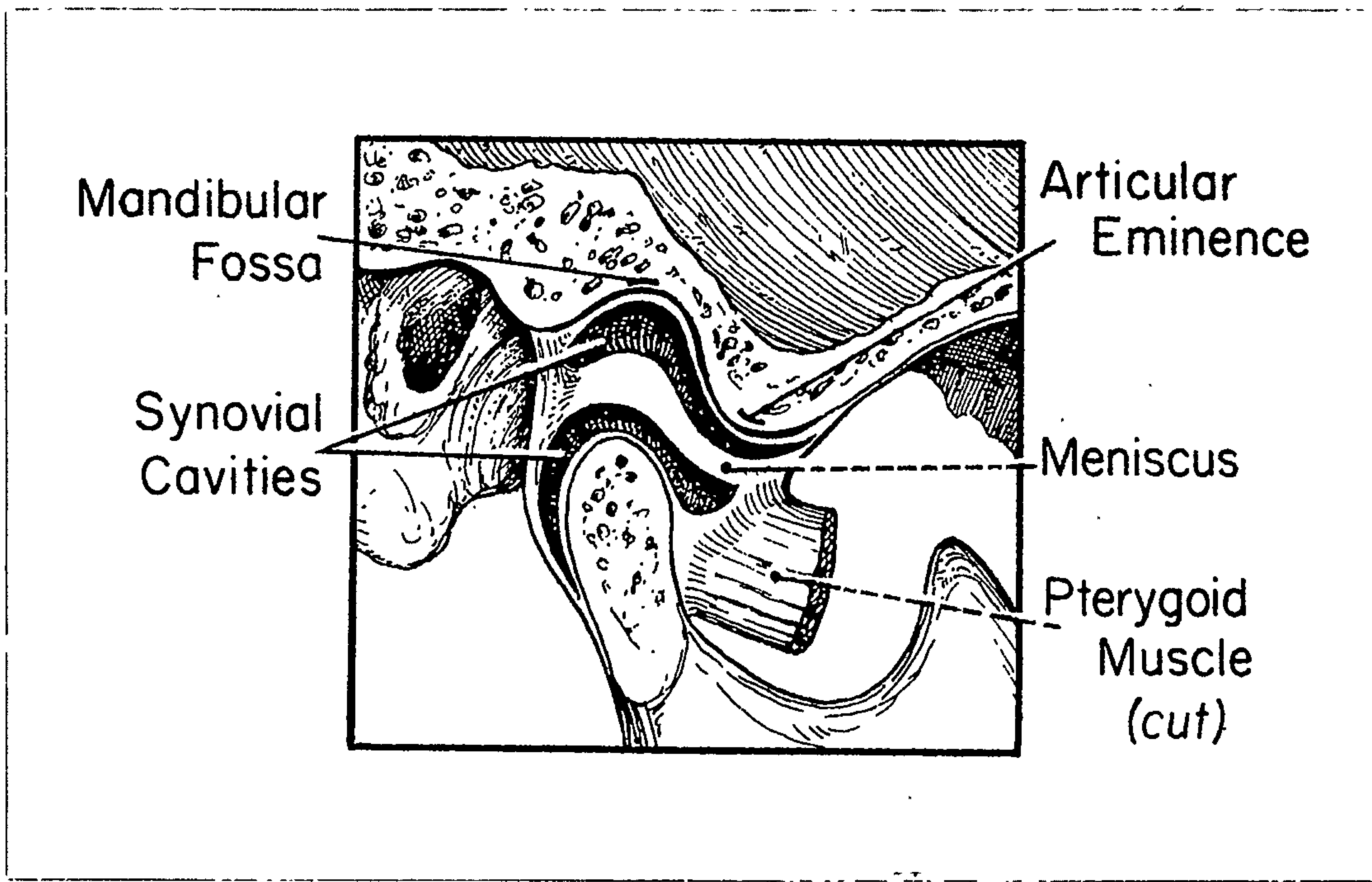
The articular disc, or memiscus, is interposed between the head of the condyle of the mandible and the glenoid fossa of the temporal bone. The medial and lateral borders of the joint follow the squamotympanic and petrotympanic fissures. (3).

The articulating surface has a well-defined cortical layer of bone which is covered by avascular dense fibrous connective tissue containing the cartilage cells. The amount of the cartilage cells depend on age and functional stress. There is no synovial membrane on the articulating surfaces of a normal joint, but a synovial capsule is attached to the articular disc around its circumference and it forms small folds at the distal and lateral borders of the disc. Anteriorly, these folds form bursal sacs to provide space for the head of the condyle in the opening movements of the jaw. Normally, a small amount of synovial fluid is present.

The articular disc consists of dense collagenous connective tissue

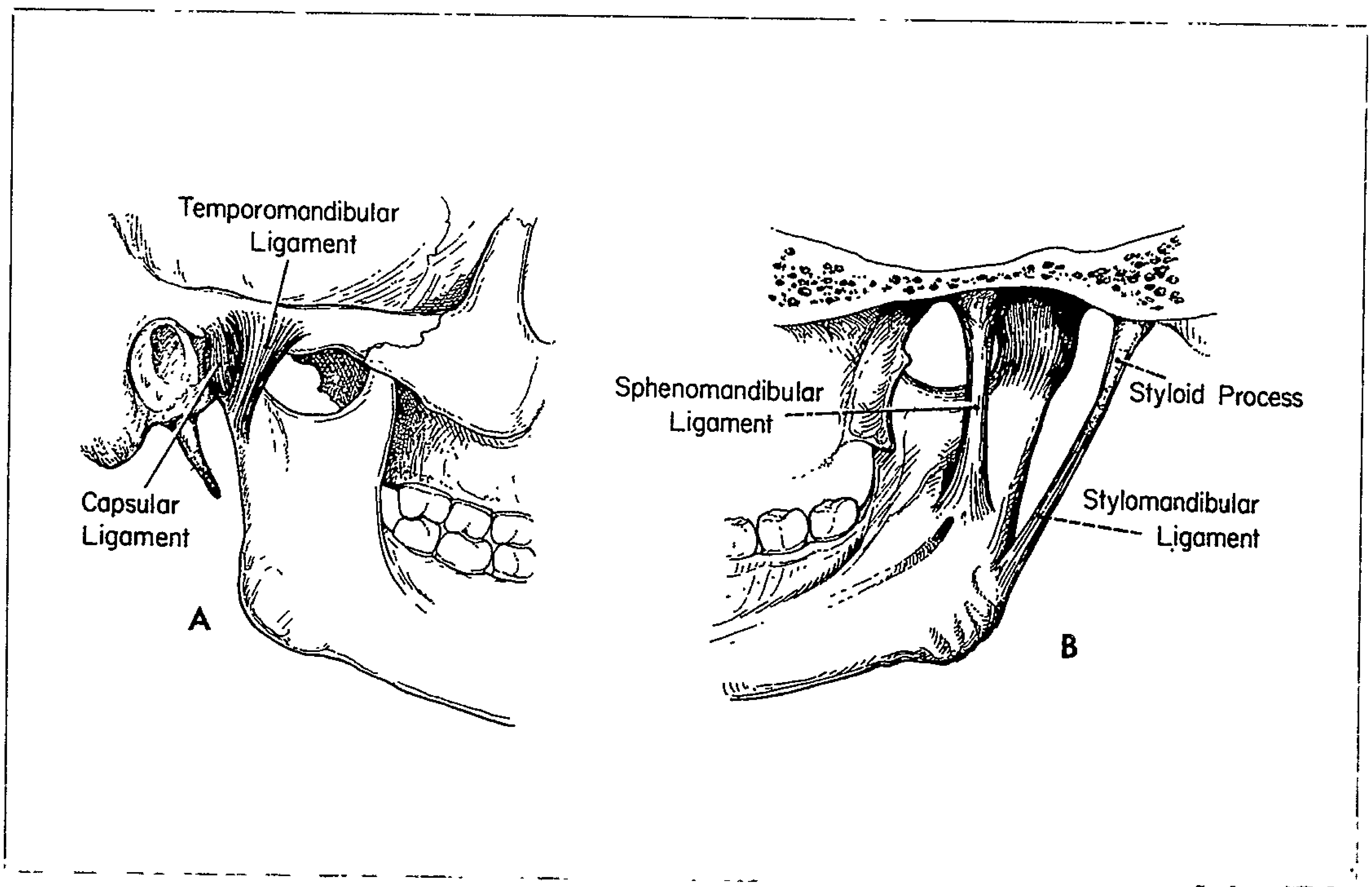
FIGURE 1 Schematic representation of the anatomical features of the temporomandibular joint. From Ramfjord and Ash (2).

FIGURE 2 Illustration of the ligaments of the temporomandibular joint A - lateral view B - medial view. From Ramfjord and Ash (2).



Mandibular Fossa
Articular Eminence
Synovial Cavities
Meniscus
Pterygoid Muscle (cut)

FIG. 1.



Temporomandibular Ligament
Capsular Ligament
A
Sphenomandibular Ligament
Styloid Process
Stylomandibular Ligament
B

FIG. 2.

The central area is avascular, hialine and without nerve tissue. The disc has a smooth surface but lack of definite synovial lining. Small blood vessels and nerve fibres can be seen in the peripheral areas. Posteriorly, the disc fits into the glenoid fossa and extends for a short distance down on the distal surface of the head of the condyle. Behind the extension of the disc there is a soft vascular connective tissue with abundant nerve endings. Thus, the condyle cannot be moved up and back, but can be moved down and back.

The disc is attached to the connective tissue of the joint capsule and anteriorly is connected to the external pterygoid muscle. The external pterygoid muscle also has a strong attachment to the neck of the condyle.

The fibrous capsule of the joint is attached to the temporal bone along the borders of the articular eminence and the glenoid fossa and also to the neck of the condyle and to the articular disc.

The ligaments of the temporomandibular joint include: See Fig. 2.

1. <u>The temporomandibular ligament:</u>
   It extends from the base of the zygomatic process of the temporal bone downwards and obliquely to the neck of the condyle.
2. <u>The stylomandibular ligament</u>:
   It extends from the styloid process to the posterior border of the ramus and angle of the mandible.
3. The sphenomandibular ligament:
   It extends from the spine of the sphenoid bone downwards and laterally to the region of the lingula.

CONDYLAR POSITIONS AND MOVEMENTS

When the jaws are closed the condyle contacts the disc and the disc contacts the glenoid fossa. If there is a contact between the upper and lower teeth during gliding movements, the contact relationship between the condyle, the disc and the glenoid fossa is maintained.

During opening movements, a gliding relationship between the parts of the temporomandibular joint also is maintained. The movements in the lower (condyle-disc) part of the joint are mainly hinge-like, with a limited amount of slide. In the upper (glenoid fossa-disc) part of the joint, the disc glides with the condyle during opening movements and follows the condyle head all the way anteriorly.

The observations of Rees (4) made on dissected cadavers revealed the possibilities of movement up to a distance of 8 mm between the condyle and meniscus from the retruded position to full opening. It was calculated that the total forward condyle movement from the retruded position to full opening was at least 15 mm and at the same time, the meniscus would move forward at least 7 mm on the temporal bone. Another observation made by Rees was that there is no air space in the joint cavity and the space vacated by the condyle in its forward movement is occupied by the soft bilaminar zone tissue.

The classical concept of the rotation and the glide within the temporomandibular joint can be questioned in light of the investigations of the movement patterns of the condyle by cinefluoroscopic recordings. (5). It was suggested that there is a zig-zagging up and down and back and forth movement of the condyle.

MUSCLES OF MASTICATION

The muscles directly responsible for the movements and positions of the mandible are called muscles of mastication, or jaw muscles. See Figs. 3,4.

The masseter muscle has a rectangular shape and is made up of two main muscle bundles that extend from the zygomatic arch to the ramus and the body of the mandible.

The temporal muscle is a flat, fan-shaped muscle, which originates partly from the temporal bone and partly from the temporal fascia. The anterior part of the muscle, which is the most powerful, has a vertical direction; the posterior part is horizontal. The temporal muscle is the most important postural muscle of the mandible.

