AN EVALUATION OF BASIC ARTICULATORS AND THEIR CONCEPTS

Part II. Arbitrary, Positional, Semiadjustable Articulators*

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ARTICULATORS have been classified as arbitrary, positional, semiadjustable, and fully adjustable. The concepts associated with each articulator will be described and evaluated as well as the accuracy of the occlusion produced on the instrument.

ARBITRARY (MONSON SPHERICAL THEORY)

Monson[1] felt that the condylar path and the occlusal plane form a curve. Bonwill[2] said that the two condyles and the incisors formed an equilateral triangle with sides of 4 inches. Monson associated Bonwill's triangle with his own observations and formulated his "spherical theory." The condylar path and occlusal plane form a curve which is part of an 8 inch sphere (Figs. 1 and 2), the center of which is the common center of mandibular motion. This sphere touches the apices of the Bonwill triangle.

The Monson theory states that the lower teeth move over the surfaces of the upper teeth as over the surface of a sphere with a diameter of 8 inches, with the center of the sphere located in the region of the glabella and the surface of the sphere passing through the condyles or centric with the condyle paths.

Monson Articulator.—Monson believed that all jaw movements take place around two axes. One axis runs through the "common center" and the other is located around the condylar axis. His articulator has shafts that correspond to the respective axes (Fig. 2).

Hagman Balancer.—The Hagman balancer differs from the Monson articulator in that it has a universal joint mechanism that allows movement from Monson's "common center."

EVALUATION OF MONSON'S THEORY

The three-dimensional relationships of the components of the Monson theory are seen in Fig. 3. Lines joining the condyles and incisor point form an equilateral (Bonwill) triangle. The Balkwill angle[3] is formed between the occlusal plane and the Bonwill triangle. The Monson theory requires, within close limits, a condylar

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inclination of 35 degrees and a Balkwill angle of 15.5 degrees.[4] These angles do not coincide with the average values found by Gysi[5] and Balkwill[3] of 30 degrees for the condylar inclination and 26 degrees for the Balkwill angle.

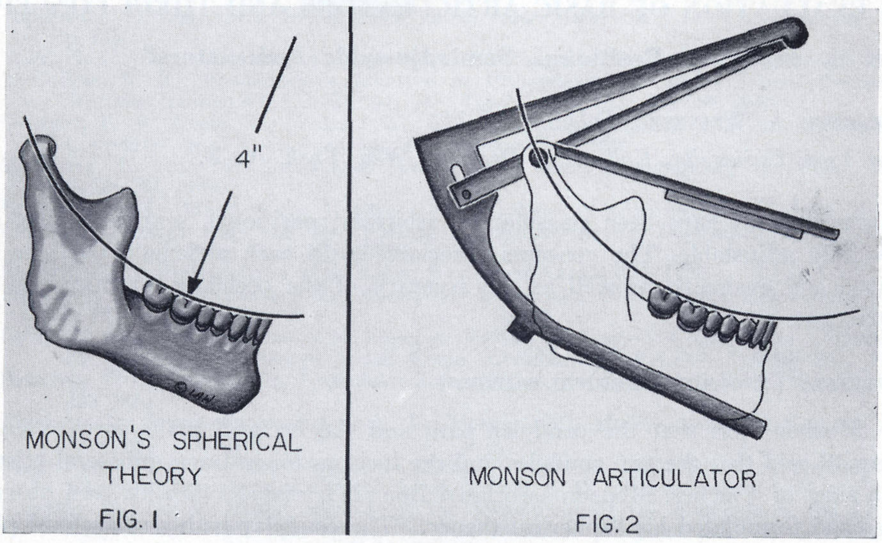


Fig. 1.—Monson believed that the condylar path and occlusal plane formed a curve which was part of an 8 inch sphere.

Fig. 2.—The two axes of Monson's articulator correspond with his theory of jaw movements.

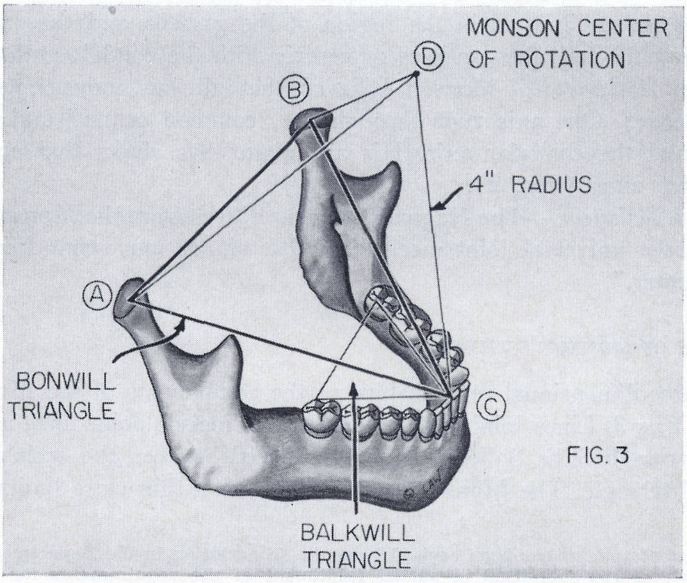


Fig. 3.—An equilateral (Bonwill) triangle is formed by lines joining the condyles and the incisor point. The angle between the occlusal plane and the Bonwill triangle is the Balkwill angle.

The lack of adjustability in the Monson theory can be seen in Fig. 4. As the dental arch widens posteriorly, the position of the teeth must be elevated so that the occlusal surfaces can remain on the curve of the 8 inch sphere. The level of the occlusal plane and the resulting Balkwill angle cannot deviate and, at the

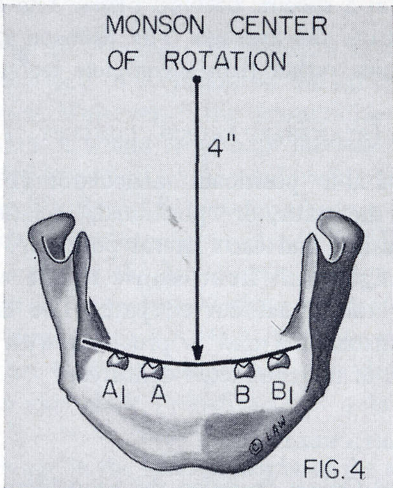


Fig. 4.—The Monson theory is a nonadjustable system. As the arch widens from *A-B* to *A_1-B_1* the position of the teeth must be elevated to remain on the curve of the 8 inch sphere. The level of the occlusal plane and the resulting Balkwill angle cannot deviate and at the same time remain on the curvature of the sphere.

