Research studies on the temporomandibular joint: their interpretation and application to clinical practice

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Numerous investigators have become intrigued with one of the most interesting mechanisms of the human body, namely, the temporomandibular joint. Countless experiments by a wide variety of methods have been employed to understand its inner workings. The anatomy and growth of the joint is well understood, and of considerable significance are the contributions of Brodie,[1,2] Sicher,[3,4] and Thompson,[5] in their individual writings and in their collective writings on the temporomandibular joint.[6] However, disagreement exists concerning the physiology of the joint and much of it is dependent upon the method employed by the investigator.

The temporomandibular joint is a complex mechanism in which two joints must function in unison and also in harmony with the precise interlocking of the teeth during mastication, thus, making it different from all other joints in the body. It is generally agreed that the articulating or functioning surfaces of the joint are the anterosuperior surface of the condyle and the posteroinferior surface of the articular eminence. These surfaces should be in close approximation with the thin portion of the oval articular disc resting in between. These relations of the joint structures have been observed on skull and cadaver material with the teeth in occlusion and are accepted generally by most anatomists as being normal.

In recent years interest in the position of the condyle in the fossa with the mandible at rest position as well as with teeth in occlusion was stimulated by the work of Lindblom[7] and Thompson.[8,9,10] Lindblom planned his restorative dentistry on observations made by comparing the position of the condyle at rest with that when the teeth were occluded. He accepted the rest position as being the more nearly correct if the two positions were found to be different. Thompson also emphasized the rest position and the movement of the condyles in function. He introduced the controversial issue of posterior mandibular displacement, it having been usually accepted that the condyle should occupy the most retruded position in the fossa. In this respect Gillis[11] wrote, "Study of the temporomandibular joint with the aid of x-rays discloses that the condyles are not in their most retruded position when the mandible is at rest position; nor are they ever in their most retruded position in their fossae except when traumatized and malfunctioning or under extra stress."

In regard to the physiological rest position Gillis,[11] Neiswonger,[12] Boos,[13] Brodie, and Thompson,[14] have contributed to the idea that this position is relatively stable. It is not, however, without its variables and these are being better understood as time goes on. The important point to remember is that the rest position is influenced

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by factors other than mastication, *viz.*, posture and speech and these more often than not are normal or at least natural functions of the individual.

One variable is the position of the head at the time the rest position is recorded. When speaking of the rest position, it is assumed that the patient is in an upright position with the head oriented in Frankfort plane. An experiment to show the influence of deviation of the head from this position on location of the condyle was performed on an adult possessing excellent occlusion of the teeth. Temporomandibular radiographs were made of the right condyle of the subject with the mandible at rest and with the head inclined at 30° and 15° above Frankfort, at Frankfort and 15° below Frankfort. Care was taken to preclude any variation in the rest position. Superimposition of the outline tracings of these radiographs shows the change in rest position coincident to the change in posture. As the head is inclined above Frankfort horizontal the condyle is retracted in the fossa, and as the head is inclined down from Frankfort, the condyle moves downward and forward out onto the eminentia. Therefore, it is of utmost importance that the head be positioned in natural posture before any attempt is made to register the true rest position. Furthermore, the lips must be in their natural unstrained relation for the given dentition.

During the past six years a unified program of study on various aspects of the temporomandibular joint has been in progress in the Orthodontic Department of Northwestern University. Various graduate students in orthodontics, periodontics, and prosthetics have been assigned certain avenues of the problem. This investigator conducted one phase of the study and was given the additional responsibility of compiling all of the studies into this report.

A main consideration has been to study the relationship between the position of the condyle when at rest, and when the teeth are in occlusion in various groups of subjects. The groups studied so far have included adults, young adults, and children possessing excellent occlusion of the teeth and young adults possessing Class II, division 1 malocclusion before and after orthodontic treatment. The purpose of this paper is to report the findings of these investigations and to discuss somewhat their clinical application.

The method of approach has been largely radiographic, the reason being that only with the radiographic technique may normal and abnormal cases be studied without altering the function or physiology of the living subject. In selecting a temporomandibular radiographic technique for this study it was necessary to find one which would, (1) yield clear images with sharp outlines of the condyle, (2) provide for the taking of two exposures without altering the relation of the tube, patient, and film, (3) allow the seating of the patient in an upright, comfortable, and relaxed position with the head oriented in the Frankfort plane and, (4) not include any mechanical contrivance which could in any way influence mandibular position.

