THE TRANSOGRAPH AND TRANSOGRAPHIC ARTICULATION

JEROME M. SCHWEITZER, D.D.S.

New York, N. Y.

INTRODUCTION

TWO ARTICLES WERE PUBLISHED in the *Dental Digest* in 1951 which interested me. The first was "Centric and Hinge-Axis,"[1] and the second was "The Bennett Movement."[2] The latter one mentioned the fact that an articulator had been built which was able ". . . to inject the Bennett movement while operating in conjunction with the asymmetrical axal center or hinge-axes principle" and, in addition, ". . . accepting instantly and perfectly wax bites of widely varying thicknesses and bite depths on any given dentulous case."

The United States Patent Office awarded the Transograph this trade mark: "Jaw Recorder and Duplicator."* The dictionary[3] states: *trans,* a Latin prefix meaning across, beyond, through; *o-,* an ending for the first element of many compounds; and *graph,* a word element from the Greek meaning an apparatus for drawing, writing, or recording; in other words, a writing of jaw movements carried over to an articulator. The question that naturally comes to mind is: what does this articulator claim to do? Its whole purpose is to record and duplicate functional jaw movements. Function is difficult to copy. Most of us still insist that it is impossible to copy jaw function on any machine. The inventors claim, however, to literally take the patient's head and place it upon the laboratory bench.†

Let me first present some of the historical background which was responsible for the development of the articulator. To Beverly B. McCollum and the Gnathological Society goes all the credit for the principles upon which this theory and technique are based.[4, 5] They are the principles of (1) the rotational control centers, (2) the cranial plane, (3) the Bennett movement, and (4) the envelope of motion. There is a large school of thought which feels that these principles are sound.

THE ROTATIONAL CONTROL CENTERS OR HINGE AXES

This concept stresses the uselessness of a centric relation record in the following line of reasoning.[1, 6] Every rotating body turns upon some fixed or imaginary line, whether it be the earth or a small wheel spinning upon an axis going through its hub. The condyles, which are irregular bodies, have imaginary hinge

Received for publication Nov. 5, 1956; revised by the author April 1, 1957.

*Harry L. Page: Personal communication, Feb. 11, 1956.

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axes which pierce them transversely, horizontally, and sagittally (Fig. 1). These axes direct the arcs through which the condyles rotate. The condylar hinge axes must be first found and duplicated upon an articulator before any centric relation record can be used, otherwise the use of this centric relation record or needle point tracing will serve only to relate the flat occlusion rims at one static position. Should the articulator be moved even the slightest degree vertically, horizontally, or transversely, the results will be inaccuracies. In addition, should the flat occlusion rim surfaces be changed to irregular cusp surfaces without accurate hinge

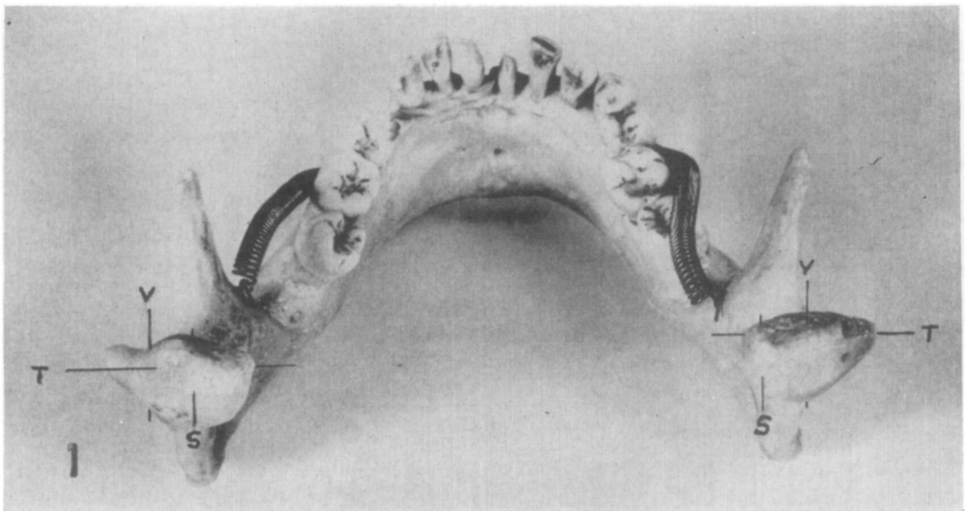

Fig. 1.—The condylar axal centers are independent of each other. *T*, Transverse; *V*, vertical; *S*, sagittal. (From Harry L. Page, Dental Digest, April, 1956, p. 163.)

axis controls, these results will be inaccurate; in other words, centric relation will hold only as long as no motion takes place—but should function begin, centric relation is of no value.

The arcs of closure for each mouth are different. They depend upon the rotational centers of the condyles. Looking at the head from the rear, if the condylar axis on one side is higher than on the other side, then, regardless of the perfection of the occlusion rims and needle point tracing, the teeth will touch only on the side in which the articulator and condylar hinge axis coincide, whereas, on the opposite side, they will be separated.

When using a centric relation record to mount casts, how often do we hear the expression, "The recording wax should be thin and the cusp imprints should be shallow"? If the wax interocclusal record is too thick or the cusp imprints too deep, we are fearful that the record will not be correct. With a thin record, we are hopeful that even though the casts are not mounted on the closure axes, we are close to them. "At no time, regardless of the type of face-bow used, is it safe to make centric relation records at an opening greater than the rest position of the mandible."[7] Transographics states that if this is true, then is not that an admission of the fallacy of centric relation, of the fact that it is a static record only for that special vertical position, and that it is immediately destroyed when functional chewing begins? If the diagrams are drawn[8] representing the paths of tooth travel for dentulous and edentulous cases mounted by means of centric relation records, it will be shown that the diverging arcs of closure will cause cuspal interference, but, in the edentulous case, the interference will be heaviest at the cusp tips and none at all at centric relation (Fig. 2), whereas, with a dentulous case, the interference will be none at all at the cusp tips, but a great deal at the final closure position (Fig. 3). In the edentulous case, the wax rims contact at the static position of centric relation, and the teeth set up from this point had the cusps open 2 mm. It was, therefore, at the start of closure that the arc

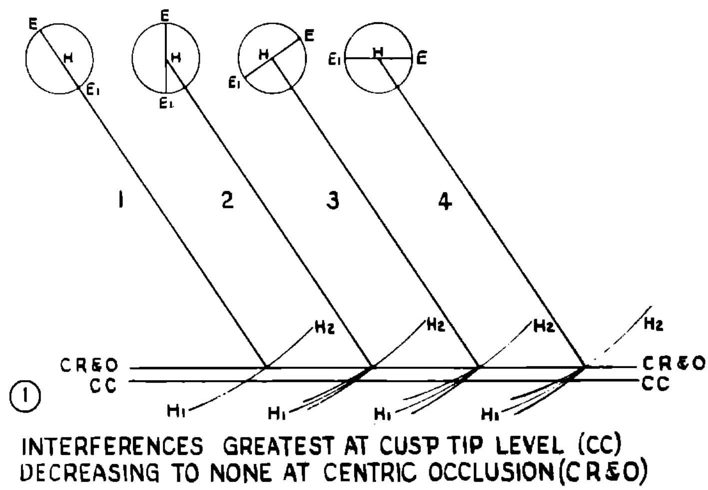

Fig. 2.—The fallacy of centric relation in the edentulous case. (Courtesy of Harry L. Page and Dental Digest.)

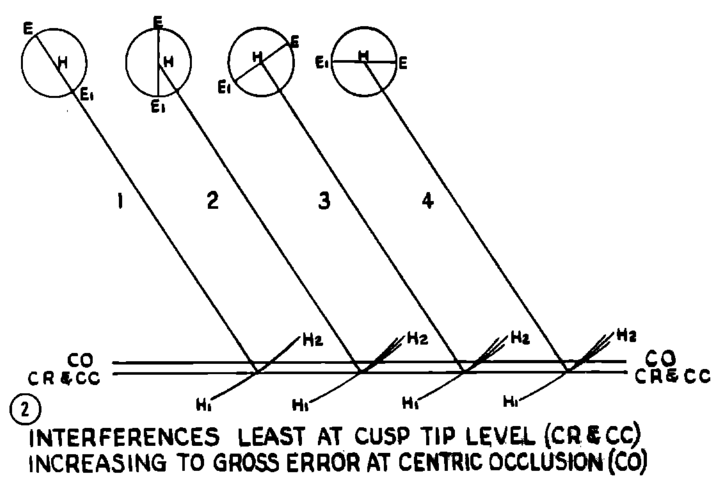

Fig. 3.—The fallacy of centric relation in the dentulous case. (From Harry L. Page, Dental Digest, Jan., 1955, p. 20.)

was different; whereas, in the dentulous case, the centric relation record was made with the cusps just out of contact. Therefore, the clash could come after the cusps closed the 2 mm. necessary for final closure and, at final cusp contact, centric relation would be a destructive position.