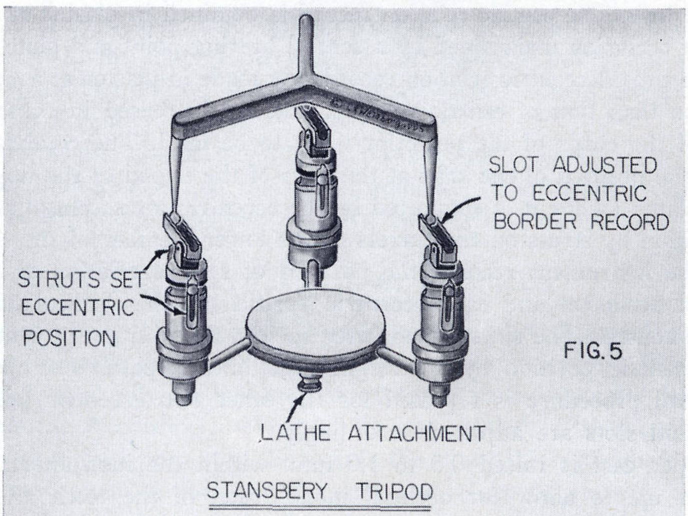


Fig. 5.—The slot is adjusted to the interocclusal record so that the static or "positional" relationship of the mandible in centric relation, protrusive, and each lateral position is obtained. (The devices for mounting the casts to the instrument have been omitted to show the positional controls more clearly.)

same time, remain on the curvature of the sphere. The three-dimensional interrelationship of these factors dictates only one set of conditions that will fit the theory.

A spherical theory does not take into consideration individual variations which always exist. This theory does have some value in establishing a general curve of the occlusal plane. When opposing teeth are together, mandibular guidance is related to tooth inclines on a specific occlusal plane. The cuspal inclines allow for the individual variation from the average. The Monson theory should be limited to its use to a general guide rather than a complete technique.

POSITIONAL ARTICULATOR (STANSBERY TRIPOD) CONCEPT

The Stansbery tripod is a "positional" articulator (Fig. 5). The objective of this concept is to obtain the static, or "positional," relationships of the mandible in centric relation, protrusive, and each lateral position.[6] Within cuspal distances it is assumed that a straight path from centric to the eccentric positions is an acceptable substitute for the actual curved path. The articulator was designed primarily for denture construction and is provided with a lathe attachment for "milling in" the occlusion of the completed dentures.

USE OF THE POSITIONAL ARTICULATOR

The Stansbery Dental Orient preceded the Stansbery tripod and did not have a face-bow mounting attachment. The tripod has an optional device for attaching a face-bow. The upper member of both instruments has provision for a hinged vertical raising or lowering of the maxillary cast. The technique devised by Stansbery applied to both instruments.

The casts are mounted in an arbitrary position in the instrument *without* the use of a face-bow. The centric relation record is obtained in plaster at the vertical dimension of occlusion maintained by a central bearing point and plate attached to the occlusion rims. Eccentric relation records are made in plaster at a greater vertical dimension than that of centric relation, and are increased in accordance with the height of the cusps of the posterior teeth to be used. The condylar slots are adjusted to the position of the balls at the ends of the tripod of the upper member of the articulator (while it is supported by the eccentric interocclusal record), and fixed in position by struts on the turrets of the lower member of the tripod (Fig. 5). Thus, the instrument records the position of centric relation at the vertical dimension of occlusion and each eccentric position at the vertical dimension of cusp-to-cusp contact. The slots are adjusted to join the position of centric relation with one eccentric position by a straight (rectilinear) path. The plaster interocclusal record procedure is repeated for the other two eccentric positions, and the turrets and slots are adjusted accordingly.

The upper cast is raised 0.5 to 1.0 mm. within the instrument, before the teeth are set up, to allow for occlusal modification of the teeth after they are processed. After the dentures are processed, they are replaced on the instrument *before* being removed from their original casts. A metal mounting plate is set in the base of each cast to key it to the mounting plaster. A built-in lathe attachment is used to mill in the occlusion with abrasive paste, to restore the *original* vertical dimension of occlusion, and to develop the final form of the occlusal surfaces of the teeth. Stansbery did not intend that dentures would be remounted by means of new interocclusal records made after the insertion of completed dentures in the mouth.

EVALUATION OF THE POSITIONAL ARTICULATOR

Orientation.—As long as Stansbery's procedure is followed, and there is no change in the vertical dimension of occlusion on the articulator, the positional jaw relation records are of value. However, if the dentures have settled and remounting by new records is necessary, it would require an *increase* in the vertical dimension to permit the centric relation record to be made without tooth contact.

A face-bow mounting is essential to transfer a centric relation record accurately when an increase in vertical dimension is involved.[7] Unless the maxillary cast can close *in a hinge movement from the hinge axis,* the face-bow transfer is useless. The tripod was then modified to incorporate these two features if the dentist wished to use the instrument for remounting.* A shaft can be inserted in the upper member of the instrument for a face-bow mounting when it is desired. The maxillary cast has a hinge closure from this shaft (which acts as a hinge axis) rather than a vertical drop.

Limitations.—No change in the vertical height of the cusps, or incisal guidance, can be made during construction of the restorations without making new eccentric interocclusal records. Furthermore, milling of the teeth removes tooth substance from the occluding surfaces of both the upper and lower teeth. A deflective occlusal contact in lateral excursion can cause a loss of tooth substance from *both* upper and lower cusps. If this is uncontrolled, it would interfere with centric relation.[8-11] Excessive grinding is avoided in the Stansbery tripod by controlling the milling in with the slots of the tripod. The vertical dimension of all occlusions can be maintained by means of the support provided by the slots controlling the movement of the upper tripod. The milling device also provides an elliptical horizontal freedom of the occlusion in centric position.

The concept of positional records has a great deal of engineering merit. However, its chief limitation is that the incisal guidance (cusp height) can be planned but *not altered* without making new eccentric interocclusal records.

SEMIADJUSTABLE ARTICULATOR (HANAU MODEL H) CONCEPT

The Hanau model H is one of the most commonly used semiadjustable articulators. It was primarily designed for complete denture construction. The objective of the technique is to closely produce mechanical equivalents of mandibular movements on the instrument. According to Hanau,[12] the less "realeff" ("resiliency and like effect" of the soft tissue) present in the mouth, the closer the instrument will simulate mandibular movement. A face-bow transfer and a centric relation record orient the casts on the articulator. Lateral movements are simulated by first obtaining an individual protrusive interocclusal record for adjusting the vertical condylar

*Boucher, Carl O.: Personal communication.

guidance inclination. The Bennett angle (medial inclination) of the balancing condylar mechanism is calculated by formula and then transferred to the instrument by rotating the condylar posts. The working condylar movement is built into the machine and varies only in amount, depending upon the angulation of the balancing condylar movement and the amount of rotation of the balancing condylar posts.

