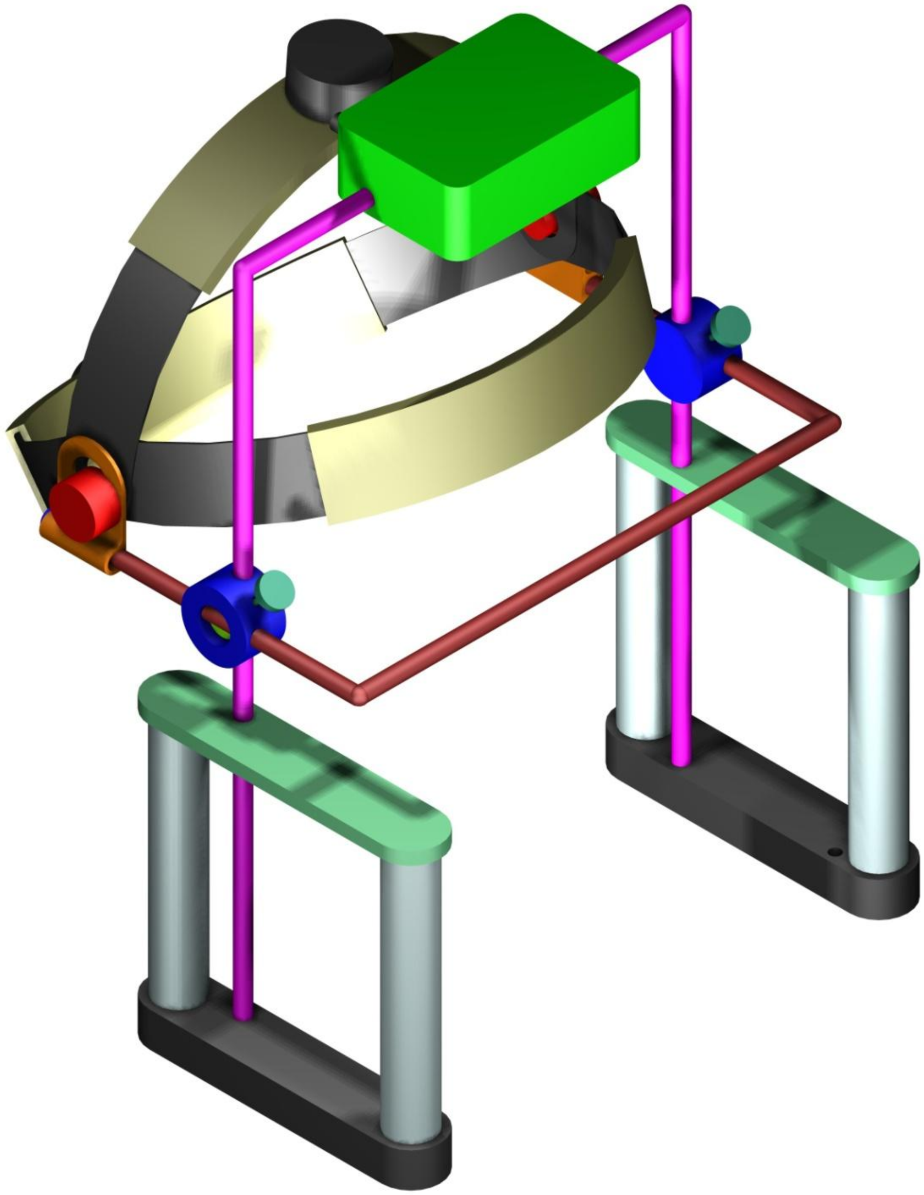

# Analysis of JT-3D Magnetic Jaw Tracker Traces

**John C. Radke**

# The Magnet-based JT-3D Electrognathograph

The magnet-based 3-dimensional Jaw Tracker or Electrognathograph was originally developed as a tool to record jaw motions during natural functions without any interference from clutches.[1, 2] A single small magnet is adhered to the lower incisors and adjacent gingival tissue in the labial vestibule. The sensor array is placed on the patient with a head-band that is adjusted to a snug fit. The patient is instructed by the operator to complete a standard series of jaw motions. The traces are saved to the computer hard disk and the patient is dismissed. All of this occurs within a few minutes and is typically accomplished by an assistant. The jaw tracking records represent not only the present masticatory status, but also a permanent reference for the future. Every patient is an unique individual, thus having a record of a patient's healthy function is very valuable.

The JT-3D, compared to previous models, has the added clinical advantage of a quicker setup, easier operation and a Universal Serial Bus (USB) interface that communicates with virtually all modern computers, tablets, etc. that are Windows® compatible. The current *BioPAK*™ *Software for Windows*, which has been developed over the past 20+ years, is also user friendly and quite intuitive to operate.

