Prosthodontics has long been recognized as both an art and a science. Much of what is done in this discipline is the result of tradition and evolution. Sometimes in the search for clinical tools a reaction is observed and a theory of causal relation is empirically developed. One becomes satisfied to acknowledge that a phenomenon exists, establishes a clinical practice based on the phenomenon, and accepts the ascribed explanation of why that phenomenon occurs. The improperly attributed causal theory may not detract from the usefulness of the effect, but it can perpetuate a chain of improper practices secondary to that effect. Such is the case in the common teaching and clinical use of the transverse horizontal axis. The purpose of this article is to briefly review the history and development of the theory and practice of transverse horizontal axis location, its application in clinical practice, and some of the controversies which have evolved around that use, and to offer some clarifying concepts.

HISTORY AND DEVELOPMENT OF THE HINGE AXIS CONCEPT

Prosthodontic history is somewhat incomplete as to the origins of the thesis of a transverse horizontal axis. The first actual kinematic location was evolved through the California Gnathologic Society under the leadership of Dr. B. B. McCollum, and credit for the idea of the mechanical location of an axis was given to Dr. Robert Harlan. The first locations employed a modified Snow face-bow and consumed as much as 8 hours. Current devices have evolved from this first crude mechanism and its attendant theories and observations. Many present-day concepts and fallacies may also be traced to this origin.

In its purest form, the transverse horizontal axis is usually thought of as exhibiting a two-dimensional effect and as being independent of the vertical and sagittal axes. This may not be true, for this hypothesis assumes a situation which complies with the tenets of solid-body mechanics and pure rotation.

Accuracy of location

Some investigators have sought to explore what degree of precision may be expected with an axis location procedure. Kurth and Feinstein, using a Hanau articulator, concluded that axis location could be limited to a 2-mm radius when opening was restricted to 3/4 inch at the incisal pin. Borgh and Posselt in a similarly designed project found the accuracy of location to be within 1.5 mm when a 10-degree arc was used, and within 1.0 mm when the arc of movement was increased to 15 degrees. Lauritzen and Wolford used a specially designed precision instrument to test the ability of different groups of individuals to locate an axis, and they were able to achieve accuracy within 0.2 mm when using a 10-degree arc of movement. In each of these experiments there was a definite mechanical axis to be found, and only the ability of an operator to find it was studied. The instrumentation employed undoubtedly played a part in the results, and such factors as the sharpness of the styli and the length of the locating stylus cannot be ignored in the search for accuracy.

Other studies have sought to relate the range of deviation of arbitrarily selected points to that of the kinematic center. Scallhorn found 95% of the axis points located 13 mm anterior to the posterior margin of the tragus on the tragus-canthus line to be within a 5-mm radius of the kinematically located axis. Lauritzen and Bodner employed a Richey condyle marker to locate a point similar to that used by Scallhorn. They found only 33% of the “true” hinge axis points to be within a 5-mm radius of the arbitrary point.

The colinear, noncolinear controversy

A major challenge to the traditional concept of a single “intercondylar” axis was hurled by Harry Page in his proposal of the transographic concepts. He postulated the existence of two mutually independent, noncolinear axes or, simply, that each condyle had its own axis of rotation. Page theorized that since the mandible is flexible, such independence from a mutual axis is mechanically possible and anatomically allowable. Page offered as evidence of the validity of his concepts the consideration that the hinge axis locating device is
a right-angle system and that, since a body may only move at right angles to its plane of rotation, the axis stylus is, in its entirety, at right angles to that plane. Since most observers have verified Stuart and McCollum’s original work regarding the asymmetry of axis points, then two axis pins asymmetrically placed, rotating at right angles to their respective contralateral axes, would serve as proof that these axes are parallel but non-intersecting, that is, noncolinear.

This postulation by Page started a burst of “counter-proofs” dedicated to showing that one and only one axis could exist. Although initiated or replicated by others, the study by Aull is representative of the design of single-axis “proofs.” The design employs four styli from one mandibular clutch-supported rod. The mandibular axis was located on four grids supported from the maxillary clutch. The proof was purported as being demonstrated by the fact that all four points located (two on each side) lay in a straight line and, therefore, both condyles must have a common, colinear axis.

