

Instrumental Functional Analysis: An Orthodontic Perspective

Chetan Patil¹ Pavankumar Vibhute² Pradeep Kumar³ Amol Pharande⁴ Aameer Parkar⁵
Prajyot Marawade⁶

¹Professor and Head, Department of Orthodontics and Dentofacial Orthopedics, Yogita Dental College and Hospital, Khed, Maharashtra, India,

²Professor, Department of Orthodontics and Dentofacial Orthopedics, Yogita Dental College and Hospital, Khed, Maharashtra, India.

³Reader, Department of Orthodontics and Dentofacial Orthopedics, Yogita Dental College and Hospital, Khed, Maharashtra, India.

⁴Reader, Department of Orthodontics and Dentofacial Orthopedics, Yogita Dental College and Hospital, Khed, Maharashtra, India,

⁵Senior Lecturer, Department of Orthodontics and Dentofacial Orthopedics, Yogita Dental College and Hospital, Khed, Maharashtra, India.

⁶Senior Lecturer, Department of Orthodontics and Dentofacial Orthopedics, Yogita Dental College and Hospital, Khed, Maharashtra, India.

ABSTRACT

Background: Orthodontists strive to create both aesthetically pleasing and functionally sound masticatory systems for their patients. A deep understanding of cranio-mandibular articulation is vital, especially given the rise in TMJ complaints. Instrumental functional analysis helps evaluate jaw function and its relationship to the occlusion. An articulator mounting, unlike hand-held casts, reveals how the temporomandibular joints interact with the occlusion. The SAM II articulator, along with the MPI and axiograph, aid in diagnosis. The MPI measures mandibular deviation, while the axiograph records mandibular movement, offering insights into joint function and aiding in splint construction. The axiograph provides a more dynamic assessment, considering factors like musculature and the periodontal ligament, compared to the MPI's static analysis using mounted casts.

Keywords: Instrumental Functional Analysis, Orthodontics, dentistry.

INTRODUCTION

Orthodontists are constantly being challenged with the task of providing their patients with acceptable esthetics and masticatory function. Although esthetics is often the patients immediate and primary goal, function becomes far more important over the lifetime. So developing a sound functional masticatory system is the primary goal of orthodontic therapy. To give the patient a sound masticatory system, orthodontists need to know the cranio- mandibular articulation thoroughly. The cranio-mandibular articulation is a complex synovial system composed of two temporomandibular joints together with their articular ligaments and masticatory muscles.

The frequency of TMJ complaints has multiplied in last few years. This may have been brought about by the increased stresses of our fast paced world, or at least we now recognize that there is a stress

strain tension release syndrome that often manifests itself with nocturnal parafunctional activity. Instrumental functional analysis is a consideration for every case of orthodontic treatment. If the patient does not show any signs or symptoms of TMD, a limited instrumental analysis should be done. The mouth is the worst articulator, since the final position of the jaws that we see is one that is influenced by –

1. The morphology of the occlusal surfaces of the teeth, the most dominant determinan of mandibular position
2. Neuromuscular adaptation to the occlusion (proprioception).
3. The morphology of the hard and soft structures of the temporomandibular joints.

Received: May. 4, 2024; Accepted: June. 15, 2024

*Correspondence Dr. Aameer Parkar.

Department of Orthodontics and Dentofacial Orthopedics, Yogita Dental College and Hospital, Khed, Maharashtra, India.

Email: dr.aameerparker@gmail.com

4. Compromises necessitated by various skeletal patterns. (inclination of teeth, growth pattern, functioning of the joint.)

5. Head posture and its relationship to the cervical spine, which can be influenced by total body posture.

6. The limits of motion established by ligaments attached to the mandible.

Hand held casts (which are held according to the occlusion that we see in the mouth) only tell us how teeth fit together. An articulator mounting with instrumental analysis allows you to know how the temporomandibular joints are functioning in relation to the occlusion. The articulator mounting gives information of how the jaws are related. Any plan of changing occlusion must be based on mounted casts.

Once the casts are mounted on the articulator,

- One can compare the patient's centric relation with centric occlusion
- One can see, accurately, what the exact maxillo-mandibular relation is, without the influence of occlusion/ occlusal interferences.
- The position of the condyles in the glenoid fossa can be determined three dimensionally, and the effects of the occlusal disturbances can be noted.

