Gnathology and Pankey-Mann-Schuyler: fulfilling the requirements of occlusion in oral rehabilitation

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FINAL APPROVAL OF SCHOLARLY PROJECT
Master of Science in Biomedical Sciences
Concentration in Oral Biology

Gnathology and the Pankey-Mann-Schuyler Technique:
Satisfying the Requirements of Occlusion in Oral Rehabilitation

Submitted by

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In partial fulfillment of the requirements for the degree of
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Gnathology
and
Pankey-Mann-Schuyler
Fulfilling the Requirements of Occlusion
In Oral Rehabilitation

Master of Science
Scholarly Project

Gary M. DeWood, D.D.S.
Medical College of Ohio
2004
Dedication

This could not have happened without the assistance and support of many people:

Cheryl, who provided me with an example of perseverance in reaching for the stars and who loves me and cheers me on no matter what stars I reach for.

Patty, Dale, and Katie, who gave both Cher and I the freedom to “go for it” when it would have been easy to just want mom and dad to stay at home.

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Gary DeWood April 30, 2004
Abstract

The historical development of instrumentation in dentistry, of gnathology, and of the Pankey-Mann-Schuyler technique is presented followed by a literature review of the constant and variable concepts that must be addressed in oral rehabilitation. Gnathological methods for gathering that information from the patient, setting the articulator to recreate the patient’s movements with great accuracy, and then rehabilitating the occlusion is compared with the use of the Pankey-Mann-Schuyler technique to create the same end result, a fully functional stable occlusion. The two methods achieve similar results via different routes to that end.
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Gnathology and the Pankey-Mann-Schuyler-Technique

Fulfilling the Requirements of Occlusion in Oral Rehabilitation

A Historical Discussion and Review of the Literature

Restorative dentists have always sought to understand, capture, and recreate the movements of the mandible in an attempt to create a mechanical simulation of the patient upon which prostheses can be fabricated. Successful re-creation of each individual patient’s unique functional and non-functional movements would greatly improve the final prosthetic device when delivered to the patient. The reduced stress of a successful prosthetic experience where little adjustment is required in the mouth is evident in both the real and perceived success of the prosthesis. The search is on-going.

This review will discuss the history of the clinicians and researchers who never stopped asking how they could provide a better service to patients, the variable and constant factors that must be accounted for in any successful oral rehabilitation, the recording and transfer of these factors to appropriate instrumentation in the Gnathological and PMS methodology, and a review of instrumentation throughout the evolution of oral rehabilitation.
History

At the end of the nineteenth and beginning of the twentieth centuries the majority of creative dental thought among restorative dentists revolved around improving prosthetic function through better fitting and functioning dentures. Other than extraction, patients were more likely to experience this interaction with a dental profession than any other service. Dental problems were usually dealt with quickly and with seeming efficiency by removal of the offending tooth or teeth. People did not spend resources on preventing and treating dental disease because of the general belief that such action was doomed to eventual failure in any event, and extraction was kinder from a financial and pain-and-suffering point of view. This was a time in America when the doctor was an authority whose recommendations were generally unquestioned, leaving many young, healthy people to cope with all of the problems created when a removable, prosthetic device is asked to perform the functional and esthetic requirements of an important body part.

The goals of dental health, maximum comfort, function, and esthetics, remain constant regardless of any treatment completed or the methodology employed by the practitioner in completing that treatment. Throughout dentistry’s history various camps have grown up, matured, and in most cases disappeared, around the theories and techniques of creative individuals who sought the best way to insure that these goals were met in a repeatable and predictable manner. The earliest researchers in dentistry were innovators searching for a better way because they were clinicians first.

According to recorded data the first dental impressions were completed by Phillip Pfaff, court dentist to Frederick the Great. He used softened beeswax as a
bite and molding material to provide a relationship and model for prosthesis fabrication.¹ The first articulator was developed by a Frenchman named Garriot around 1800,² with patents awarded to James Cameron and Daniel Evans shortly after.³ In the middle of the eighteenth century W.G.A. Bonwill studied the relationship between the condyle centers and the mandibular incisors to create what became known as Bonwill’s Triangle, an equilateral triangle with an average side length of 10 cm. In 1858 he created an articulator using these guidelines that would provide balanced occlusion in forward and lateral movements.⁴,⁵,⁶ In 1896 Walker noted that dentures that had been properly set up on the Bonwill Articulator never fulfilled the requirements for balanced occlusion when seated in the patient, a discrepancy that apparently had gone unnoticed or unreported for many years.⁷

F.H. Balkwill, in 1886, demonstrated rotational movement of the mandible throughout the downward and forward thrusts as well as bodily movement of the condyles during lateral motions (later named for W.G. Bennett). He was also the first to describe the action of the canines in guiding the movements of the mandible.⁸ F.G. Von Spee theorized that the mandible moved along a path prescribed by the curves of the dental arches. He reduced the height of the canines in denture as well as natural teeth because they prevented posterior contact in excursive movement.⁹ The curve of the dental arches in an anterior – posterior direction was named for him, although his removal of natural canine height to achieve posterior contacts has survived only in denture occlusion. Around 1900 Christensen was working to account for gaps between wax rims that appeared when the patient moved the mandible from a closed bite position. He developed a method for intraoral registration which permitted adjustment of the condylar inclination to adjust the instrument for these gaps. The Christensen Effect was
named for the separation of posterior teeth caused by the slope of the articular eminence against which the condyle was moving downward as it moved forward.\textsuperscript{10, 11} It was slightly before this time that W.E. Walker had developed the first adjustable articulator. Condylar incline and lateral condylar movement could be set specifically for each patient.\textsuperscript{12}

It is interesting to note that most of the very early prosthodontic experiments did not include a connection between the position of the teeth in space and the hinge axis of the joints. Hayes had designed a method of orienting a maxillary cast to the joints in 1887, but it was not until B.B. Snow altered the \textit{facebow} in 1899 that it came into greater acceptance and use.\textsuperscript{13, 14} G.G. Campion recorded the movements of the mandible with a device connected to a tray cemented to the mandibular arch. His studies from 1902 through 1905 led to the conclusion that models should be mounted in an articulator so that the rotational axis coincides with the hinge axis of the patient because the mandible’s opening movements are comprised of two parts, rotation of the mandible through the condyles and a translational movement forward and downward.\textsuperscript{15} In 1903 J.B. Parfitt described three types of movement of the mandible, rotation around the hinge axis, translation forward and downward, and rotation around a vertical axis when the mandible is displaced laterally. He was the first to describe differences in the right and left condylar paths and grind these into articulator settings.\textsuperscript{16} W.G. Bennett, in 1907, reported the movement of the working side condyle laterally and downward and the movement of the balancing side condyle inward and upward. This movement, which was given his name, was described by Bennett without knowledge of the earlier work of Balkwill.\textsuperscript{17} In 1908, Gysi, a pioneer of prosthodontics, developed an adjustable articulator (\textit{The Adaptable}) with moveable condylar paths and incisal guides. He used a recording unit to capture the precise
course of the condyles and reproduced these mechanically on the articulator. He made use of the *Gothic Arch Tracing* first described by Balkwill in 1865 to set the maxillo-mandibular relationship in centric. Although this articulator represented a technological breakthrough it was a clinical failure because it was understood by very few dentists and used by even fewer.\textsuperscript{18,19} He followed the *Adaptable* with the *Simplex* articulator in 1912. With its fixed condylar path slope of 33° it found wider acceptance and use among dentists of the day.