The external (lateral) pterygoid muscle has two heads; one head of the muscle originates from the outer surface of the lateral pterygoid plate, the other head originates from the greater sphenoid wing.

The main insertion of the external pterygoid muscle is to the anterior surface of the neck of the condyle. There is also an insertion of some muscle fibres to the capsule of the temporomandibular joint and to the anterior part of the articular disc.

The internal (medial) pterygoid muscle is a rectangular muscle with its main origin in the pterygoid fossa and its insertion on the medial surface of the angle of the mandible.

FIGURE 3 Masseter and temporal muscles. From Sicher (6).

FIGURE 4 Lateral and medial (external and internal) pterygoid muscles. From Sicher (6).

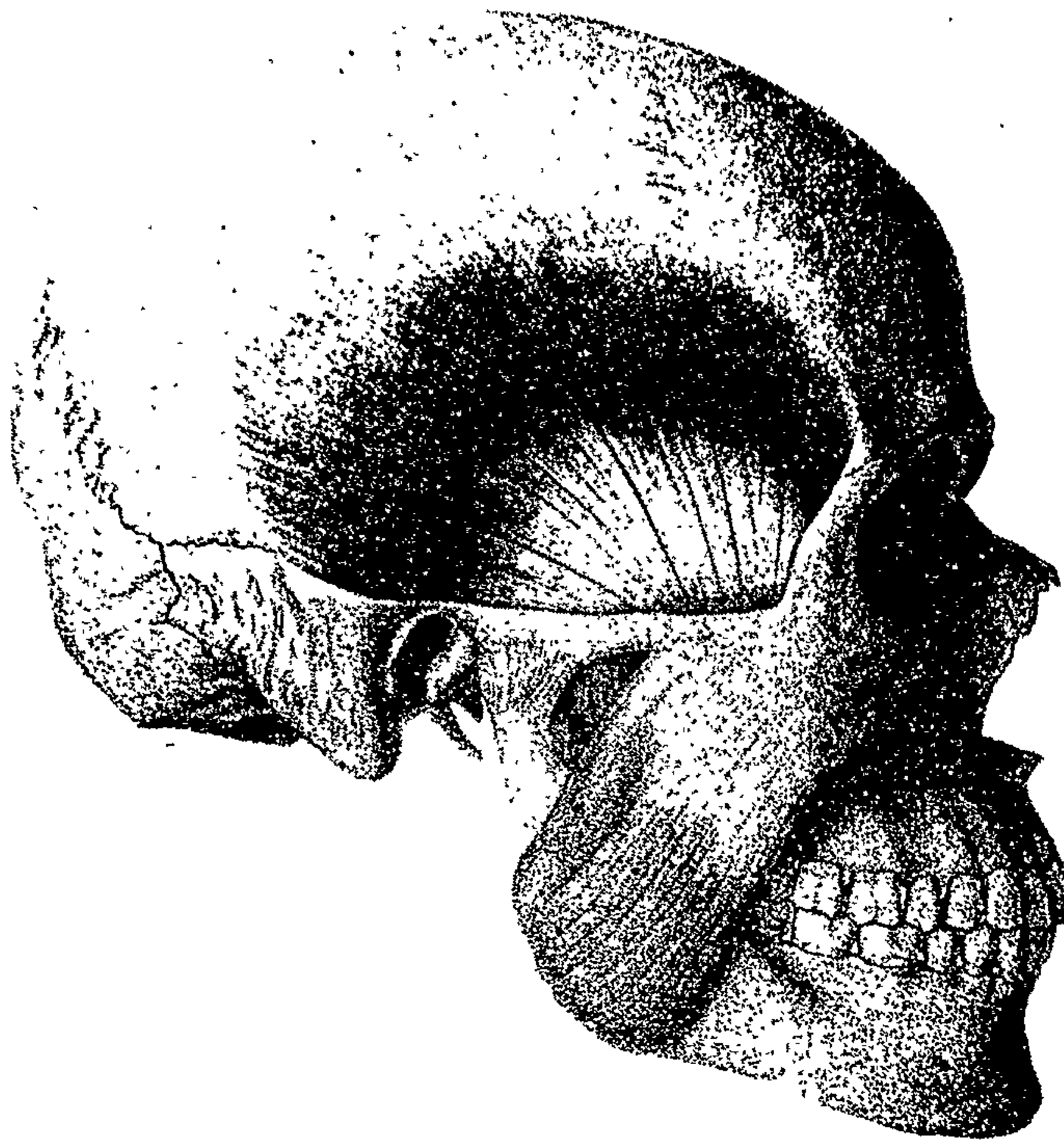
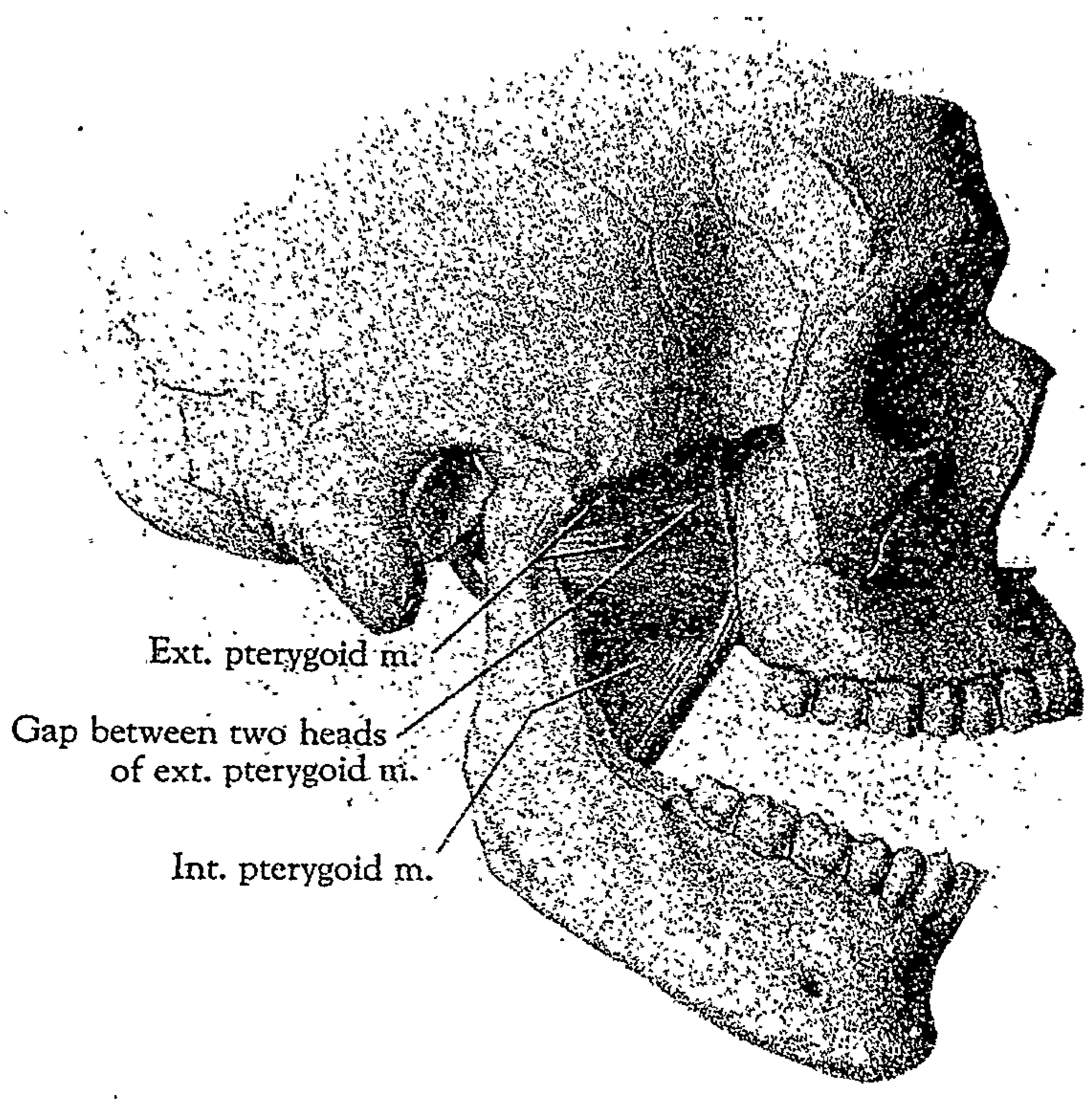


FIG. 3.



Ext. pterygoid m.
Gap between two heads
of ext. pterygoid m.
Int. pterygoid m.

FIG. 4.

MANDIBULAR MOVEMENTS

1. The form and function of the bilateral temporomandibular joints enable the mandible to make a variety of movements.

   The movements of the mandible are classified according to the direction of movement of the incisal point which is the point between the incisal edges of the two mandibular central incisors.

   From the intercuspal position in natural dentition the mandible can move downwards; during this movement contact between the upper and lower teeth is lost.

   With or without contact between the upper and the lower teeth the mandible can be moved forwards, to the sides and generally, backwards to a slight extent.

   These movements are called basic movements. (7).

   Basic mandibular movements include:

   1. Opening and closing movements.
   2. Forward movement with tooth contact (protrusion) and backwards gliding movement to the intercuspal position.
   3. Backwards gliding movement (retrusion) from the intercuspal position.
   4. Lateral gliding movement from the intercuspal position.

2. The functional limits of the temporomandibular joints are not unbounded. The limitation of movement is a consequence of bony or cartilaginous restraints imposed by the joint

capsules and the ligaments. If the mandible moves along the limits of motion, one may speak of border movement.

Posselt (8), (9), (10), (11) has demonstrated that the border movements of the mandible are unique and reproducible for each individual.

The border movements of the mandible recorded in the saggital plane are shown in Fig. 5.

When the mandible is in a retruded position, a hinge movement can be recorded for the incisor point, from CR to B. In this movement, called the terminal hinge movement of the mandible, the rotation axis through the two temporomandibular joints is stationary. Under normal physiologic conditions of the masticatory system this centre of rotation and the path of the mandibular movement is constant and reproducible.

The position CR is called centric relation, terminal hinge position, or retruded contact position. Since this position, or path is determined by the ligaments and structures of the temporomandibular joints, it has also been called the ligamentous position.

This position is the posterior functional range of the mandible. It is defined as the most retruded position of the mandible from which opening and lateral movements can be performed comfortably.

FIGURE 5 Border movements of the mandible recorded in saggital plane. From Ramfjord and Ash (2).

FIGURE 6 Border movements of the mandible recorded in the horizontal plane. From Ramfjord and Ash (2).