**Other investigations**

Hickey and associates undertook a most unique approach to study mandibular movements by inserting a pin into the condyle on two subjects. On one subject the pin was inserted through the skin at a point located by the kinematic method, while on the second subject the condyle was located only by palpation. Observation of the hinge movement was a small part of this study, and the conclusions are not detailed. Some points from this study are pertinent to this discussion and will be dealt with later.

Trapozzano and Lazzari reported the location of multiple hinge axis points along the path of the translatory movement of the condyle. They used two ipsilateral styli from the same anterior clutch-supported
rod. This study was also unique, and its conclusions bear some later scrutiny to resolve the enigma created.

The anatomic relation of the transverse horizontal axis has been explored by a number of investigators, and most have made statements regarding the relation of the axis to the condyle. No unanimity of opinion exists, and the conclusions range from “the transverse axis passes through or near the condyles” to “we never found the axis located in the condyle.”

**Influences manifest by axis transfer**

When the differences in concepts are regarded, certain considerations must be recognized. Many variables exist among operators, patients, and equipment. The more experienced and meticulous the operator, working rationally, not mechanically, the better his result. He will use magnification and adequate light and will observe the stylus movement directly, not obliquely. Patients must be trained, relaxed, and, when necessary, depogrammed by splints or medication. They must be positioned to allow ample freedom of mandibular movement. The equipment must be rigid and the styli sharp. The grid or table against which the stylus is to be viewed must be stable. There are times when these conditions are met that the experienced operator will admit that he has still not been able to observe a strictly rotary movement. This is acknowledged by Gregory and associates in their statement that “in observing the recording of several patients it appears as though some cannot produce a true hinge movement.”

**Effects of asymmetry**

**Superoinferior.** When using a kinematic axis to transfer a cast to an articulator, the anatomic asymmetry of the contralateral points will result in certain distortions when that axis is transferred to an articulator where the mechanical axis produces symmetry. If the distortion is a difference in the superior-inferior relationships, then the most inferior of the points must be raised to the level of the contralateral point on the articulator (except in transographics) (Fig. 1). When anterior restorations are fabricated on the instrument or an occlusal plane is established, the bench top and the baseline of the restorations are made parallel. When the restorations are returned to the mouth, the plane will slope up toward the superiorly located axis. This problem can be solved by raising the base of the articulator to meet the most superior axis and allowing the anterior rod of the transfer bow to remain horizontal. This is often done in several face-bow transfer systems, but then the articulator is usually returned to its original position, defeating the purpose.

**Anteroposterior.** When the asymmetry is anteroposterior, i.e., when one point is further from the tragus than the other, then the casts are dislocated in the horizontal plane and the midline of the casts may be shifted in relationship to the face (Fig. 2). The midline is...
then shifted toward the most posterior axis in the sequence of patient-transfer-restoration-insertion. Complex variations result when both superoinferior and anteroposterior variations exist. The extent to which these deviations will affect esthetics is largely dependent on the degree to which the located axis points are asymmetrical. Usually, however, the cause for these distortions goes unnoticed, but recognition of the potential for alteration by the transfer of a kinematic axis is the first step toward correction of the problem.

Other considerations. In fixed prosthodontics, meticulous cusp placement is more important than in complete denture prosthodontics because the operator is dealing with a fixed base. This is not an attempt to justify a casual approach, but rather to consider the relative merits and comparative variables. The axis is important not only when changing vertical dimension but is also relevant whenever cusps have vertical height and the potential for clashing if not meticulously placed. Developing and adjusting an occlusion for a fixed partial denture with functionally integrated cusps on a firm base is considerably different from setting monoplane teeth to an area contact on a movable base.

RESEARCH ON COLINEAR-NONCOLINEAR CONCEPTS

The author and Dr. E. N. Kopp conducted experiments in 1968 on 22 patients in an attempt to resolve the colinear-noncolinear theories. A modified axis-locating mechanism had a head-cap holding four grids, similar to that of Aull, Lucia, and others, and a mandibular clutch with two long styli held in the center by a universal joint (Fig. 3). The styli varied from 2 to 16 inches, but the 12-inch styli were used most frequently. This modification of conventional equipment was designed on the hypothesis that if the styli could be made to rotate along their entire lengths without translation during retruded mandibular opening and closing, then the entire axis would be demonstrated on each side of the head, not merely at a point or two on that axis.