USE OF THE SEMIADJUSTABLE ARTICULATOR

Orientation of the Maxillary Cast.—The hinge axis is located by using an anatomic average measurement of about 13 mm. (½ inch) anterior to the auditory openings on lines toward the outer corner of the eyes. The selection of the anterior point of reference can be made directly by use of the orbital pointer (recent models) or indirectly by lining up the incisal edges of the teeth or upper occlusion rim with the notch on the incisal pin of the articulator.

Centric Relation Record.—Centric relation is the most important of all of the records. Hanau[12] states that the "Gysi Gothic arch" tracing is the most admired method. Interocclusal wax records or other materials are acceptable.

Protrusive records.—The protrusive record described by Christensen[13] is deemed an essential step (Fig. 6). The condylar inclination of the patient is recorded by a protrusive interocclusal record. The relative thickness of the record at the incisor and molar areas is influenced by the degree of downward drop of the condyle (Fig. 7). To transfer this condylar drop (angulation) to the articulator, the maxillary cast is placed into the protrusive record. The condylar guidance

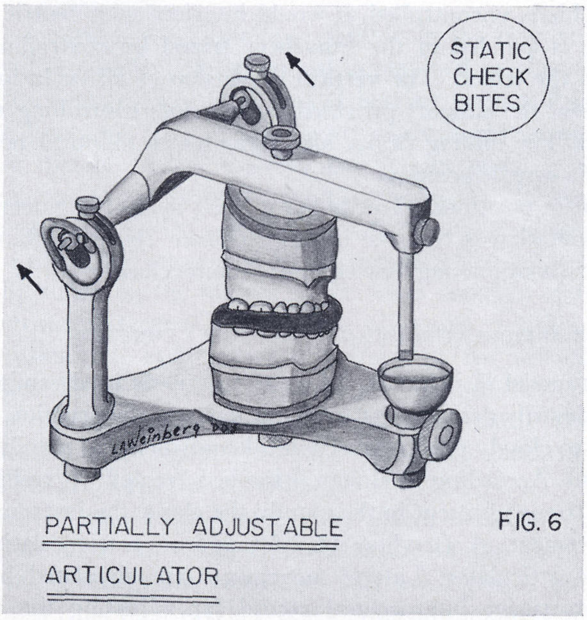


Fig. 6—A protrusive interocclusal record is used to adjust the vertical condylar guidance inclination of the Hanau Model H articulator.

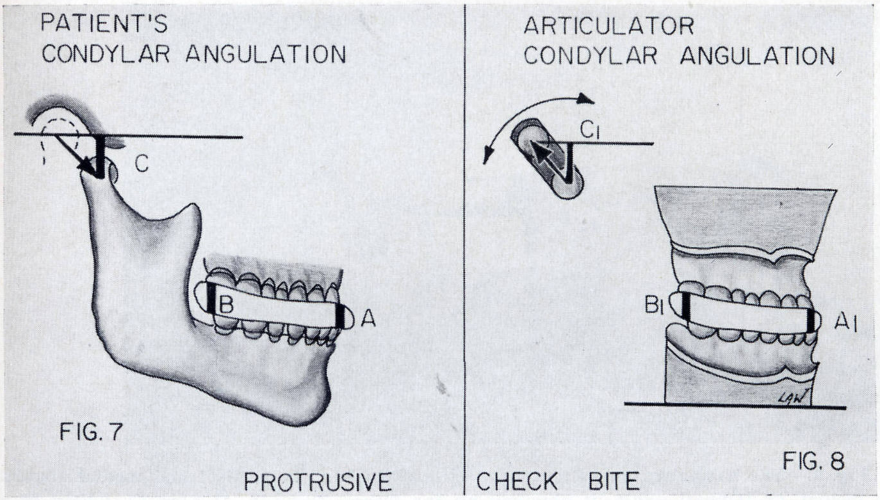


Fig. 7.—The condylar inclination of the patient is recorded by a protrusive record. The relative thickness of the record at the incisor and molar areas, *A-B*, is influenced by the degree of downward drop of the condyle, *C*.

Fig. 8.—The maxillary cast is placed into the protrusive record and the condylar slot *C* is then rotated until the maxillary cast fits the record exactly, B_1-A_1.

slot mechanism is then rotated until the maxillary casts fits the record exactly (Fig. 8).

The condylar angulation on the instrument is said to be a mechanical equivalent of that of the patient. Since it is a positional record, a marked occlusal curve will not alter the record.

Balancing Condylar Motion.—The balancing condylar motion of the patient is downward, forward, and medially, and is measured by its vertical and medial angulations. The protrusive condylar inclination is considered accurate enough to be used for the downward component of the balancing movement. The medial or Bennett angle, is obtained by the Hanau formula $\frac{H}{8}$ plus 12, where H is the protrusive angulation of the condylar guidance mechanism. (Fig. 9).

Working Condylar Motion.—The Hanau Model H articulator has no individual accommodation, as such, for the working condylar motion (Fig. 10). To facilitate description, the articulator movement will be described *in the same direction* as that of the patient. (The upper member of the articulator is held firmly while the lower member is moved.)

The working condylar motion of the Hanau H is mechanically simulated by combining the *balancing* condylar motion with the placement of a nonadjustable fulcrum on the opposite working side. The working condylar ball remains in the original position (acting as a fulcrum) but the intercondylar pin is free to move laterally through the ball.

The balancing condylar movement is downward, forward, and medial, which causes the intercondylar rod to pass laterally through the working condylar ball. This produces upward, backward, and lateral working condylar motion. The work-

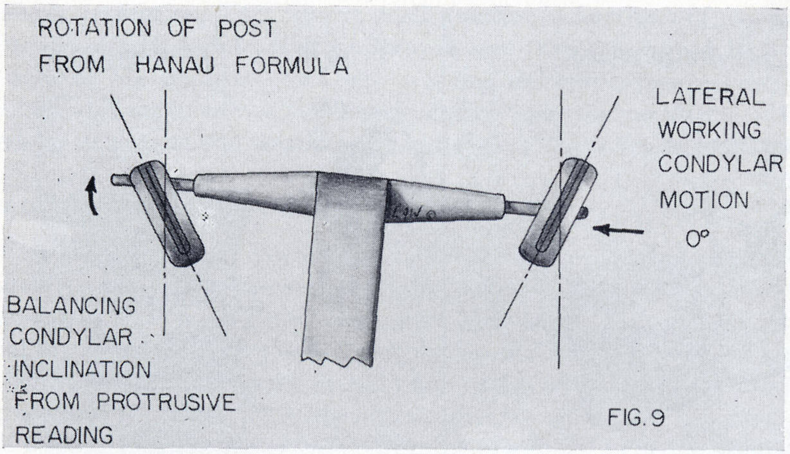


Fig. 9.—The balancing condylar motion is measured by its vertical and medial angulations. The medial, or Bennett angle, is obtained by the Hanau formula, $\frac{H}{8}$ plus 12, where H is the protrusive angulation.

ing condylar (Bennett) movement is built into the machine; however, the Bennett movement varies only in amount rather than in direction. The degree of variation, with normal operation, depends on the balancing condylar movement.