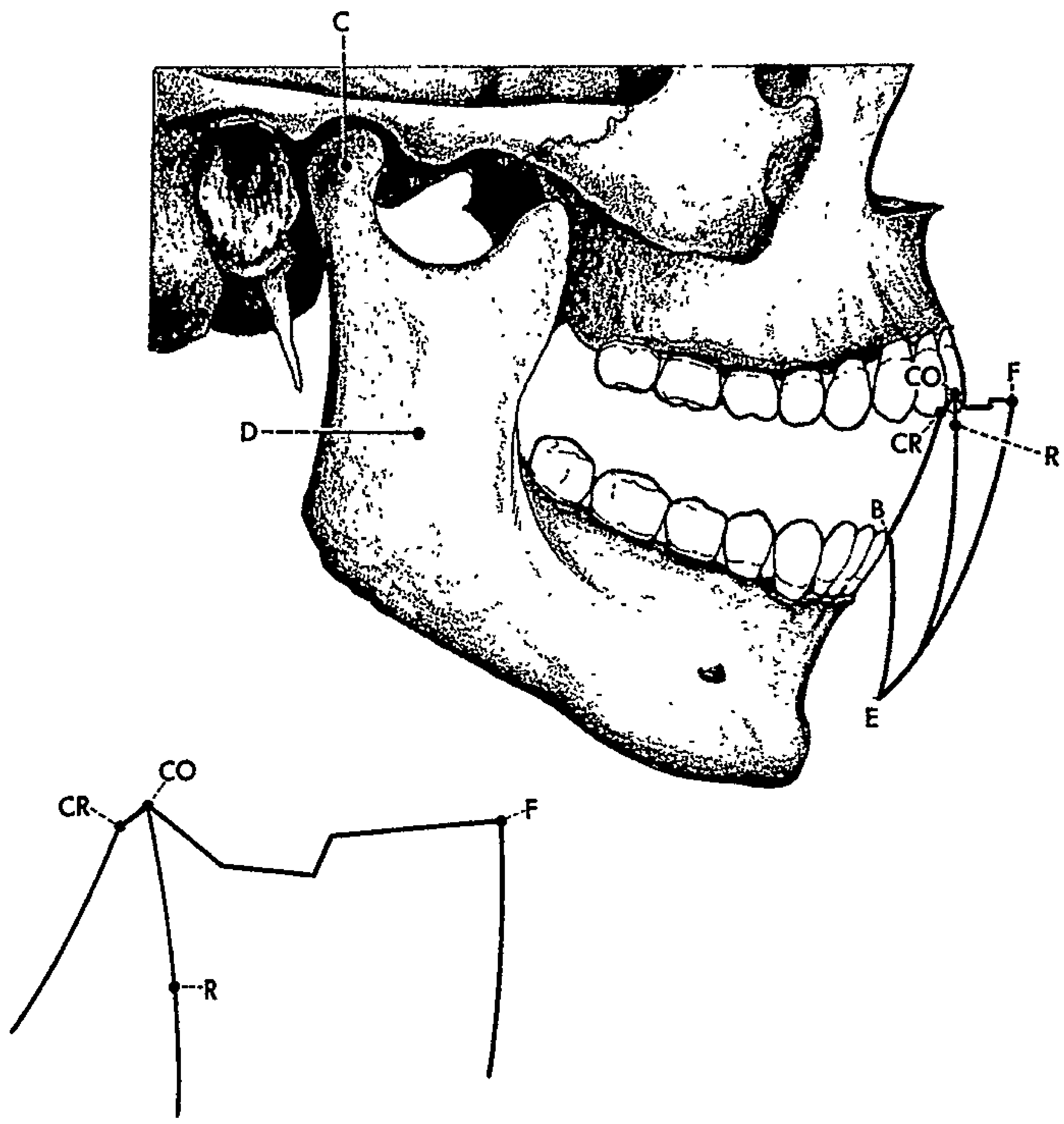


FIG. 5.

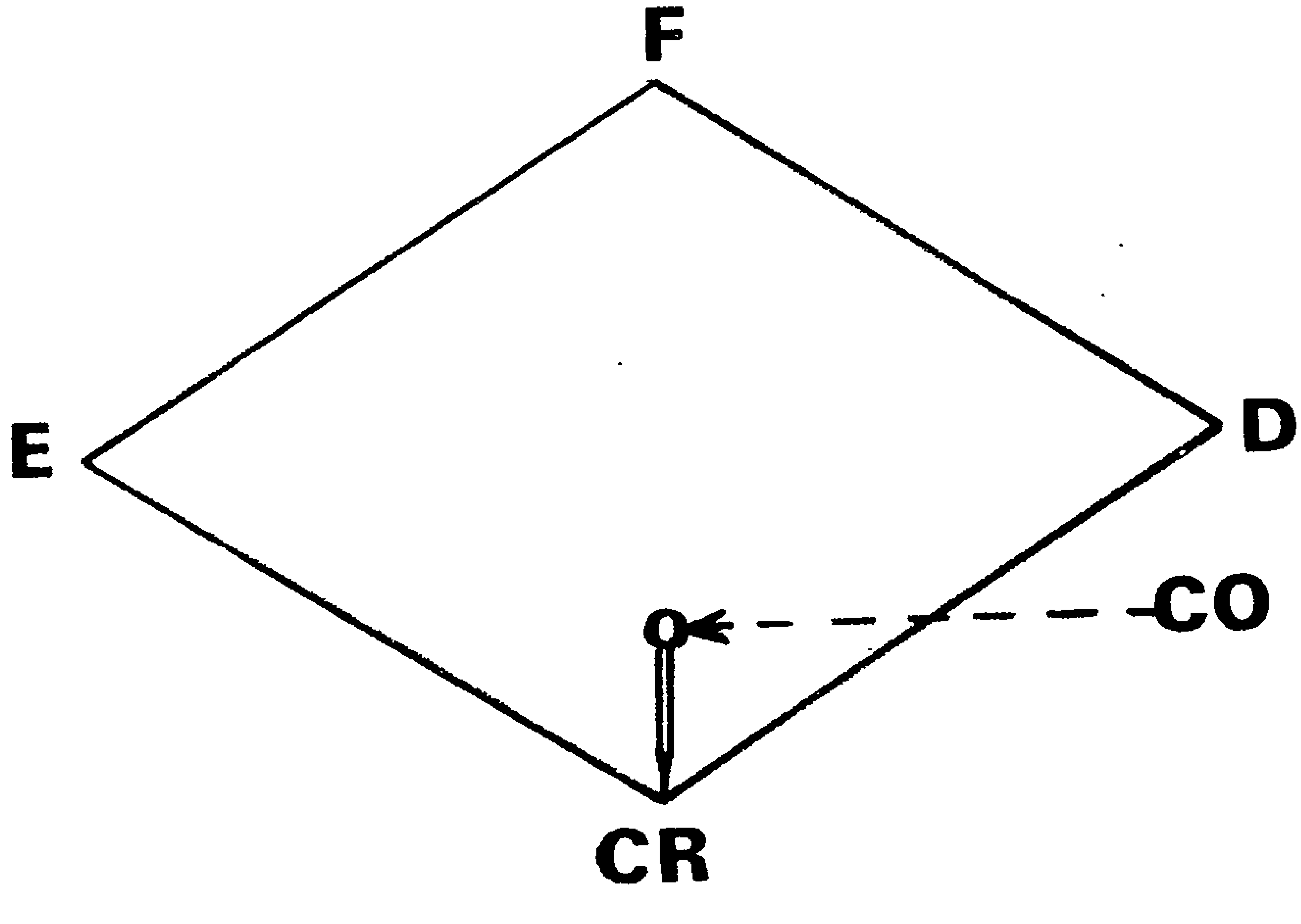


FIG. 6.

The position CO is the position of the mandible in which the cusps of the mandible and maxillary teeth interdigitate maximally and is called centric occlusion.
A short movement path can be recorded between CR and CO by bringing the teeth into centric relation (CR) and squeezing jaws together into centric occlusion (CO). This movement is called slide in centric.

If the jaw is opened in a retrusive path below B, the movement changes character and the axis of rotation is D, behind the mandibular foramen, and the incisal point moves down to E. Then closure will follow the path E to F. The path from F to CO (while the teeth are in contact) is determined by the occlusal relationship of the teeth in upper and lower arches.

R is the rest position of the mandible.

This geometrical figure of the mandible movements is called "The envelope of motion".

The mandibular movements also can be projected perpendicular to the horizontal plane. See Fig. 6.

The border movements for the incisal point can be traced by gothic arch or Gysi tracing (12) in the horizontal plane.

When the mandible is in the stationary hinge position, or centric relation point, CR corresponds to centric relation (also called the arrow point in Gysi's tracing).

When the mandible moves in retrusive lateral excursions, the incisal point records the line from CR to D. From D, the mandible can be moved forward and medially to point F. A similar tracing can be done from the other side to point E from point CR. The point CO represents centric occlusion.

The mandibular movements also can be projected into the frontal plane. See Fig. 7. Most common in persons with free occlusal contact movements is a smooth path of movements that return very closely to the same closed position for every chewing stroke. (13).

Hickey, Allison, Woelfel, Boucher and Stacy (14) described their method of three-dimensional motion picture photogaphy to investigate mandibular movements. The movement of a pin inserted directly into the condyle was observed and compared with the movement of a pin attached to the lower incisor teeth. The activity of both pins was recorded in the horizontal, saggital and frontal planes by three synchronously running motion picture cameras. Their report indicates that various masticatory movements are more complex than was generally previously believed.

BASIC POSITIONS OF THE MANDIBLE

A basic position is a mandibular position used frequently during function or alternatively a reference position against which other positions, or movements, can be compared.

The three most important basic positions are:-

1. Rest position:

   The rest position is the position from which function starts; such being the normal position of posture of the mandible.

FIGURE 7 Jaw movement in function recorded at the midline (ML).. From Ramfjord and Ash (2).

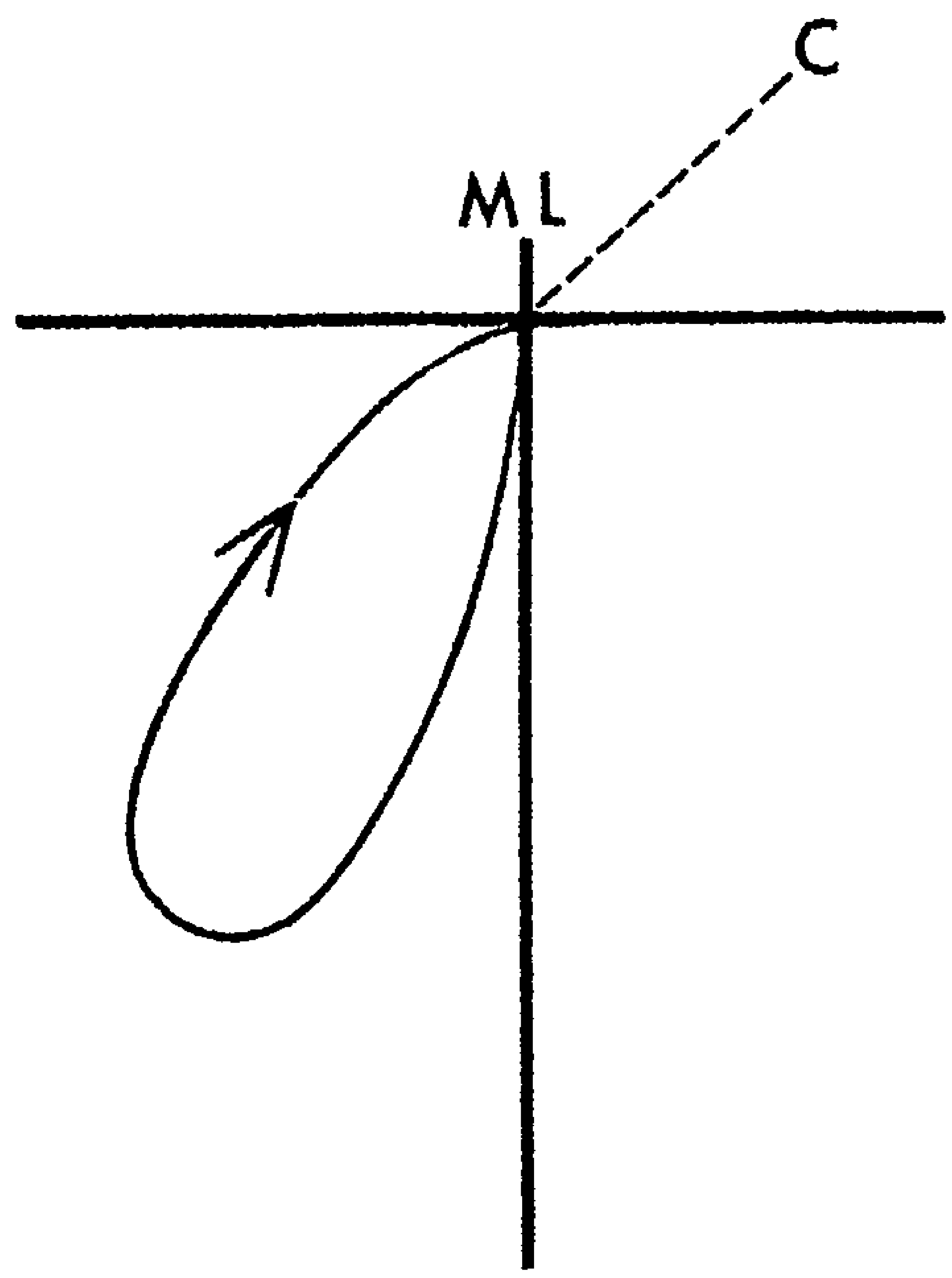


FIG. 7.