The SAM II articulator has been made for the purpose of diagnosis because the condylar guidance, incisal guidance etc can all be adjusted. The MPI (mandibular position indicator) and axiograph are two important accessories of the SAM II articulator. The MPI is a tool for measuring the deviation of the mandible in all three planes of space, as it moves from recorded condylar position (RCP) to intercuspal position (ICP). The axiograph is an instrument which records how the mandible moves. It can be used to show whether the joint is experiencing compression, distraction, or anterior position, and what would be the correct position of the mandible for construction of a splint.

This information can be seen on the MPI, but the MPI uses mounted casts. The axiograph is mounted on a patient. The influence of the periodontal

ligament, musculature etc are also taken into account by the axiograph. In a way, the MPI is more static, and the axiograph more dynamic.

Procedure of mounting casts on the SAM II articulator.

1. Accurate impressions – stone casts
2. Base is poured in a split cast former. First half the thickness then put a metal plate into the stone. Apply separating media to the base, and put a magnet on the metal plate, and then pour the rest of the thickness of the base.
3. A face bow oriented to the soft tissue Porion and Orbitale is used to record the relation of the maxilla to the cranium.
4. Face bow record is transferred to the upper member of the articulator, with the help of the mounting jig.
5. Once the plaster has set, the lower cast can be mounted. For this, a record of the patients centric relation (recorded condylar position) is needed.
 - a. To obtain the RCP, the muscles are first deprogrammed. This is done by asking the patient to bite into some rolls of cotton for about 5 mins.
 - b. Then, modeling wax, or any bite registration wax is softened, and placed on the teeth. The patient is then instructed to close the mandible, which is guided by the operator by placing the thumbs on the chin, and the fingers applying a mild upward pressure at the gonial angles.
 - c. **Roth power centric technique** – This technique utilizes the patient's own musculature to guide the mandible into centric relation, when resistance is applied in the anterior region.
 - i. Delar blue bite registration wax is used. Three strips, one of six thicknesses, and two of two thicknesses, are softened.
 - ii. The first strip (6 thicknesses) is placed over the upper or lower anterior teeth, and the patient is instructed to close, while being

guided in the previously mentioned way. Closure is continued until the posterior teeth are separated by about 2 mm.

- iii. The wax is air cooled and placed in cold water.
- iv. The blocks of about two thicknesses is then warmed until dead soft. The clinician places the warm wax strip over the patient's posterior teeth and the cold wax block over the anterior teeth. The patient closes on the established anterior index, thus establishing a bite registration on the softened posterior section.
- d. The registration is used to orient the mandibular and maxillary casts, and the mandibular cast is mounted in this relation to the lower member of the articulator – with the vertical pin at the 0 mark.
- e. Ideally, three bite registrations should be taken and the upper cast is split away from the mounting and checked for accuracy.

Use of the Mandibular position indicator.