The Lindblom orienting device for obtaining radiographs of the temporomandibular joint was selected because it fulfills these conditions. First, the registration of the condyle is clear and sharp because of the fact that the central ray coincides with the long axis of the condyle in most instances and also avoids much superimposition by passing over the dense petrous portion of the temporal bone. Second, it provides cassettes which may be changed rapidly without moving the patient or apparatus. Third, an ordinary dental chair with head rests is used, which permits the seating of the patient in an

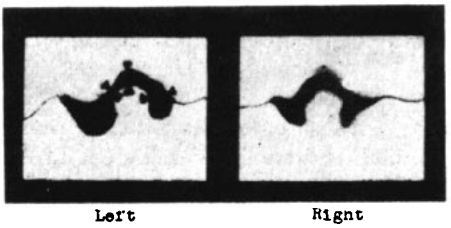

Fig. 1. Plaster models obtained from wax impressions of temporomandibular articulation. Markers on model of left articulation indicate points at which measurements were taken.

upright, comfortable position with the head oriented in the Frankfort plane, Fourth, the apparatus embodies nothing which could in any way influence mandibular position.

The method and each investigator were first tested on a dry skull. In order to determine what portion of the condyle, fossa, and eminentia were being most clearly observed on the radiographs the following test was performed. Brass wires were adapted to the contour of the condyle and to the fossa and eminentia in a sagittal plane at various areas and sealed down with wax. The areas selected were the lateral border, the junction of the middle and lateral thirds, the junction of the middle and medial thirds and the medial border of both the condyle and the fossa and eminentia. A radiograph was made with the wires in each of these positions. Only one wire was present on each radiograph.

It was found that the areas seen with the greatest clarity on the radiographs most nearly approximated the position of the brass wire at the junction of the lateral and middle thirds of both the condyle and the glenoid fossa and articular eminence.

A further test of the radiographic technique was performed by Martin.[15] Wax impressions were made of the fossa and eminentia, with the condyle in position, of twenty-five skulls possessing excellent dental occlusion. These impressions were invested in plaster blocks which were then sectioned in a sagittal plane passing approximately through the middle of the condyle. Measurements were then made from the condyle to the eminentia, to the fossa superiorly, and to the fossa posteriorly. (Figure 1) These measurements were then compared to the same measurements made on temporomandibular joint radiographs. Statistically there was a positive correlation between the measurements on the skulls and the radiographs. These experiments indicated that a reliable registration of the outline and relations of the condyle were being made on the film.

The first group to be studied consisted of 25 adults and young adults possessing excellent occlusion of the teeth. This phase of the study was done by Boman.[16] Excellent occlusion cases were selected rather than a cross section in order to eliminate as much as possible the inclusion of abnormal conditions in an investigation whose primary purpose was to study the ideal or so-called normal condition. It is probable that had cross section or "average" material been used, greater variation would have been evident in the results.

Two lateral cephalometric radiographs and two radiographs of the right and left joints were made, one with the mandible at rest and the other with the teeth in occlusion. Tracings of the resulting radiographs were superimposed and composite tracings were made. The type of movement exhibited by the condyles as the mandible moves from rest to occlusal position was observed directly on the composite tracings.

Figure 2 shows all of the composite tracings of the 25 cases arranged in order of the amount of translatory movement of the condyle. It may be observed that of these cases, approximately 14 show pure rotary movement of the condyle, 8 primarily rotary with