2. Intercuspal position:
   The intercuspal position in normal cases is the harmonious functional contact.

3. Retruded position:
   Retruded position is the reference position on the terminal hinge path.

PROTRUSION

The total protrusive path starts from the retruded contact position, passes through the intercuspal position and edge-to-edge occlusion and ends in the protruded contact position.

It is anterior in the direction and is directed in some angulation to the horizontal plane. The condyles move in the saggital plane in pure protrusive excursions. The protrusive movement from the intercuspal position to the edge-to-edge occlusion produces a shift of condyles which averages about 5 mm (8).

Considerable significance is attached to the protrusive movements of the mandible due to their frequent use in equilibration, reconstruction of natural dentition and the fabrication of complete dentures.

The flatter protrusive condylar path requires the short cusps and the shallower fossae of the posterior teeth. The greater slope of the protrusive condylar path requires the higher cusps and the deeper fossae of the posterior teeth.

CONTROL OF MANDIBULAR MOVEMENTS

The control of the mandibular movements is reflex in nature, the co-ordination of the mandibular muscles occurs without conscious awareness.

It is very precise and at the same time a very variable mechanism, working on the basis of occlusion and type of food.

In the control of the mandibular muscles, afferent influences are derived from the peripheral receptors (segmental control) and from the central nervous system (suprasegmental control) which synaps finally with either alfamotorneurones or fusimotorneurones in the motorneurone pools of the particular muscles concerned. (15).

SEGMENTAL CONTROL

The receptors which provide the segmental reflex control of the mandibular muscles can be divided into intraoral and extraoral.

INTRAORAL RECEPTORS

1. Dental Receptors:

The mechanoreceptor responsible for transmitting stimuli from the tooth pulp is still not known with certainty, although the odontoblast and its process has been implicated either as a receptor unit alone or in combination with nerve fibres contained within the dentinal tubules. (16).

2. Periodontal Mechanoreceptors:

It was thought that the receptors in periodontal ligament played a major part during the control of the mandibular movements, but work on subjects with full upper and lower dentures when eating different foods has shown that the cycles are the same as with natural teeth. (17).

3. Mucosal Mechanoreceptors:

Tactile receptors in the oral mucous membrane provide a continual stimulus to masticatory movements by virtue of the contact made by food with the mucous membrane. It has been proposed that following tooth loss, pressure of a denture base overlying the mucous membrane provided stimulation of a large population of mucosal receptors, which become important in the control of masticatory muscles in edentulous patients.

4. Periosteal Mechanoreceptors:

They display rapidly adapting responses to stretch as would be provided by muscle pull and so stretch of periosteum, and they may also be stimulated as a result of the denture base pressure.

EXTRAORAL RECEPTORS

1. Temporomandibular Joint Mechanoreceptors:

They have been characterized morphologically and physiologically into types I, II, III and IV. (18),(19). Most information is related to types I and II.

Type I mechanoreceptors are active at all times (although the frequency of their discharge varies with capsular tension) and they thus provide a continual contribution to co-ordinated muscle behaviour and perceptual awareness of the joint position.

Type II mechanoreceptors are active only at the commencement of the jaw movements and so make phasic contribution to muscle co-ordination.

2. Muscle Receptors:

Four different types of muscle receptors play an important role in the reflex control of muscle behaviour.

They are:-

(a) the muscle spindle which is the most important muscle receptor and lies in parallel with the muscle fibres;
(b) Pacinian corpuscles in the connective tissue elements of the muscle;
(c) Golgi tendon organs in muscle tendons;
(d) free nerve endings which can be found throughout the muscle.

SUPRASEGMENTAL CONTROL

Reticular formation is a very important area of suprasegmental control in the brain stem. Within the reticular formation there are two groups of cells:-

1. Medial - inhibitory
2. Lateral - facilitary

Cortico - bulbar system, vestibular system, also plays a role in the suprasegmental control mechanism.

FUNCTIONAL MOVEMENTS AND ARTICULATOR MOVEMENTS

If the temporomandibular joint acted as a simple hinge during functional movements of the mandible, a plain line articulator would satisfy the mechanical requirements for the setting up of artificial teeth for an edentulous patient. However, we know that when the mouth is opened for the apprehension and mastication of food, the condyles move forward and downward, the direction of the movement being determined by the curvature of the articular eminences of the temporal bone.

So that the teeth may be set up to allow for specialized movements of the mandible during function, an anatomical articulator must be used which will allow movements similar to the functional movements of the mandible. As the functional mastication movements vary for each individual, it is necessary that the articulator should be adjustable to compensate for these variations.

There are factors which must be borne in mind when attempting to correlate the mouth movements with articulator movements.

1. The functioning of an anatomical articulator is purely mechanical and makes no allowance for the condition found in the mouth and described by Hanau (20), (21), as a "REALEFF" (resilience and like effect of the mouth tissues). This resiliency is effective in the mucous membrane and the tissues of the temporomandibular joint.

2. The condylar path is not straight, but curved (22), (23). The mechanical equivalent on the articulator, the condylar guidance,is straight on practically all anatomical articulators. Where the condylar guidance is curved it is purely arbitary and non-adjustable.

The movements to which the mandible is subjected during function and which should have a mechanical equivalent on anatomical articulator are:

1. Protrusive movements from centric occlusion.
2. Right and left lateral movements from centric occlusion.
3. Intermediate movements combining 1 and 2.

PROTRUSIVE MOVEMENTS

Protrusive movements of the mandible are the first essential movements during mandibular function as they are necessary for the apprehension and incision of food.

For the simple protrusive movement, both condyles move forward and downward, the direction being determined by the curvature of the articular eminences of the temporal bones. This movement is carried on until the lower incisor teeth meet in an "edge-to-edge" relationship with the upper incisors. In this protruded position, it is important that there be balance in the posterior portion of the denture to prevent dislodgement of the dentures during function.

LATERAL MOVEMENTS

During the lateral functional movements the mouth is opened and the mandible is swung into the lateral position. The jaws are then closed and the food is crushed on the inclined plane of the posterior teeth. When the posterior teeth on one side meet so that the buccal cusps of the lower teeth are in line with and touching the buccal cusps of the upper teeth, this side is described as a "working side" of the denture. On the balancing side, the buccal cusps of the lower posteriors have a contacting relationship with the lingual cusps of the upper posterior teeth.

Unless this balance is achieved, displacement of the dentures is likely to occur when the teeth come into actual contact in the working side during function.

FACTORS IN THE LAWS OF ARTICULATION

In the mechanism of the correctly articulated teeth, there are five factors which have interdependent and reciprocal relationship. (21). They are:-

1. The inclination of the condylar guidance.
2. The inclination of the incisal guidance.
3. The inclination of the compensating curve.
4. The inclination of the plane of orientation.
5. The height of the cusps of the teeth.

1. Condylar guidance:

The condylar path is the path traversed by the condyle in relation to the articular eminence when the mandible is moved either laterally or protrusively from centric occlusion. The condylar path, therefore, has a lateral, as well as, horizontal component. The condylar path differs in its curvature in different individuals and on either side of individuals (24), (25). This path is curved and cannot be accurately reproduced on a standard articulator.

Lindblom (3), (26) found that the condylar path became slightly less steep with age in a large number of patients with functional disturbances of the pattern of occlusion. Such changes in the condylar path were not significant for the control of patients without functional disturbances. Also, there was no correlation between the pattern of occlusion and the shape of the temporomandibular joints.

The mechanical equivalent to the condylar path is the condylar guidance. The condylar guidance follows the general direction of the condylar path within functional limits.

Sicher (27) made the point that when non-contact movements are carried out within the limits of the movement space the character and shape of the temporomandibular joint are of no significance for the movement of the mandible. However, when contact movements are performed, the path of the molar cusp, for example, is influenced by both the incisal and condylar guidance.

In an experiment of Posselt (28) with McCollum Gnathograph, fixed to a patient with a normal dentition, various tooth guidances, flat or curved, were made to influence gliding movements of the mandible. Registration of the saggital condylar path were identical for these various guidances and also when the patient chews with full contact of his own teeth. These results are similar to those obtained by McCollum (29), Stuart (30) and Cohen (31). Munzesheimer (32) made similar recordings and gained similar results from graphic records on edentulous patients.

Because of the lateral, as well as horizontal component of the head of the condyle during lateral movement of the mandible, need for provision for this type of movement on an anatomical articulator is evident. Some articulators provide for adjustment of the condylar posts to allow for a lateral movement.

Hanau's formula $\frac{H}{8} + 12 = L$ is of practical importance where H equals the inclination of condylar guidance in degrees and L is the lateral articular condyle guidance inclination. (21). This is an "experience formula" which proves satisfactory in practical application.

By the inclination of the condylar guidance is meant the angle formed by the horizontal condylar guidance with the horizontal plane.

2. Incisal guidance:

The function of the incisal guide plane, when used in conjunction with an incisal pin, is to impart an opening movement to the articulator in lateral and protrusive movement of the articulator, similar to those produced in the mouth by sliding of the inclined planes of the cusps of the opposing natural posterior teeth and the sliding of the incisal tips of the lower anterior teeth on the lingual surfaces of the upper anterior teeth, if they contact during protrusion.

No information can be obtained from the edentulous patient which will indicate specifically what this incisal guidance should be.

By the inclination of the incisal guidance is meant the angle made by the incisal guide plane with a horizontal plane of the reference - the base of the articulator.

3. The compensating curve:

In the natural dentition, the mandibular teeth are arranged in a curve known as a "Curve of Spee". Intent of this curve is to permit a contact of the natural incisor teeth in the incising relationship without interference by the cusps of the posterior teeth. This curve is developed because the natural teeth have cusps and because in practically all dentulous humans there is positive inclination of the condylar path and without the curve, contact of the incisors in protrusion would be impossible due to cusp interference of the molar cusps. It is necessary in the artificial denture construction to develop a curve similar to the "Curve of Spee".

The curve which is developed in full dentures is known as a compensating curve. It is purely mechanical device and must not be confused with a "Curve of Spee", which is purely an anatomical expression.

The compensating curve commences on the incisal tips of the upper central incisors and passes over the crests of the buccal cusps of the maxillary bicuspid and molar teeth of the denture.

4. <u>Plane of orientation:</u>

The plane of orientation is purely a geometrical factor. It is described as a flat plane which passes through the contact point of the upper central incisor teeth and the summits of the mesiobuccal cusps of the upper second molar teeth.

By the inclination of the plane of orientation is meant the angle formed by the plane of orientation with the horizontal plane of reference. This horizontal plane of reference may be the base of the articulator, or the flat tooth plane established on the occlusal rims in the mouth, and transferred to the articulator, so that it is horizontal to the base of the articulator.

5. Cusp height:

Cusp height is defined as the projection on a vertical plane of the distance between the cusp summit and the imaginary individual cusp height.

Variation of any one of the five variable and interrelated factors will cause a variation in one or another of the remaining factors if harmony of balance is to be maintained. Hanau (21) expressed the mathematical possibilities in regard to these five factors effecting balance in protrusion in forty laws. He produced "The Articulation Quint", which diagrammatically sets out the above laws.

ESSENTIAL RECORDS

For correctly mounting the casts on the anatomical articulator, the following records are essential:

1. Face bow record
2. Centric relation record
3. A protrusive record

The purpose of protrusive jaw relations record is to adjust the condylar elements of the articulator, so that they will present inclinations which are, as nearly as possible similar, or equivalent to those of the patient. The practice of setting condylar elements of the articulator on an average figure appears to be unsatisfactory.