In 1918, G.S. Monson described a sphere that passed through the joints and the occlusal surfaces of the teeth. His *Skull Cap* theory of occlusion used an average radius of 10 cm and predicted that both joints would be in geometric harmony.\textsuperscript{20} Although Wright demonstrated in 1927 that he had never seen geometric harmony between the right and left joints,\textsuperscript{21} Monson’s visualization of a sphere has been used by many dentists and technicians to understand and create the curves of Spee and Wilson in restorative treatment, and the radius he envisioned was used by Broderick in creating his device for evaluating these in diagnostic and treatment situations. By 1921 Gysi had calculated the slope of the occlusal facets of the premolars and molars geometrically starting with the shape of the gothic arch, the slope of the condylar paths, and the slope of the anterior teeth moving over each other. He recommended the use of a facebow when condylar path and anterior tooth guidance did not coincide. He was the first to record the Bennett (Balkwill) movements and the first to understand the importance of the anterior teeth as guiding elements for mandibular movement.\textsuperscript{22} In 1921 R.L. Hanau, an engineer, developed an articulator still used today, the Model H. In 1926 he established a quintet of factors that were interrelated in making a balanced occlusion possible, condylar path, incisal guide path, height of the cusps, slope of the cusps, and the occlusal curve. The *Articulation Quint* illustrated the
interdependence of these by illustrating the effect of changing any one of them on all of the others.\textsuperscript{23, 24, 25} In 1929 C.H. Schuyler stated that maximum intercuspation must occur in the retruded mandibular position (centric relation) under all circumstances.\textsuperscript{26, 27} As an eminent prosthodontist his publications regarding occlusion and anterior guidance had wide impact.

B.B. McCollum graduated from dental school in 1907 and into the quest to create the better denture. His interests led him to expand the quest to include natural dentitions. With Dr. Harvey Stallard he coined the word \textit{“Gnathology”} in 1926 to describe the study and treatment of the entire mouth as a functioning unit. With R. Harlan he developed a practical method for determination of the hinge axis and mandibular recordings based on the earlier work of Balkwill, Bennett, Campion, and others.\textsuperscript{28} \textit{“Pantographic”} tracings and data, collected through one of the descendents of McCollum and Harlan’s original device, remain the standard for recording mandibular movement for transfer to a fully adjustable articulator. With C.E. Stuart he created the first \textit{fully adjustable} articulator, the \textit{Gnathograph}. Several instruments have followed, some remain with us today. The \textit{Stuart} and the \textit{Denar D5A} are the two most frequently recognized in the United States.

\textit{A Gnathologic Society} was formed of interested researchers and practitioners. With McCollum’s guidance a \textit{gnathological concept} was developed that clearly stated the significance of occlusion for patients who are completely or partially edentulous as well as for the completely dentulous patient. The Gnathological Society developed parameters that must be recognized, captured, and understood. These parameters are dictated by several factors present in every patient, some variable and alterable by the restorative dentist, some fixed and constant for each individual and unalterable in oral rehabilitation.
Variable factors that can be dictated by the needs of restorative dentistry and esthetics include tooth shape and position (which incorporates compensating curves), vertical interarch dimension, anterior guidance, and the occlusal scheme. The Constant factors that must be accounted for are: the intercondylar distance, the hinge axis position, the condylar path as it moves in the glenoid fossa, and the relationship of the maxilla to the mandible. These represent individual characteristics that must be considered as they occur in the patient when planning an oral rehabilitation and completing treatment.\textsuperscript{29}

In 1933 F.S. Meyer described full denture construction using a generated path to create a fully balanced occlusion.\textsuperscript{30} It incorporated capture of the constant factors that affected function into a plaster path against which teeth could be set and ground in. Although the occlusal interaction was different in the dentate patient, Arvin Mann and L.D. Pankey realized that the creation of a static model of the dynamic movement of mandibular function created a matrix that could be used for designing any occlusion in fixed prosthodontics as well as removable. The Functionally Generated Path did not require the use of a pantographic tracing or a fully adjustable articulator. They developed the Pankey-Mann Technique of oral rehabilitation and tested the idea, asking a selected group of eleven dentists to work with it and give them feedback. Gratified by the results they were determined to share the technique with the profession.

Instrumental in the development of their technique (as well as the evolution of gnathology) was the occlusal concept of anterior guidance, first published in a short article by Clyde Schuyler in the 1926 edition of the New York Dental Journal. Mann and Pankey invited Dr. Schuyler to join them in their presentations to dentists. Dr. Schuyler, a prominent prosthodontist from New York City and one of the best known dentists in the country, declined.
After a short time teaching their new technique, Mann and Pankey realized that the concept of anterior guidance was not understood, in fact most dentists had never heard of it. “Occlusion” was not being taught in any dental school in the United States at that time. They returned to Dr. Schuyler and beseeched him to join them and share his work. Reluctantly at first, Dr. Schuyler eventually left clinical practice and devoted the remainder of his career to teaching the Pankey-Mann-Schuyler Technique in seminars held throughout the United States and around the world.31

An informal survey of dental laboratory technicians reveals that most dentists routinely utilize concepts and methods first developed through Gnathology in providing prosthetic services. An attempt is made to mimic the patient in varying degrees in the prosthetic fabrication process. Even in major cases of oral rehabilitation however, most do not utilize them fully. The Pankey-Mann-Schuyler Technique for oral rehabilitation, although it incorporates all of the concepts crystallized by Gnathology, is understood by very few dentists or dental laboratory technicians and utilized by still fewer.

For the adept restorative dentist a working knowledge of the PMS technique represents another tool for designing appropriate treatment outcomes in a truly individualized manner. For the master restorative dentist its study represents another tool in helping others study and understand occlusion and the factors that affect how our stomatognathic system works.
Constants

Patients present in our practices with functional determinants that are unchangeable by the restorative dentist as part of their present condition. These *constants* include intercondylar distance, hinge axis position, the relationship of the maxilla to the mandible in centric relation, and the path of the condyle-disk assembly in the glenoid fossae. These constants must be evaluated, recorded, and transferred to a patient simulation device accurately enough to permit diagnostic planning prior to treatment and the fabrication of dental restorations during treatment.