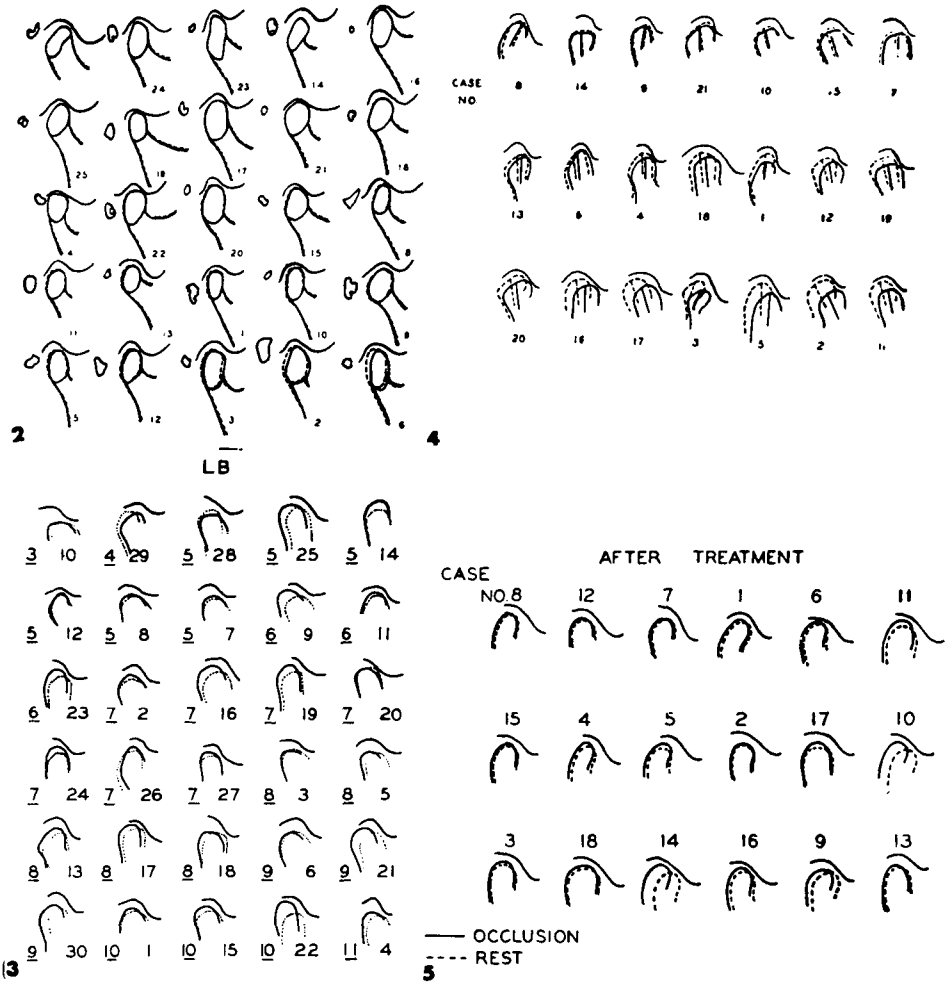

Fig. 2. Superimposed tracings of temporomandibular radiographs of the twenty five cases arranged in order of degree of condylar movement.

Fig. 3. Tracings of temporomandibular radiographs of a young group (3 yrs. to 11 yrs.) possessing excellent dental occlusion. The underlined number represents the age of the individual. (- - - Rest Position) (———Occlusal Position).

Fig. 4. Superimposed tracings of temporomandibular roentgenograms with mandible at rest position and with teeth in occlusion arranged in sequence of degree of condylar displacement.

Fig. 5. Superimposed tracings or temporomandibular roentgenograms with mandible at rest position and with teeth in occlusion arranged according to case number shown in figure.

very slight translation, and 3 a combination of rotation and translation. This grouping by movement described as pure rotary, primarily rotary, and a combination of rotary and translatory is arbitrary, the groups being selected by judgment as there is a blending from one group to the next.

The tracings of the lateral cephalometric radiographs showed that in all cases, except the three showing an appreciable amount of translation, the body of the mandible moved upward and forward during closure from rest to occlusion.

Alexander,[17] a graduate in periodon-

tics, studied the positions of the condyle at rest and occlusion in 50 individuals with complete permanent dentitions that were observed to have healthy supporting tissues. In these 50 individuals and 100 articulations, fifty percent showed a pure rotatory movement from rest to occlusion, forty percent showed slight bodily movement, and ten percent showed considerable bodily movement.

Another investigation utilizing a different method of approach was carried out by King[18] on 8 adults also possessing excellent dental occlusion. On these patients the axis of rotation of the condyles was determined according to the McCollum technique incorporating the use of a cast metal clutch and the McCollum face bow. The rotation axis was then marked with a lead point and registered on a lateral cephalometric radiograph. Comparison was made of the center of rotation as determined mechanically and radiographically. In all cases the center of rotation fell either within the condyle or very close to it; showing again that the condyle either simply rotates or primarily rotates as the body of the mandible moves from rest upward and forward to occlusion. The body of the mandible moves upward and forward, any point on it traversing an arc which is a portion of a circle whose center is in the vicinity of the condyle. This is the type of movement that is desirable not only in finished orthodontic cases, but also in cases of corrected temporomandibular joint disturbance, full mouth reconstruction, and complete denture service.