Posselt and Nevstedt (33) determined the condyle path inclination on one hundred and one persons. The error of a single observation on the Dentatus articulator as used in this investigation has been calculated previously. (34). The condyle path inclination as determined by interocclusal wax records varied between 0 and 60 degrees. They concluded that individual registrations of the condyle path inclinations should be used instead of the mean value adjustment.

CHRISTENSEN PHENOMENON

It was previously stated that it is important to maintain the balance in the protruded position to prevent dislodgement of the dentures during incisive contact and that the condylar path, cusp height, cusp angulation and compensating curve have important effect on protrusive excursions.

Christensen (35), (36), (37) brought attention to the phenomenon which occurs during protrusive movement and its significance in denture construction.

The occlusal surface of properly shaped occlusal rims contact each other evenly in centric relation. The mandibular condyles are located in the glenoid fossa.

When the patient moves the mandible forward (protrusive movement) a wedge-shaped gap, which widens distally is formed between the occlusal rims on either side. Only the anterior parts of the rims are in contact. The mandibular condyles are located on the tuberculum articulare incline.

This is the Christensen phenomenon.

The basis of the Christensen phenomenon is that the plane of contact of the occlusal rims is not parallel to the condylar path. During protrusive movement both condyles lower themselves during slide over tuberculum articulare incline and both ends of the lower occlusal rim lower themselves with the condyles.

Thus, Christensen phenomenon originates.

METHODS FOR OBTAINING PROTRUSIVE RECORDS

Christensen introduced the method of securing protrusive relations of the mandible to maxilla intraorally by means of "protrusive wax check bites". (36). This record is used to record the condylar inclination of the patient and to transfer this inclination to the condylar guidance mechanism of the articulator.

In the method of Gysi (38), the saggital condyle path inclination is obtained by graphic recording extraorally. In this technique, the condylar rods of the face bow make tracings on cards held on the balancing sides during alternate lateral movements.

According to the Gysi technique, "the straight part of each condyle path tracing" is extended upwards and downwards by the use of straight edge. The cards are cut along the extended lines of the condyle path tracings and this oblique edge is used to adjust the condyle guide inclination of the Trubite articulators*. (39).

Other techniques also have been suggested for recording protrusive movements. They include Stansbery's technique, engraving and chewing-in methods. (40), (41).

Pantography has been noted for its advantages in the recording of jaw movements, but has not been totally accepted by complete denture prosthodontists because of the heavy equipment and movable bases encountered with this method. (42).

* Dentists Supply Co. New York. N.Y.

The principles involved in the pantographic technique, their practicality, and their reproducibility, have been questioned by many authors (Hall (43), Kurth (44), (45), Sheppard (46), Landa (47), Shanahan and Leff (48), (49), (50), (51), (52), (53), (54), Page (55), Watt (56)), and advocated by others (McCollum (29), Cohen (31), Posselt (28), Kotowicz, Clayton and Smith (57), Clayton, Kotowicz and Meyers (58), Clayton, Kotowicz and Zahler (59)).

Lucia (60) and Gouchet (61) demonstrated the use of the pantograph in complete denture prosthesis. Research concerning reproducibility of tracings, or articulator settings for edentulous patients, could not be found.

ARTICULATORS

There are different types of articulators which have provision for adjusting the condylar guidance.

First group of instruments simulate condylar pathways by using averages, or mechanical equivalents, for all, or part of the motion. These instruments allow for joint orientation of the casts and may be Arcon and non-Arcon instruments. These instruments accept static protrusive registrations and use equivalents for the rest of the motion.

Christensen's Arcon instrument was the first in this group of articulators. (35).

The most commonly used articulators in this group are:

(i) Snow's "New Century" instrument. *
(ii) The Hanau Model H. **
(iii) "Dentatus". ***

* Gibling Bros., Sydney. N.S.W.
** Hanau Engineering Co. Inc., Buffalo. N.Y.
*** A.B. Dentatus, Stockholm. Sweden.

The second group of instruments accept three dimensional dynamic registrations. These instruments have condylar paths that can be angled and customized either by selection from a variety of curvatures, by modification, or both.

The McCollum's Gnathoscope and Gouchet's Denar**** are examples.

Lee (62) described his technique of engraving pathways in a plastic block by the turbine drill as the patient's mandible moved in straight protrusive direction.

CRITICAL INVESTIGATIONS

Methods for recording and reproducing saggital path inclination have been investigated critically. Some of the aspects of investigations are:

INTRAORAL VERSUS EXTRAORAL JAW REGISTRATIONS TECHNIQUE

Posselt and Skytting (63) investigated the variation of the saggital condyle path inclination as obtained by graphic recording and compared them with the results obtained from the intraoral wax record method.

Ten undergraduate dental students were used as a subject in the investigation. All subjects had complete, or had almost complete complement of their teeth. Ten registrations were made on each side of each mouth by means of Gysi face bow.

The error of the graphic method was found to be about twice that of the intraoral wax method.

**** Denar Instrument Co., Anaheim. Calif.

Narbe and Arstad (40) also compared the intraoral wax record method with the Gysi graphic method. They made experiments using complete denture subjects and used a central bearing point. They concluded that the intraoral method is more reliable.

Arstad (41) made cross comparisons of articulator settings for various techniques of recording eccentric movements for seven complete denture patients. The technique included those of Gysi (with central bearing point), Stansbery, Hanau and the engraving and chewing-in methods. He concluded that none of the methods using situational interocclusal records can be considered reliable when a thermoplastic material is used and that functional engraving, or grinding-in techniques register movements of the mandible, plus those of the bases on the soft tissues. Arstad believed that none of the methods mentioned guaranteed a correct registration of mandibular movements.

THE INFLUENCE OF ARTICULATOR DESIGN ON THE REPRODUCTION OF THE ANATOMIC INCLINATION OF THE CONDYLAR PATH - (ARTICULATORS OF NON-ARCON TYPE VERSUS ARCON TYPE)

Posselt and Franzen (34) made a comparison of the variations in the saggital condylar path inclination with certain degrees of protrusion using the Dentatus (non-Arcon) and Bergstron (1954) model articulators (64) (Arcon) and Gnathothesiometer (65). They showed that the amount of protrusion recorded should be 4 mm. They thought that 6-8 mm was best from a mechanical stand-point and 2 mm most favourable from a physiological stand-point. 4 mm was suggested as a compromise.

They found that Dentatus and the Bergstrom articulators showed relatively good accordance with each other and that the unreliability of a single observation on Gnathothesiometer is larger than for other instruments.

VARIATIONS OF THE CONDYLE PATH IN DENTULOUS SUBJECTS AS RECORDED BY THE SAME PERSON AND AS RECORDED BY DIFFERENT PERSONS

Nevakari (66) recorded and read the saggital condyle path inclination on seven persons with complete natural dentition. He used a Brandrup-Wognsen articulator. Both the registration and the reading were carried out also by a second dentist.

Due to considerable variations of results obtained in two series, Nevakari considered the results of the intraoral wax recording technique to be unreliable.

Frazier, Lutes, Rayson and Rahn (67) examined the relative repeatability of plaster interocclusal records for articulator adjustment in the construction of complete dentures. A Kinematic face bow transfer was made to a Whip-Mix articulator.*

A centric relation plaster interocclusal recording was used to mount the mandibular cast. The selected artificial teeth were set and the centric relation mounting verified. With the teeth set in wax, multiple protrusive and right and left lateral plaster, interocclusal records were recorded by three different dentists. Each dentist used the records he made to adjust the articulator. Articulator calibrations were read and recorded by a trained dental assistant. In an additional part of the study, four dentists set the instrument to plaster interocclusal records taken from casts mounted in an articulator with known condylar settings.

* Whip-Mix Corp., Louisville. Ky.

After a statistical analysis, they concluded that the greatest error occurs in making the record. Each dentist was highly consistent with himself for a given patient, but was not as consistent with other dentists using the same patient.

Beyron (68) wrote that a person trained in the maxillo mandibular registration technique obtains considerably better results than an untrained person.

DIFFERENT MATERIALS USED FOR RECORDING PROCEDURES

Shanahan and Leff (69) made a comparison of accuracy of wax interocclusal records with a record made in cold-cure acrylic resin. They came to the conclusion that the baseplate wax and impression wax did not make satisfactory interocclusal records for mounting casts on an articulator and the cold-cure acrylic resin was preferable for this purpose.

Skurnik (70) compared wax, zinc-oxide, and eugenol paste and acrylic resin for making interocclusal records. He came to the conclusion that a high-quality wax is a useful and versatile material for registering occlusal records.

Millstein, Kronman and Clark (71) in their study tried to determine the optimal procedures to be used in making wax interocclusal records.

They suggested the use of air cooling instead of cold water for storage of wax registration, because it showed the least change.

They came to the conclusion that even under highly controlled conditions of the study, exact reproduction of the original wax recording was never achieved.

DISCUSSION

Recording eccentric jaw relations considered by some authors to be too time-comsuming for any advantages gained.

Craddock (72) recorded multiple protrusive and lateral wax interocclusal records and made roentgenograms (after Lindblom) on three dentulous patients. He analyzed the articulator settings and roentgenograms and found the use of intraoral wax records of eccentric jaw relations for the adjustment of the saggital condylar guidance on anatomical articulators to be invalid and unreliable. He mentioned that :

> "To get an eccentric interocclusal record that can be used, the degree of protrusion is beyond the functional range."

Craddock believed the inconsistency would be greater in complete dentures because of tissue resiliency and that a change in 10^{o} horizontal condylar inclination produces a change of 0.5 mm in the second molar region.

Narbe and Arstad (40) experimented with Stansbery's and Gysi's techniques. They stated:

> "Provided the centric position is correct, exact adjustment of the condyle path of the articulator is not of vital importance because the resilience of the mucosa will, to a certain extent, compensate for any such incorrectness."

Dubois (73) conducted a study to determine if changes occur in the protrusive condylar inclinations during the first ninety days that complete dentures were worn. He concluded that the condylar path may change during the first ninety days following denture construction. Dubois advocated the use of correct condylar inclination in complete denture construction.

PART II

AUTHOR'S INVESTIGATIONS

MATERIAL

Eleven adult edentulous males were selected from the patient population of the Dental School, University of Sydney and the United Dental Hospital, Sydney. All cases had a firm, healthy mucous membrane and no history or clinical signs of the temporomandibular joint dysfunction.

The age distribution was between 24 and 52 years.

PROCEDURE FOR OBTAINING PROTRUSIVE RECORD

Complete dentures were constructed according to the procedures accepted in the Department of Prosthetic Dentistry, Dental School, University of Sydney. (74). The articulator used was the Dentatus.*

The protrusive records were taken at the maxillo-mandibular relationship recording stage, at the try-in stage, and at the primary issue and secondary issue stages.

For the better stability of the occlusal rims during record taking, the bases of the occlusal rims were constructed from heat curing acrylic resin and later used as the denture base.

The protrusive records were taken as described by Smith (75) with a protrusion of 4 mm as suggested by Posselt and Skytting. (63).

1. The inclination of the condylar guidance of the condylar elements of the articulator were set at 25^{o}. The condyle posts were adjusted to a Bennet angle of 0^{o}.

* A.B. Dentatus, Stockholm. Sweden.

2. A small notch was cut in the maxillary occlusal rim on the right and left sides in the region of the first molar. These notches act as a guide in making the protrusive record and prevent the occlusal rims from sliding over one another during the adjustment of the articulator to the protrusive record.

3. The incisal guide pin was dropped about 3 mm. This space provides sufficient wax thickness to permit modification of the articulator record in the mouth without the loss of vertical dimension. A mark was made with an indelible pencil on the incisal table of the articulator 4 mm behind the centric jaw relation position of the incisal pin.