1. The incisal pin assembly is placed onto the upper member of the articulator. An adhesive grid paper is attached to the incisal table on the lower member. The upper member is lowered in RCP until initial tooth contact. The incisal pin is lowered until it touches the incisal table and is locked in this position. The articulator is now reproducing the hinge-axis of each condyle in the unstrained bite position at the point of first contact of teeth. A piece of red articulating paper is placed on the incisal table under the incisal pin to mark the pin position with a light tap. The height of the pin is recorded in plus or minus millimeters. The three coordinates of the plane of the mandible— two hinge-axis positions and incisal pin position— uninfluenced by teeth, are now fixed in space on the articulator and recorded.
 2. The maxillary split cast, mounting plaster, and ring are transferred to the M.P.I., which replaces the upper member of the articulator. The M.P.I. and the upper part of the SAM II articulator are identical, except that interference of the condylar housing of the articulator is eliminated in the M.P.I. The condylar housings are replaced with sliding blocks that interface medially with the condylar posts. This enables complete freedom of movement of the maxillary cast when the incisal pin is retracted. The casts can then be occluded to a position of maximum intercuspation, or tooth-dominated position (ICP), for comparison to the joint-dominated position (RCP).
- The M.P.I. is designed to accept the maxillary cast in the same coordinate system it had on the articulator, and the incisal pins of the articulator and the M.P.I. have similar measurements.
3. The mandibular cast remains on the lower member of the articulator. The M.P.I. is placed above it, and the mounted maxillary cast is interdigitated with it.
 4. Adhesive grids with X, Z coordinates are placed on the black lateral sliding blocks of the M.P.I. The dial gauge is adjusted to zero.
 5. The M.P.I. is moved into position between the condylar balls of the articulator; the blocks are medially positioned without allowing the hinge-axis needles to perforate the grid paper. The maxillary cast is interdigitated with the mandibular cast in a maximum intercuspation position. This position is maintained during the remaining procedures.
 6. The incisal pin of the M.P.I. is lowered to the incisal table and locked. A piece of black articulating paper is placed between the incisal pin and the incisal table, and a mark is made on the incisal table grid by tapping the pin.
 7. The incisal pin's vertical value is read and recorded. The anteroposterior distance between the black ICP dot and the red RCP dot is measured and recorded as the Delta L value.
 8. Black articulating paper is placed next to the sphere of one condylar post, and the black sliding cube with its grid paper is tapped against it, marking the hinge-axis position on the grid paper. This procedure is repeated on the other side.
 9. The pin from the dial gauge is placed into its slot in the black cube. The cube, with grid paper still attached, is slid over to the condylar ball without the articulating paper. The dial gauge is read. A recording on the Y axis going to the right is a negative value; to the left is a positive value. The smaller dial within the gauge gives the millimeter amounts and direction of movement. Red indicates

right, black indicates left. The dial gauge reading is recorded as plus or minus Delta Y in tenths of millimeters on the diagnostic sheet.

10. The M.P.I. is removed from the articulator. The black cubes are pushed medially so that the hinge-axis needle will perforate the grid paper to transfer the original hinge-axis position. If the hinge-axis perforation and black dot coincide, the area is circled with a pen. It is important not to perforate the grid paper before this time, so that distortions do not occur when marking with the articulating paper.
11. The grid papers are removed from the cubes and placed onto the diagnostic sheet. The X, Z measurements are read off the grid and recorded. A black dot above the perforation is given a plus value to reflect a compression situation; if it goes below the perforation, it is given a minus value indicating distraction. If the black dot is anterior to the perforation, it is positive; if it is posterior, it is negative.

Evaluating M.P.I. Data

Once all the data are documented, an analysis of the difference in mandibular position from maximum intercuspation to the recorded contact position is made, based upon the changes in the coordinates:

Delta H = vertical increase or decrease

Delta L = protrusive or retrusive movement

Delta Y = right or left transverse movement

Delta X = protrusive (+) or retrusive (-)

Delta Z = compression (+) or distraction (-)

The vertical RCP/ICP difference, as read off the incisal pin, is designated as Delta H; the horizontal difference between RCP and ICP, as recorded at the incisal table, is designated as Delta L. The differences in the condylar area are described by the coordinates X, Y, and Z: horizontal = Delta X, vertical = Delta Z, and transverse = Delta Y. Thus,

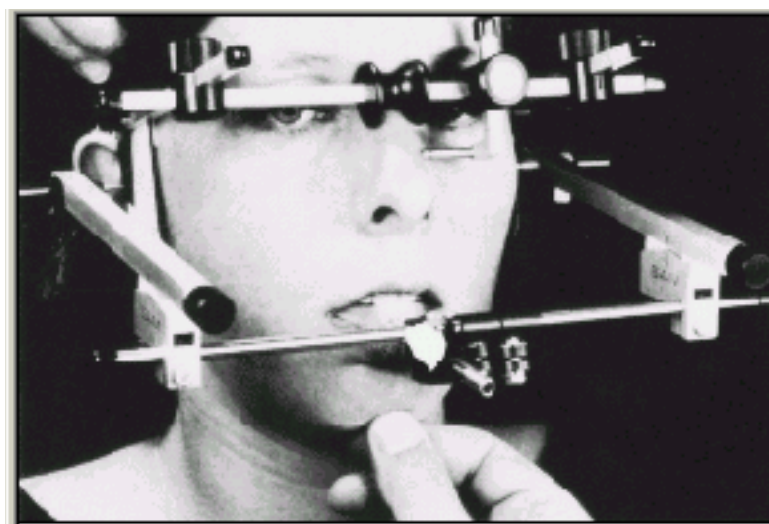
the system differences are clearly determined in three dimensions.