This is the reason that a thick centric relation wax is not advisable when using conventional articulators. However, in Transographics, "when using hinge-axes and cranial planes that have been proved correct, there is no need to fear the mechanical difference in the mouth and instrument closure paths or the incorrect occlusion that are so disastrously common to centric relation mountings."[8]

THE BENNETT MOVEMENT[2, 10, 11]

There are several components to jaw motion, each of which must be recognized and incorporated in the articulator. The Bennett movement has been looked upon as a definite bodily side shift as the jaw moves laterally. It has always been accepted as a component of lateral jaw motion. It has been called the "power movement," and it has been said to have more influence upon the articulating surfaces of the teeth than any other component of jaw motion.[4] In Transographics, the Bennett movement is not considered as a component of lateral motion, but rather as a component of "natural functional movements, the major one of which is the vertical movement."[11] It is said to be due to the asymmetry of condylar positions, sizes, and shapes. It is explained as follows:

If the condylar hinge axes are asymmetrical, then there will be small collateral movements upon closure. The condyles are loosely encapsulated. Therefore, there can be a bodily shift in any single plane or in all three planes simultaneously, with condylar movement in the same or in a different direction. Then again, there are differences in the ramus and body length of one side of the mandible as compared to the opposite side. This will cause divergent centers and radii and will force a collateral translatory movement upon every opening and closing. Using this knowledge, the Transograph is said to have incorporated in it a Bennett movement with the shift taking place automatically while operating in conjunction with the asymmetrical hinge axis principles.

THE ROLE OF THE TEMPOROMANDIBULAR LIGAMENT

The condyles use the restriction of the temporomandibular ligaments as radii and swing upward and sometimes forward to attain their fulcral position on the posterior inferior slope of the articular eminence (Fig. 4). They are held in their fulcral position by these ligaments while the internal pterygoid muscles, the anterior part of the temporal muscles, and masseter muscles act in power closure. This ligament also helps bear the heavy tension of power closure. When a strong force attempts to retrude the mandible, the temporomandibular ligament arcs the condyle upward and occasionally slightly forward, while the body of the mandible moves backward. When relaxed, the condyles drop bodily to their physiologic rest position. The conventional theory is that, from this rest position, the mandible simply rotated to its fulcral position. However, if a hingebow is observed closely when it is used to locate the hinge axis, it may be observed that, when the mandible drops to its rest position, translation, and not rotation, takes place. It appears from this that the physiologic rest position should not be used as a starting point in mounting casts upon an articulator.[12, 14]

PLANES OF THE HEAD AND THE HINGE AXES

The different planes of the head and hinge axes have been stressed by others, but this concept caused additional attention to be focused upon them. There are

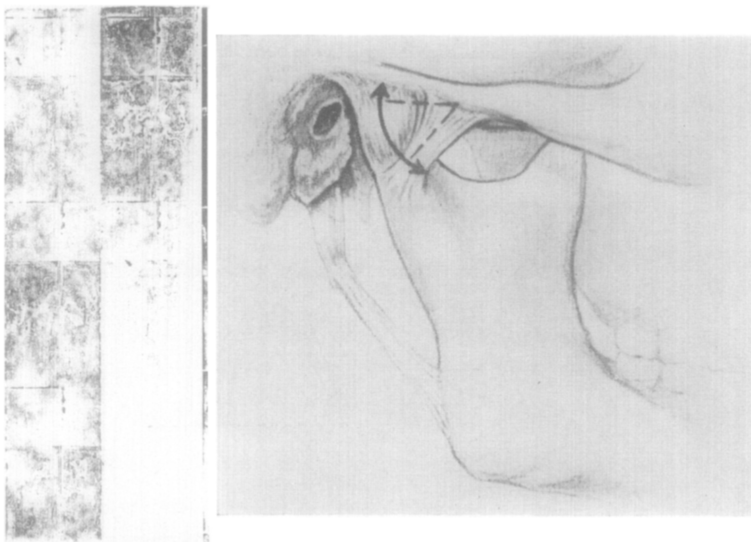

Fig. 4.—The temporomandibular ligament, condylar guide, and anchor in a power closure. (From Harry L. Page, Dental Digest, Jan., 1955, p. 20.)

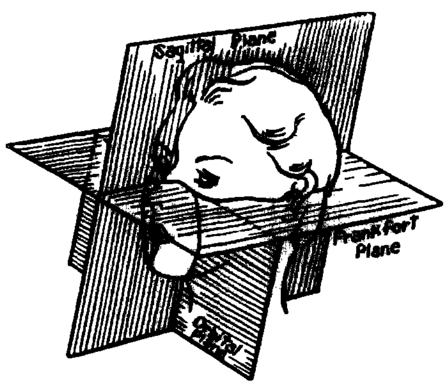

Fig. 5.—Three planes of space as related to the head. (From J. A. Salzmann, Principles of Orthodontia, J. B. Lippincott Co., 1943.)

three planes which are used in describing jaw movements in the head, namely: (1) sagittal, (2) transverse, and (3) horizontal (Fig. 5).

In kinematics, there are rotations which are controlled by hinge axes. There are three different kinds of axes which are found in the head: (1) vertical axes, (2) transverse axes, and (3) sagittal axes. These three axes control rotation in different planes (Fig. 6). Transverse axes control rotation in the sagittal plane. Vertical axes control rotation in the horizontal plane, while sagittal axes control rotation in the transverse plane. In all, there are eighteen axes in the skull. Three are in each condyle, three in each ramus, perhaps, near the mandibular foramen or nearer to the gonial angle, and, finally, three in each articular eminence, described by Hjortsjö as "axes of movement passing through the center of the articulator tubercle and about which the tuberculum rotated."[15]

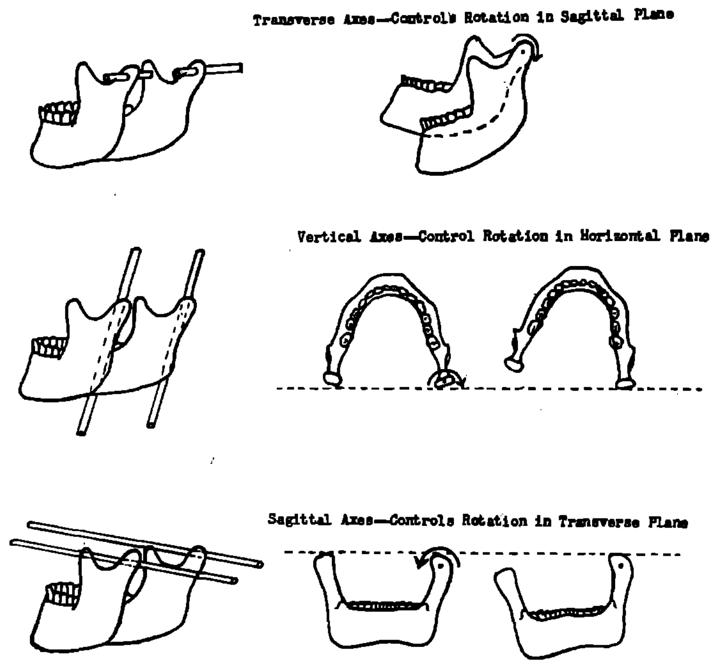

Fig. 6.—The transverse, vertical, and sagittal axes. (Modified from Hjortsjö, Acta odont. scandinav. 2:17-18, 1953.)

AXAL CENTERS VERSUS POINT CENTERS

Axal centers versus point centers is another very controversial subject brought to the fore by this concept, which is described[13] as follows:

"A hinge axis has been defined as . . . a theoretic axal center that pierces a condyle transversely."[16] Each condyle has its own axal center, and this is not a point center. Each axal center is independent of the other. They are asymmetrical. The claim is made that the Transograph is the only articulator which has axal centers and that other articulators, regardless of their shape, including the Gnathoscope, have a mechanical connection between their two bearings. This constitutes a solid axis. The condyles have their junction in the symphysis which is an offset point. The Transograph has its condylar bearings joined only by means of casts that represent and duplicate the patient's maxillary and mandibular arches (Fig. 7).[16]* It is also denied that a hinge axis is scientifically constant to the mandible or to the articular disk even in simple rotation, not to mention a combination of rotary and lateral movements. The irregular condyles make it