The long styli served to greatly magnify the translatory movement, since the distance from the side arm and universal joint offered a longer radius for movement. One investigator manipulated the mandible while the other adjusted the styli. When both investigators agreed that only rotation was present at both ends of both styli, the patient was photographed from anterior, posterior, and superior aspects. Frequently other observers were present to attest to the accuracy of the location.

The photographic transparencies were projected and traced. The styli images were measured to insure that no photographic distortion was present, and an assessment was made of the colinearity or noncolinearity of the styli in the two planes of each photograph. The colinearity of the contralateral styli was observed in only four of the 19
Fig. 4. A, A traditional axis-locating device. B, Schematic representation of (A) with ideal parallelism of anterior cross-rod transverse horizontal axis and an all-right-angle system. C, A diagrammatic representation of B. D, The “nonright-angle system” as traditionally conceived. Nonright angles of stylus to side arms are only hypothetical and not encountered in axis location devices. E, Typical clinical situation. Anterior cross-rod does not parallel axis, and axis is not parallel with frontal plane. F, Similar to E but with axis parallel to frontal plane and locator cemented asymmetrically. G, Only tips of styl have meaning. Configuration of mechanism joining clutch mechanism to the tip is irrelevant and contrary to transographic theory.
valid measurements. The question persisted, however, as to whether this demonstration of noncolinearity in most subjects would serve as a vindication of Page’s theories.

**DISCUSSION**

When theory and practice do not reinforce one another, the scientist is forced to either prove his theories, modify his practice, or establish a resolving concept. The project described above was initiated in an attempt to prove or disprove the noncolinearity theory. A simple consideration of the mechanics of hinge axis location indicates that neither our investigation nor others of a similar nature prove the existence of a single axis common to both condyles. In any system of kinematic axis location an essential prerequisite is the attachment of a clutch to the mandibular teeth. An anterior crossbar which holds the stylus is anchored to this clutch. These stylus can only locate the arc center of the rigid components of the combined mechanism, i.e., the crossbar, the clutch, and those teeth firmly grasped by the clutch. What is occurring at the condyle and the adjacent soft or hard tissues may or may not be in concert with the observations of the anterior components. Neither of these conclusions can be drawn that could infer that such an arc could have more than one center of rotation. If it is an arc, there is one arc center. If it is not a pure arc, then a moving center exists, and no “true” hinge axis can really be found. Sufficient evidence has been gathered to dispel any belief that the condyle follows solid-body mechanical principles. It is capable of displacements in three dimensions, and such displacements cannot be empirically discounted even during operator manipulation. The condyle is not a sphere contained within a controlling channel. Condyles are asymmetric bodies confined only to certain limits of questionable exactness by muscles and ligaments. The condyle act asymmetrically positioned in their relation to the cranium and to one another. The mandible functions as a unit in spite of these asymmetries, and the resulting movement may be or resemble an arc. The operator seeking an axis either can or cannot locate the arc center of the clutch (and the aforementioned arcs). There is no logical justification for feeling that one is locating any other point.

Page felt that he had found two arcs because two asymmetrically located points were found, and an engineering hypothesis states that a body can only rotate at right angles to its axis. This does not relate to hinge axis location. The axis locater is not an axle, a determiner of motion—it is a seeker of a center of motion. It does not matter if the points located are connected to the side arms by a right angle, any other angle, or a complex spiral, as long as that connection is rigid. Only the point of termination (the tip of the stylus) has validity, and it only has validity in relation to the overall apparatus and its movement.

The whole concept of the right angle–nonright angle system as it is traditionally spoken of and drawn does not even apply except in one instance (Fig. 4). All typical hinge axis–locating devices employ a right-angle system within the device itself. However, when that device is placed on the mandible with the clutch, then the right-angle system may be lost in relation to the axis, since there is little probability of placing the anterior crossbar parallel to an axis which is not yet located. The only locater system that does not consist of a series of right angles is that described by Gregory and associates and commercially available as the “Loma Linda Hinge Axis Locater.”