## What are the main Objectives of EGN Recording?

I. *Range of Motion* (ROM):[3] Three planar views show any limitations, deviations or deflections
II. Protrusive guidance:[4] The significance of *Protrusive Guidance* Vs *Anterior Misguidance*[5]
III. *Velocity*:[6] Speed and smoothness of function in open-close and in mastication
IV. The stability of the *Rest Position*[7] and *Freeway Space*[8]
V. Significance of the location of the *Rest Position* in relation to the *Intercuspal Position* (ICP)[9]
VI. Normal or abnormal masticatory Average Chewing Patterns (ACP)[10] and their significance
VII. *Segmentation* of masticatory function into individual cycles and *Quantitative Analysis*[11]

## I. Range of Motion (ROM)

It has been well documented in the past that the normal Range of Motion exceeds 40 millimeters and that it can exceed more than 70 millimeters.[12] It is also not fully understood by all that ROM includes the lateral and protrusive ranges as well (Figure 1). The significance of recording lateral and protrusive is based on the relative translation of the two condyles. If condylar translation is equal or nearly so, the amount of lateral excursion will be similar for left and right movements (frontal and horizontal views) and the protrusive movement will not deflect to one side.

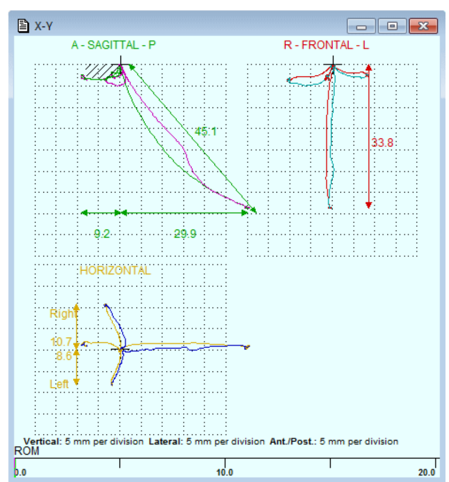


Figure 1. A 45 millimeter Range of Motion with no deviation or deflection in the sagittal, frontal and horizontal views

In the lateral dimension it is important to detect deviation and deflection.[13] The former includes movements away from the midline that return to the midline at maximum opening. By contrast, a deflection is furthest away from the midline at maximum opening. **The significance of a deviation:** During opening a deviation indicates a resistance to translation of the ipsilateral condyle (on the side that the deviation goes towards). However, a deviation that occurs during closing (see figure 2) indicates a resistance to translation of the contralateral condyle. **The significance of deflection:** The most common reason for a deflection is an internal derangement with an anteriorly displaced disk limiting the translation of the ipsilateral condyle. If the deflection is large and the ROM is less than 40 millimeters, it will interfere with mastication on the contralateral side. If the deflection is less than 3 millimeters and the ROM is within normal limits (40 – 70+ mm), the deflection may be due to a mild asymmetry of the jaw or to some degree of hyper-translation of the contralateral condyle. The former case may benefit from any type of treatment that reduces the disk displacement and improves joint function, but the latter case can best be ignored. A large deflection will cause the patient favor chewing on the side of the displaced disk. A patient that chews exclusively on one side will usually develop an asymmetrical musculature due to the lesser effort required from the contralateral side muscles.

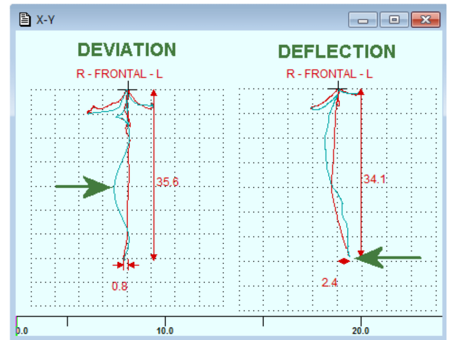


Figure 2. Two EGN frontal traces showing deviation and deflection red = opening, blue = closing

## II. Protrusive Guidance

It is a misconception that the anterior teeth should somehow guide closure during mastication.[4] Actually, the normal pattern of masticatory movement includes a lot of vertical and lateral movement, but relatively little antero-posterior movement (see the later section of this document describing mastication). In contrast, a normative envelope of speech movement includes mainly the vertical and antero-posterior directions with only a small lateral component. Thus, the arrangement of the incisors is actually far more important for speech. A number of phonetic sounds, mainly those related to consonants such as F, S and V, are produced with the maxillary and the mandibular incisors in very close proximity ...within tenths of a millimeter (see Figure 3). The loss of anterior teeth makes legible speech difficult, but has little effect on a patient's ability to masticate food. Mastication properly occurs within the premolar and molar regions of the dentition.[14]