In the condylar area, we are now able to differentiate the following situations:

- RCP and ICP correspond.
- ICP is displaced below RCP. This is termed Distraction.
- ICP is above RCP. This is termed Compression.
- Plus or minus Delta Y values indicate that the condyle is being repositioned medially or laterally by the maximum intercuspation of teeth.

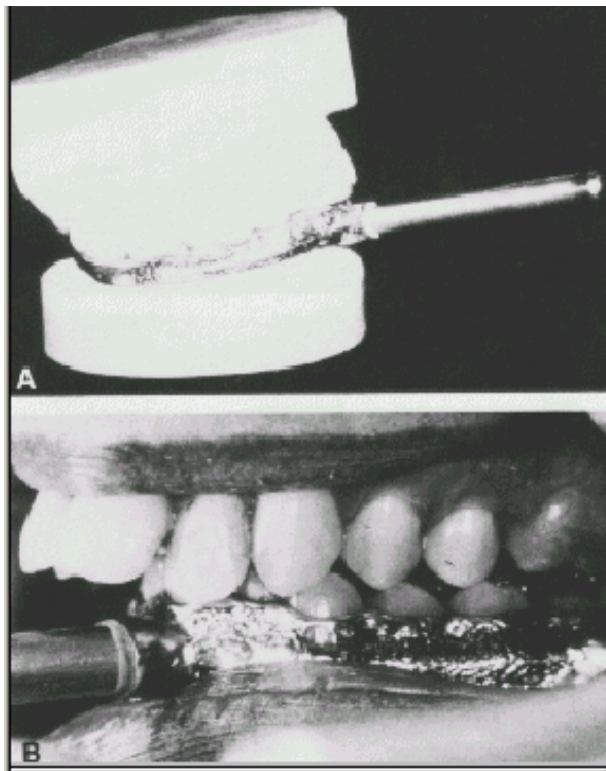
Axiography

The axiograph is an instrument which records mandibular movements in all three planes of space. Its greatest value is in the early detection of sub – clinical disk derangements and other factors that may lead to dysfunction. The axiograph consists of two parts – a face bow which is anchored to the cranium. This consists of two vertical bars (called the parasagittal flag bows) to which are attached two grids, on which the mandibular path is marked. The bars are oriented along the axis orbital plane.



The second part is anchored to the mandibular teeth, using either a tray or a 'para occlusal clutch' (shown below). This adapts around the crowns of the mandibular teeth, but keeps the occlusal

surfaces free to occlude. The tray can be used for quick diagnosis. The para occlusal clutch is custom made for a more precise procedure.



Once the clutch is in place, the mandibular part is fixed to it. The orbitale point is marked on the lateral border of the nose, and the hinge axis is to be located. To locate the hinge axis, the patient's mandible is *lightly guided* into a posterior position, and the patient is instructed to close the mandible. The closure is stopped before the teeth contact. This is repeated a few times to confirm the hinge axis position. In patients with deranged joints, it may be difficult to locate the hinge axis correctly. This is now the reference position. Normally, adults should function in this position. Adolescents usually function 1 mm ahead of this position. The reference position is marked on the graph paper in red. The stylus is then replaced with a dial gauge.



The following movements are made -

1. Protrusion-retrusion; opening-closing; unguided mediotrusion-medioretrusion, right and then left; guided mediotrusion-medioretrusion, right and then left.
2. During the lateral movements, the Bennet movement is recorded from the dial gauge. The tracings indicate movement in the vertical and sagittal plane, and the dial gauge in the transverse plane. The dial gauge should be observed during all movements to note any transverse deviation of the mandible.
3. Do a joint resiliency test.

This determines the ability of the condyle to be moved to a superior and anterior position when it is loaded. It is done by applying superior force at the gonial angles, and simultaneously rotating the mandible at the chin. This pressure is held for 20-30 seconds and the hinge axis is marked.