Border Movements of the Instrument.—The degree of lateral shift depends on the "Bennett angle," the greater the "Bennett angle," the more the lateral shift. The "Bennett angle" is calculated by formula from the protrusive (vertical) condylar guidance inclinations. However, the angle does not vary a great deal. When the protrusive reading is 0 degrees the Bennett angle is 12 degrees ($\frac{H}{8}$ plus 12). Increasing the protrusive angulation to 50 degrees only increases the Bennett angle from 12 to 18 degrees.

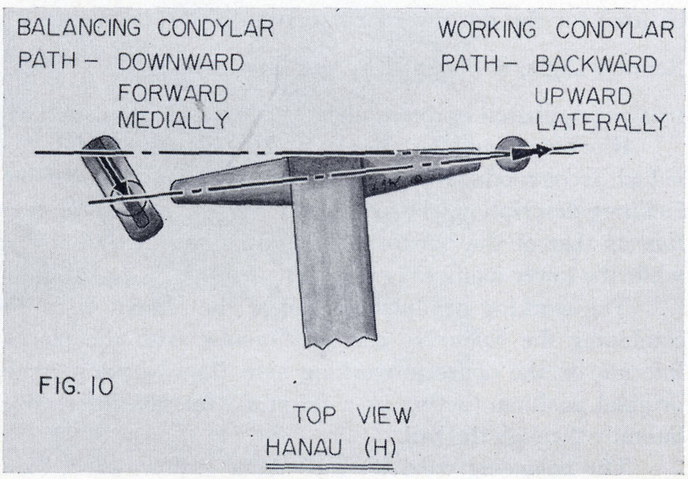


Fig. 10—The instrument has no individual accommodation, as such, for the working condylar motion.

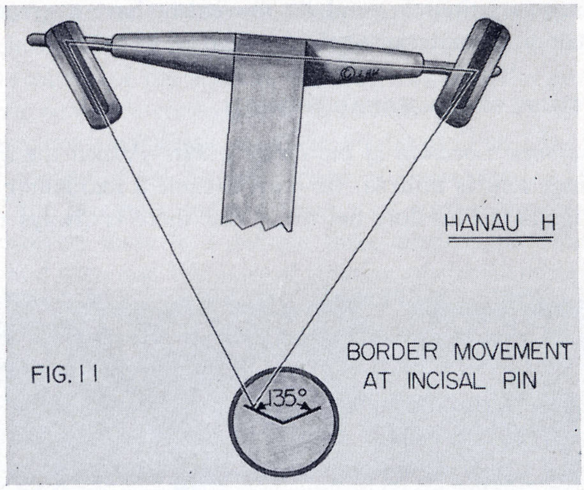


Fig. 11.—The angle that is formed in the needlepoint tracing by the lateral border movements of the incisal guidance pin is approximately 135 degrees.

The "Gothic arch tracing" that is formed at the incisal pin is a measure of the border movement of the articulator. According to Bergstrom[4] the angle between the lateral border movements of the incisal guidance pin is approximately 135 degrees (Fig. 11).

RATIONALE FOR MATHEMATICAL STUDY

The error in occlusion that is produced by various articulators should be calculated mathematically to indicate the feasibility of clinical experiments. These errors may be so small that they would be completely absorbed in the biologic variations discussed previously. In that instance, clinical experiments which lead to a comparison between articulators would not be valid.

There are two main problems to be considered in this regard. First, what is the theoretical standard and is it justified? Second, does the information gained apply only to the one set of conditions?

The geometry of the hypothetical patient is based on averages of skull measurements. Preliminary work by the author[7] when compared to the results obtained by Brotman[14] has shown that reasonable variations in the geometry of the system produce results that vary in the magnitude of hundreths of a millimeter. On this basis, the hypothetical patient of average measurements can be used as an arbitrary standard for comparison.

The conditions of this evaluation are such that the occlusal errors produced by the clinical procedure identified with each articulator are cumulative rather than self-correcting. An *error* can be defined as "deviation from the truth," and *truth* as "agreement with reality."[15] When applied to the study of articulators, an error produced in the occlusion will be considered as deviation from the known hypothetical patient from whom all measurements have been made, as prescribed by the particular technique. The second molar cusp height has been selected for the calculations because variations in condylar movement have a greater effect on the posterior teeth than on the anterior teeth.

MATHEMATICAL STUDY OF THE HANAU MODEL H

Average Anatomic Location of the Hinge Axis.—When the average anatomic location of the hinge axis is utilized, we must assume a maximum error of plus or minus 5 mm. (Fig. 12). This does not mean that there is always that much error,

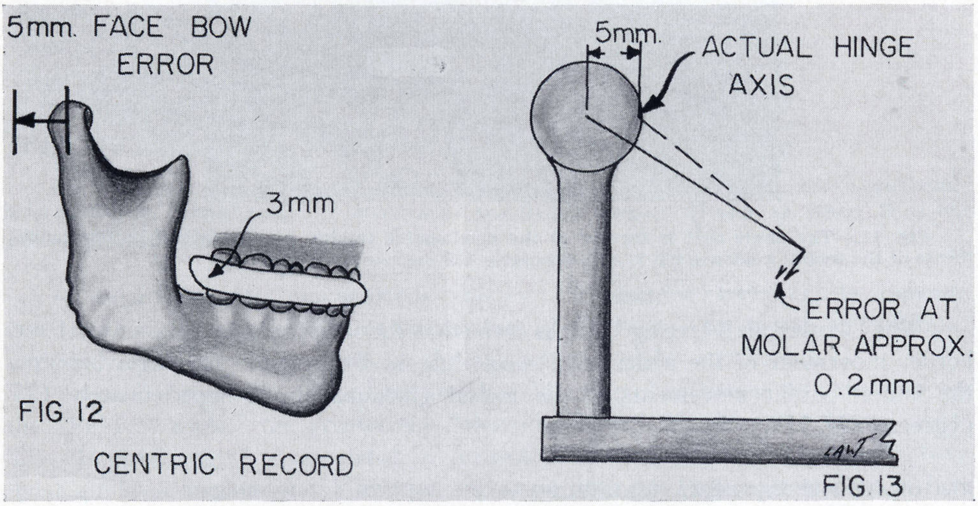


Fig. 12.—The average anatomic location of the hinge axis introduces an error of ±5 mm. in its location.