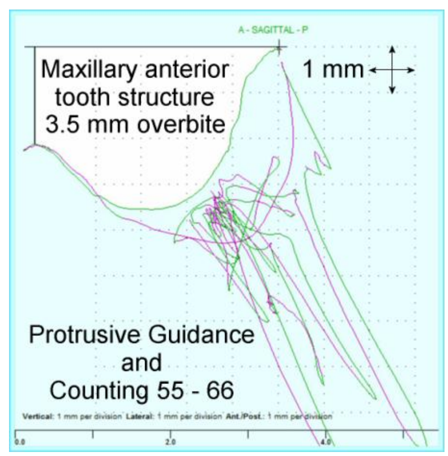


Figure 3. Protrusive guidance followed by counting from 55 to 66 – the space between the incisors is about 0.2 mm

### Protrusive Non-Guidance Vs Misguidance

A complete lack of anterior guidance can occur with excessive over-jet or an anterior open bite. These conditions do not interfere with the patient's ability to chew, but may affect the patient's speech (see Figure 4). The relationship of the anterior teeth is only critical for 2 functions; 1) the incision of food and 2) the accurate pronunciation of words. In contrast the presence of a very steep anterior protrusive guidance in a "deep bite"

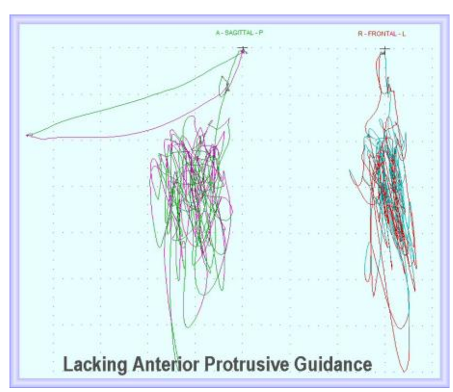


Figure 4. Excessive over-jet = no anterior tooth related guidance for speech

overbite dentition, such as with a Class II div 2 malocclusion, can interfere with the patient's ability to chew (see Figure 5). Osaka University Professor Takao Maruyama, the retired chairman of prosthodontics for the School of Dentistry, coined a term for this condition which he called, "Anterior Misguidance."[5] This can also occur with an anterior crossbite, either a partial (one tooth) crossbite or a complete anterior crossbite (Class III malocclusion). Although anterior misguidance interferes with mastication it is usually not a problem with speech for the Class II div 2 occlusion. However, the class III malocclusion often interferes with precise pronunciation and can cause an obvious speech impediment.

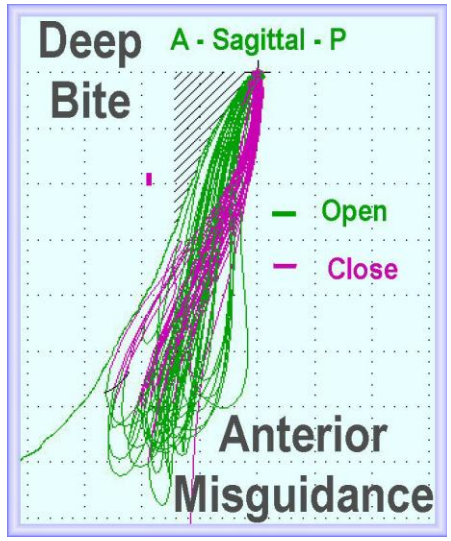


Figure 5. Sagittal view of a subject chewing with anterior misguidance

## III. Velocity

The velocity of specific mandibular movements can be very indicative of dysfunction or good function.[6, 15] Every type of dysfunction, whether related to joint dysfunction or muscle dysfunction, tends to slow down movements and make them more variable. A simple open and close movement or the more complicated movements of chewing are both affected by dysfunction and exhibit a measureable reduction in velocity. The smoothness of jaw movement is also reduced by dysfunction and the variability of the particular pattern increases as well. Good overall jaw function is indicated when a patient can open / close fully, rapidly, smoothly and consistently with peak open and close velocities exceeding 400 millimeters/second (see Figure 6).

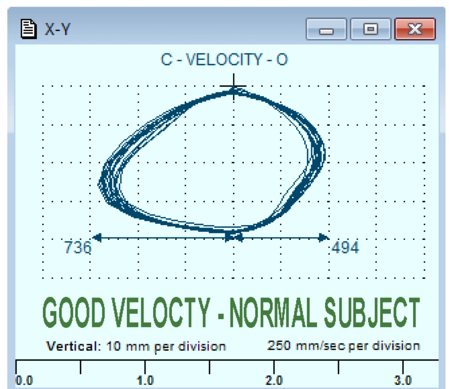


Figure 6. Normal subject with good velocity and smooth movement

### Anterior Misguidance Vs Reducing Displaced Disk

Anterior misguidance can reduce the closing velocity (Figure 7), but leave the opening velocity only half way abnormal. The avoidance of excessive anterior tooth contact is the reason for the closing reduction in velocity. An increase in variability during opening and slow closing occurs.