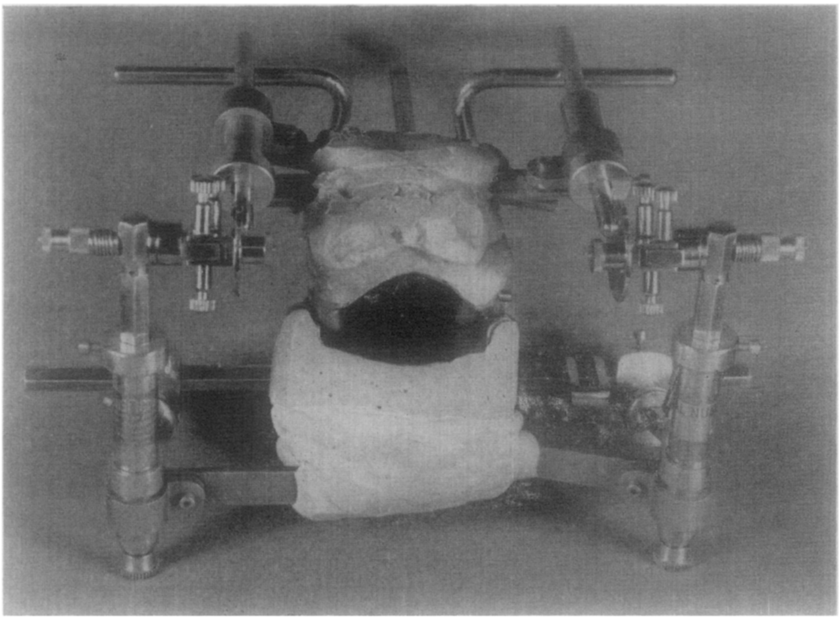

Fig. 7.—A rear view of the Transograph showing the split axes joined only by the casts.

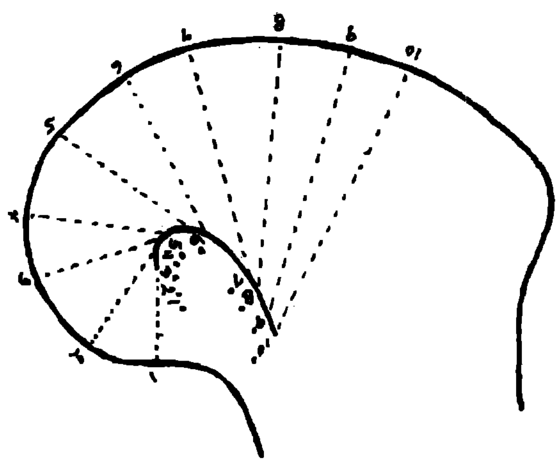

Fig. 8.—A spiral joint (femoral condyle in profile) in which the axis of movement is not fixed but changes with its position. The various circle centers are situated along a curved line, the evolute. Such is the case in the upper division of the temporomandibular joint. This suggests that the transverse hinge axes are not scientifically constant to the meniscus. (Redrawn from Fick, 1911.[21])

impossible for the various individual axes to be constant, even in simple rotation.[16] Hjortsjö[18] found that in extensive rotation of the condyle, with no forward movement, the result of the locus of the consecutive axis centers took the form of an evolute curve (Fig. 8). The slope of the fossa resembles somewhat a parabolic

*Harry L. Page: Personal communication, April 19, 1956.

curve when viewed in the sagittal plane according to the same investigator. This suggests that the transverse hinge axis is not constant to the mandibular meniscus during combined rotary and lateral movement.[19-21] However, both Page and Hjortsjö state that this inconstancy is slight during jaw motion within the terminal functional orbit.[20]* This is contrary to the concept of Gnathology which maintains that the hinge axis is constant to the mandible.[22]

The vertical axes control motion on the horizontal plane, but there is no definite way known to locate them in the skull. The Gnathoscope uses its so-called anterior envelope of motion to have the styli move along the border paths, while the posterior mechanism of the instrument is adjusted to these movements. In that way, the vertical axes are supposedly located. In Transographics, an attempt is made first to locate the vertical axes of the condyles inward from the skin three-eights of an inch (Fig. 9). It is admitted that this is arbitrary, but the claim is made that it is close. In making the face-bow record, the pins are kept close to the skin in order to capture the intercondylar width as accurately as possible.

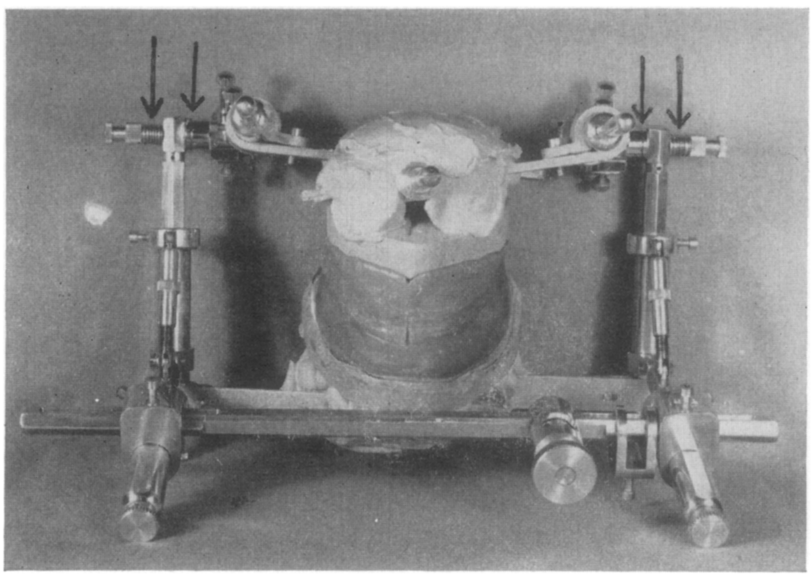

Fig. 9.—A metal plate, ⅜ inch thick, used to locate the condyles inward from the skin. Springs on the transverse axes relieve the instrument of torque.

It is stated that the movements in the horizontal and transverse planes are small as compared to movements in the sagittal plane, but these movements in different planes must be duplicated on the articulator, and this cannot be done with point centers and a rigid intercondylar axis. The only object in which there can be a common center for all planes is a perfect sphere. The condyles are irregularly shaped. Because of their irregular shape, the articulator must be provided with asymmetrical axal centers individual to each condyle. According to its inventor, the Transograph makes provision for this in its broken axis. The jaw provides for these collateral movements by moving bodily. It can do this

*Harry L. Page: Personal communication, March 14, 1957.

because of the looseness of its suspension in the capsular ligament sling and the accessory muscles. *The bone does not bend as so many have inferred.*[16]

The condyles are not rigidly controlled as in an articulator. They can slide bodily along paths produced as a result of these asymmetrical rotational centers. The articulator must be flexible enough to arc in order to reproduce these collateral shiftings in three different planes which cannot have a common control center. With this slight bending or torque, these movements, which are controlled by the sagittal and vertical axes and take place along the transverse and horizontal planes, will occur. In the Transograph, it can be detected by observing the slight twisting of the instrument ". . . a sort of mechanical protest against being forced to rotate upon untrue bearings."[16] Page states: "That the Transograph flexes is often cited against it by those who have no understanding of the principles involved. It would help them if they realized that the jaw, too, is a sensitive apparatus. It makes many collateral movements such as the Bennett during normal function. While a mechanism might be built that would copy these collateral shifts, it is much simpler and just as effective to use flexing to produce what are commonly known as mechanical equivalents. Proof that these are true equivalents lies in the constant acceptance by the visibly flexing Transograph of tight-fitting wax matrices made in the mouth at various occlusal separations.

"When the instrument is chewing, there is considerable torque created by the axal centers of rotation. To relieve the instrument, springs were put on the transverse axes so that they would slide back and forth in their bearings. It turned out that, in some cases, the combination of torquing and guidance from the cams caused the vertical hinge axes to trace their correct positions for all degrees of horizontal movement: axes moving inward with the opening and outward with the closing stroke."*

REFERENCE PLANES

Twenty-five years ago, McCollum[4] established what he called an axis orbital plane as a necessary part of the process of mounting casts on his articulator, either for dentulous or edentulous cases. About the same time, Wadsworth drew a line from the condyle to a point near the corner of the eye for use as a reference. Simon used a tragus orbital plane as a reference for mounting casts. McCollum established the axis orbital plane by lines running from the hinge axes on the right and left sides to points on the floor of each orbit, which he later transferred to one point on the side of the nose corresponding to the right orbit point. The axis orbital plane extends from the axes to the infraorbital points. He said the plane was horizontal when the body is erect and that, with its establishment, the slant of the anterior teeth may be established and an idea of the long axis of every tooth on a cast may be obtained. He said, also, "The slant of the condyle path [of the instrument] is not relatively the same, but is then identical with the slant of the path in the face . . . the proper plane of occlusion may be established . . . without the establishment of the axis orbital plane . . . the teeth stand one chance in a million of being properly placed."[4]

*Harry L. Page: Personal communication, Dec. 30, 1955.