The location of medial and lateral points on either side of the head merely attests to the investigator’s ability to locate an apparent arc center on the same patient. It does not do anything to resolve the single or independent double condyle axis controversy. The author believes that the observations of Trapozzano and Lazarri may be attributed to the evasiveness of a single definite arc center when traditional axis location apparatus is used. Our research using 12-inch and 16-inch stylus (6-inch and 8-inch radii) showed how little is actually seen of the stylus tip translation during its nonarc movement. Short stylus arms and bluntness of the stylus detract from accuracy. To conclude, however, that two centers are possible with a single arc is to defy geometric laws and overlook the more tenable conclusions of inaccurate observation or absence of a true point center.

Most dentists with experience in hinge axis location admit that there are times when no hinge axis can be located. If there is myospasm or muscle or joint pathosis, then the mandible will act arc freely and preconditioning is needed. If the condyle is grossly asymmetric, it may not be capable of simple rotation but will act as a cam with a moving center of rotation. This
may well be the phenomenon observed when the stylus tip moves up and down and no rotation center can be found. If a camming can occur through interposed soft tissues, then either the mandible must flex to compensate the distortion or movement will occur in the frontal as well as the sagittal plane, i.e., there will be a lateral bodily shift. The fact that there are so many asymmetries involved and that the mechanisms of a rigid system do not strictly apply would seem to limit the potential accuracy of clinical hinge axis location to less than that experienced in experimental replication with precise mechanical systems.5-7

In the study by Hickey and associates,3 there was little difference when the condylar pin was inserted after a kinematic location and when the condyle was merely palpated. This study assumed that the entire sheath directing the pin into the condyle lay on the axis, when in fact only the medial tip located that axis. This problem was pointed out by Cohn21 in discussion of the work. Hickey22 in rebuttal noted that a rigid transfer bow was used after the kinematic bow had located the two axis points. He pointed out that when such a bow was used the entire axis was delineated, regardless of asymmetry. This is an interesting point, but it assumes one condyle axis. If an axis is an asymmetric colinear axis (Fig. 5) and if the mandible opens at right angles to this axis, then the subject must open by deviating from a strict vertical opening. It was upon this observation that Page9 based his concepts of accommodation to noncolinear axes and attributed the mandibular lateral side shift (Bennett movement) to this need to adjust to the misaligned axes.

Obviously, the location of a transverse horizontal axis has many complexities. The question has been raised whether the degree of absolute accuracy sometimes attested to is possible—in light of both research and clinical experience. There is also the question of what degree of accuracy is needed. Pragmatism would dictate that with each patient consideration must be given to procedures for that particular clinical practice. An error in axis location is worse in some directions than in others. Missing an axis in a superior-inferior direction will produce a greater error than missing it by the same amount in an anterior-posterior direction (Fig. 6). But if the axis is not located how can one be sure of in what direction the error occurs? The kinematic location of a transverse horizontal axis has definite merit, but the axis located may not be the one so frequently spoken of in writings on this subject.

**SUMMARY AND CONCLUSIONS**

1. Within the limits of accuracy imposed by individual operators, equipment, and patient variations, a single
transverse horizontal axis can usually appear to be located.

2. Location of a kinematic axis is a worthwhile clinical procedure to transfer an arc of rotation in the sagittal plane from the patient to an articulator.

3. Past experiments have been useful, but none have proved or disproved the presence of colinear or non-colinear condyle arcs. Only the arc of the rigid clutch and its associated mechanism is located. Such an apparent arc may result from the resolution of compound condylar movements.

4. The right angle–nonright angle concept is misleading and generally is not applicable to clinical procedures.

5. The anatomic asymmetries of the axis transfer procedure may result in cast dislocations that may produce undesirable alterations in esthetic tooth positions.

6. The single transverse horizontal axis exists as a fact in articulating instruments and as a theory in the human craniomandibular complex.

7. The terms “transverse horizontal mandibular axis” and “intercondylar axis” should not be confused or used as synonyms. The term “transverse horizontal mandibular axis” (“hinge axis”) should be used instead of “condylar” or “intercondylar” axis.

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