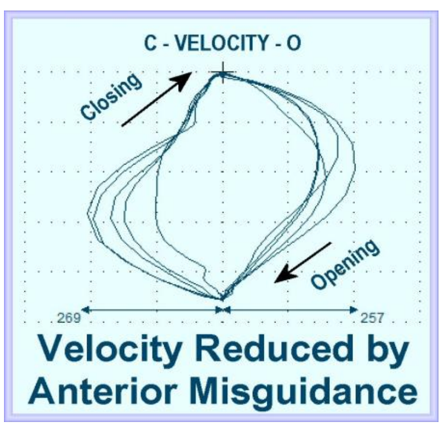


Figure 7. Closing velocity slow down due to the presence of "Anterior Misguidance"

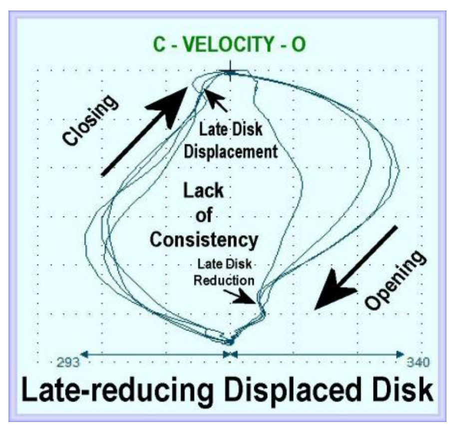


Figure 8. Velocity slow down in opening & closing due to reducing displaced disk

A reducing displaced disk is another factor that can alter the velocity both in opening and in closing.[16] The opening velocity slows down right before the reduction occurs and speeds up immediately afterwards creating a dip in the velocity at the point of the reduction (see Figure 8). It is also true, but to a somewhat lesser extent, that at the point during closing where the disk displaces again a slow-up occurs. The disk displacement is usually a less forceful event, which alters the velocity less when it occurs. Thus, with a reducing disk displacement (DDR), the velocity is reduced and the pattern variability is increased.

### ACP Chewing Velocity is Affected by Dysfunction [17]

An example of the ACP velocity during gum chewing from a subject without any dysfunction is exhibited in Figure 9. The closing peak velocity and opening peak velocity are usually very similar in amplitude and usually well above 100 mm/s. In this example the maximum peak opening velocity is 169 mm/s and the maximum peak closing velocity is 154 mm/s. The average peak opening velocity for this trace is 115.7 mm/s and the average peak closing velocity is 115.4 mm/s.

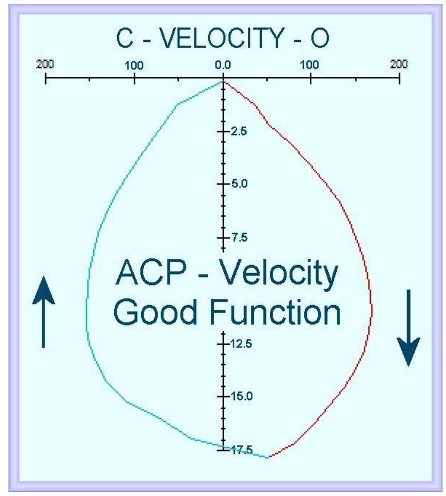


Figure 9. ACP Velocity of a normal subject chewing gum without any sign and/or symptom of dysfunction

The general shape of the pattern is egg-shaped with a mean vertical maximum of 16 mm and a top that approaches to within 0.1 mm or 0.2 mm of the intercuspal position. This averaged pattern is convex both in opening and in closing throughout the complete cycle, which indicates smooth non-jerky movement. [17]

An example of the ACP velocity of a very dysfunctional patient during gum chewing is presented in Figure 10. While the maximum peak opening and closing velocities appear similar in amplitude (92 mm/s and 86 mm/s respectively), they are much slower than shown for the normal example. The average peak velocities are 62 mm/s for opening and 57 mm/s for closing, far below the 100 mm/s expected from more normal subjects. [17]

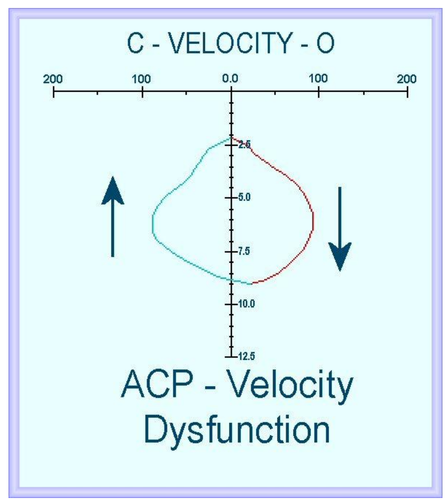


Figure 10. The ACP velocity pattern from a dysfunctional patient chewing gum.