CRANIAL PLANE

According to Transographics, however, the important reason for establishing this plane is in order to be able to repeat natural deviations of functional jaw movements from off the sagittal plane on the articulator. Without this plane, off-sagittal function on the articulator has no useful relation to off-sagittal function in the mouth. The cranial planes or axis orbital planes of Wadsworth, McCollum, and Simon run from and to some specific anatomic landmark and are repeatedly taken from these same positions. In Transographics, it is not necessary to return to the same anatomic landmark (Fig. 10). The claim is made that it is only important that the point established in each operation be repeated on the machine. The cranial plane is defined as "the relationship of any convenient cranial reference point to the hinge axes."[23]

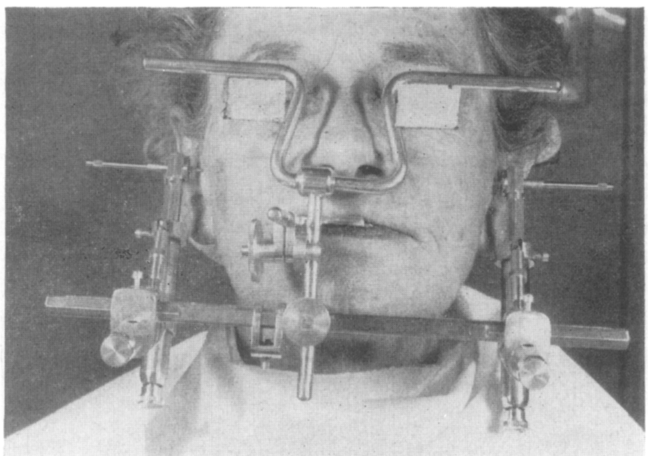

Fig. 10.—The cranial plane is established by the head relator.

The establishment of a cranial plane makes possible the projection of the rotational centers of each condyle. (These points are located in the skin and are regarded as the posterior apexes to a third anterior apex.) A relationship is established between the entire cranium, the maxillae, and the transverse hinge axes which is carried over to the articulator by means of a wax interocclusal record on a bite fork that is attached to a cranial plane indicator called a head relator (Fig. 11).[18] With these relationships established, the vertical dimension may be changed on the machine without interfering with mouth function.

A hinge "bite" is defined as "the relationship of properly oriented bite-blocks or wax bites to the hinge-axis."[18] A hinge relation is defined as "the relationship of any convenient cranial reference point to the hinge-axis."[18] On the Transograph, this is done by having the hinge-bow and cranial plane indicator (head relator) locked to a hinge interocclusal record, and adjusting these on the machine so that, on the machine, the measurements will agree with the measurements in the head. The wax interocclusal records can now be removed, and the relationship of the opposing bases or teeth will be one of hinge occlusion which is defined as "the relationship of naturally occluded teeth to the hinge relation."[13]

LATERAL JAW MOVEMENTS VERSUS NATURAL JAW FUNCTION

Lateral jaw movements versus natural jaw function is another controversial subject. Jankelson,[25] Kurth,[26-28] Boswell,[29] Hildebrand,[30] Payne,[31] Shanahan,[32] and others have done research along these lines. This concept not only agrees with them but even goes further.[10, 24]

When a person chews naturally, he does not move his jaw horizontally from side to side and protrusively forward. He opens his mouth liberally, moves his jaw to one side, grasps the food, and then closes his mouth during which time, in the closing stroke, the mandible travels upward, inward, and forward to make contact with the opposing teeth. The cusps rarely, if ever, engage in lateral movement on the horizontal plane. As the cusps of the natural teeth close from the

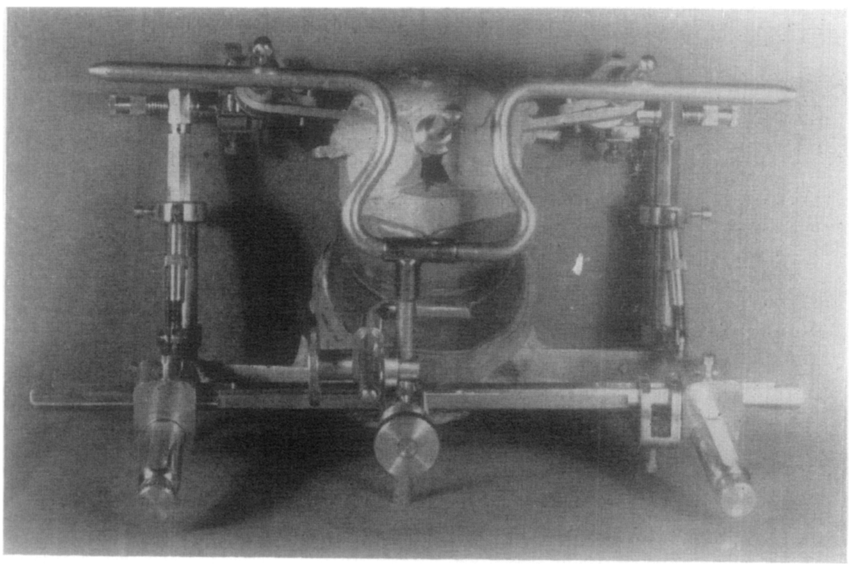

Fig. 11.—The relationship between the cranium, the maxillae, and the transverse hinge axes is carried over to the articulator.

open position, they assume an angle of closure that enables them to clear the opposing cusps until they attain complete closure. Ask a person to close his teeth with or without food, and you will observe that even in quick closure, there is never a cusp interference in any normally good occlusion, in spite of the fact that in most persons with excellent teeth and bone structure, there is rarely a simultaneous contact in work and balance, which is the stated aim of all of our artificially fabricated occlusions.

The angle of closure is all-important in order that the cusps avoid clashing while the functional closing stroke is being used. There is a certain angle within which the jaw moves in final closure in the transverse plane. This angle bounds functional jaw movements; therefore, it must be incorporated in the articulator. It is within the patient's natural envelope of jaw motion. According to Transographics, the functional jaw movement pattern differs considerably from the envelope of motion that limits the range of artificial radial lateral movements. The angle of final closure is somewhere over 50 degrees and under 70 degrees off the cranial plane.[23] This becomes of extreme importance in the final short range of interdentation. If that angle is recorded on the articulator, any of the closure strokes used by the patient may be reproduced with accuracy. In the calculation of the angle of final closure, the works of Boswell,[33] Kurth,[26] and Hildebrand[30] were used for comparison, in addition to the experimentation of the inventors. The flattest angle was around 50 degrees off the cranial plane. The steepest angle was under 70 degrees. To reproduce the flattest angles, a jaw-movement guide with adjustable cams is attached to the Transograph (Fig. 12). These are set slightly above the flattest closure angle revealed by the patient's pantographic records. In actual practice, this turns out to be 55 degrees. The cams are set initially at 55 degrees.*[16, 23]

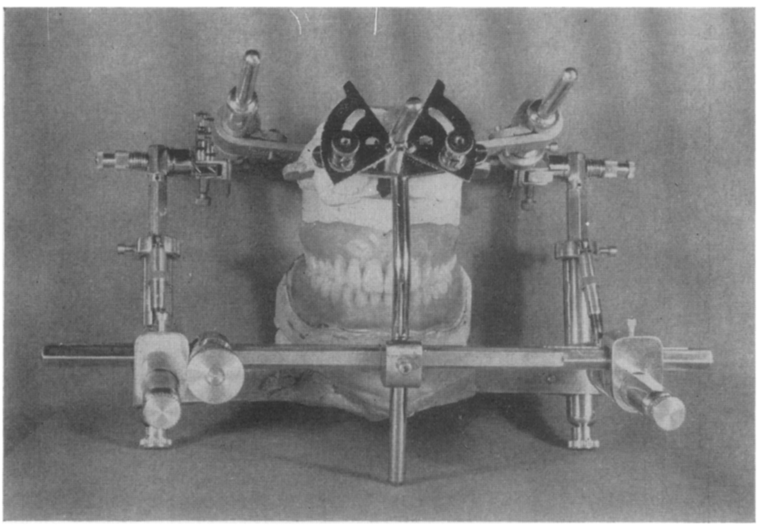

Fig. 12.—The jaw movement guide with the cams set at 55 degrees off the cranial plane is attached to the instrument.