Fig. 13.—A small occlusal error is produced when the interocclusal record of centric relation is removed, because of the average anatomic location of the hinge axis.

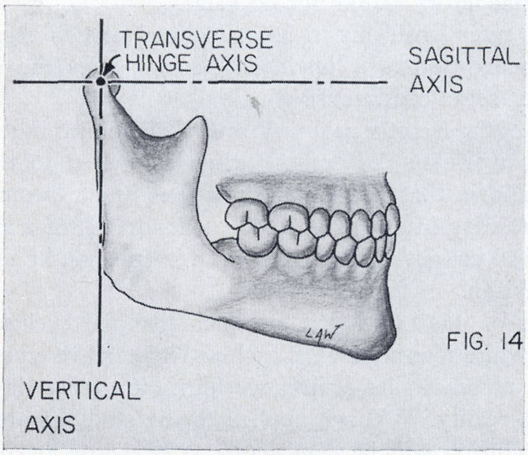


Fig. 14.—The anterior point of orientation of the face-bow and the hinge axis establishes the horizontal plane of reference.

but we should be prepared to deal with this maximum amount and its resultant effect on the occlusion. If the relation of the jaws to the hinge axis of the patient differs from the relation of the casts to the hinge axis of the instrument, when a 3 mm. wax centric record is removed and the articulator is closed, an anteroposterior error of approximately 0.2 mm. would be produced (Fig. 13).[14,15]

Arbitrary Location of the Anterior Point of Orientation.—The anterior point of orientation of the face-bow and the hinge axis establishes the horizontal plane of reference. However, there is a definite three-dimensional relationship between the maxillary dental arch and the axes of rotation of the mandible (Fig. 14). The relationship of the maxillary arch to the vertical and sagittal axes of the patient will not be the same as that on the instrument with arbitrary location of the horizontal plane of reference (Fig. 15).

The incisal edges of the teeth, or occlusion rim, can be made level with the notch on the incisal pin. In later models, the Hanau articulator is supplied with an axis orbital pointer. An elevation of the anterior part of the face-bow decreases the protrusive condylar reading and, conversely, a lowering of the face-bow increases the condylar reading.[16] Any of the commonly used arbitrary anterior points of orientation can change the vertical height of the face-bow mounting not more than plus or minus 16 mm.

The hypothetical patient has a 40 degree condylar inclination to the horizontal plane of the head when the patient is in the upright position (Fig. 16). When the face-bow mounting is oriented too high, there is a reduction in the condylar reading (Fig. 17).[16] This inclination is measured from the horizontal plane of the instrument which is parallel to its base.

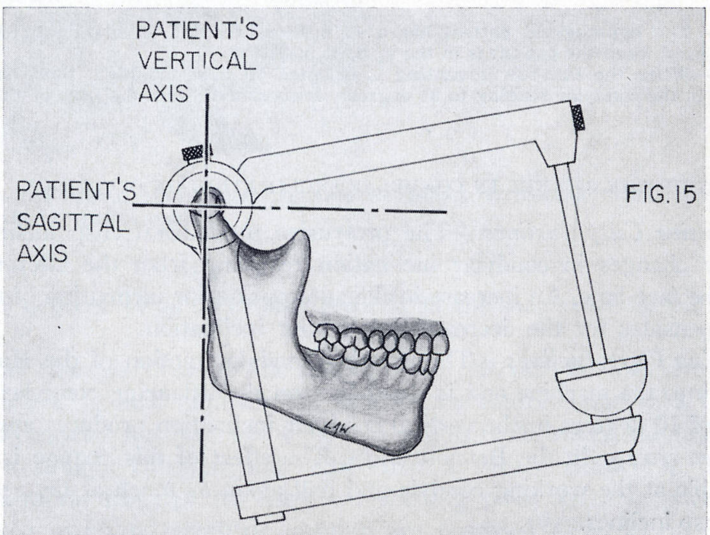
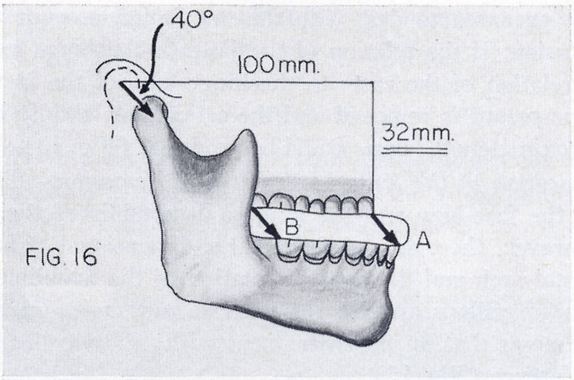


Fig. 15.—The relationship of the maxillary arch to the vertical and sagittal axes of the patient will not be the same on the instrument with an arbitrary location of the horizontal plane of reference.



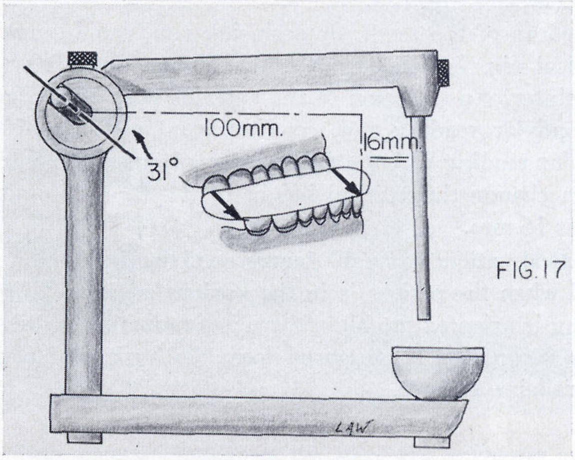


Fig. 16.—The hypothetical patient has a 40 degree condylar inclination to the horizontal plane of the head when the patient is in the upright position.

Fig. 17.—When the face-bow mounting is oriented 16 mm. too high, there is a reduction of 9 degrees in the condylar reading to 31 degrees, as measured from the base of the instrument.

THE EFFECT OF THE CHANGE IN CONDYLAR INCLINATION ON OCCLUSION

Protrusive Cusp Inclines.—The protrusive mesiodistal cusp inclines are not affected by changes in condylar inclination resulting from the alteration of the height of the face-bow. An increase in the anteroposterior inclination of the occlusal plane compensates for the decrease in condylar inclination.

Working Cusp Inclines.—The working condylar motion of the Hanau Model H is built into the machine and is dependent on the balancing condylar motion. A difference of 10 degrees in the vertical condylar inclination produces approximately a 1.3 degree change in the Bennett angle. The effect of this change is practically immeasurable at the working condyle and half again as much at the second molar working cusp inclines.