A child should have approximately 1mm of resiliency, a young adult .5mm, and middle-aged or elderly patients .3mm.

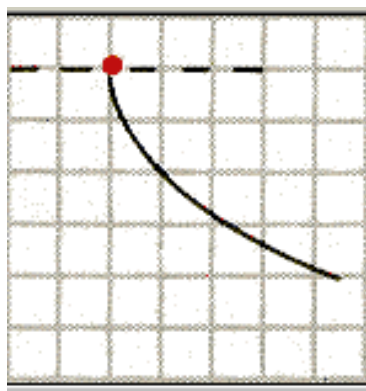
With no joint resiliency, the joint has no buffering elasticity against strong forces, and this is a dangerous situation. It results in deroundation—flattening of the condyle head. Resiliency factors below the norms stated above may indicate splint therapy and definitive treatment plans to restore this component of the stomatognathic system and prevent early discopathy.

4. Ask the patient to close in maximum intercuspation and mark the position.
5. Ask the patient to close in habitual occlusion and mark that position.
6. Ask the patient to do various exercises – phonation, mastication, rest position, swallowing – in order to record the border positions. (These are the maximum movements of the mandible when all ligaments are unstrained.)

Interpretation of the Axiographic Tracings

Sagittal movements

All sagittal movements should coincide for the first 10-12 mm



This includes the opening and closing movements, although these movements will be the longest. Bilateral tracings of the same movement should be identical. There should be no Bennett movement (ie no mediolateral movements during sagittal movements) but 0.2-0.3 mm is acceptable.

If the movements are not similar bilaterally, it can be due to muscle in-coordination. This can be related to the clinical functional analysis. Usually, in muscle related problems, the characteristic of the path will remain the same, but the action cannot be repeated along the same path.

Protrusion and Retrusion

The tracings during protrusion and retrusion should coincide. If not –

Ligaments of the joint may be loose. This can allow the meniscus to change its position over the condyle. Then its biconcave shape will alter the space between the condyle and the eminence.

The tracing shows a superior path on protrusion and inferior on retrusion.

Such a condition may be enhanced by inco-ordination of the superior head of the lateral pterygoid.

Apart from coinciding in the three planes of space, the movements should also coincide in timing. If there is any in-coordination, it should be related to the clinical examination of the masticatory muscles. Ideally there should be no Bennett movement. If there is, then the observation should be correlated with clinical examination of the medial and lateral pterygoids, which have a medial vector of action. The cause of the unwanted Bennett movement can be muscular, or derangement in the condyle-disc system.

Mediotrusive movement

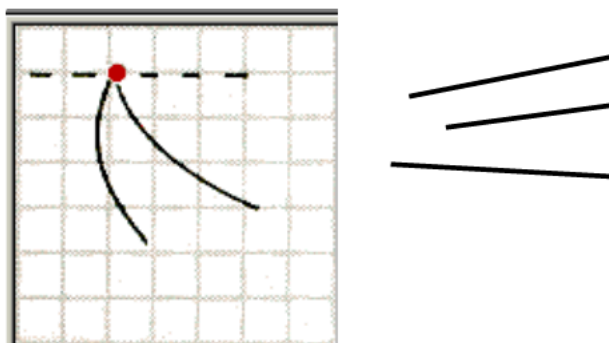
During mediotrusive movement, the condyle rotated in the inferior concavity of the disc, while the disc translates along the articular eminence. Hence the axiograph tracing obtained during mediotrusive movement is an indication of the shape of the articular eminence.

The patient is asked to move the mandible to one side, and back to the centre. The tracings should coincide. If not, possible causes are –

1. loose ligaments
2. subluxation
3. luxation
4. reduction

(These terms relate to the articular disc being dislocated out of its correct position, into a more antero-medial position.)

The displacement of the articular disc will generally restrict the movement of the condyle.



The mediotrusive movements are first performed unguided by the operator, and then guided. This is done to rule out the involvement of ligaments. (How?) The two tracings must be compared.