Teeth articulated to function with the conventional articulators are prepared on the wrong surfaces, because when the mandible moves in a medial-lateral direction while gliding on a horizontal plane, the movement of the occlusal surfaces is retrusive, whereas, while closing in the medial functional stroke, the natural occlusal movement is protrusive. The claim is made that the Transograph is the only articulator that is capable of reproducing the natural functional movements.[10, 14]

OCCLUSAL CURVES

Occlusal curves in an orthodox occlusion are supposed to be generated by the condyle paths. According to the proponents of Transographics, these curves

*Harry L. Page: Personal communication, April 16, 1956.

are generated when horizontal lateral movements, which are artificially induced, are made. These curves can be made with contacting occlusion rims in edentulous cases. However, when we chew naturally, there is no tooth contact until the final closure is made or until the swallowing act occurs, which takes place in final closure. Therefore, these occlusal curves generated by artificial lateral movements are artificial curves. The natural curve anteroposteriorly must be the product of radii from the hinge axis to each tooth, modified by the mandibular or gonial

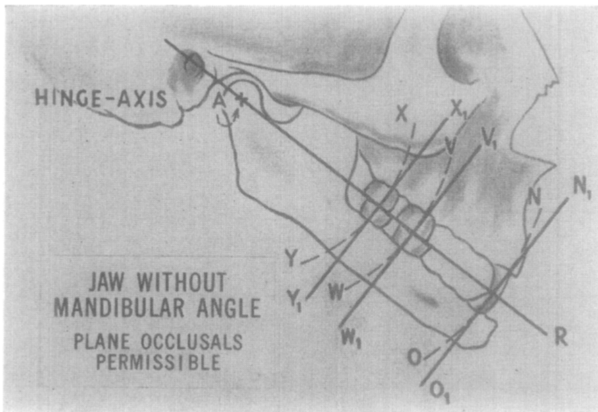

Fig. 13.—A jaw without a mandibular angle. (From Harry L. Page, Dental Digest, Jan., 1952, p. 20.)

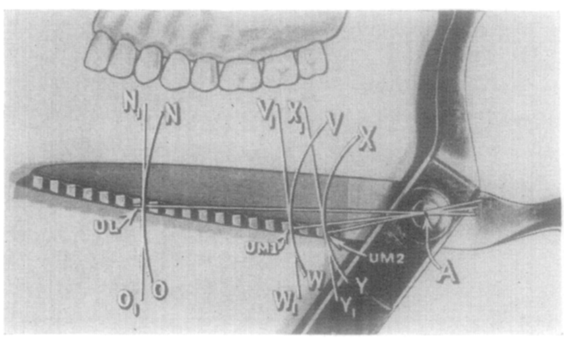

Fig. 14.—The influence of a mandibular angle. An occlusal curve is unavoidable. (From Harry L. Page, Dental Digest, Jan., 1952, p. 20.)

angle. *"The occlusal curve is a composite of opposed occlusal surface curvatures in the sagittal, frontal, and horizontal planes"*[17] and not a by-product of condyle paths. If the ramus and mandible were a straight line from the condylar hinge axis to the incisal edge of the anterior teeth, and the mandible simply opened and closed under these conditions, we could have plane occlusion and plane occlusal surfaces (Fig. 13). The human jaw does not happen to be built that way. The mandibular angle together with the hinge axis results in the anteroposterior occlusal curve common to human occlusions (Fig. 14).[17]

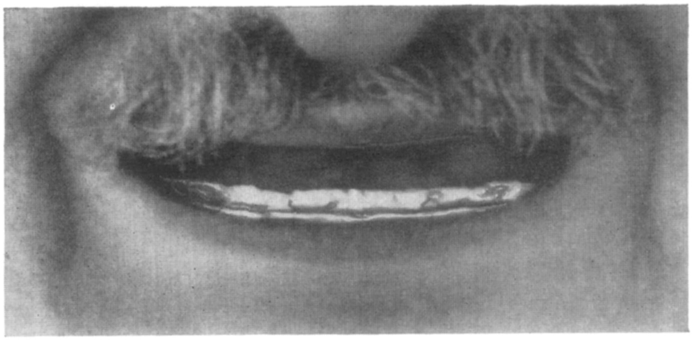

Fig. 15.—Functional "bite plates" in the patient's mouth. These are chewed-in protrusively and right and left laterally, with the upper and lower occlusal surfaces of the records contacting. (From Schweitzer, Restorative Dentistry, The C. V. Mosby Co., 1947.)

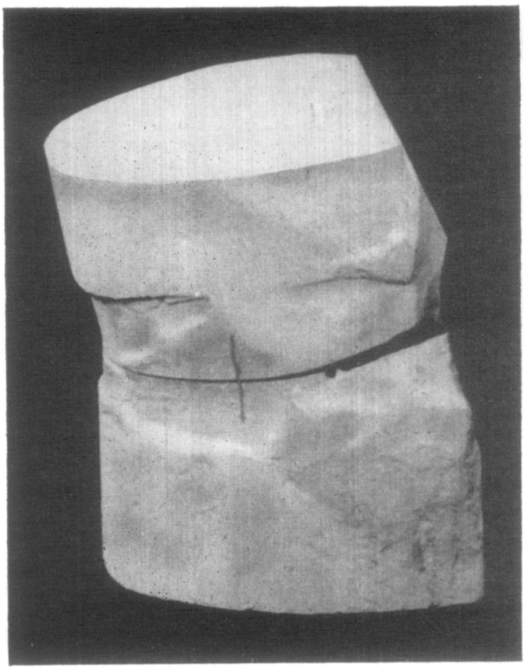

Fig. 16.—When the functional "chew-in" records are poured, the occlusal curve shows a space posteriorly. Transographics explains why this space is present. (From Schweitzer, Restorative Dentistry, The C. V. Mosby Co., 1947.)

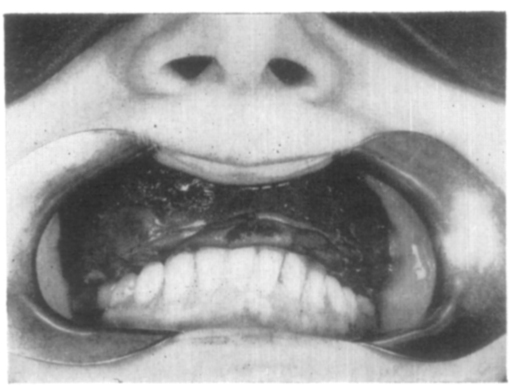

Fig. 17.—The patient "chews-in" occlusal paths on a modeling compound rim. (From Schweitzer, Restorative Dentistry, The C. V. Mosby Co., 1947.)

DIFFERENCE IN ENVELOPES OF MOTION

Kurth stressed the fact that natural jaw function differed completely from the movements controlled by the stylus and metal plate so often used even today in obtaining records with which to adjust articulators.[28] The Transographic concept seems to agree with him and briefly describes it as follows:

When a (Gothic arch) needle point tracing is made with a stylus and a metal plate, the apex of the tracing is said to indicate the most retruded position from which lateral movements can be made at a given vertical height. However, when a patient opens at the start of function, the body of the mandible drops further back, instantly, along the opening arc. Therefore, in all functional movements, the occlusal surfaces of the lower teeth are behind the artificially induced horizontal lateral movements. The base lines of the needle point tracing represent the forward terminal of all functional movements. Therefore, these two types of movements are entirely different. Lateral motion may be indulged in, but it is not used in function. The envelope of motion which is drawn on a single plane does not represent function because it is entirely distal to, i.e. outside of, function.[10, 14-16]

"CHEW-IN" TECHNIQUE AND ITS RESULTS

In the "chew-in" technique, as described by Christensen in 1902, and by Patterson[31-36] and Meyer,[37, 38] interocclusal waxes were used with plaster or carborundum paste in a special trough built in the occlusion rims, and functional paths were generated. I have often wondered why there was always a space between the posterior ends of the generated paths! I remember the advice to take the upper second molars out of occlusion in edentulous cases. The "chew-in" is started with the vertical dimension overraised, and, as the "chew-in" takes place, the operation is halted at the correct vertical dimension (Figs. 15-17). Sometimes a central bearing instrument is used to control the grinding, or three simultaneous central bearing instruments are built into the occlusion rims.[39, 40] This concept claims that these spaces result from voluntary radial lateral motions, both in dentulous and edentulous cases and, therefore, these horizontal lateral motions are ruinous to articulation.[16] Experiments were performed[24] in which the upper and lower denture bases were made with wax occlusion rims. "They have been made by taking impressions and pouring stone models of the originals after the latter had been fitted and apposed properly in the patient's mouth."[24] The Transograph was used as the articulator, and it reproduced the patient's static and kinematic head relationships. When lateral movements were used, the nonworking side collided violently. Just as soon as the return stroke was used, the occlusion rims were released. If the occlusion rims were set to contact each other or were slightly separated, the posterior portions of the rims are ground away in radial lateral strokes (Fig. 18).