**Intercondylar Distance**

Some facebow systems make it is possible to determine the distance setting between the two condylar elements on a fully adjustable articulator and relate the position of the terminal hinge axis to the maxillary model.\(^{29}\)

Intercondylar distance affects the angle at which cusps move through grooves and across ridges. A change in intercondylar distance therefore causes changes in the ridge and groove positions in excursions. As intercondylar distance increases the grooves on mandibular molars move distally.\(^{32}\) A 5 mm change in the intercondylar distance setting causes a difference of 0.2 mm.\(^{33,34}\) (see figure 1)
All fully adjustable articulators permit the setting of intercondylar distance. The Whip-Mix articulator has a three position condylar element, permitting intercondylar distance settings of 100, 110, and 120mm. Most semi-adjustable articulators have a fixed intercondylar distance, usually 110 mm.

Even when utilizing a fully adjustable articulator the distance between the condylar elements represents an arbitrary representation of the distance between the hinge axis points of the condyles. This is caused by the inability to directly access these points. All systems assume a distance between the facial surfaces and the hinge axis points and build this assumption into the articulator. The facebow system used with the Pantograph (Denar Corporation) assumes this distance to be
12 mm, an assumption that may cause error. Because the changes caused by very slight differences in intercondylar distance are quite small there is minimal clinical significance. This illustrates clearly however why even restorative dental protheses accomplished with highly sophisticated equipment are almost always finalized in the patient.

**Facebow - Terminal Hinge Axis Position**

The transverse hinge axis is a line which passes through the centers of rotation in the condyles. The reference position of the condyles for recording this axis is centric relation and the line passing through them defines the *Terminal Hinge Axis*. Projection of this line to each side of the face indicates the axis points. A third reference point and the terminal hinge axis points define a reproducible plane to which the maxilla may be oriented on the articulator by a facebow.
Fig. 2 Gysi’s kinematic method to locate the terminal hinge axis (Clapp)

Fig. 3 Pantograph terminal hinge axis location (Lucia)
A *Kinematic Face-Bow*, such as those illustrated above, uses an extra-oral device to locate the axis points on the face. Sometimes these points are tattooed onto the patient. These devices are firmly attached in some manner to the teeth or the ridges and ride intra-orally against each other with a bearing point. An *Arbitrary Face-Bow* uses axis points located on the face through observation or feel or uses a positioning device that seats in the external auditory canal.
Fig. 5  The Denar Earbow Transfer Assembly (Dawson)

Fig. 6  The SAM Earbow Assembly (Great Lakes)
Purely rotational movements at the terminal hinge axis can be performed but it is not a movement that coincides with natural opening even in its initial phase. McCollum, Beyron, and Good found that axis points in the condyles identified by the terminal hinge position fell within the condyle but not in any regular relationship to any definite part of it. Posselt found that for hinge openings of up to 20 mm the actual terminal hinge axis makes only very minor shifts throughout the movement. He concluded that a kinematic facebow recording, while not exactly precise, can be regarded to simulate the terminal hinge axis on the articulator. Lauritzen and Wolford showed that clinicians can repeatedly
locate the terminal hinge axis within 0.2 mm.\textsuperscript{40} Schallhorn studied arbitrary axis recording and found the terminal hinge axis as arbitrarily recorded within 5 mm of the kinematic axis in 98\% of a patient population.\textsuperscript{41} Teteruck and Lundeen compared the accuracy of an earbow with an arbitrary hinge axis and kinematic hinge axis location and found that 33\% of the arbitrary hinge axis positions were within 6 mm of the kinematic axis and 56\% of earbow located hinge axis positions were within 6 mm of the kinematic axis.\textsuperscript{42} Zuckerman analyzed the significance of errors caused by differences in location of the hinge axis. He reported the following: 1.) An error that places the hinge axis location superior or inferior to its actual position produces errors of greater magnitude than equivalent errors in a posterior or anterior position; 2.) When the hinge axis location is in error superiorly, the mandibular teeth will return to the vertical dimension of occlusion on the articulator in an anteriorly displaced position; 3.) When the hinge axis location is in error inferiorly, the mandibular teeth will return to the vertical dimension of occlusion on the articulator in a posteriorly displaced position; 4.) The magnitude of the occlusal error is directly proportional to the magnitude of error in locating the hinge axis; 5.) The magnitude of the occlusal error produced increases as the vertical dimension at which the interarch relation is recorded increases; 6.) The magnitude of the occlusal error produced decreases as the distance between the terminal hinge axis and the occlusal elements increases; 7.)
The position of the occlusal plane relative to the terminal hinge axis modifies the magnitude of the occlusal error – occlusal errors in the anterior direction are enlarged while occlusal errors in the posterior direction are diminished.\textsuperscript{43} An error in position of 2 mm has been shown to create measureable effects on the relationships in the set up of teeth in both maxilla and mandible.\textsuperscript{44} It is clear that an arbitrary hinge axis location and an earbow hinge axis location increase the potential for error to be introduced. It is also clear that the significance of this error to the restorative dentist will be greatly affected by the skill of the practitioner, and can be clinically insignificant with an adept operator. While the terminal hinge axis location with a kinematic face-bow presents the smallest opportunity for error to be introduced, it must be remembered that it is still an arbitrary measurement due to the assumption made in transferring the true hinge axis points within the condyle to the accepted hinge axis points on the face.

\textbf{Interarch Records}

Interarch records relate the mandible to the maxilla in their changing relationship to each other as movement occurs. The records obtained are usually divided into two types, a \textit{centric relation} record and a \textit{condylar guidance} record. Lucia defined the centric relation record as capturing the relationship of the arches when the condyle is at the terminal hinge axis position as described above (the
center of vertical rotation) and is coincident with the lateral hinge axis position (the center of lateral rotation of the working side condyle). The condylar guidance record captures the relationship of the arches throughout the range of mandibular movement or at static points in the envelope of motion. Condylar guidance records are used to create a simulation of the pathways traveled by the condyles in function so that diagnostic and treatment decisions can be made on the articulator.

**Interarch Records – Terminal Hinge Axis**

The terminal hinge axis is considered by most authors to occur at Centric Relation. Comparing and contrasting Gnathological techniques with those of the Pankey-Mann-Schuyler technique and the functionally generated path reveals little disagreement in this position. The entry into the literature of the myocentric position has added a new controversy. Strohaver showed that recordings of neuromuscular centric position were more variable than recordings obtained by clinician positioning at the terminal hinge axis. Jankelson showed that recordings obtained by clinician positioning involved retrusive force that caused more variability in the interarch recordings of centric relation than in recordings using a myo-monitor and recording neuromuscular centric position. The controversy continues. For the purpose of this review the neuromuscular centric position is
considered as a static relationship at some point in the Condylar pathways because it occurs at a point other than terminal and lateral hinge axis position. The Gnathological definition of centric relation as occurring at the terminal and lateral hinge axis is consistent in both methods of oral rehabilitation being considered. However defined, the position must be consistent and reproducible as a minimum requirement. Because the centric relation record provides the relationship of the maxilla to the mandible at the point of rotation around the terminal hinge axis, it is possible to mount the mandibular cast at an open vertical dimension and occlude the casts on the hinge axis. Theoretically, the vertical dimension is irrelevant since any movement is around a circle with the hinge axis as its center. In reality, the arbitrary nature of the location of the hinge axis points as previously noted means that the smaller the vertical dimension at which the record is gathered the smaller the error in the relationship between the two casts when they are occluded on the articulator. The centric relation record is registered by placing a recording material between the arches. Numerous studies have illustrated the reproducibility of the centric relation position when recorded by an adept operator.
Fig. 8 Chin Point Guidance into Wax Wafer Bite (Bauer)