4. A roll of soft wax was added to the entire occlusal surface of the mandibular occlusal rim and the occlusal surface of the maxillary occlusal rim well covered with petroleum jelly. Both rims were placed on their respective casts in the articulator. The upper member of the articulator was closed until the incisal guide pin struck the incisal guide table 4 mm behind its centric jaw relation position. The rims were held in this relationship until the wax cooled.

   If there was no lateral deviation on the incisal guide table, there would be an equal backward movement in both condylar elements.

5. Both occlusal rims were removed carefully from the articulator and a wax record chilled. The occlusal rims were separated and a wax record carefully trimmed on the mandibular rim to the outline of the labial surface of the maxillary occlusal rim. Two vertical cuts were made through the labial surfaces

of the maxillary and mandibular occlusal rims in the right and left canine regions. The anterior relationship of the occlusal rims and the small locking triangles were used as guides in the positioning of the patient's mandible into the desired protrusive position. The positioning of the rims, so that the cuts on the maxillary and mandibular occlusal rims coincide and form straight lines on both sides, would prevent lateral deviations during recording in the patient's mouth.

6. The maxillary occlusal rim was placed in the patient's mouth. The wax on the mandibular occlusal rim was gently flamed and tempered and the rim placed in the mouth. The patient was told to protrude the mandible and to close slowly. The patient was instructed in the positioning of the mandible until the anterior borders of the occlusal rims coincided. The small wax triangles seated into the grooves on the maxillary occlusal rim and the cuts on both rims coincided and formed straight lines on both sides.

The patient maintained the mandible in this protrusive relation and gently closed an additional 2 mm. This closure modified the articulator record to conform to the slope of the articular eminence of the patient.

7. The occlusal rims were removed carefully from the mouth, thoroughly chilled and separated. All excess wax was removed from the mandibular occlusal rim and the record returned to the mouth for rechecking of simultaneous contact of the entire occlusal rims.

8. Both condylar elements of the articulator were loosened and freed. The maxillary and mandibular occlusal rims were placed on the casts in the articulator. The incisal pin was raised and the articulator closed in protrusion, allowing contact between the occlusal surfaces of the occlusal rims. The condylar elements of the articulator were adjusted until the entire occlusal surface of the maxillary occlusal rim was in contact with the entire occlusal surface of the mandibular occlusal rim.

The condylar elements were tightened. The condylar guidances of the articulator were thus adjusted to the movements of the condyles of the patient when the record was made.

The same procedure of protrusive record taking was employed also in the try-in stage, primary issue and secondary issue. All results were recorded in the specially designed chart. See Fig. 8.

FIGURE 8 Recording chart.

FIG. 8

PATIENT ____________________ REG. NO __________ AGE ______

INCLINATION OF CONDYLAR GUIDANCE OF THE ARTICULATOR

RECORD	READING	
	Right	Left
Setting of condylar elements of articulator		
Protrusive with bite rims		
Protrusive in try-in stage		
Protrusive in primary issue		
Protrusive in secondary issue		
Cephalometric roentgenograms		

After delivering dentures to the patient, standard right cephalometric roentgenograms were taken in the centric occlusion position and in protrusion (edge-to-edge contact of the incisor teeth). Then tracings were made from the cephalometric roentgenograms and the condylar path inclination determined as related to the Frankfort plane and the result compared with settings of a right condylar element of the articulator.

CEPHALOMETRIC RADIOGRAPHY

The roentgenographic procedures were carried out in the Radiography Department of the United Dental Hospital of Sydney. See Figs. 9, 10.

The following radiographic factors were used:-

Film: Screen film RP/S X-Omat*

Source: Film distance 70 inches

Exposure factors: 70 K.V.P., 40 m.a., 0.64 sec.

RADIATION HAZARDS

The International Commission on Radiological Protection (I.C.R.P.) states that the permissible dose of radiation for an individual is that dose accumulated over a long period of time resulting from a single exposure, which in light of present knowledge, carries a negligible probability of severe somatic or genetic injuries.

For whole body exposure, the maximum accumulative dose rate to gonads, the blood-forming organs and the lens of the eyes, at any age over 18, is governed by the formula:

* Eastman Kodak Company, Rochester. N.Y.

FIGURE 9 Cephalostat.

FIGURE 10 Subject seated in cephalostat.

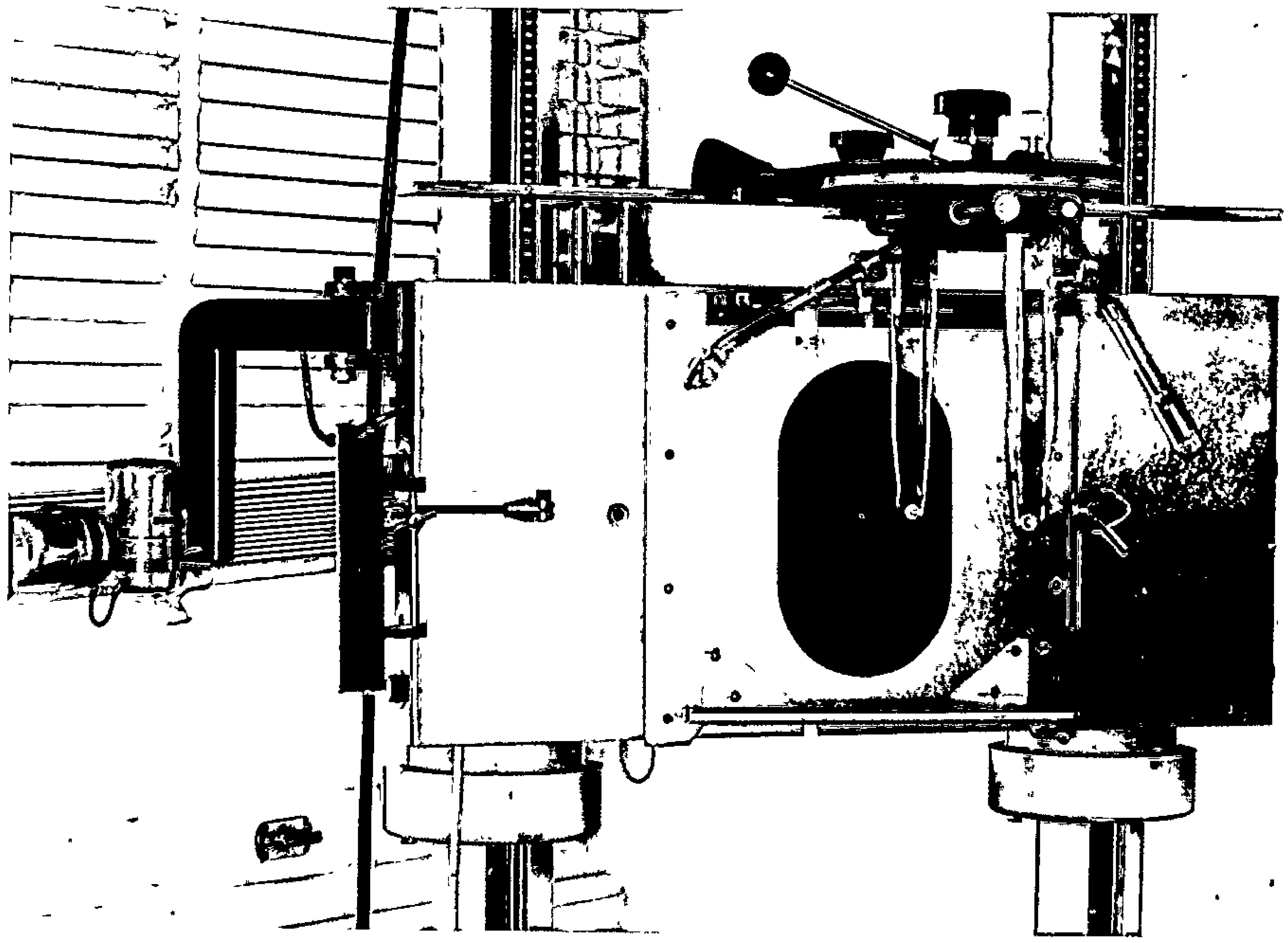


FIG. 9.

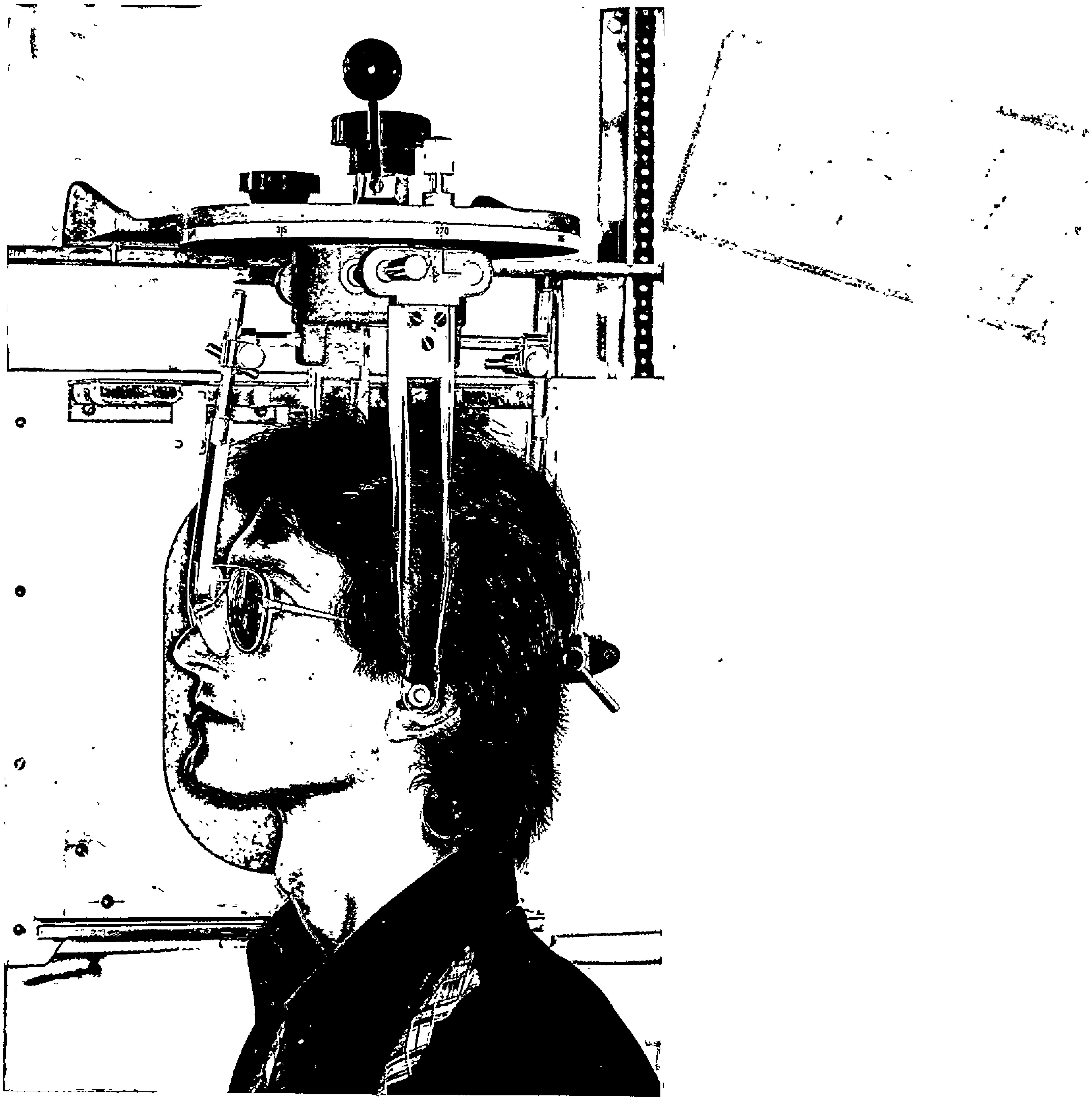


FIG. 10.

$$D = 5(N - 18)$$

where D is tissue dose in rems and N is the age in years.

This means that the average maximum permissible dose to the population's reproductive cells from radiation above the natural background radiation should not exceed 10 roentgens over the period from conception up to age 30 and one-third that amount in each subsequent decade thereafter. (76).