Milling teeth in the mouth is claimed to cause the same results. All the milled teeth have surfaces which in no way resemble natural teeth. It makes little difference whether the so-called envelope of motion is developed by a single tracing device or by the elaborate technique used in Gnathology. The envelopes of motion recorded are distal to, and not the same as, those developed when using a natural functional masticatory stroke. It has been said repeatedly that grinding teeth in the mouth is ruinous to correct occlusion—that teeth do not grind themselves into balanced occlusion, but out of it. There is little difference whether the artificial voluntary lateral movements which are so often used in bruxomatic movements do their grinding with or without tracing devices—the results are the same. An envelope of motion is used which is entirely different from that developed in the natural jaw synergy.[18]

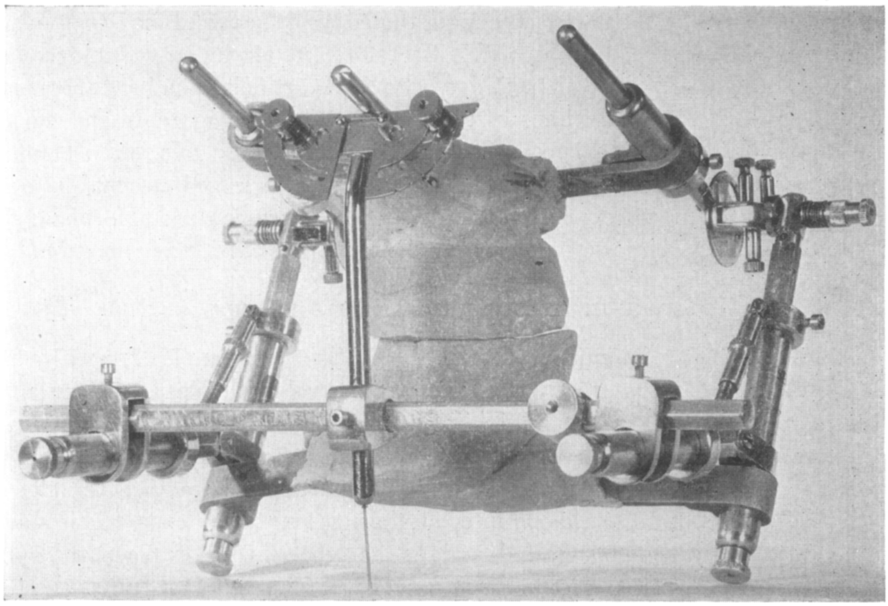

Fig. 18.—Abrasion resulting from right lateral strokes. The left posterior (nonworking) rims were out of contact in simple closure. (From Harry L. Page, Dental Digest, May, 1954, p. 204.)

CONDYLE PATHS HAVE NO VALUE

This concept is by no means the first to discredit the importance of condyle paths in establishing balanced occlusion. Boswell[29] stated: " . . . a record of condyle path movement is not one of condylar guidance, but is one of response to limitation, and can have no value when the mandible moves to any other position." Kurth,[27] Craddock,[41] and others could be quoted with reference to the fallacy of condylar guidance and balanced occlusions, but the Transographic concept emphasizes the lack of importance of condyle paths.[10-12] The condyles do not move in inflexible grooves. The path which is always recorded is that of the nonworking condyle. In making lateral interocclusal records of right mandibular movement, it is the left condylar path which is set and vice versa when the right condylar path is set. This nonworking condyle glides in all three planes upon the posterior slope of the articular eminence and also upon the inner curbing of the bone of the fossa.[15] These slopes have different angulations, but the nonworking condyle rotates and translates freely in all planes just as a perfect universal joint. It acts to protect the mechanism against sudden force, but in no way does it control jaw function. The working condyle is also a universal joint but not to the same degree. It rotates and translates in three dimensions, but when it finally reaches its fulcral position on the posterior slope of the articular eminence, it then becomes the fulcrum for jaw power. It is anchored there by muscles, the tension of which is partly relieved by the temporomandibular ligament. The nonworking condyle "idles along," rotating and translating until it, too, finally reaches its fulcral position on the posterior slope of the articular eminence. Both condyles are then in their hinge positions. Both then rotate in these fixed positions. There is no longer translation except for the Bennett movement.[14]

Kurth,[28] Craddock,[41] and Jankelson[25] stressed the lack of value of the condyle paths and of balanced cusp relationship as a part of functional jaw synergy. The dental schools teach that the ideal occlusion is one in which there is simultaneous cusp contact in lateral and protrusive movements, anteriorly, laterally, and posteriorly. Clinically, such occlusions are very rare. To deny such control factors as the condyle paths is still heresy.

Some among those who use standard concepts, and at the same time agree that condyle paths are unimportant and lateral motions are artificial, offer a new version. This group claims that since most people idly grind their teeth, smooth lateral paths must be provided to permit these pathologic movements to continue. Transographics states: "Essentially, this new rationalization agrees that laterals are worthless functionally but elevates bruxism and bruxomania to the status of virtues where once they were injurious and factors to be eliminated by every possible means."[10]

There are adjustable condyle slots on the Transograph. These were placed there for commercial reasons. The inventors felt that since they do no harm, they might as well be left adjustable for those who are still not convinced that condyle paths have no value.* They can be adjusted to any angle and, if the jaw movement or chewing angle guide has its cams lowered, the Transograph may be used as any other articulator to utilize voluntary radial lateral motions. The inventors, however, disapprove of the articulator being used in that manner.†

MANDIBULAR CLOSURE

The mandibular body, in the early phases of closure during the period in which the condyles are translating, has its axes in the mandibular angle. The masseter and the internal pterygoid muscles form its sling (Figs. 19 and 20). Transographics claims that these fibers, being directed inward and forward, tend to arc the body of the mandible upward and slightly forward, while the condyles are moving upward and backward along the anterior fossal slope, being aided in this movement by the posterior fibers of the temporal muscles. When the working condyle reaches the hinge position, the axis changes to within the con-

*Harry L. Page: Personal communication, Dec. 30, 1955.
†Harry L. Page: Personal communication, Feb. 11, 1956.

dyle, and the condyle can only rotate while the closing musculature applies the power.[14] It is argued that the cusps never completely interdentate until total closure, or until deglutition takes place.[25]

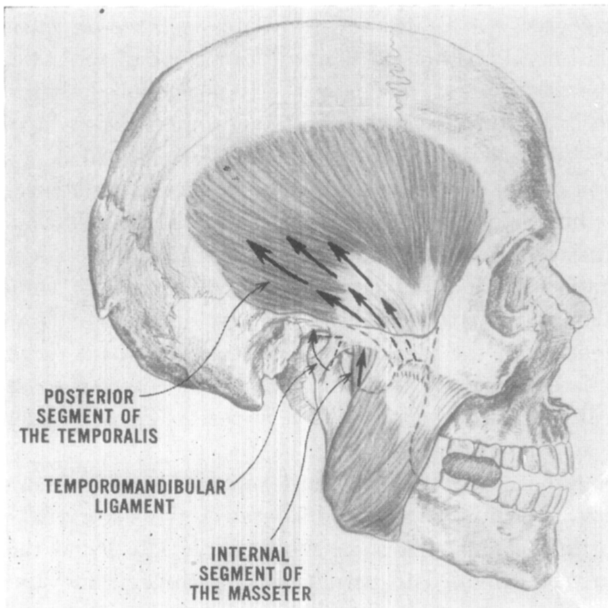

Fig. 19.—The working condyle is anchored in hinge position during the final power closure. (From Harry L. Page, Dental Digest, Feb., 1954, p. 56.)

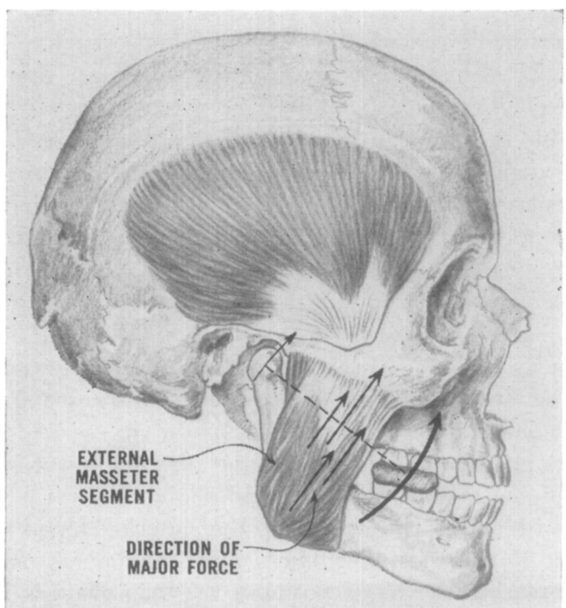

Fig. 20.—The fossal slope prevents a forward arcing of the condyle during function. (From Harry L. Page, Dental Digest, Feb., 1954, p. 57.)