Fig. 9 Lauritzen Centric Bite  Notice Chin Guidance  (Bauer)
Interarch Records – Condylar Pathways

The Pantographic Tracing

Purely rotational movement around the terminal hinge axis creates a point of intersection of three spatial planes, sagittal, coronal (frontal), and horizontal. While it is doubtful that the three intersect at a common point in the living condyle, they always intersect at such a point in an articulator. This point is defined by locking the device in centric relation. Because condylar pathways involve translatory movement, where each point in the mandible moves within a given plane, lines of movement are created in that plane. In translatory movement the
distance any one point in the mandible moves relative to any other point is one to one. In rotary movement the distance any one point in the mandible moves relative to another point is directly proportional to their distances from the center of rotation. Because the temporomandibular joint is ginglymoarthroidal, rotation is possible at any point in the translatory movement within any plane. In fact the mandible rotates and translates in all of the planes simultaneously in function. In this regard it is unique among joints in the human body.

Fig. 12 3 Planes of Mandibular Movement (Guichet)
Fig. 13  Axes of Rotation in the Condyle  (Bauer)
Each Condyle has a Vertical and Sagittal Axis, they share a Horizontal Axis

Fig. 14  A) Movement of entire body of mandible  B) Movement around an Axis of Rotation  
C) Relative Movement in Translation and Rotation  (Guichet)
Recording methods have been created and advocated to form,\textsuperscript{54} mill,\textsuperscript{55} or adjust\textsuperscript{56} condylar control mechanisms of articulators in an attempt to precisely simulate the function of the temporomandibular joint. Posselt (and many others) showed that border movements of the mandible are reproducible and that all other movements take place within the framework of the border movements.\textsuperscript{57} As noted previously, in function the mandible rotates and translates in all of the planes simultaneously.

Border movements in the sagittal plane include rotation around the terminal hinge axis (Fig. 15 \textbf{CR} to \textbf{B} around axis point \textbf{C}). This is the \textit{centric relation} described previously. With wider opening of the mouth rotation continues around axis point \textbf{C} but a new rotational movement occurs around an axis in the body of the mandible bringing the condyle forward and the chin down and back (Fig. 15 \textbf{B} to \textbf{E} around axis point \textbf{D}). The movement to \textbf{E} brings the condyle as far forward as it is possible for it to move, rotation around axis point \textbf{C} establishes the anterior border of movement (Fig. 15 \textbf{E} to \textbf{F}). The final border of movement in the sagittal plane is established by teeth when they are present (Fig. 15 \textbf{F} to \textbf{CR}). The point \textbf{CO} is noted because most individuals present with a \textit{slide} from \textit{centric relation} (determined by the terminal hinge axis) and \textit{centric occlusion} (determined by maximum intercuspation of teeth). The presence of a slide averaging 1mm or less in the majority of individuals was noted as long ago as 1918 by Harris.\textsuperscript{58} A part of
the movement from F to CO and all of the movement from CO to CR is determined by the movement of teeth against teeth when they are present. In edentulous patients the movement from F to CR will be an uninterrupted movement because CO is not present.

Fig. 15 Movement in the sagittal plane. (Ramjford & Ash)

Point R illustrates rest position. While not a border movement it is illustrated because CO to E is the virtual border movement under normal circumstances. Rarely do individuals go into protrusion except in para-function.
One can trace border movement in the horizontal plane similarly to recordings in the sagittal plane. The dark area noted as MR$_2$ represents the approximate regions of function in the latter stages of mastication. The area noted MR$_1$, with IEC (Incisal Edge Contact) point at its anterior border, represents the approximate region of function during earlier stages of mastication.

![Diagram](image)

Fig. 16 Movement in the Horizontal Plane (Ramjford & Ash)

A tracing of border movements in the frontal plane will vary greatly depending on occlusal contacts because when teeth are present half of the border will be defined by teeth against teeth.$^{59}$ Lateral masticatory function and bruxism patterns are recorded more meaningfully however in the frontal plane. Uninhibited
masticatory movements produce a uniform, wide oval form. The mean contact range from first contact to intercuspation is 2.8 mm at the incisors.\textsuperscript{60} (Fig. 17). While the opening stroke varies in all subjects, in persons with unrestricted freedom of occlusal contact the most common path seen is a smooth, uncrossed path of movement that returns very closely to the same closed position for every chewing stroke.

![Diagram of chewing movement](image)

Fig. 17 Right Side Chewing Functional movement in the Frontal Plane (ML is the midline) (Ramjford & Ash)

The pantograph provides a guide for adjusting settings on the articulator to simulate the border movements of an individual patient. The shape of the glenoid fossa, the condyle, and the path taken as they move against each other determine all border movements not created by teeth against teeth. When recording this data with the pantograph teeth are removed from consideration by means of a central bearing point upon which the patient may move freely in any and all directions permitted by their individual anatomy.
*Bennett Movement*, or immediate lateral shifting of the condyle, has been controversial since it was first reported by Balkwill in 1886, and then Bennett in 1907. Dawson has attributed the tracings that show immediate side shift as artifacts due to the change in distance between the stylus and the tracing plates on the side of the orbiting condyle.

Fig. 18  A & B  Stylus movement creating immediate side-shift *artifact* (Dawson)

Whether or not a clinician agrees with Dawson or with Balkwill, Bennett, McCollum and Stuart regarding immediate side shift, all agree that *progressive*
side shift not only occurs, but will cause differences in the design of restorative prostheses.\textsuperscript{3,17,28,61} The clinical significance of variations in the glenoid fossa and condyle lies in the determination of unique pathways of the condyles in function causing differences in the direction and position of grooves and ridges and in the height of cusps.

The medial wall, the posterior wall, and the lateral lip of the fossa affect occlusal morphology in the horizontal plane. The effect from the medial aspect functioning against the orbiting (balancing) condyle on occlusal morphology is illustrated in figure 19. As side shift increases ridges and grooves must be placed to the mesial on mandibular teeth, to the distal on maxillary teeth. The lingual concavity of maxillary anterior teeth increases.
Fig. 19 Effect of side shift from medial aspect of fossa on occlusal morphology of maxillary teeth (Ramjford & Ash)

The effect from the posterior aspect and lateral lip of the fossa functioning against the rotating (working) condyle is illustrated in figure 20. When the rotating condyle moves to a lateral and retrusive position (LR), the ridges and grooves must be placed more to the mesial on mandibular teeth, to the distal on maxillary teeth when compared to straight lateral (SL) and lateral and protrusive (LP) movements.
The superior wall of the fossa and the amount of immediate side shift affect cusp morphology and height and groove depth in the vertical plane.