In Figure 10 an example of a dysfunctional ACP velocity pattern shows a vertically squashed shape when compared to the normal egg-shaped pattern. The mean vertical maximum is only 9 mm. There is a slightly concave area near the intercuspal position (at the zero of the vertical axis) during the opening. In closing the concavity is more pronounced approaching occlusion. The top of the pattern, which represents the position of maximum bolus crush, is about 2 mm from the intercuspal position. This indicates that the bolus (gum) is not being crushed very much at all.

## IV. Stability of the Rest Position

When the mandible is at rest the elevator muscles of the masticatory system (masseter, temporalis, etc.) are expected to be passive, not contracting.[18] If muscle activity is present the muscles are actively posturing the mandible instead of being at rest. Posturing is a compensatory activity indicating that a maxillo-mandibular mal-relation exists, but the patient may be otherwise asymptomatic if the posturing requirements are within the patient's adaptive range. The posturing activity may be present in one or several muscles depending on the posturing requirements, but in either case the rest position will be varying over time. This can be seen with a jaw tracker monitoring the rest position continuously for a few minutes.[2] Figure 11 shows an ideal resting position with almost no movement while figure 12 shows a typical unrelaxed patient's moving rest position. When a patient is identified with an unstable rest position it is appropriate to apply a type of relaxation therapy. Once a stable rest position has been verified, anyone can measure the freeway space with the JT-3D Jaw tracker. This is accomplished by recording the specific patient at rest, swallowing, back to rest, closing into the intercuspal position, tap-tap-tap and then protruding with the teeth in light contact (see Figure 13). The purpose of the swallow is to determine if the teeth come together or stay apart during the swallow, such as with a tongue-thrust swallow. The rest-to-close distance is the freeway space. The tap-tap-tapping establishes the habitual closing trajectory. The protrusion shows the protrusive guidance or misguidance as the case may be in relation to the rest position.


Figure 11. Ideally relaxed and stable rest position with little movement


Figure 12. Unrelaxed and unstable rest position with movement

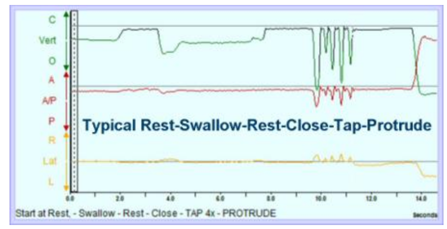


Figure 13. Rest-Swallow-Rest-Close-Tap- Protrude

## V. Significance of Rest Position

When a symptomatic patient exhibits an overclosed bite (more than 1 to 3 mm), as in Figure 14, the Jaw Tracker can be very helpful in deciding where to record a new bite position. The 3.9 mm freeway space in this example may be considered excessive, suggesting treatment by appliance could be one option. The clinician can decide how much to open the bite with the appliance and place a target on the screen to guide the bite taking procedure. As the bite record is taken it can be viewed on the computer screen to verify the correct relationship. Once the bite record is set, it can be checked to see that it matches the target. It is even possible to re-check the appliance at the time of delivery by just having the patient close into the intercuspal position and then inserting the appliance. If made correctly, the position of the appliance will overlap with the sagittal and frontal Targets (+) on the screen which were previously saved with the trace.[19]

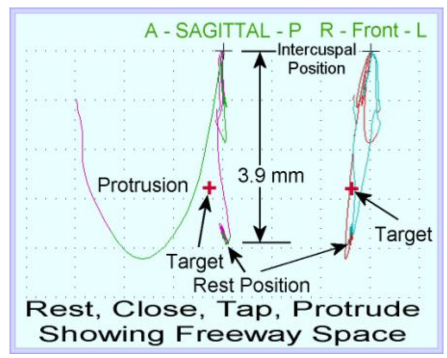


Figure 14. X – Y view of the Rest, Close, Tap and Protrude, Showing Freeway Space and Protrusive Guidance

## VI. Bilateral Normal or Abnormal Masticatory Average Chewing Patterns (ACPs)

There are 4 general patterns of chewing gum in the frontal plane including; 1) F1 = normal, 2) F2 – most often associated with disk displacement with reduction (DDR), 3) F3 – most often associated with acute disk displacement without reduction (DD) and 4) F4 – most often associated with chronic-adapted DD.[10, 20] As shown in Figure 15, the left and right-sided patterns are mirror images of each other since chewing is an unilateral and asymmetric activity. While the general overall shapes in figure 15 are indicative of joint function or dysfunction, they relate to the non-working side joint.