Cusp contact during the chewing of food is highly controversial, but an excellent case has been built up to support the theory of no contact until final closure.[25, 32, 42-46] If this is so, why is it so necessary to obtain simultaneous "balancing" contact? It follows that if cusp contact cannot be achieved in order to initiate the guiding of the tooth surfaces of the opposing arches over each other, then a supposedly balanced glide from the lateral working occlusion in the horizontal plane medially to centric position in normal natural dentition is a myth[24] and impossible to attain. Lateral movement of natural teeth in mouths in which the teeth are in normally good condition will generally result in contact only in the extreme molar areas on the nonworking side. The anterior teeth will contact in protrusive movements and leave the posterior teeth apart.[24]

A PROTRUSIVE WAX INTEROCCLUSAL RECORD USED TO SET THE CONDYLE PATHS

Transographics states that a protrusive wax interocclusal record, which is a conventional method of setting a condyle path, is difficult to duplicate. No two recordings could be the same except by accident. Since none is the same, the only safe conclusion must be that none is correct.[10] Craddock proved this.[47] This was also substantiated by Beck and Morrison. "In the condylar articulator, the setting of the condylar indications by a protrusive interocclusal record is influenced by the magnitude of the protrusive movement, the path and deviation from plane motion of the incisal guide point, the inclination of the incisal guide, the position of the incisal guide, the amount of opening or closing of the occlusal relationship, the inclination of the interocclusal record, the relationship of the plane of the condylar slot with the sagittal plane, and the position of the interocclusal record."[48] The results are only the effort of a universal joint in adapting itself. This record is not accurate, nor is the straight protrusive record correct in reproducing lateral protrusive movements as is common procedure. With the fossal curvatures of different shapes medially and protrusively, how can one record determine both angulations?[12]

FALLACY OF THE USE OF A CENTRAL BEARING PIN

When a central bearing pin is used, some of the very muscles which are employed to perform the natural chewing stroke are immediately eliminated. All of the closing muscles, namely, the masseter, the anterior fibers of the temporal, and the closing fibers of the internal pterygoid are taken out of the functional closing synergy. The muscles that operate are the internal pterygoid pulling medially, and the nonworking temporal fibers pulling posteriorly. The jaw cannot open or close since its movements are confined to a metal plate by the stylus and by the voluntary action of the patient. The jaw moves medially and retrusively in the horizontal plane only. The usual procedure employs radial lateral movements in making jaw records. Here, Transographics, contends the situation is even worse, only the external pterygoid muscle on the nonworking side and the posterior fibers of the working temporal muscle are active. All of these are nonfunctional movements. What effect, under conditions such as these, are condyle paths and Bennett movements recorded by the most accurate articulators? They may be repeated with accuracy, but they do not prove function. They are solely controlled by the pin on the incisal guide plate.[10]

Experiments have been performed to prove that the occlusal surfaces disrupt the paths taken by the translating condyles and that the condyles conform to occlusal interferences.[10]

DISCUSSION

Many are not yet convinced that all voluntary lateral jaw movements on the horizontal plane are nonfunctional and pathologic. There are those who are inclined to feel that with certain types of food these horizontal lateral movements may be normal for some people.

The theory of Transographics provides for the use of steep cusps (35, 40, and 45 degrees), which, in turn, discourage the patient from making radial lateral motions which are considered bruxomatic and pathologic. Where the periodontal structures are weak, and where there has been considerable loss of the supporting bone, the theory of steep cusps does not seem to be logical. Many would prefer to use a flatter than normal chewing angle with flatter cusps. Although the Transograph will accept any chewing angle, the theory of Transographics does not accept it. In their opinion "it is poor practice."*

I feel that some of the settings of the Transograph are arbitrary. They admit that the distance between the condyles is arbitrary, but the claim is made that it is close. On the more recent models, they have made provision to measure this distance more accurately. It must be admitted, however, that standard instruments have an even greater inaccuracy (Fig. 9).

The jaw movement guide is set at an average of 55 degrees off the cranial plane. If the natural chewing stroke is somewhere between 50 degrees and 70 degrees off the cranial plane, the 55 degree setting is arbitrary. This chewing angle controls the cusp angles at final closure so that an error may be introduced here, although it must be admitted that it is a negative error. Only the transverse hinge axes were actually located. The vertical and sagittal axes which control motion on the horizontal and transverse planes were only pantographed from the experiments formerly referred to of Boswell, Kurth, Hildebrand, and the inventors. More substantial proof of these experiments, including those of the author, should be presented.

Another point which needs further clarification is the total separation of the two envelopes of motion, namely, that produced by so-called nonfunctional radial lateral movements and that produced by the so-called natural jaw synergy or true function. Unless all function occurs on the hinge axis, there would be a "crossing over," at various levels, of these two envelopes of motion when looking down from above the head on the horizontal plane, or when viewing the head from the side on the sagittal plane (Fig. 21). Inside the envelope of motion is a pattern of function. If this pattern of function were to be drawn diagrammatically in the sagittal and horizontal planes, its position would be somewhere forward

*Harry L. Page: Personal communication, Feb. 11, 1956.

of the hinge-axis line. The line representing the hinge axis position would be its posterior boundary. At final interdentation, however, the posterior border or hinge position would be reached.

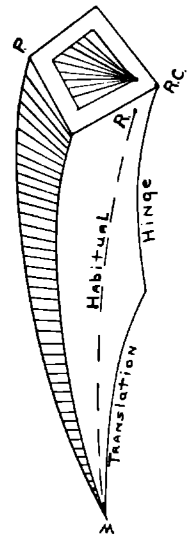

Fig. 21.—The pattern of jaw function within the envelope of motion. Habitual motion does not take place on the hinge axis but anterior to it. When the mandible opens from the retruded contact position (*RC*) it can be made to move along the arc representing the hinge axis, and then the arc representing translation. Habitual eccentric movements, however, take place slightly forward at about rest position (*R*). Therefore, there will be an overlapping of the two envelopes of motion during mastication. No movements will be found to the right of the hinge translation line; all movement takes place to the left of it. (*M*) indicates maximal opening. (Modified from H. L. Beyron: J.A.D.A. 48:648-656, 1954; and from Ulf Posselt, Odont. Scan. 10:94-95, Sup. 10, 1952.)

When in operation, the vertical axes act as the pivoting mechanism for either the right or left sides, respectively. It seems, therefore, that these axes are arbitrarily in direction and rigid in their control of movement. It is not possible to locate accurately the vertical and sagittal axes. These were pantographed from the patient's chewing angle. Relative to my questions concerning these points, the inventor admits that the location of the vertical axes is not entirely accurate. Then he states, "In functional motion, the slide and slider assembly with the spring on the transverse axes operates first to create and then to accept a torque that sways the upright arm or slides the transverse axis somewhat. This, in conjunction with the functional jaw pattern inside the envelope of motion created by the jaw movement guide cams, shifts the vertical, sagittal, and transverse axal centers into composite positions equivalent to the same positions they hold in the head while moving the jaw along the same path. Under these conditions, it is not important whether the articulator hinge axis does or does not intersect the transverse hinge axis . . . . I have computed the amount of allowable error and have seen to it that the tolerances for avoiding cuspal interference were given a generous safety factor."*

The transverse axal centers of the Transograph are always parallel to each other on the instrument (see any photograph of the instrument). It is true that

*Harry L. Page: Personal communication, April 19, 1956.

one of the right or left axal centers may be higher or lower than the other, or forward or backward of the other, but they are still always parallel. This would hardly be possible in the skull where one axal center may converge toward the other if it were projected as a transverse axis. To this question of the parallelism of the transverse axal centers, the inventor has this to say, "All Transograph parts except mandibular angle are perpendicular or parallel to each other in order to capture head asymmetries accurately." "An axis is invariably perpendicular to the plane of rotation. A wheel never rotates at any but a right angle to its axle."*

Transographics admits the location of definite transverse axal centers and marks their external location by points on the skin. Some operators claim to record areas, not points.[7,19,49,50] Therefore, the accurate location of the projection of these centers on the skin is questionable. Transographics claims that this tends to substantiate the claim that the rotational controls are asymmetrical axal centers, and not point centers. Therefore, when the head records are transferred to the instrument, it twists the same way that the jaw twists when the styli give the appearance of locating areas on the skin.

An important objective in this theory is that the so-called hinge "bite" (interocclusal record) be made with the mandible in its most retruded position. Adherents of this theory use manual pressure in obtaining these records. In patients with temporomandibular dysfunction which is due to posterior condylar displacement, this method of registration may serve only to aggravate an already pathologic condition. Therefore, the theories of Transographics would not apply to these treatment cases. The inventor agrees with this.

It is difficult for many men to concede that condyle paths have no value and that the nonworking condyle "idles along" until it reaches its hinge position. According to this theory, the nonworking condyle acts as a universal joint and conforms to any and all occlusal interference. They maintain that only the working condyle controls jaw movement arcs within the terminal functional orbit. While the experiments of Kurth,[51] in which he claimed to demonstrate the wide variance of condylar angulation in the sagittal plane when different surfaces were used on intraoral tracers, seemed to agree with Transographic concepts, those of Downs[52] disagreed with them. Downs claims that his investigations have shown that if the point of the transverse hinge axis is projected onto the face, and if the condyle path is started at this point, then the central bearing plate in the mouth may be changed from convex to concave to flat with no effect upon the condyle path.