Figure 21 illustrates the effect as the rotating (working) condyle functions against the superior contour of the fossa. The clearance available for the passing cusp will vary depending on the condylar movement laterally. A movement in the
lateral and superior (LS) direction reduces available space when compared to a straight lateral (SL) or lateral and inferior (LI) movement.

Side shift effects on cusp morphology and height and groove depth are illustrated in figure 22. As the immediate shift increases the cusps and grooves become flatter.
Orbiting (Balancing)  

Rotating (Working)

Fig. 22 Effect of side shift on morphology and height of cusps and depth of grooves. (Ramjford & Ash)

The Pantographic Tracing

Fig. 23 Pantograph fitted to patient and recording movements (Denar)
The pantograph captures condylar pathways via tracings (lines) that illustrate the path the mandible travels. The lines are mirror images of the actual movement because the tracing tables move with the mandible against the styli which are fixed onto the maxillary member.

Fig. 24 A protrusive movement illustrating marks scribed by styli as *mandible* moves (Dawson)
The tracings above on the horizontal recording plane illustrate:

- $C' - P'$ Centric relation to full protrusive path
- $C' - O'$ Centric relation to full orbiting (balancing) path
- $C' - R'$ Centric relation to full rotating (working) path
The tracing above illustrates the *shift* of the mandible to the right as the lateral path is traversed. The C’ to S’ line scribed on the right side illustrates the path of the rotating (working) condyle from centric relation directly to the right in *sideshift* along the C’ – R’ path. The C’ to S’ line scribed on the left side illustrates the path of the orbiting (balancing) condyle to the right in *immediate sideshift* along the C’ – O’ path. As noted above, Dawson has concluded that this traced line is due to the downward movement of the tracing table while the stylus maintains contact. Figure 28 illustrates recordings of the
C’ – O’ path with variations in the C’ – S’ portion of the tracing. Figure 29 illustrates a frontal view of the mandibular movement that accounts for these tracings.

![Diagram showing variations in sideshift pathways](image)

Fig. 28 Variations in sideshift pathways (Guichet)
Fig. 29  Sideshift to the right viewed in the frontal plane (Guichet)
Fig 30 Anterior tracing tables. Mandibular movement to the left is shaded to show pathways (Guichet)

The anterior tracing tables track the movement of the mandible in the horizontal plane.

Movements in the sagittal plane are recorded by tracing tables aligned vertically at the posterior of the pantograph.
Extraoral tracing of condylar movements permit transfer of these pathways to a fully adjustable articulator and may, in some applications permit transfer of some of the information to a semi-adjustable articulator. When utilizing semi-adjustable articulation however the most common method for collecting the pathway information is the use of interocclusal lateral and protrusive checkbites. These relate the upper to lower dentition at a point in the envelope of function that permits the adjustment of condylar inclination and in some cases the progressive side shift. Intraoral registrations have been subject to criticisms regarding accuracy because of the dimensional instability of registration materials.\textsuperscript{62,63} Millstein, in several studies, illustrated that accuracy can be greatly influenced by the type of material used in the interocclusal record. Metalized laminated wax wafers demonstrated significantly less distortion than other waxes.\textsuperscript{64,65,66} Curtis compared the information regarding condylar pathways collected with a pantographic tracing with both protrusive
interocclusal records and lateral interocclusal records using laminated wax and polyvinyl siloxane (Regisil). He found that the protrusive condylar inclination recorded in wax was less than that recorded by a pantograph. The inclination recorded with polyvinyl siloxane displayed no statistically significant difference. Lateral records displayed a difference only if the sideshift was induced. If the sideshift was guided there was no difference in pantographically produced pathways and laminated wax records or polyvinyl records.

**Transferring Constants to the Articulator**

**Fully Adjustable Articulators**

The positioning of the condylar elements to establish intercondylar distance is arbitrary. As noted above, an assumption regarding the distance from the skin surface to the condyle is made permitting adjustment of the condyle elements when the hinge axis locator or the facebow is attached to the articulator. Finer adjustment is achieved when the pantograph tracing is followed and all elements are adjusted to fit the pathway.

The facebow, determined by location of the terminal hinge axis, is used to relate the upper cast to the articulator.
Because this facebow represents a true hinge axis location determined by a kinematic facebow recording the axes on the patient and on the articulator are identical.

The lower cast is attached using the interarch record. The casts are marked at the gingival margin of two anterior opposing teeth, hand articulated, and the distance between these marks is measured. The interarch record is then insinuated between the casts and the distance measured again. The difference between these is the distance that the pin will be opened to allow Maximum Intercuspal Position to occur near zero on the pin. This adjustment serves to keep any changes made to the vertical interarch relationship within the working limits of the articulator. It is important to firmly attach the casts to each other.
so that the record is intimately contacting them throughout application and set of mounting stone.

Fig 33  Positioning the lower cast with an interarch record  (Bauer)

Fig 34  Attaching the lower cast the articulator (Bauer)

Both pantographic tracings and protrusive and/or lateral checkbites may be used to set up condylar pathways on a fully adjustable articulator. Using checkbites to adjust a fully adjustable articulator would utilize only a portion of the adjustability however and would result in the utilization of the instrument as
a *semi*-adjustable articulator. For the purpose of this discussion we will assume use of a fully adjustable articulator implies use of a pantographic tracing to set constants.

Fig. 35 Connecting the pantograph to the Denar D5A (Denar)

The transfer of mechanical pantographic tracing information is accomplished by attaching the device to the articulator and adjusting the settings to match the movements recreated by the tracings.
By tracking the articulator through the pathways created by the pantographic tracing the fully adjustable elements of the articulator are made to mimic the patient’s anatomy and thereby the patient’s movements. To accurately approximate all movements the condylar elements are ground to the curved shapes required to track the pathways. These elements become specific to the patient recorded. The settings are recorded and archived with the patient record so that adjustment of the articulator to a specific patient’s recordings can be accomplished quickly and accurately even if the articulator is utilized for multiple cases simultaneously.
Semi-Adjustable Articulators

Intercondylar distance is pre-set on all semi-adjustable articulators. All but one are set at 110 millimeters. As noted earlier, the Whip Mix has three settings, 100, 110, and 120 millimeters.
The facebow utilized with a semi-adjustable articulator in almost all cases is an earbow. The attachment of the upper cast to the articulator and the relating of the lower cast through the use of the interarch record are identical to the methods employed with a fully adjustable articulator.

Setting the condylar pathways with a semi-adjustable articulator is accomplished through the use of checkbites. While the pantograph provides an actual pathway that the mandible, and hence the articulator, is moved through, checkbites provide the position of the mandible at some point in the patient’s envelope of function. The articulator is adjusted to mimic the functional relationship at this static point. As noted earlier, a protrusive checkbite and/or lateral checkbites are the information recorded. Either may be utilized in recording condylar inclination relative to the occlusal plane; lateral checkbites may also be utilized to adjust progressive side-shift on semi-adjustable articulators equipped with adjustable medial wall components.
After the articulator is set to mimic the constants dictated by the patient the restorative dentist is prepared to create variables on the instrument that may be transferred to the provisionals and ultimately to the final restorations.
Mounted Study Casts

After the constants have been applied to the articulator a thorough evaluation of the mounted casts is completed. This process permits the visualization of potential changes of the existing variable determinants that may be required to accomplish stable rehabilitation of the occlusion.