In any one week the gonadal dose should not exceed 100 mr. (77).

CALCULATED DOSAGES

Duncan and Williams (78) calculated a dose at the film position of 15 mr or 1.5 mr/mas, using 70 kvp, 10 mas and a 60 inch target distance.

Moyers and Weber (79) calculated a dose of 2.5 mr/mas at 80 kvp and 60 inch target film distance.

In the present investigation using 70 kvp, 40 ma, 0.64 sec exposure factors, a check on the radiation dosage per one exposure gave figures between 35 and 45 mr.

The approximate weekly dosage would be between 70 and 90 mr. Therefore, the amount of radiation is not exceeding the safety limit of 100 mr per week.

These figures can be accepted as a rough guide only, because of the many variable factors such as the size of the cone of radiation, the scattered secondary radiation from surroundings and the amount of soft x-ray filtration.

METHOD OF TRACING FROM CEPHALOMETRIC ROENTGENOGRAMS

To ensure the identical outline of the head of the condyle in tracings from both cephalometric roentgenograms the following method of tracing was employed:

1. The constant reference points on the skull were traced from both cephalometric roentgenograms to the Kodapak cellophane.* The following reference points were used (4): see Fig. 11.

Bolton point - B

The height of the curvature posterior to the condyle between it and the basal surface of the occipital bone.

Nasion - N

The point where internasal and nasafrontal sutures meet.

Nasospinale - NS

The mid-point on a line which connects the lowest points of the border of the piriform aperture on either side. It is situated at the base of the anterior nasal spine.

Orbitale - O

The lowest point of the infraorbital margin.

2. The Frankfort horizontal which passes through the lowest point in the margin of the orbit and the highest point in the margin of auditory meatus was marked on both cellophanes.

*Eastman Kodak Company, Rochester, N.Y.

FIGURE 11 Diagram of reference points commonly used in cephalometric radiography. The landmarks utilized in the present survey are B. N. NS. O. From Sicher (4).

FIGURE 12 Tracings from cephalometric roentgenograms.

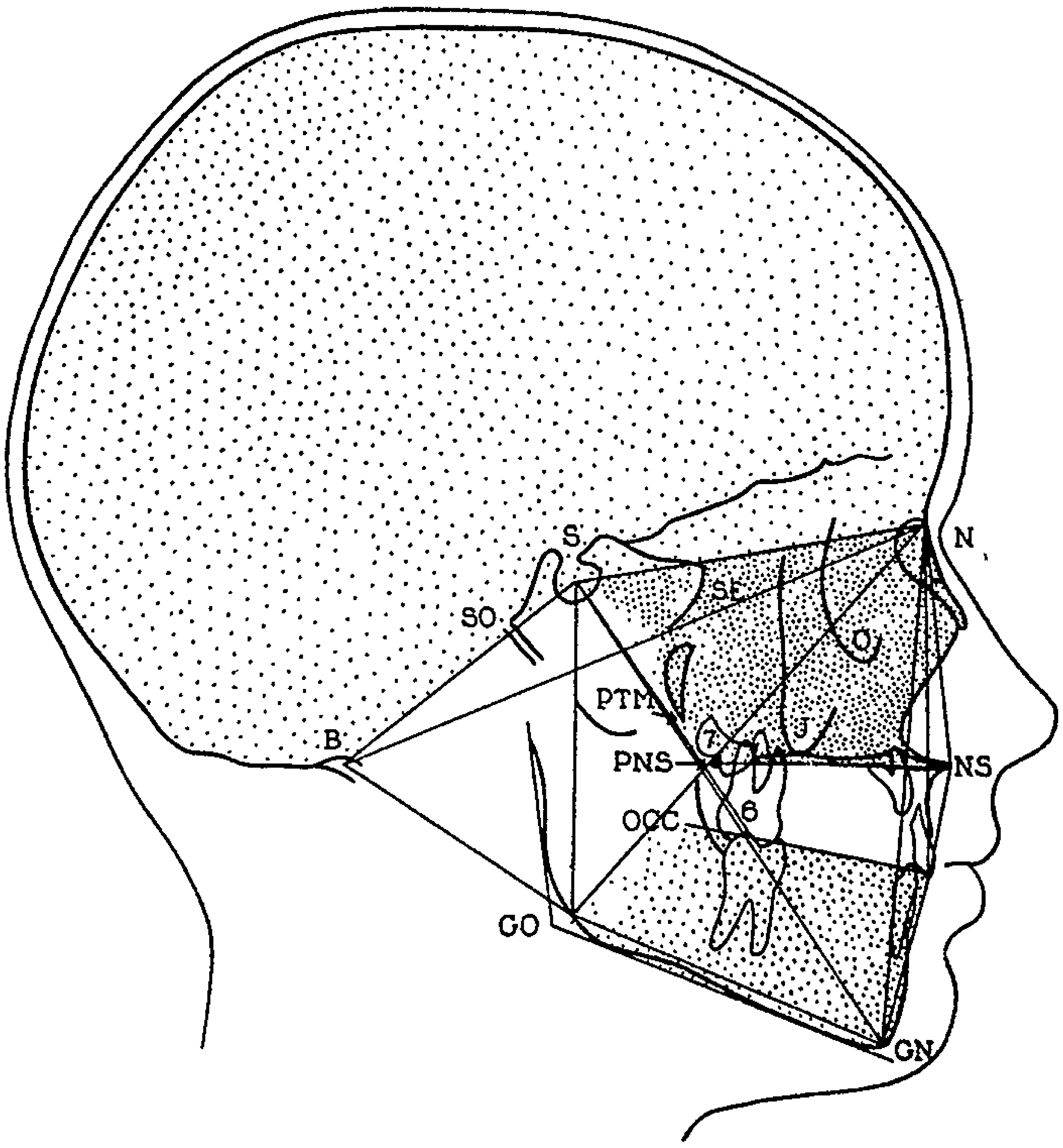

S
N
SE
SO
O
PTM
J
7
PNS
NS
B
6
OCC
GO
GN

FIG. 11.

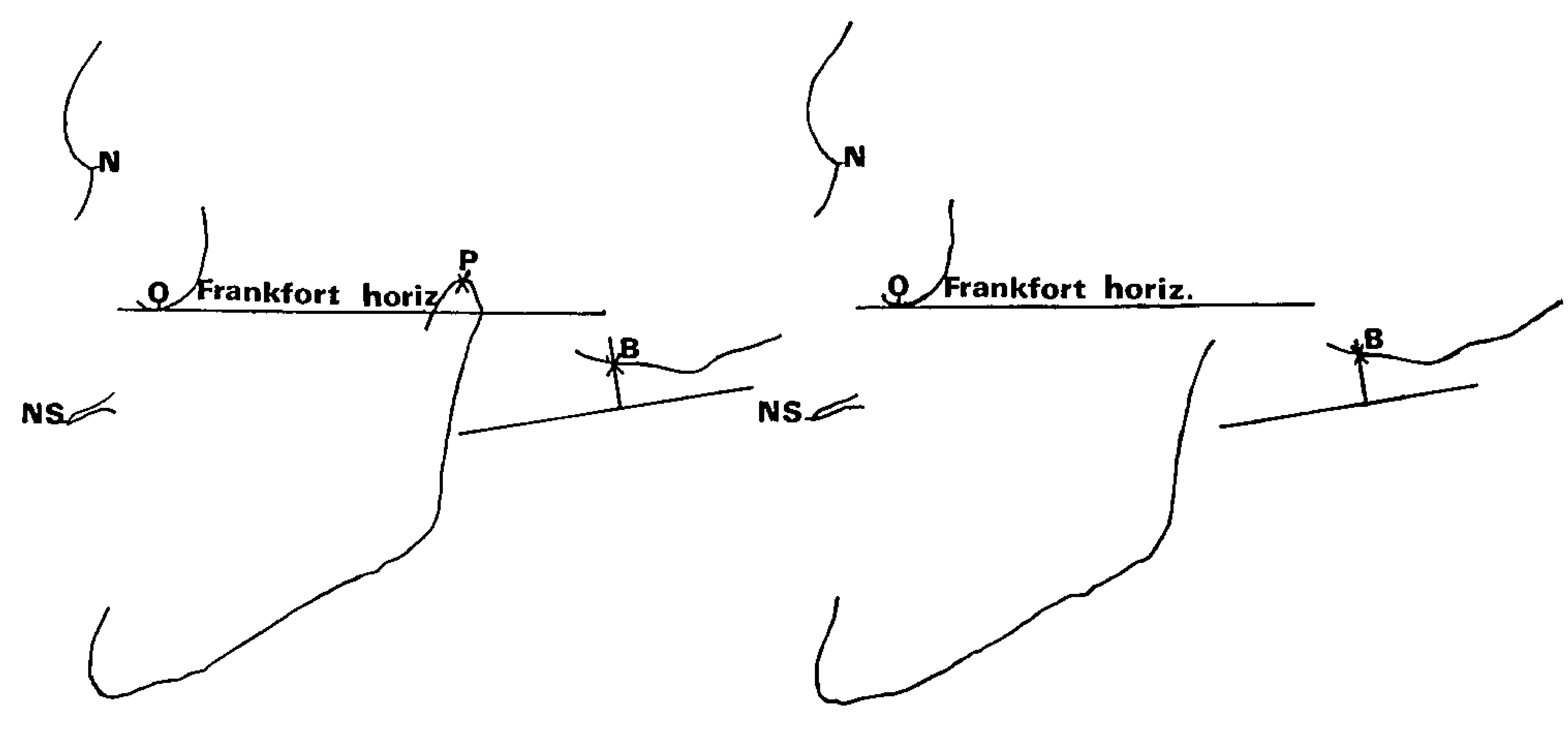

N
O
Frankfort horiz
P
B
NS
N
O
Frankfort horiz.
B
NS

FIG. 12.

3. The outline of the head of the condyle and the lower border of the mandible were traced from cephalometric roentgenogram in protrusion (usually the condyle can be seen better in protrusive position). The arbitrary chosen point was marked on the outline of the head of the condyle.

4. The lower border of the mandible was traced from the cephalometric roentgenogram in centric occlusion. See Fig. 12.

5. The tracing cellophane from roentgenogram in centric occlusion was positioned on the tracing cellophane from roentgenogram in protrusion so that tracings of the lower border of the mandible coincide. See Fig. 13. The outline of the head of the condyle with the marked arbitrary point on the tracing cellophane from roentgenogram in protrusion was transferred on the tracing cellophane from roentgenogram in centric occlusion.

Thus, we received two identically outlined tracings of the head of the condyle with marked arbitrary chosen point.

METHOD OF MEASUREMENT OF THE INCLINATION OF THE CONDYLAR PATH

The tracing cellophane with tracings from roentgenogram in protrusion was placed on the tracing cellophane with tracings from roentgenogram in centric occlusion so that reference points B, N, NS and O and Frankfort horizontal lines coincide. The line was drawn through the arbitrary chosen points on both tracing cellophanes. See Fig. 14. The angle between the Frankfort horizontal and drawn line was measured. This angle represents the inclination of the path of the condyle.

The result was recorded in the patient's chart.

FIGURE 13 Tracings positioned so that lower borders of the mandible coincide.

FIGURE 14 Tracings positioned so that the reference points B. N. NS. O and Frankfort horizontal coincide.