Donovan studied a young group varying in age from 3 to 11 years, selected on the basis of an excellent dental occlusion (Fig. 3). In addition to the Lindblom joint and cephalometric radiographs a right angle joint radiographic technic was included. The three methods showed generally uniform results, one technic confirming the others. In this young group, there was considerably more variation in the type of condylar movement. Possibly this was based on the difficulty of recording the rest position in young children, except that one method checked the other and they were generally uniform. It seems likely that the changing dentitions, eruption of teeth, growth of the condyles and growth of the musculature requires or leads to a wider range of variation of position of the condyle in the fossa, and in the type of movement from rest to occlusion in a growing child. As the individual approaches adulthood, and condyle and muscle growth diminishes, a more constant position of the condyle in relation to the eminence is noted. Furthermore, the path of closure approaches the hinge type observed in the studies of Boman, Alexander, Thompson, and King, and may be considered the usual or normal situation.

When the teeth are in occlusion in these cases comprising the excellent occlusion control group, the condyle is in a balanced position in the fossa. The anterosuperior surface is in close approximation to the posteroinferior surface of the articular eminence with the articular disc interposed between. It is also the most retruded unstrained position, although, anatomically it is possible further to retrude the condyle.

In another study performed by Blume,[20] temporomandibular radiographs and lateral cephalometric radiographs at rest and occlusion were made on 25 individuals possessing Class II, Division 1 malocclusion. The composite tracings of the temporomandibular radiographs arranged in the order of the amount of translatory movement are shown in Figure 4. These cases fall roughly into three equal groups. The first shows a pure rotary or primarily rotary type of movement, similar to that shown by the excellent occlusion cases.

The second group shows an appreciable amount of translation in combination with the rotation, which may or may not in an individual case be within normal range. The third groups shows a considerable amount of translation, or bodily upward and backward movement. In the last group and to some extent in the second group the path of closure of the mandible as shown by the lateral cephalometric radiographs was of an upward and backward nature rather than the desirable upward and forward. The relations of the molar teeth when the mandible was at rest position was either completely or partially Class I as compared to the full Class II relationship when the teeth were in occlusion. It was also observed that the interocclusal clearance (freeway space) was wider than average. At the time this work was done these cases were considered not to be true Class II cases. It was thought that the condyle was being retruded backward and upward as a matter of convenience or accommodation to the occlusion. Therefore it was expected that a simple forward repositioning of the mandible, bringing the condyle down out of the fossa to a position on the eminentia corresponding to its position when at rest, would be the main consideration of the case. Even then, however, it was recognized that in some of these displacement cases, the position of the condyle at rest seemed to be in partial protrusion. Only since the completion of the most recent phase of this program of study have these cases been better understood.

Three years after Blume's investigation eighteen of these same individuals, having in the meantime received complete orthodontic treatment, were studied by Glowacz.[21] Temporomandibular and lateral cephalometric radiographs were made with the mandible at rest and with the teeth in occlusion. Analysis of the lateral cephalometric radiographs showed that 15 of the 18 cases exhibited a normal path of closure as compared to six before treatment, and only three cases exhibited an abnormal path of closure as compared to 12 before treatment. In the three cases there was a marked degree of improvement of this abnormal path, but not sufficient to be called normal. The response could in no way be correlated to a particular type of orthodontic treatment. The composite tracings of the temporomandibular joint radiographs of these cases after treatment arranged in order of the amount of translatory movement noted are shown in Figure 5. Analysis reveals that all but a few of the cases now exhibit rotary or primarily rotary types of movement. This should be compared to Figure 6 which shows the composite tracings of the same cases before treatment arranged in the same order as they were in Figure 5. Although there was no apparent change in the type of movement of the condyle in cases showing pure rotary or primary rotary movement before treatment, in all of the other cases but two (10 and 14) the amount of translatory movement was either completely eliminated or substantially reduced. This correction of condylar movement was expected during treatment, but not in the manner in which it was apparently accomplished.