Balancing Cusp Inclines.—The hypothetical patient has 40 degree balancing cusp inclines (Fig. 18). The 9 degree reduction in the protrusive reading, due to the elevation of the face-bow, decreases the second molar balancing cusp inclina-

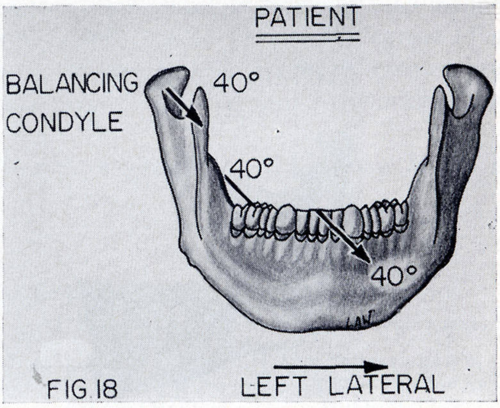


Fig. 18.—The hypothetical patient has 40 degrees balancing cusp inclines.

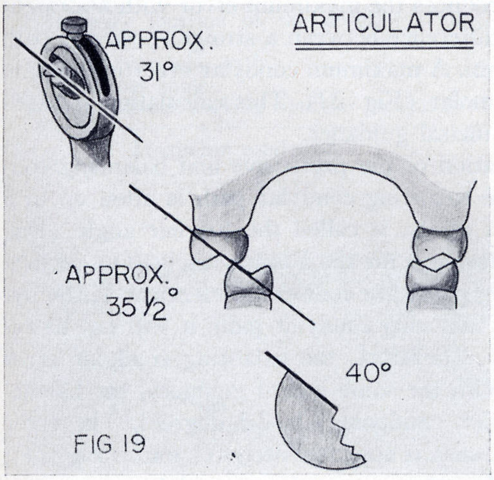


Fig. 19.—The second molar balancing cusp inclination is reduced to 35.5 degrees by the reduction in the protrusive reading.

tion to 35.5 degrees (Fig. 19). This error is in the magnitude of 0.2 mm. for a 3 mm. cusp.[16]

Straight Condylar Path.—The average condylar path follows a curvature of approximately a ¾ inch radius.* The smallest curvature found in a Gnathologic study of 72 condylar readings was a 0.5 inch radius.[17] However, the Hanau articulator uses a straight condylar slot rather than a curved path (Fig. 20). When dynamic extraoral tracings are used, the starting point (centric relation), individual curved path, and eccentric position are recorded (Fig. 21).

With static records, only the centric relation and eccentric positions are re-

*Granger, E.: Personal communication.

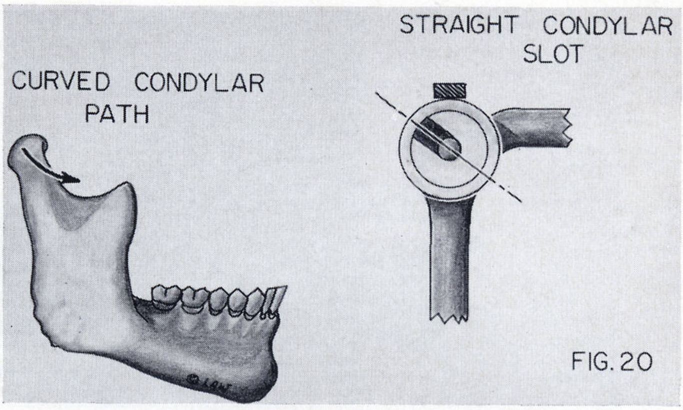


Fig. 20.—The Hanau articulator has a straight condylar slot rather than a curved path.

corded. The midpoint of the excursion produces the maximum error with a straight condylar slot (Fig. 21). The maximum difference between a straight condylar path and one that has a ½ inch radius is 0.4 mm. A maximum condylar error of 0.4 mm. produces a 0.2 mm. error at the second molar (Fig. 22). This calculation is based on a 3 mm. cusp height and a constant incisal guidance.

Fischer Angle.—The vertical inclination of the protrusive and balancing condylar paths are usually not identical. The balancing condylar path is often up to 5 degrees steeper. This difference, when it exists, is called the Fischer angle (Fig. 23).[18] The Hanau Model H makes no allowance for the Fischer angle. The vertical angulation of the protrusive and balancing paths are considered identical. If the hypothetical patient has a 5 degree steeper balancing condylar path, it will not be recorded as such on the Hanau articulator. Therefore, the balancing condylar error on the articulator would be 5 degrees. With the same incisal guidance, the balancing cusp incline error at the second molar (midpoint) is 2.5 degrees. The error produced at the cusp height with a 3 mm. cusp is approximately 0.1 mm. (Fig. 24).

Working Condylar Movement.—The effective working condylar movement as it is built into the Hanau Model H articulator is upward, backward, and lateral. The working condylar movement on this articulator varies only slightly in degree, depending on the Bennett angle and vertical inclination of the *balancing condylar* motion. The patient may have a different working condylar motion as compared to the articulator.

The working condylar path, working cusp inclines, and the incisal guidance may be considered to be approximately in a straight line. If the hypothetical patient has a rotating working condyle with no lateral Bennett movement, the working cusp inclines will generally reflect the incisal guidance. For example, when the incisal guidance is 30 degrees, the working cusp inclines will be approximately 30 degrees (Fig. 25).

The working condylar motion on the articulator contains a lateral Bennett shift of approximately 0 degrees. The working cusp inclines at the second molar (midpoint) would be the average between the extreme guidances, namely, 15 degrees (Fig. 26). Therefore, the articulator would produce working cusp inclines at the second molar of 15 degrees while the patient would require 30 degrees (Fig. 27). When these restorations are placed in the mouth, a 15 degree differences produces an opening (negative error) of approximately 0.8 mm. at the working cusp height.

A composite of the amounts of the errors possible on the Hanau Model H articulator is seen in Table I.