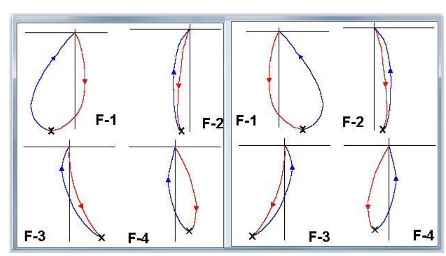


Figure 15. Right and Left-sided Frontal Chewing Patterns

Thus right sided chewing reveals left joint dysfunction and vice versa. Note that the F-1 (normal) and F4 (adapted) patterns are fully convex throughout the complete cycle. This is another characteristic associated with good function, especially in the areas of the pattern approaching or departing from occlusion. A concavity there indicates an avoidance of premature occlusal contact. Figure 16 shows a contrast between an ideal F1 pattern in the left image (just the last few millimeters before centric occlusion) and something less than ideal. The left image is an ideal masticatory pattern, but the right image shows a grinding pattern with some reversals during opening. The less than ideal pattern may not indicate a problem when no other signs/symptoms are present. However, the rather steep opening angle and the presence of some reversals during opening suggest the possible presence of an opening occlusal interference.[21] To determine whether successful adaptation or dysfunction is present, it is necessary to record EMG activity of the masseter and anterior temporalis muscles simultaneously along with the chewing movements.[17] The absence of silent periods would indicate successful adaptation.

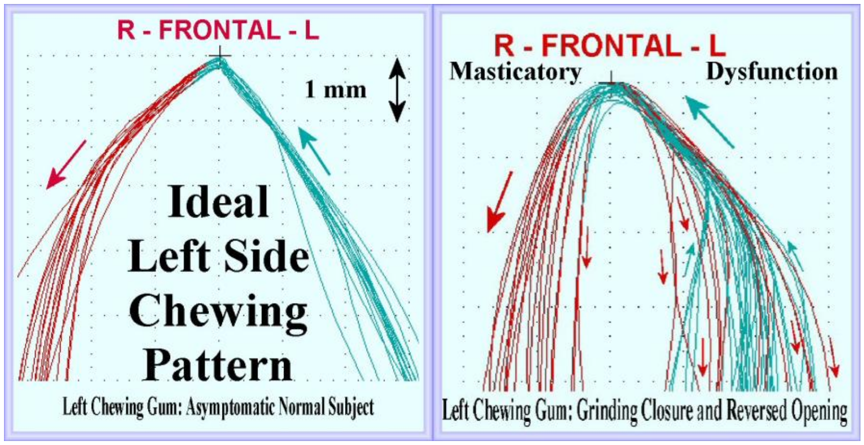


Figure 16. Ideal F1 pattern (left image) and one that is adapted to occlusal wear (right image). A very adaptable patient may not show any other signs/symptoms.

## VII. Segmentation of Masticatory Function into Individual Cycles

In order to calculate the Average Chewing Pattern (ACP) it is necessary to segment the chewing sequence into individual cycles.[22] Segmentation is done automatically in the BioPAK program according to the setting of the [Chewing Parameters] under [Options] in the Review Mode. The operator can set the following parameters:

1) The first cycle to be used in the analysis (usually the second cycle)

2) The number of cycles to be used in the analysis (the default number is 15)

3) The distance from maximum bolus-crush of the previous cycle to the onset of opening in millimeters as well as the end of closure (typically set somewhere between 0.2 and 1 mm)

4) The number of Standard Deviations (SD) to be used (range of 1.0 to 3.0) in determining the acceptance or rejection of cycles (with a default value of 2 SD).

The default scenario would start the analysis with the second cycle due to excessive bolus manipulation often occurring within the first cycle. The first fifteen "good" cycles would be used to calculate the ACP with any "bad cycles" within that range being rejected. The distance from centric occlusion to the onset of opening can be set by the operator (for example) to 0.3 mm, meaning the "beginning of opening" is established at 0.3 mm from the maximum bolus-crush of the previous cycle and the "end of closure" is set to 0.3 mm below the maximum bolus crush of the next cycle. A so-called "bad cycle" would be one that falls more than 2 standard deviations below or above the mean cycle of the entire sequence in values of either positioning or timing. All of this is done to create consistency and to eliminate swallows and/or excessive bolus manipulations from being included in determining the frontal, horizontal, sagittal and velocity Average Chewing Pattern (ACPs). This process is also critically needed to facilitate the analysis of masticatory muscle function with EMG. Since muscle activity also varies from cycle to cycle it is necessary to calculate an Average Chewing Cycle (ACC) of EMG activity to understand how the muscles are working during mastication. If one uses as a reference one muscle (which has been done in the past), the variability of the reference muscle gets erroneously transferred to the rest of the recorded muscles. Using jaw movement as the reference allows the variability of each muscle's activity to remain intact.