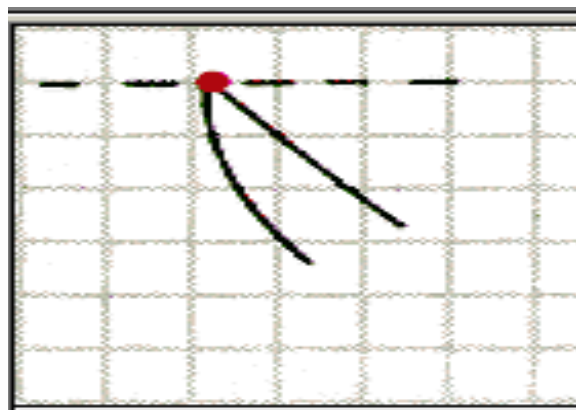
In mediotrusive movement, there should be a positive Bennett movement towards the opposite side. If this is not seen – It indicates a muscle-induced avoidance reflex. (avoidance of occlusal prematurities). In some cases there may be a negative Bennett movement, that is, the condyle first moves laterally, and then medially. This indicates an anteriorly or medially displaced disc.

Opening and closing

In protrusion as well as mediotrusion of the mandible, there is minimal rotation of the condyle. Most of the movement is of the articular disc along the surface of the glenoid fossa. But opening and closing movements involve rotation of the condyle. Hence these movements are important to diagnose *flattening of the condylar head*.

In short, translatory movements represent the upper compartment of the joint, and rotational movements represent the lower compartment.

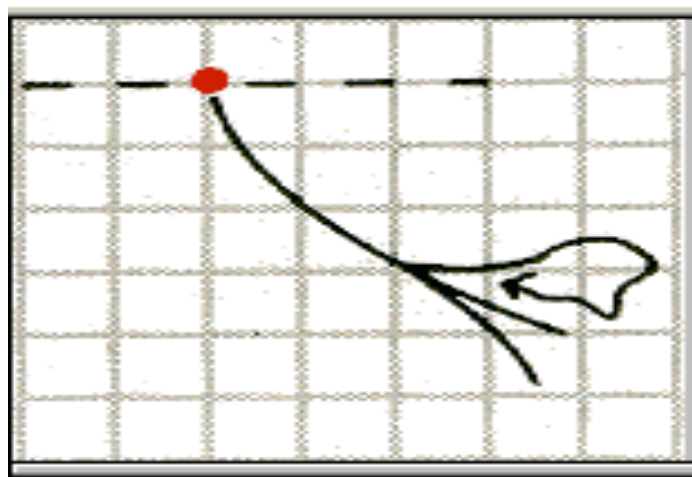
If the head is flattened, the condyle will not rotate along a single hinge axis, and opening and closing tracings will not coincide.



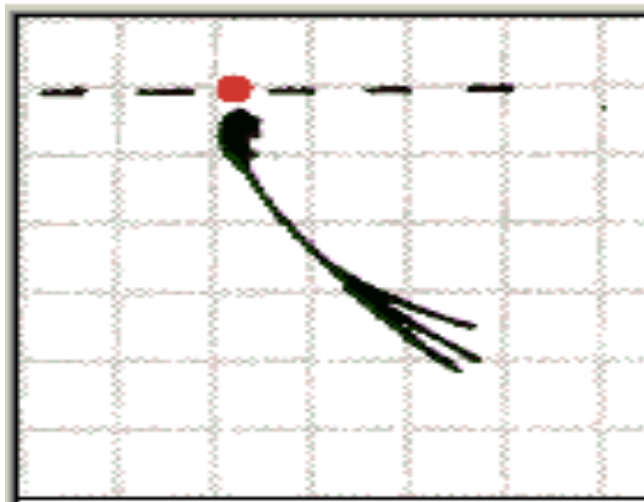
If this is noted, a radiograph can be taken to confirm the flattening of the condylar head. Also, the findings must be correlated with clinical functional analysis, case history and other examination. Also, signs of degenerative bone diseases must be noted in other joints. Presence of pain gives an indication that the disease is still progressing.