TABLE I. SUMMARY OF MATHEMATICAL STUDY OF THE HANAU MODEL H ARTICULATOR

	APPROXIMATE ERROR AT THE SECOND MOLAR BALANCING CUSP HEIGHT (MM.)	APPROXIMATE ERROR AT THE SECOND MOLAR WORKING CUSP HEIGHT (MM.)
1. Average anatomic location of the hinge axis	0.2	0.2
2. Arbitrary location of the anterior point of orientation	0.2	No error
3. Straight condylar path	0.2	0.2
4. No Fischer angle	0.1	No error
5. No individual working condylar motion	No error	0.8
Maximum total error	0.7	1.2

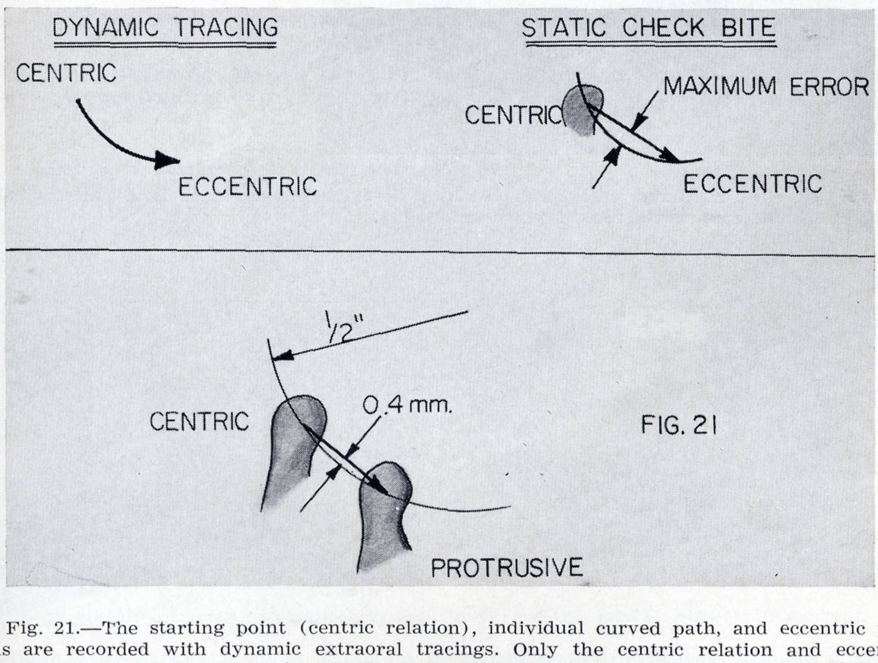


Fig. 21.—The starting point (centric relation), individual curved path, and eccentric positions are recorded with dynamic extraoral tracings. Only the centric relation and eccentric positions are recorded with static records. A protrusive excursion of 6 mm. results in a maximum difference between a straight condylar path and one with a ½ inch radius of 0.4 mm.

EVALUATION OF THE CONCEPTUAL BASIS OF THE HANAU MODEL H ARTICULATOR

The Hanau Model H articulator was primarily designed for complete denture construction. Therefore, it should be evaluated on that basis. The total maximum error calculated for the working and balancing second molar cusp heights needs interpretation. These are *relative* numbers that will be calculated in the same manner for each articulator examined. On this basis, a quantitative comparison between articulators can be made. The total error calculated need not necessarily be *expected* with the clinical use of the instrument. The errors were purposely made maximum and additive. However, in a practical situation, many of the errors produced may tend to cancel out each other.

However, the most significant error is that produced by the lack of individual working condylar motion. When the working condylar motion of the patient is

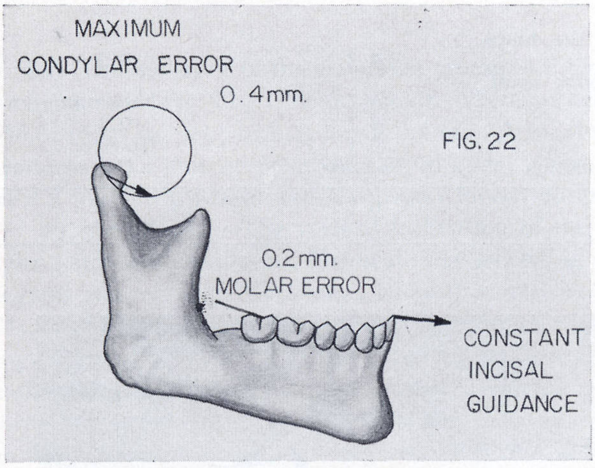


Fig. 22.—The maximum error produced by a straight condylar path is 0.4 mm. which develops a 0.2 mm. error at the second molar (midpoint).

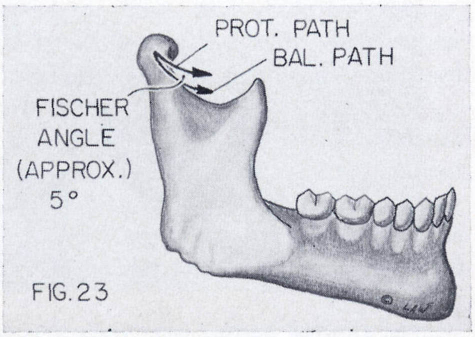


Fig. 23.—The difference, when it exists, between the balancing and protrusive condylar paths is called the Fischer angle.

similar to the articular movement, the occlusion produced may harmonize closely with his biologic movements.

CLINICAL EVALUATION

Complete Dentures Versus Fixed Prostheses.—Because of the relative mobility of denture bases, the Hanau Model H articulator and others of this type are adequate. However, fixed restorations require a higher degree of accuracy in lateral excursions than complete dentures.

The most significant handicap of the instrument is its lack of individual work-

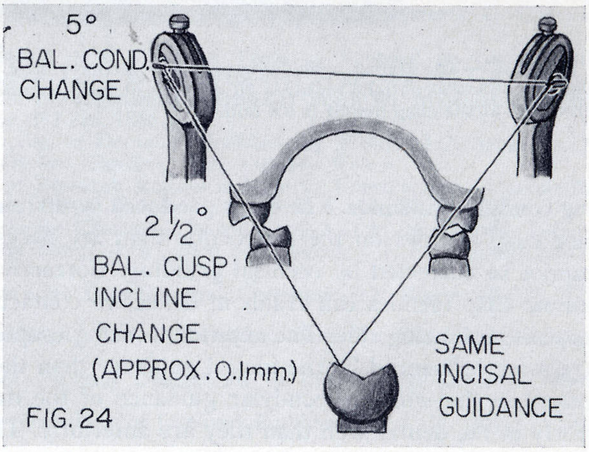


Fig. 24.—A balancing condylar path that is 5 degrees steeper on the patient than the articulator creates an error on a 3 mm. second molar cusp of approximately 0.1 mm.