Figure 17 is an example of a segmented gum chewing sequence. Cycles 1, 7 and 14 have been removed from the analysis by the BioPAK program and cycles 16, 17 and 18 have been added to replace them. The green vertical lines in the upper graph mark the beginnings of the openings and the red vertical lines mark the ends of closures, so the operator can see at a glance that the segmentation has been accomplished correctly. The dashed cyan vertical lines mark the Turning Points where openings change over to closings. In the lower X-Y graph each cycle is depicted as a plane of movement in Frontal, Horizontal and Sagittal views.

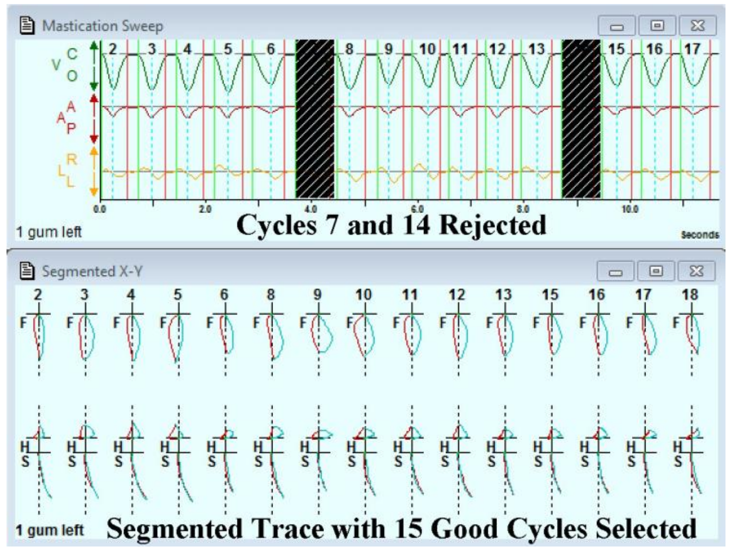


Figure 17. Typical segmentation of a left-sided gum chewing sequence from a very normal subject

Once segmentation has been completed it is possible to calculate the ACP (Average Chewing Pattern) for the plane views (Frontal, Sagittal & Horizontal) and for the velocity (Figure 18). The dark lines in the 3 planes represent the mean patterns of a very large group of asymptomatic subjects and can be thought of as a target for good function. This subject's patterns nearly coincide with the mean values, although matching the shapes is more significant than dimensional values. A person with a large mouth will have a larger pattern than someone with a small mouth, but the shapes of the patterns will both match the normal pattern if normal.

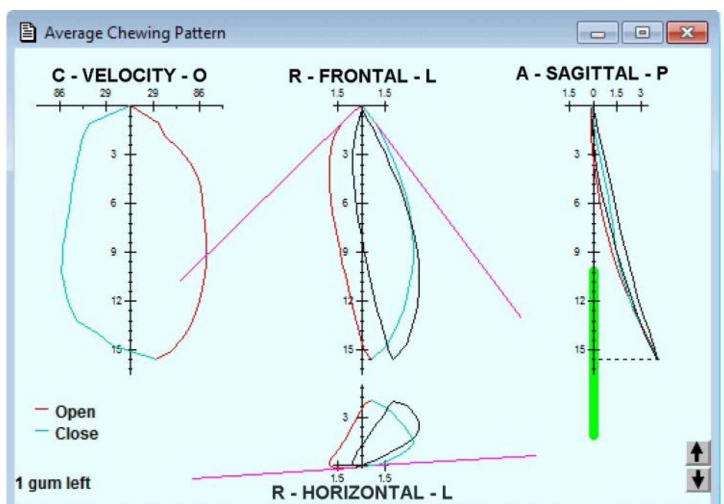


Figure 18. The ACP is calculated from the segmented data and displayed as 3 planes and 1 velocity pattern

In addition to evaluation of the movement pattern shapes, segmentation allows us to evaluate the timing of the mastication activity. This includes the Opening Time, the Closing Time and Occlusal Time (the time during which the bolus remains crushed and the jaw is not moving) and the complete Cycle Time.[23] Ideally, the three parts of the cycle each represent about 1/3 of the total with the Occlusal Time being slightly shorter than the other two.[24] The presence of dysfunction slows down all 3 parts, but especially the Closing Time.[25] It also increases the variability of the timing as well as the variability of the movement patterns.[26] Dysfunction also tends to reduce the amplitude of the overall patterns. Thus, when a patient experiences dysfunction, mastication becomes; 1) slower, 2) smaller and 3) more variable. Conversely, when function is restored, the patterns typically increase in speed, amplitude and consistency.