Special Situations That Can Be Diagnosed By Axiographic Tracings

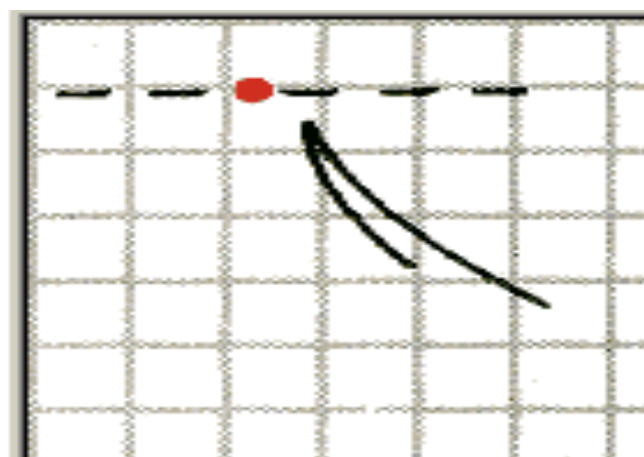
At the end of full mouth opening, in some cases, the mandible can over-rotate. This is seen as an irregular pattern on the tracing.



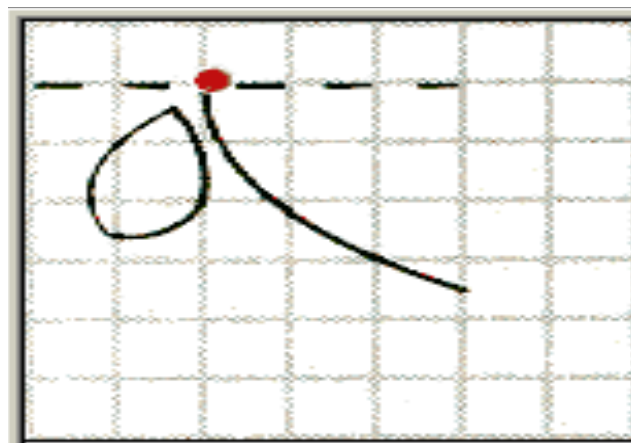
Sometimes the tracing terminates inferior to the reference position. This is usually indicative of the opening muscles pulling the condyle away from the disc, or the disc and condyle away from the fossa. This is termed muscle distraction. It is also associated with muscle pain and bilateral differences between the muscles.



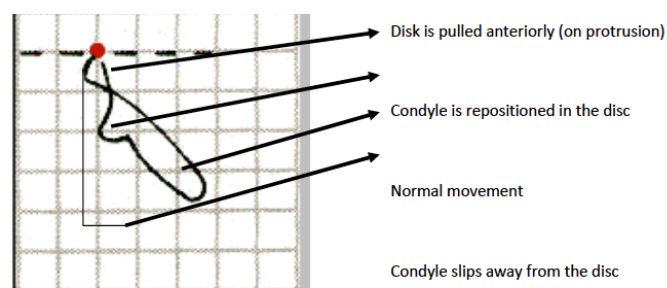
If, after retrusion of the mandible back to position, the tracing ends anterior to the reference point, it indicates looseness of ligaments and hyperactive muscles.



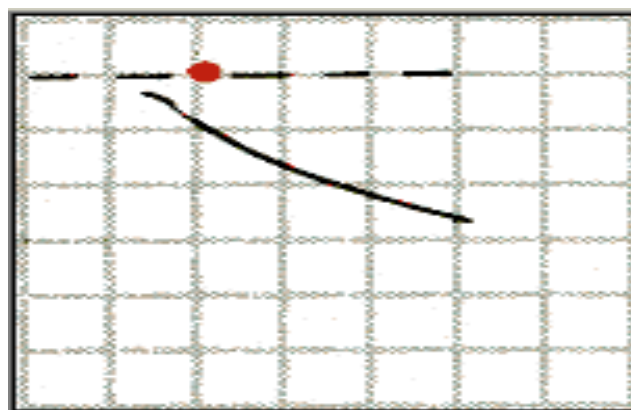
During intercuspation, field of condylar positions may appear in an area inferior and posterior to the reference position. This indicates distraction of the joint due to occlusal interferences. This can happen if there are prematurities in the posterior dentition, and the person tries to achieve complete intercuspation.