The composite of the tracings of the position of the condyle with the teeth in occlusion before and after treatment (Figure 7) reveals that in almost one-half of the cases this position of the condyle was the same after orthodontic treatment as before, and in the other cases it moved slightly in a posterosuperior direction. In not one case was the condyle located in a more anterior position after treatment.

The composite of the rest position tracings before and after treatment (Fig. 8) shows what happened to that position of the condyle during treat-

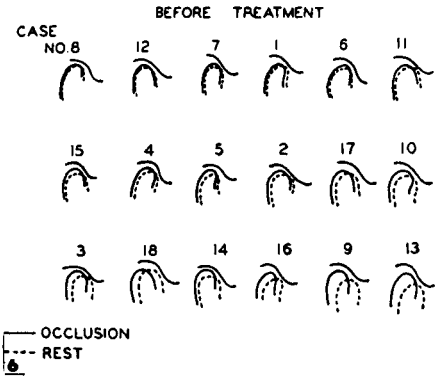

Fig. 6. Superimposed tracings of temporomandibular roentgenograms with mandible at rest position and with teeth in occlusion arranged in order of condylar movement.

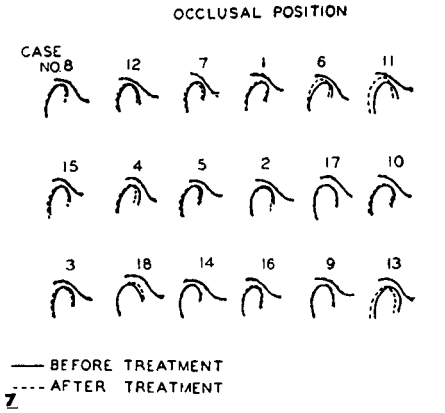

Fig. 7. Superimposed tracings of temporomandibular roentgenograms with mandible at position established by the occlusion of the teeth before and after treatment.

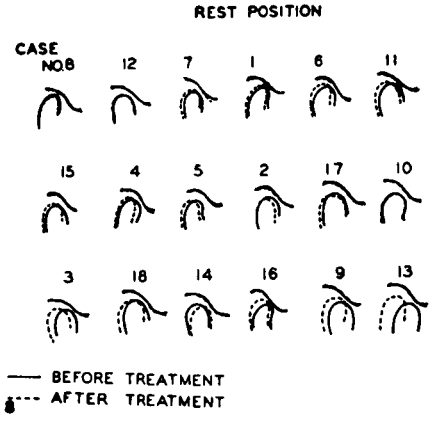

Fig. 8. Superimposed tracings of temporomandibular roentgenograms with mandible at rest position before and after treatment.

ment. With but two exceptions, the position of the condyles moved in a posterosuperior direction and, in general, by an amount proportional to the amount of original displacement. This seemed to indicate a change in rest position of the mandible, but analysis of the lateral cephalometric radiographs shows that in these cases the rest position *of the body of the mandible* remained the same or moved forward and downward or downward as the face and musculature grew. The change then in a posterosuperior direction is limited to the condyle. Of several explanations for this phenomenon the one provided by a growth hypothesis seems the most tenable.

If it is assumed that during growth the condyle grows faster than is indicated by the downward and forward positioning of the body of the mandible, the condyle would then be expected to grow into a deeper position in the fossa, that is, to its normal adult position. This assumption is not too preposterous, for we know the condyle to be the most active growth site of the mandible. Also a comparison of the condylar position as demonstrated by Donovan in the young group ranging from three to eleven years in age with that of the adult group shows that the older group has a more posterosuperior position of the condyle in relation to the articular eminence.

One might speculate then that should the growth necessary to position the condyle into the fossa not occur, an upward and backward path of closure would develop. In the two cases, 10 and 14, in which the rest position of the condyle did not change, the path of closure also did not change from an upward and backward to a normal path.

Carrying this line of reasoning further it can be reasoned that if the displacement (upward and backward path of closure) were removed by moving the occlusal position of the condyle forward to approximate its position when at rest, growth could again take place. Clinically, however, this does not seem to occur merely as a response to treatment. If growth did take place during treatment then both positions of the condyle would move deeper into the fossa and comparison of the before and after treatment radiographs would show only a change in the rest condylar position. This is exactly what has been observed and it is possible that in time the growth hypothesis will be proven to be reasonably correct.