Variables

It’s fortunate that the restorative dentist is not forced to deal only with the constants that the patient presents with in planning and completing oral rehabilitation. The ability to change specific aspects of tooth form and position as well as the interarch dimension at tooth contact (vertical dimension of occlusion) permits the establishment of anterior guidance and an occlusal scheme appropriate to each individual patient. Coordinating these variables with the patient’s intercondylar distance, terminal hinge axis, centric relation arc of closure, and envelope of function permits re-creation of the form present prior to tooth breakdown and the creation or re-creation of appropriate function. It may also permit creation of new tooth positions and/or an altered vertical dimension of occlusion from that presented at initial evaluation. A pre-determination of the
variables will be completed on the articulator as a *mock-up* and then tested in the patient through the use of provisional restorations. The accuracy of the mock-up is dependent on accurate transfer of the constants to the articulator and on observations and notes made in examination and evaluation with the patient. It is the ability to capture and use the constants that makes it possible to mock-up anticipated changes to the variables. It is the ability to alter the variables that makes it possible to *restore* a patient, but alteration of any variable is only possible within the functional possibilities of the constants for each patient.

**Tooth Form and Position**

Much has been written in the prosthodontic literature regarding positioning of the anterior teeth.⁶⁹,⁷⁰ Pound espoused esthetic positioning of the maxillary anterior teeth and positioning of the mandibular anteriors through observation in function (speech).⁷¹ Because the placement of these teeth is based on functional approximation of the facial-incisal angle of the mandibular incisors with the lingual surface or incisal edge of the maxillary central incisors the variations in freeway space and in envelope of function are accounted for. While the placement of teeth in full denture prosthodontics may permit greater freedom in determining their exact position, the methods of evaluation are extremely useful to the restorative dentist in fixed partial denture and full coverage cases of the anterior teeth. These evaluations are made utilizing provisional restorations. The form of
anterior teeth, primarily considered an esthetic selection when viewed from the facial, nonetheless represents the functional movement of the mandible as traced by the mandibular anterior teeth when viewed from the lingual. It is the position and contour of the lingual surface of the maxillary anterior teeth, in conjunction with the position of the mandibular anterior teeth that determines guidance and functional movements in most patients.

Posterior tooth position may be altered through orthognathics, orthodontics, or restorative procedures. The position selected for the functional surfaces will create the first determinant of posterior tooth form. The final form taken is determined by this position, intercondylar distance, terminal hinge axis, centric relation, condylar pathways, and the anterior guidance.

**Vertical Dimension of Occlusion**

The glossary of prosthodontic terms defines *vertical dimension* as *the distance measured between two points when the occluding members are in contact* and as *the length of the face as determined by the amount of separation of the jaws*. The theories and techniques regarding the appropriate location of this dimension have been historically within the realm of removable prosthodontics as applied to full denture design and orthodontics as applied to mandibular position.

The use of swallowing to determine the vertical dimension of occlusion was a technique used for many years. In 1968 Ismail made comparisons between pre-
extraction vertical dimension of occlusion and that established in the subsequent full dentures showing an average 3mm increase.\textsuperscript{72}

Earl Pound’s technique utilizing the closest speaking space\textsuperscript{73} in determining vertical dimension is extremely useful in creating dentures that function beautifully in speech, but fails to account for the fact that denture patients with reductions in vertical dimension of up to 10mm through wear of the teeth are still able to say “Mississippi” with their existing prosthesis. If the closest speaking space was precisely related to the physiologic vertical dimension of occlusion these patients would not be able to make the “s” sound because their teeth would be more than 12mm apart.\textsuperscript{74}

The use of the physiologic rest position has been utilized by some practitioners and researchers in inferring the vertical dimension of occlusion. Physiologic Rest Position, or the \textit{Vertical Dimension of Rest}, is defined by minimal activity of the muscles of mastication. Prior to the availability of EMG devices the position of the vertical dimension of rest was located clinically by directing the patient through swallowing, lip closure techniques, and observation. Research has shown however that vertical dimension of rest is highly variable and influenced by airway posture, emotional factors, and even a 10-degree difference in head posture.\textsuperscript{75,76} The relationship of the vertical dimension of occlusion of the teeth as
it relates to the vertical dimension of rest has never been established other than the fact that it is always less.

Maximum bite force as measured by EMG has also been shown to be unreliable in determining the vertical dimension of occlusion. Manns, Mirales, and Palazzi have shown that maximum bite forces as determined by the optimal working length of a muscle at the most efficient electromyographic activity are 10 to 21mm beyond existing vertical dimension of occlusion.\(^{77}\)

Swallowing, speech, vertical dimension of rest, and maximum bite force can not be considered reliable determinants of a precise and appropriate vertical dimension of occlusion.

Tallgren reported in long-term follow-ups that severe wear did, in fact, result in a loss of facial height and that the rate of the wear influenced this loss.\(^{78}\) Changes to the vertical dimension of occlusion are not only tolerated by the body, they are a natural outcome of function. Several studies have shown stable adaptation following alterations to the Vertical Dimension of Occlusion.\(^{79-81}\)

If Vertical Dimension of Occlusion is to be changed it would seem that there is a lack of precise guidance regarding where it belongs. Restorative procedures provide the practitioner with a method of evaluating alterations to the vertical dimension of occlusion through the use of provisional restorations. The unreliable nature of techniques to locate it notwithstanding, subjective feedback from the
patient and observation of the provisional restoration will reveal the probable
stability of the vertical dimension of occlusion in the final restorative result. The
variability of the response to changes in the vertical dimension of occlusion has
been demonstrated to be more related to the manner in which it is achieved rather
than the magnitude of the change. The fact that it *can* be changed in many cases
yields a tool for consideration in oral rehabilitation.

**Anterior Guidance**

As noted above, anterior guidance determines the form and position of the
teeth at whatever vertical dimension of occlusion is selected as the treatment
position for oral rehabilitation.

In complete dentures the six maxillary anterior teeth seldom make contact
with the six mandibular anterior teeth because this contact is not necessary for the
most favorable distribution of stress over the maximum denture load bearing area.
Contact of these teeth in the natural dentition is not only most common, it is
essential for the most favorable distribution of forces over the maximum number of
teeth.