In operations where the disk has been removed, it has been shown often that the condyle path is immediately changed, and the occlusion is interfered with as a result. They concede that this is a change in tooth interdentation but maintain that it is due to a new hinge position of the working condyle as a result of the removal of the meniscus and its external pterygoid attachment.† While it is true that tooth structure is hard and unyielding, and while the condyles are loosely encapsulated and exhibit much more flexibility, still experience has shown that tooth

*Harry L. Page: Personal communication, April 27, 1956.
†Harry L. Page: Personal communication, March 14, 1957.

cusps, masticatory muscles, and condyle paths all exhibit some degree of control over each other which will vary with the individual. "If the temporomandibular joint enjoyed the latitude of free movement and adaptability which some individuals claim it is capable of, then there would be no such pathologic entity as a temporomandibular joint disturbance directly traceable to a malocclusion, and very few teeth would be lost because of traumatic occlusion."[53]

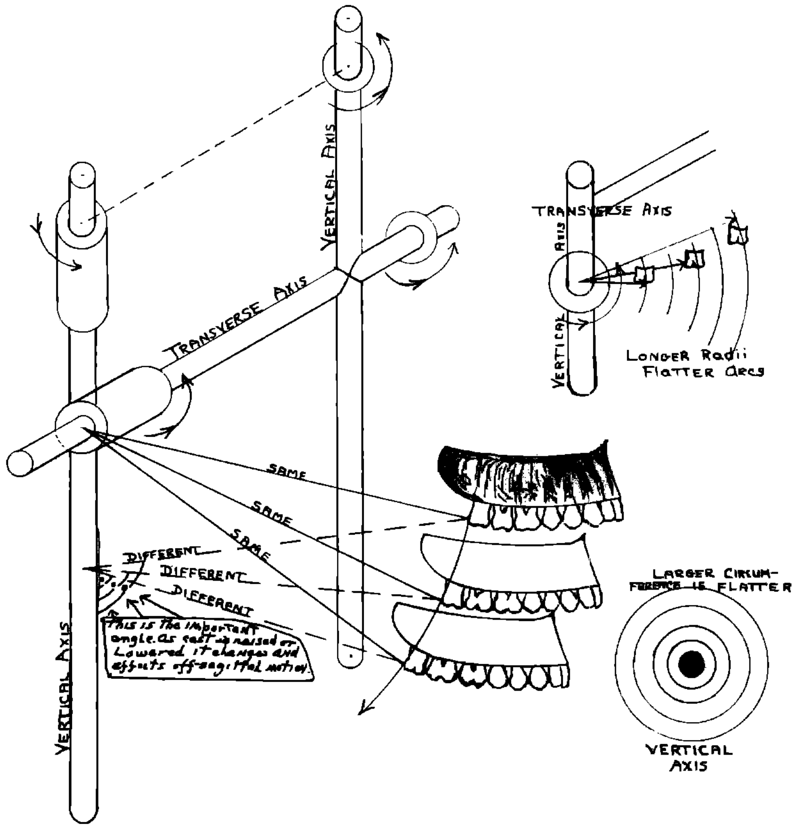

Fig. 22.—The cranial plane necessary to record equivalents of the off-sagittal plane movements made by the subject in function.

The inventors state that one of the most convincing demonstrations of the entire theory is the ability of their instrument to accept various thicknesses of hinge "bites." They claim that this is difficult, if not impossible, with the conventional articulators. During the past year, I have conducted three experiments to test the greater accuracy claimed for the Transograph over conventional articulators. All three competitive instruments which I used seemed to be equally accurate so that, in honesty, I cannot discredit the conventional articulator, nor can I discredit the claims of the inventors as to the accuracy of their machine. My experiments were not conclusive enough to me to prove anything.

A clever arrangement of the Transograph is its ability to check the correctness of different wax interocclusal records. The arrangement of the condylar slide plate and slider is the most accurate method of checking interocclusal records that I have ever seen on any articulator.

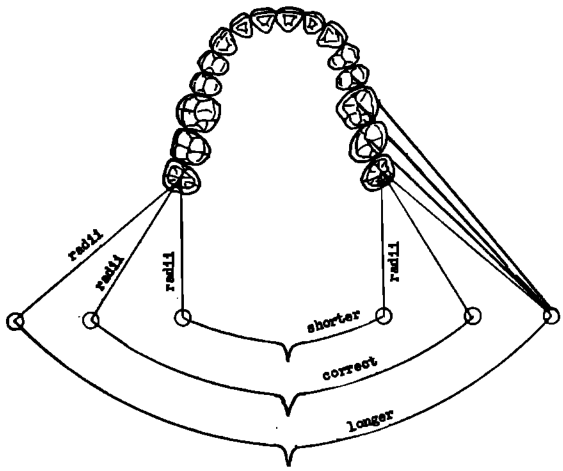

Fig. 23.—The importance of using the correct intercondylar distance. If vertical axes are not the same distance apart on the articulator as they are in the head, the radii will be different as they relate to each tooth. They will be shorter, if closer, and longer, if further apart. This will also affect the cusps of the teeth in off-sagittal motion on the horizontal plane. Therefore, the intercondylar distance should be the same on the articulator as in the head.

The concept of the cranial plane is the most difficult one to understand. Its purpose is to establish the correct relationships of axes to occlusal surfaces and to the cranium so that off-sagittal plane movements on the horizontal and transverse planes, regardless of how small they may be as compared with sagittal movements, are equivalent to off-sagittal plane movements made by the subject in function. My understanding of their concept is as follows: The transverse axes record rotational movements in the sagittal plane so that the occlusal surfaces have the same radii with reference to the transverse hinge axes as they have in the subject. If it were only to relate the occlusal surfaces in that plane, you could safely divide the distance between the upper and lower articulator frames as is the usual procedure in the Hanau Model H or the Kinescope (Fig. 22). In fact, various teeth. But horizontal and transverse plane movements, as small as they desired without changing the lengths of the radii from the transverse axis to the various teeth. But, horizontal and transverse plane movements, as small as they may be in the natural jaw synergy, are controlled by vertical and sagittal axes (Figs. 23 and 24). These or their equivalents must be recorded and related to the occlusal surfaces in the articulator. This is done in Transographs by the use of a cranial plane. In Gnathology, it is done by the use of the axis orbital plane.

The important angle to consider is the one made by the upper occlusal plane and the vertical axes. Then, horizontal or transverse movements of the occlusal surfaces will have the same radii at all times as they had in the subject's head, and interdentating cusps, whether in edentulous patients or in dentulous patients, will move along the proper arcs when they are returned to the mouth.

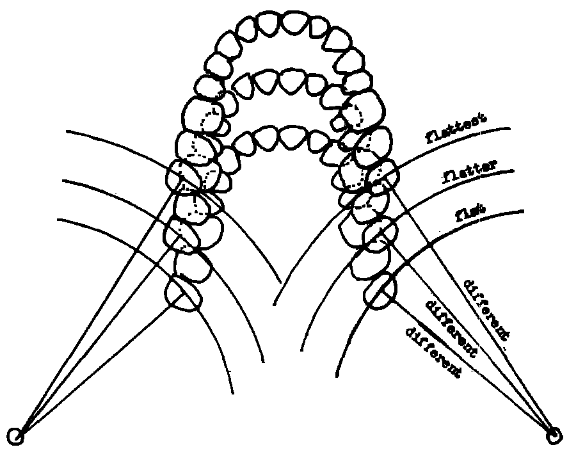

Fig. 24.—The importance of cranial plane and the effects of raising the casts on the articulator. As the cast is raised on the articulator, the teeth are moved further forward. The radii from the vertical axes to each tooth on this horizontal plane get longer as the cast is mounted higher on the articulator. This makes flatter circumferences of the arcs of the concentric circles, and, therefore, will affect the cusp form in off-sagittal motion on this horizontal plane.

CONCLUSION

An attempt has been made to present the theory and practice of Transographics. Although it claims very few original ideas, its concept and instrument represent something new and intriguing. It is entirely different from our traditional ideas. There is a big difference between the Transograph and conventional articulators. One must open his mind to receive these concepts without being prejudiced by personalities. Our profession has never had any fear in being exposed to new theories. As time goes on, it will be able to evaluate this one.

In this article, I have made extensive use of material from the writings of Mr. Harry L. Page, one of the collaborators on the theory of Transographics, and the inventor of the Transograph. The other collaborator is Dr. Reuben N. Albinson. I have tried to condense the material while putting most of it in my own words. I wish to acknowledge the help I have received from the former of the two collaborators. Without it, this concept, which involves mathematics and engineering, would have been much more difficult for me to present. On the other hand, no restrictions were imposed upon me should my experiences prove to be contrary to those stated to have been found by him and his associates. It was agreed that I was free to form my own opinions in a personal communication dated Sept. 25, 1956.

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