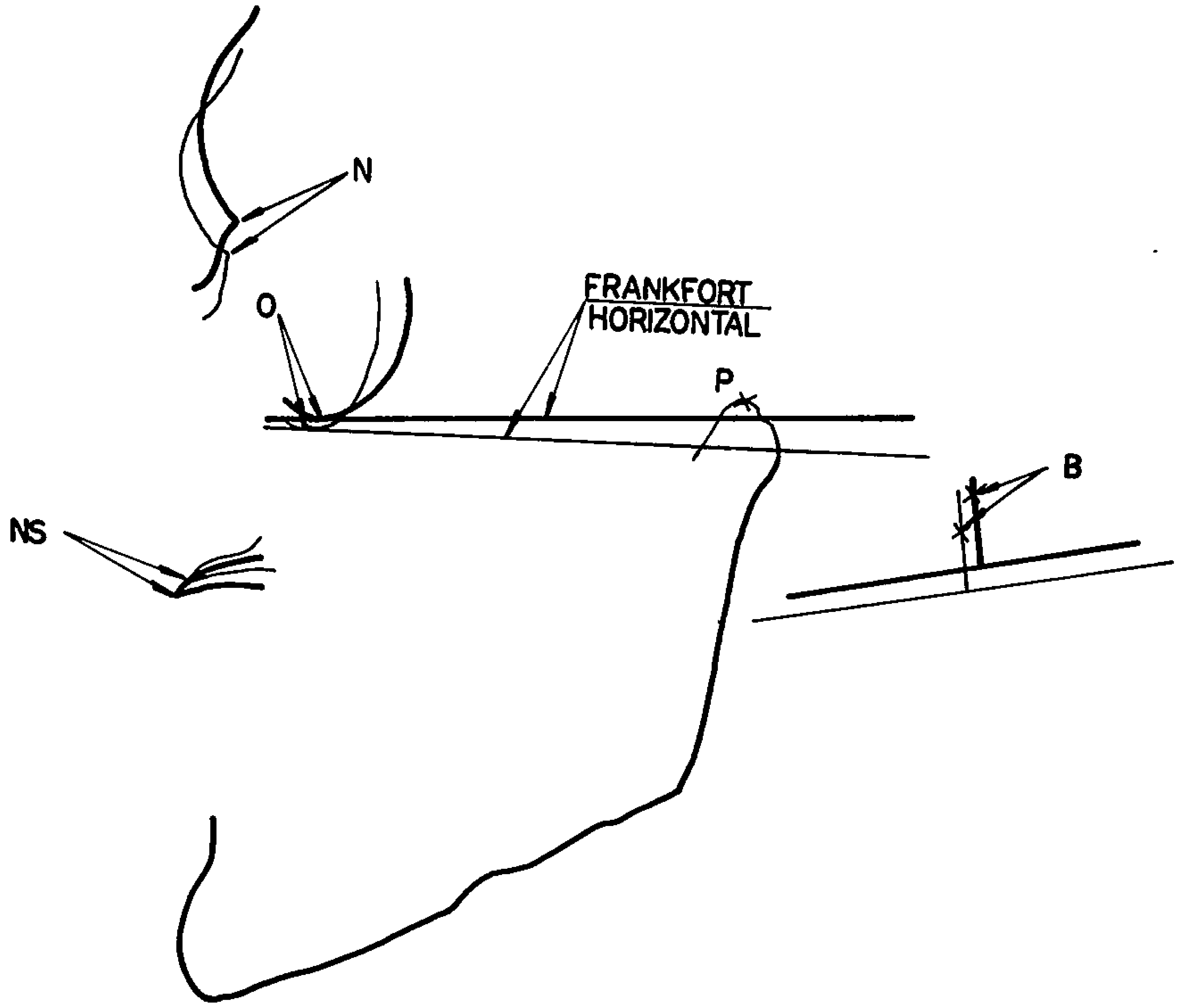

N
O
FRANKFORT HORIZONTAL
P
B
NS

FIG. 13.

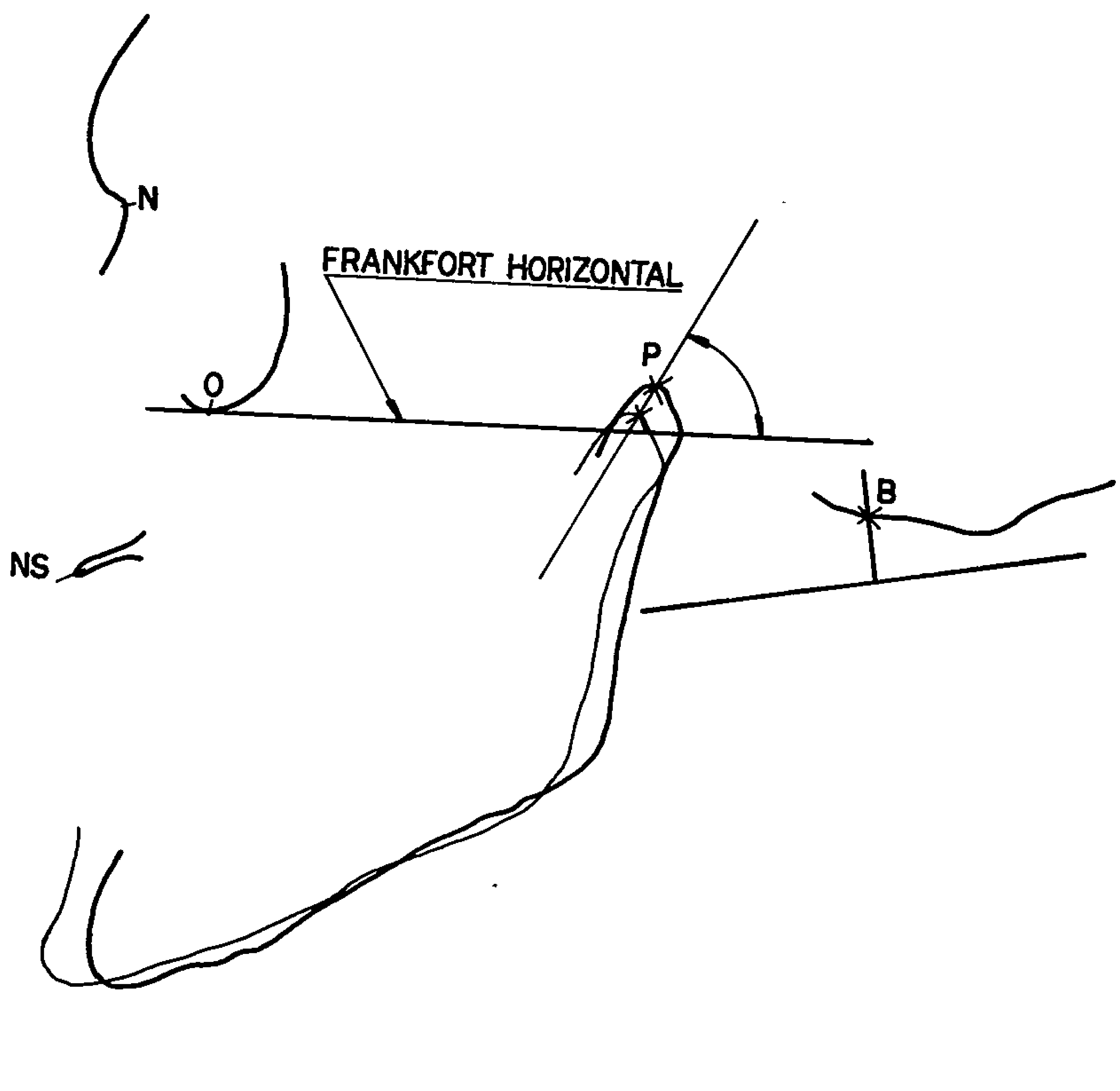

N
FRANKFORT HORIZONTAL
P
O
B
NS

FIG. 14.

RESULTS OF INVESTIGATION

The complete data obtained by clinical method for all eleven cases is shown in Table I.

Cases 2 and 7 were excluded from the final analysis. Case 2 results could not be obtained due to the fact that the Dentatus articulator could not be adjusted to condylar path inclinations steeper than 60 degrees. Case 7 results were obtained from a patient who had difficulties in relaxing, poor muscular control and a severe stutter. Difficulties were encountered in obtaining records in all stages of denture construction and results cannot be considered reliable.

The condylar path inclination, determined by the cephalometric method and its difference from mean condylar path inclination determined by the clinical method for each of the 9 analyzed cases are tabulated in Table II.

TABLE I

Angle of inclination of the right condylar path to the Frankfort plane in degrees, determined by the wax interocclusal record at A - occlusal rim stage, B - try-in stage, C - primary issue, D - final issue stage.

CASE	CONDYLAR INCLINATION (degrees)					S.D.
	A	B	C	D	MEAN	
1	32	22	24	21	25	5.0
2	50	60+	60+	60+	-	-
3	20	17	14	12	16	3.2
4	16	15	18	20	17	2.2
5	32	34	31	36	33	2.2
6	25	27	30	26	27	2.1
7	-22	-14	7	4	-6	-
8	57	55	44	44	50	6.9
9	15	14	17	16	17	2.1
10	20	17	15	18	18	2.1
11	18	20	14	17	18	2.6

TABLE II

Comparison of right condylar path inclination determined by clinical records and by cephalometric tracings.

CASE	MEAN CONDYLAR INCLINATION-clinical method (degrees)	CONDYLAR INCLINICATION -cephalometric method (degrees)	DIFFERENCE (degrees)
1	25	38	13
3	16	24	8
4	17	26	9
5	33	44	11
6	27	32	5
8	50	48	-2
9	17	24	7
10	18	28	10
11	18	26	8

DISCUSSION

The mean condylar path inclinations determined on the eleven subjects by the clinical method varied from 16 to 60^{+} degrees (see Table I). Similar results were obtained by Posselt and Nevstedt (33) who found condylar path inclinations varying from 0 to 60 degrees on young adults with natural dentition.

It is clear then, that where a "mean value" setting of the condylar path of 40 degrees is used on an articulator, as recommended by the manufacturer (80), it would be possible to introduce an error in excess of 20 degrees in the condylar slope. This error would be greater than any error that could be introduced by the variation in the actual clinical determinations based on the results of this investigation. Excluding case 7, where clinical difficulties warranted discarding the findings, the range of results varied by a maximum of 13 degrees in case 8 to as little as 5 degrees in cases 4 and 6.

In 8 out of 9 subjects the condylar path inclination determined by the cephalometric method was more steep than that found with wax interocclusal recording, (see Table II). This is similar to the findings of Lindblom (26). The greatest difference occured with case 1 which was 13 degrees, the average difference was 7.9 degrees.

This difference may be partly due to the errors of the clinical method and cephalometric method. Errors of the clinical method can be attributed to the errors of the articulator (33), registration technique employed (63), physiological factors (21), (41).

Errors of the cephalometric method will include:

1. Errors of the radiographic technique.

2. Errors of measuring between previously marked points and instrumental limitations.

Errors of the radiographic technique are the differences in the positioning of the subject in cephalostat. Tallgren (81) claims that this error may be eliminated when the head is allowed to assume its natural balance. This can be achieved by adjusting the head in cephalostat when the subject is sitting in a movable chair, fitted with wheels, in a normal upright but comfortable position, permitting relaxation of the muscles of the body, the neck, and the head.

Errors of measuring between previously marked points are usually not significant once the points have been marked. The instrumental limitations are:

(a) The size of the point of the pen used in tracings.
(b) The limit of measurement of the protractor graduated in 1 degree, which restricted the measurement accuracy to the nearest 1 degree.

No explanation can be given nor is there an explanation in the literature of the fact that the condylar path inclination, determined radiographically, in most cases is steeper than that determined by clinical method.

CONCLUSION

In this investigation it was found that "mean value" setting of the condylar path inclination on the articulator may introduce a greater error than that which could be introduced using a clinical method of determining condylar path inclination.

It can be concluded then, that in complete denture construction clinical determination of the condylar path inclination by means of interocclusal wax records allows more accurate setting of the condylar guidances of the articulator.

SUMMARY

Complete dentures were constructed for eleven healthy edentulous males on the "Dentatus" articulator. The condylar guidances were adjusted using wax, interocclusal records at four stages in denture construction.

Standard right cephalometric roentgenograms were also taken in the centric occlusion and in protrusion and the condylar path inclination determined from superimposed tracings.

Results of this investigation indicated that use of wax protrusive records for adjusting inclinations of condylar guidances of the articulator is preferable to the "mean value" adjustment.

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