Posterior teeth in complete dentures always contact throughout the range of
eccentric movements, lateral and protrusive, bilaterally. This *balancing* contact
through the functional range provides for the most favorable distribution of stress
throughout the bearing areas. In the natural dentition, contacts on the orbiting
(balancing) side seem to be non-essential. When excessive they have been included as possible causative agents in hyperactivity of muscle, loss of alveolar bone, and tooth fracture.\textsuperscript{28,29,32,36,45}

Moved by the muscles of mastication, the temporomandibular joint controls the movement of the mandible until teeth make contact, at which time the guiding inclinations of the teeth take a predominant role. Coordination of the natural dentition is accomplished through coordination of the inclines of posterior teeth with the two guiding factors, the anterior guidance and the unstrained movement of the condyles in the glenoid fossa.\textsuperscript{83}

Functional contact of all teeth throughout the range of movement constitutes anterior guidance provided by group function. In a fully balanced case the teeth remain in contact for their entire length from maximum intercuspation onto and past the opposing cusp tips. Figures 42 through 44 illustrate the contacts in a fully balanced group function case at centric relation and at the extreme working and balancing positions.
Bilateral contact of all opposing surfaces through the range of their opposition presents a picture of well supported dentition, functioning and wearing evenly. Ancient skulls often illustrate this functional pattern. A course diet absent sucrose and absent man-made materials to repair teeth create a situation in which wear can occur evenly and bilaterally. The combination of the anterior guidance
and the condylar pathway *functionally generate* a pattern of wear in the teeth that is in harmony with the anatomy of the lingual surfaces of anterior teeth and the glenoid fossa.

The concept of a mutually protected occlusion with anterior guidance on canines was first introduced by Clyde Schuyler. Williamson was the first to determine experimentally that muscles of mastication activate when posterior teeth are in contact and partially shut down when posterior teeth are not in contact. This finding has been confirmed by several other investigators including Risse and Hannam. The implication of this finding confirmed what Schuyler had observed and inferred. The lateral forces applied to posterior teeth can contribute to the loss of alveolar bone, hyperactivity of muscle, and temporomandibular joint pathology due at least partly to increased muscle activity. This data seems to conflict with the historical finding of group function as a stable, perhaps normal, arrangement for human occlusion until one considers that modern man’s teeth are rarely permitted to wear naturally. In oral rehabilitation the *created* occlusion must be designed to optimally distribute stresses over teeth while taking into consideration two or more different materials that act upon each other at the occlusal interface. If full balanced occlusion, with equal intensity centric relation stops and equal intensity contacts along all functional pathways is created in materials with equal wear characteristics the stability of the system would be
maintained. In reality this result is rarely possible and variable forces are applied
to teeth throughout the functional movement with the expected consequences to
those upon which the highest forces are applied and subsequently to the system as
a whole. Mutually Protected occlusion provides for centric relation stops of equal
intensity on posterior teeth with eccentric contact beginning on the most anterior
teeth in contact at centric relation and transitioning as quickly as possible to the
most anterior teeth possible.

The shape of a tooth involved in anterior guidance must therefore provide
for freedom from posterior tooth contact on both orbiting and working inclines
during functional movement. Figures 45 and 46 illustrate the contacts at the
extreme position in a left lateral excursive movement. No posterior teeth contact at
any point in the movement from centric relation to this position. Figures 47 and 48
show the contacts in a protrusive movement.
Fig. 45 Contacts in Extreme Left Lateral in a Mutually Protected Occlusion (Lucia)

Fig. 46 lateral Views – note NO Posterior Teeth are in Contact (Lucia)
Figure 49 illustrates the effect of the inclination of the anterior guidance teeth on posterior tooth form when the condylar inclination is not different. “A” illustrates the path against the anterior guidance and the subsequent posterior tooth form “B” created by that path. A shallower path of travel against the anterior guidance “C” creates a tooth form “D” correspondingly less steeply inclined.
If nature fails to provide this precise relationship between tooth form, condylar pathways, and anterior guidance through growth and development, it may provide it through a *functionally generated* pattern of wear that creates this precise relationship.  

**Transferring Variables to the Articulator**

Both the Gnathological and the Pankey-Mann-Schuyler rehabilitation techniques employ the use of a diagnostic work-up to apply any changes to the
variables determined necessary through the study of the mounted casts. The changes may be accomplished through:

1. **Removal** (Equilibration)

2. **Addition** (Restoration)

3. **Repositioning** (Orthodontics)

4. **Repositioning** (Orthognathics)

For purposes of discussion regarding rehabilitation we assume that the teeth are in an acceptable position without utilizing orthodontics or orthognathics.

The diagnostic work-up may be completed using wax or composite. The casts may be prepared prior to application of these materials or it may be applied directly to the unaltered cast. The changes thus made are based on clinical observation, discussion with the patient regarding esthetic changes desired, and the evaluation of the casts prior to alteration. Figures 50 and 51 illustrate a case work-up in which the anterior teeth have been adjusted through the use of equilibration and the posterior teeth through restoration.
The work-up represents the three dimensional application of the changes to the variables as determined by the constants previously set on the articulator. Having completed the case on the articulator the restorative dentist is prepared to move to the mouth. Whether Gnathology or the Pankey-Mann-Schuyler techniques are employed this first completion of the case provides the blue-print for all subsequent actions. Gnathological techniques dictate setting up
the articulator and duplicating these settings in the mouth, the Pankey-Mann-
Schuyler techniques involve working with the provisionals to provide on *on-going*
blue print for variables.\textsuperscript{44,45,84,89}
Rehabilitation

“We start our treatment with beautifully carved occlusal surfaces and how do we end? We grind until most of those beautifully carved cusps are cut away.” These words, spoken almost seventy years ago, are still the usual routine in many dental oral rehabilitation cases. Frederick S. Meyer, an engineer as well as a dentist, brought his understanding of mechanical properties to prosthetic dentistry, which he said called for “….some of the most difficult and fundamental principles of engineering”. The pioneers in Gnathology and Drs. Pankey and Mann developed their techniques to apply these engineering principles to reconstructive dentistry in a reliably repeatable manner. When followed, these techniques create restorations requiring minimal adjustment when seated. Both fulfill the requirements of oral rehabilitation although they do so through different mechanisms.

This section will follow step-by-step the procedures of oral rehabilitation with Gnathological and Pankey-Mann-Schuyler techniques, stressing the differences and the similarities of the two processes after the constants and variables have been determined in the work-up.

Provisionalization

Equilibration may be completed prior to or as part of the provisionalization process. Preparation of the teeth to be restored is accomplished and impressions
are obtained for indirect fabrication of acrylic provisionals. Depending on the amount of time the provisionals will be utilized and the variables to be altered, the decision on whether or not to complete cast provisionals must be considered.\textsuperscript{44,91}

When utilized, the Gnathological technique for refining the form and occlusion on the cast provisionals mandates remounting on the articulator so that original settings as determined by the pantograph are adhered to. The extraoral adjustment protocol for the Gnathological technique is identical for the final castings and for provisional castings when they are utilized. When acrylic provisionals are employed in the Pankey-Mann-Schuyler technique, as they usually are, they are adjusted intraorally. Introral adjustment of acrylic provisionals is not part of the rehabilitation process with the Gnathological technique. When acrylic is utilized the rehabilitation proceeds directly to the final castings. In the Pankey-Mann-Schuyler technique these adjustments of the provisional restorations become integral to the determination of the variables.
The planning and finalization of the oral rehabilitation with the Pankey-Mann-Schuyler technique involves a segmental approach. Lower anterior, upper anterior, lower posterior, and upper posterior teeth are evaluated, planned out with a wax-up, and restored in sequence. As adjustment of the provisional restorations is completed to function harmoniously with the patient’s envelope of function the tooth form and position, the vertical dimension of occlusion, and the anterior guidance are created in the acrylic. Once stable, these variables are captured and transferred to the articulator via an impression and cast of the provisional restorations.