The study has shown further that if nature is not ready to help in the form of an actively growing mandible, the problem is more difficult, for no matter how easily the mandible may be repositioned in a displacement case, *if growth does not take place the condyle will be in a prortuded relation* and the repositioning is doomed to failure. As yet, no way is known to predict the amount or time of growth that will take place. While it is generally believed that orthodontic treatment does not stimulate growth beyond the alveolar process, perhaps it may provide conditions which will permit condylar growth to occur.

In a recent study, the change in the anteroposterior relation of the mandible to maxilla during orthodontic treatment of Class II division 1 malocclusion has been measured by Carlson.[22] Fifty-six cases were divided into two groups, those presenting normal paths of closure and those presenting upward and backward paths of closure. Taking the change in difference between angles SNb and SNa, introduced by Riedel,[23] before and after treatment as a measure of the change in anteroposterior relation of the mandible and maxilla, the two groups were compared. The nondisplacement group produced an average of .3° change in the SNa-SNb difference as compared to a +1.41°

average change (difference between SNb and SNa becomes smaller) for the displacement group. These figures indicate that in displacement cases, while not always individually but as a group, the position of the body of the mandible with the teeth in occlusion tends to move further forward. This further supports the growth hypothesis and it is becoming more and more apparent that it is the amount and time of growth that is more important than the particular type of appliance therapy that is employed presuming, of course, that it is good mechanical therapy.

In the light of these recent findings some past hypotheses seems to require modification. For instance, Thompson has said, "The displacement that occurs in a large percentage of cases of this type of malocclusion (Class II) probably explain the difference in clinical response that has always been observed by practicing orthodontists and often attributed to growth, type of appliances, and particular methods of treatment. Certainly, the true Class II malocclusion (normal path of closure from rest position to occlusion) will not respond as rapidly as one that exhibits a considerable amount of displacement. They are not identical cases and they require different treatment. Again, only a functional analysis will reveal the true nature of the malocclusion. Furthermore, the entire concept of the changes that supposedly occur in the temporomandibular articulation as a result of orthodontic therapy must be reconsidered in the light of these findings concerning the position of the mandible."[9] He does not hesitate to alter these ideas in favor of the growth hypothesis brought to light by these more recent studies.

In summary — the overall program of study has indicated the following:

1. The path of closure of the mandible from rest position to occlusal position in young adults and adults with excellent occlusions is upward and forward with little if any bodily movement of the mandibular condyles.

2. More bodily movement of the condyles is observed on children with excellent occlusions. This variation from the normal path may be a normal situation resulting from a variation in the timing of the growth of the associated structures.

3. In the group of individuals having Class II, Division 1 malocclusions one third showed considerable upward and backward movement from rest position to occlusal position. Another one third showed some movement in the same direction and the remaining third exhibited the normal upward and forward path of closure.

4. Observations made before and after orthodontic treatment of the Class II, Division 1 malocclusion group indicated that the position of the condyle with the teeth in occlusion cannot be moved forward permanently any significant distance.

5. Observations made before and after orthodontic treatment of the Class II, division 1 malocclusion group indicate that the rest position of the condyle changed and became similar to the occlusal position of the condyle.

6. The paths of closure changed from upward and backward to upward and forward as the condyles grew during orthodontic treatment. If they did not grow, the paths of closure did not change.

7. Since the body of the mandible remained in its original position or moved downward and forward as the result of facial growth, the upward and backward movement of the mandibular condyle at rest position can be accounted for only by mandibular growth and should not be interpreted as a change in the mandibular rest position.

8. During treatment the forward movement of the body of the mandible in posterior displacement cases (upward and backward path of closure) will

usually exceed that of non-displacement cases.

9. It is apparent that in order to correct a Class II, Division 1 malocclusion in a satisfactory manner, mandibular growth must occur during the period of active treatment. This is the growth hypothesis and the orthodontic profession has been informed of this fact many years ago in the writings of Milo Hellman and B. Holly Broadbent.

During the same period that these studies were in progress, Dr. Robert Ricketts of the College of Dentistry — University of Illinois, was making a similar study using radiographic laminagraphy. The observations are similar, but there are some differences in interpretations.[24 25]

The reader is urged to examine these writings.

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