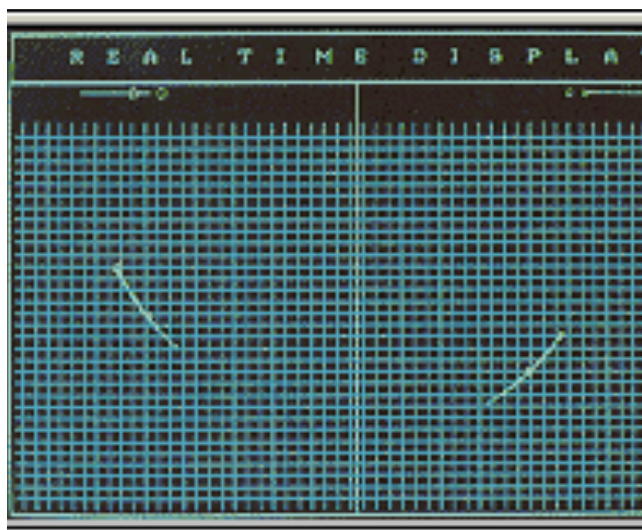
In case of a reciprocal click, the following pattern is seen –



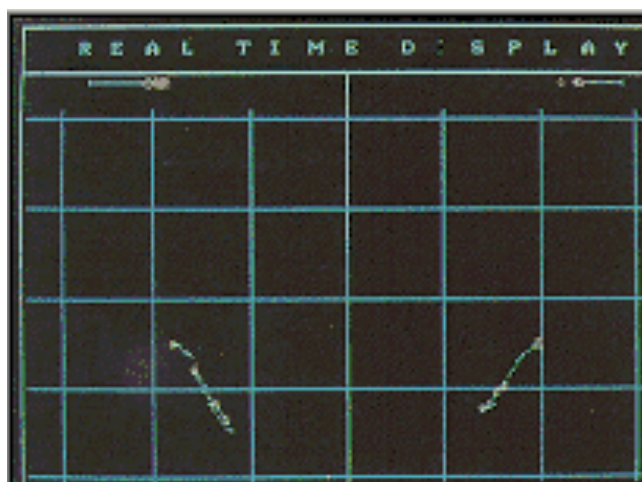
The area of normal movement should be noted, as it is in this area that the mandible has to be positioned during splint therapy. If the temporalis muscle is highly active, the condyle may come to a position posterior to the reference position.



Axiography can also be done with the aid of a computer. the advantage is that the computer records all the paths in the x,z and Y (Bennett) co-ordinates, as well as the timing of the movements of individual joints. The axiograph is set up on the patient in the same way, and the usual method of axiography is followed. The computer displays the condylar movement in real time.



For more accurate readings, the tracings can be zoomed in as well – up to scale of 3.5:1



Hinge axis is located by the computer itself, by calculating the center of the arc scribed by the

mandible during true rotation. The computer then calculates the distance of the stylus from the hinge axis, and this facilitates in accurate placement of the stylus on the hinge axis. Once the hinge axis is located, all the movements are carried out as usual.

The greatest advantage of computer-aided axiography is its accuracy. Bennett's movement is much more accurately depicted. It is quite difficult to notice Bennett movement on the dials in the manual method of axiography. Also, the timing of the movement of both sides is also indicated. The data is entered directly into the computer, and can be repeated several times, and superimposed for comparison. Dr. Slavicek uses a computer aided diagnosis system (CADIAS) which displays the data of history, clinical examination, muscle palpation, instrumental analysis, model analysis and cephalometric analysis, in order to obtain a comprehensive diagnosis for each patient. The program also allows for growth predictions, skeletal and dental VTO and different cephalometric analyses.

REFERENCES

1. JCO Interviews : Dr. Slavicek on clinical and instrumental functional analysis for diagnosis and treatment planning. July 1988
2. Clinical and instrumental functional analysis for diagnosis and treatment planning Parts 4 – 7. JCO Sept – Dec 1988
3. MDS Dissertation – Feb 1995 – Dr. Divakar H.S.
4. MDS Dissertation – Feb 1998 – Dr. Sonali M
5. Concepts in functional occlusion and management of functional disorder of TMJ - Dr. N. R. Krishnaswamy - Manual of the 7th IOS PG Convention