Figure 19 is the ACP Summary from a normal subject with a good occlusion and good masticatory function. Notice that the tricolor graphic appears to be about 1/3, 1/3, 1/3 for opening, closing and occlusion. This is an "at-a-glance" indication of good function. The normal complete cycle time should fall within the range of 600 to 900 milliseconds and it does. The Standard deviations are between 19.5 and 38.7 milliseconds, all less than 50, which is the upper limit of normal. The MEAN vertical dimension for one stick of chewing gum is 15.8 mm and this subject is "Spot On." With a standard deviation of 1.1 mm, the variability is extremely low. The Terminal Chewing Position is the point at which the bolus is fully compressed. With a good occlusion and minimal wear it is a tight point in space that varies little...in this case between 0.0 and 0.1 millimeter. The maximum lateral width is an indication of how broad or restricted the frontal pattern is. Occlusal interferences and joint dysfunction tend to restrict the pattern while excessive occlusal wear broadens the pattern. Normal subjects usually fall within a range of 4 – 6 mm with the low variability as observed in Figure 16. Normally, the maximum opening and maximum closing velocities are similar (not statistically different) and they usually fall between 70 and 140 mm/second with the average values about 20mm/second less. Frontal opening angles of 50 to 80 degrees and closing angles about 15 degrees less are typical of asymptomatic subjects. Large angles indicate a more restricted pattern, low angles a more open or worn dentition. Horizontal angles may be more variable due to variations in the sagittal alignment of the jaw tracker.

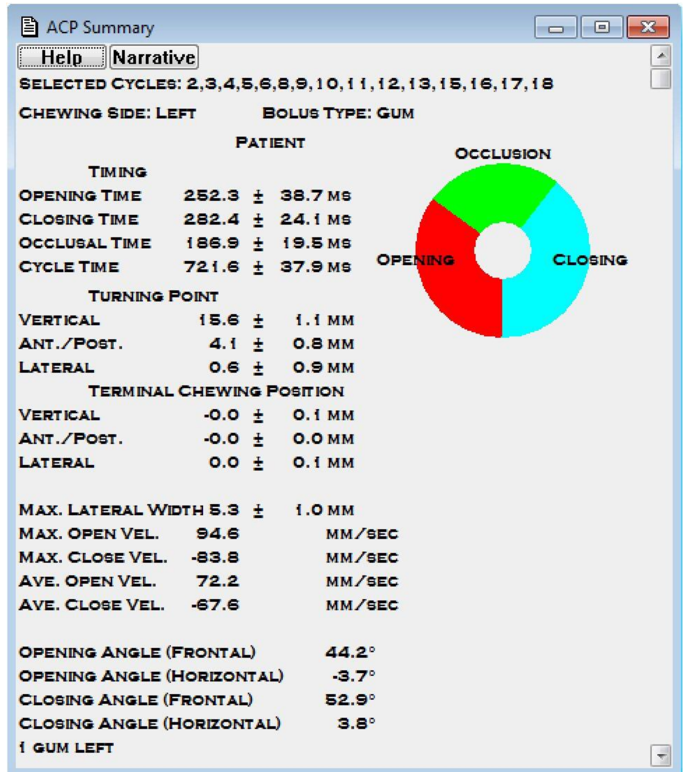


Figure 19. The ACP Summary displays quantitatively the timing and the consistency of specific aspects of the patterns.

The Horizontal View may be the most indicative of dysfunction. The pattern tends to go from one that is well organized and consistent to one that is rather randomized. When a dysfunctional pattern appears it is hard evidence that muscle dysfunction is also present. You can count on that. However, to the contrary, a normal movement pattern does not guarantee that the musculature is also functioning normally. The highly adaptable patient can produce a normal appearing movement pattern using abnormal muscle function. Thus, to completely evaluate the masticatory function of your patient it is necessary to record both the movements and the muscle activity

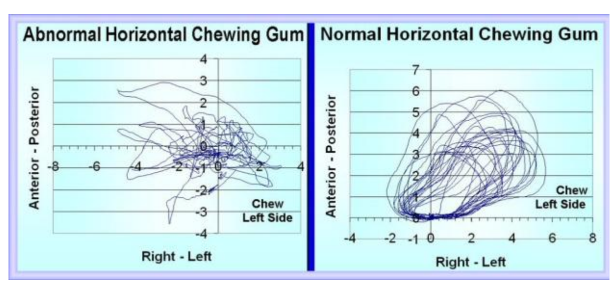


Figure 20. The dysfunctional masticatory pattern is exceptionally obvious in the Horizontal View.

simultaneously. This capability is included in the BioPAK JT-3D and BioEMG III Mastication Analysis program.

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