The cast of the upper provisional restorations is transferred to the articulator with a facebow, the lower is articulated with a very thin interocclusal record or is hand articulated and mounted to the lower member. A guide table is created which incorporates the movement of the lower anterior teeth against the upper anterior
teeth. With the position and shape of the mandibular incisal edge thus established the maxillary anterior restorations can be completed using the movement of the mandibular anteriors as directed by the guide table and therefore dictating the shape of the maxillary anterior lingual surface.

Fig 53 Guide table created from mounted casts of provisional restorations  (Mintzer)

The anterior restorations completed with the Pankey-Mann-Schuyler technique are based directly on the guidelines established in the provisional restorations. Gnathologically restored anterior teeth are completed simultaneously with posterior teeth and based on the settings created from the recordings of the
pantograph. Condylar inclination and anterior guidance are *matched* to create an identical anterior and posterior guidance angle.

The final impressions for the Gnathologically completed oral rehabilitation are completed for all teeth to be restored. The final die casts are mounted using a new facebow and articulated with an interocclusal record at the vertical dimension determined in the planning stage. Wax ups of the final castings are completed within the guidelines determined by the intercondylar distance, terminal hinge axis position, interocclusal relationship, vertical dimension, condylar pathways, and anterior guidance as set on the articulator.

![Fig 54 Wax up of final maxillary castings (Bauer)](image-url)
The wax ups are cast, adjusted on the articulator, and seated in the patient for remount.

Fig 55 Wax up of final mandibular castings (Bauer)

Fig 56 Castings seated for remount (note removal buttons) (Bauer)
After being fitted to the teeth a pick-up stent is created and impressions are completed to pick up the castings for creation of a metal model incorporating the castings for adjustment on the articulator.

The models with incorporated castings are mounted on the articulator with a new facebow. The castings are then adjusted to precisely function within all of the guidelines established on the articulator.
The castings are seated and evaluated. If further adjustment is necessary the process is repeated until the castings are correct upon seating. They are delivered with removal buttons in place using a temporary cement so they may be remounted and adjusted again in one to four weeks. It is not until they have been removed, adjusted, and approved as being exact that the removal button is smoothed and polished and the castings are cemented.

Fig 60 Final maxillary restorations (Bauer)
Through the process of planning, adjustment, and readjustment on the articulator the final restorations display the constants and variables determined and transferred to the articulator. One of the hallmarks of an appropriately finished Ganthologically driven oral rehabilitation is the absence of intraoral occlusal indicating ribbon. The meticulous gathering of data and the precise transfer of information to the articulator is the control which determines the final creation of the restorations.

The Pankey-Mann-Schuyler technique differs in its approach to completion of the rehabilitation. The precisely adjusted provisional restorations are utilized in completion of the mandibular anteriors as noted above, followed by the maxillary anteriors and the mandibular posteriors. Here the process separates dramatically from Gnathology. The maxillary posterior teeth are restored with a functionally generated path model that incorporates all movements of the mandibular teeth against the maxillary teeth within the patient’s constants (intercondylar distance, terminal hinge axis, interocclusal relationship, and condylar pathways) and the variables (tooth form and position, vertical dimension of occlusion, and anterior guidance) determined and captured in the provisionals and subsequently transferred to the completed restorations in the anterior and mandibular posterior.
Because the functionally generated path corrects for any discrepancies, remounts are not necessary.

Meyer initially described the functionally generated path as a removable prosthetic procedure. Adapted to use in oral rehabilitation by Arvin Mann it is accomplished through the creation of a *stone core*. Prepared teeth are coated with *Tacky Wax*, a wax that is soft enough to move when chewed against. Figure 61 illustrates placement of the Tacky Wax. In this figure the most posterior tooth has been left unprepared to show placement of wax. The process is not different if all posteriors are to be restored.

![Tacky wax covers surface of prepared teeth](image)

The patient is directed to move through all possible movements and chewing patterns. The wax offers no resistance to the movement and is thus *carved* into the shape of the movements of the lower teeth against it. The wax must not move on
the prepared teeth if the path is to accurately represent the complete functional and parafunctional movements.

Once shaped the image must be duplicated in a material that will not distort in use. Fast setting dental stone is used to create an impression of the tacky wax. This *stone core* represents all movements of the mandible and captures the effects of all constants and variables present.
The stone core is now articulated with the mandibular arch on a Twin Stage articulator. Figures 66 and 67 show the articulation of the stone core, the twin stage with the maxillary teeth (dies) opposing two mountings, the stone core and the mandibular model.
The final wax-up for castings can now be completed against the opposing arch for proper shape and form and against the functionally generated path for proper occlusion. If immediate posterior disclusion is wanted point contacts are created with the functionally generated path at the desired place. For group
function contact is created for all or part of the functionally generated path representing the movement in which contact is desired.

Fig 69 Final castings created using the functionally generated path and twin stage articulator (Mintzer)

The final castings are tried in, adjusted as necessary to create precise fit and occlusion, and cemented. Occlusal adjustment is usually limited to adjustment with a rubber wheel or point, even in full group function contact cases.

References for rehabilitation section: 36,44,45,56,61,84,89,92
Conclusion

Precision, the goal of excellent engineering and excellent dentistry, is a target worthy of attention. In dentistry as in engineering it represents an attempt to achieve stability in a world where entropy works against whatever is constructed by man. Gnathology mimics the envelope of motion by recreating a guide for movement, the Pankey-Mann-Schuyler technique captures a static model of that movement. Both provide a method for oral rehabilitation that permits accurate transfer of information to the fabrication of prosthetic components that meet the requirements of occlusion.

Several electronic products are available that mimic the action of the pantograph. They provide a series of settings based on the tracking of mandibular movement but do not provide precise adjustment as is possible with the pantograph. By providing the perimeter of the envelope of motion they create the fence but do not give detail about the pasture as is possible with the pantograph and the functionally generated path.

Most dentistry today is completed satisfactorily without the use of either the pantograph or the functionally generated path because the degree of accuracy required for most restorative procedures is adequately met without their use. The reduced need for their use does not diminish the need of the master restorative dentist to understand the concepts that underlie these techniques. The
Gnathological Technique and the Pankey-Mann-Schuyler Technique are both proven methods in predictably satisfying the requirements of occlusion in oral rehabilitation. They remain powerful tools that the accomplished restorative dentist must have available if he or she is to be truly a master.
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