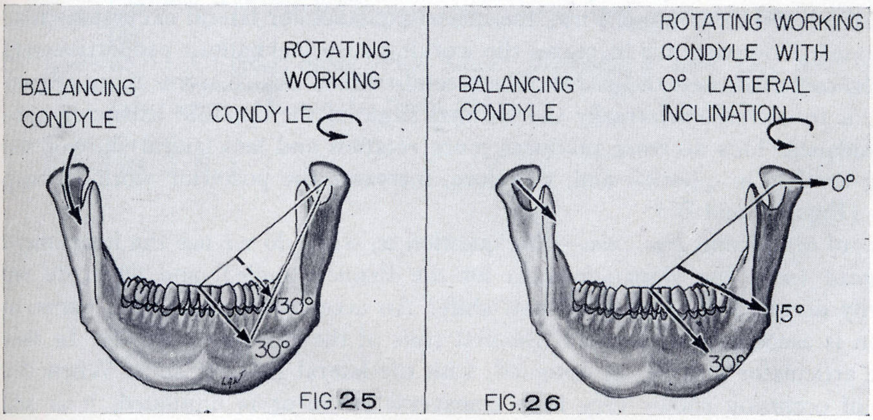


Fig. 25.—With an incisal guidance of 30 degrees and no lateral Bennett movement, the working cusp inclines will be approximately 30 degrees.

Fig. 26.—The working condylar motion on the Hanau Model H articulator contains a lateral Bennett shift of approximately 0 degrees. The working cusp inclines at the second molar (midpoint) are the average between the extreme guidances, i.e., 15 degrees.

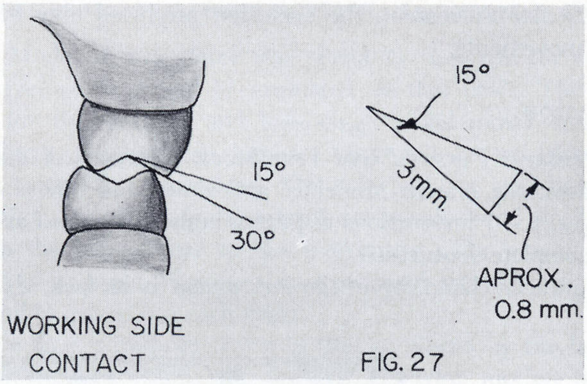


Fig. 27.—The Hanau articulator produces second molar working cusp inclines of 15 degrees. The hypothetical patient requires 30 degrees of cusp angulation. With a 3 mm. cusp, the error produced at the cusp height is 0.8 mm.

ing condylar guidance. The error produced is often negative and causes flatter posterior cusp inclines on the articulator than are necessary in the mouth. This error cannot be corrected by occlusal grinding. Corrective grinding on the bicuspid and canine cusp inclines can result in deflective contacts on the arterior teeth and the opposite balancing side. The anterior working cusp inclines (canines and bicuspids) are more influenced by the incisal guidance than the condylar guidance. Therefore, errors in the working condylar guidance of the machine are more critical posteriorly in the dental arch than they are anteriorly. The instrument was not designed to accept lateral records. The character of the patient's working condylar movement cannot be accurately determined.

If the Hanau Model H articulator is used for fixed restorations, it is possible to compensate for this negative posterior error. The posterior working cusp inclines can be increased in two ways. First, the incisal guidance for lateral excursions may be increased. However, this increases the working cusp inclinations proportionately where the correction is *least needed*. The second method, which seems more advantageous, is to decrease arbitrarily the Bennett angle of the opposite balancing condylar guidance. This decrease produces more rotation and less lateral shift of the working condyle in question and, therefore, increases the posterior working cusp inclines (Figs. 25 and 26).

Use of the Hanau Formula.—The question is, when do we use the instrument as designed (with the Hanau formula for the Bennett angle), and when do we arbitrarily decrease the lateral Bennett shift? An accentuated transverse curve of occlusion is associated with lateral Bennett shift of the working condyles. In this case the articulator is used, as designed, with the lateral Bennett shift. When the pattern of occlusion shows very little transverse curve or is mutilated, it is advisable arbitrarily to eliminate the Bennett angle of the balancing condylar motion to produce a rotating working condyle with little lateral Bennett shift. The posterior working cusp inclinations will be increased as a result. In any case, occlusal corrections will be necessary.

SUMMARY

Suggestings have been made for adapting the Hanau Model H articulator for fixed restorative prosthesis. However, the shortcomings of the instrument must be understood. A more adjustable instrument would seem to be indicated in order to reduce the degree of occlusal correction necessary to harmonize biologic movement with the occlusion produced on the articulator. On the basis of the mathematical study, the instrument is of practical value and within the accuracy of the records used for complete denture prosthesis.

REFERENCES

1. Monson, G. S.: Applied Mechanics to the Theory of Mandibular Movements, D. Cosmos. **74**:1039-1053, 1932.
2. Bonwill, W.: Scientific Articulation of the Human Teeth as Founded on Geometrical, Mathematical, and Mechanical Laws, D. Items Interest **21**:617-636; 873-880, 1899.
3. Balkwill, F.: The Best Form and Arrangement of Artificial Teeth for Mastication, Britt. J. D. Surg. **9**:278-282, Disc. 282-285, 1866.
4. Bergstrom, G.: On the Reproduction of Dental Articulation by Means of Articulators, A *Kinematic Investigation, Orebro, Sweden, 1950, Littoren Ryden.*
5. Gysi, A.: Practical Application of Research Results in Denture Construction (Mandibular Movements), George Wood Clapp, Collaborator, J.A.D.A. **16**:199-223, 1929.
6. Stansbery, C. J.: Functional Position Checkbite Technique, J.A.D.A. **16**:421-440, 1929.
7. Weinberg, L. A.: The Transverse Hinge Axis: Real or Imaginary, J. Pros. Den. **9**:775-787, 1959.
8. Sorrin, S.: Traumatic Occlusion: Its Detection and Correction, D. Digest **40**:170-173; 202-208, 1934.
9. Miller, S. C.: Textbook of Periodontia, ed. 3, Philadelphia, 1950, The Blakiston Company, pp. 343-384.
10. Schuyler, C.: The Correction of Occlusal Disharmony of the Natural Dentition, New York D. J. **13**:445-462, 1947.
11. Weinberg, L. A.: A Visualized Technique of Occlusal Equilibration, J. D. Med. **7**:9-26, 1952.
12. Hanau, R. L.: Full Denture Prosthesis, ed. 4, Buffalo, 1930, Hanau Engineering Company, p. 15.
13. Christensen, C.: A Rational Articulator, Ash's Quarterly, pp. 409-420, 1901.
14. Brotman, D. N.: Hinge Axes, J. Pros. Den. **10**:436-440; 631-636; 873-877, 1960.
15. Funk and Wagnalls New Standard Dictionary of the English Language, New York, 1952, Funk and Wagnalls, p. 848.
16. Weinberg, L. A.: An Evaluation of the Face-Bow Mounting, J. Pros. Den. **11**:32-42, 1961.
17. Isaacson, D.: A Clinical Study of the Bennett Movement, J. Pros. Den. **8**:641-649, 1958.
18. Fischer, R.: Beziehungen Zwischen den Kieferbewegungen und der Kauflachenform der Zahn, Schweiz, Monatschr. Zahnh. 36.

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