Cado-luxation of the Temporomandibular Joint

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The purpose of this paper is to provide a conceptual and experimental basis for understanding how the condyle, as depicted by the hinge axis pointer, varies in relation to different loading conditions on the mandible. The mandible was treated as a floating object loosely attached to a base—the cranium. This study addresses condylar position in relation to muscle action or muscle inaction to the mandible. The literature is replete with speculation as to why the condyle remains in contact with the eminentia articularis at rest and during movement. The 36th edition of Gray’s Anatomy states, “the condyle can only be dislocated forward on the anterior tubercle, being held in contact by the tonicity of the masseter and temporalis muscles.”

If the capsular ligament is long enough to allow the condyle to move forward in protrusion, the condyle might drop down and away from the fossa and the anterior tubercle. If this is the case, then the condyle, when in terminal centric position, might be found in the fossa (uppermost or rearmost) or against the tubercle, or it may have dropped out of the fossa. Proprioception, or anticipation, of a prematurity can initiate muscle preparation. In time pain will radiate to other structures. The potential for headaches, muscle spasms, loose and sore teeth, joint pain, sinus pain, and bone pain is great. With the many problems that result from surgical intervention of the masticatory system, it is prudent to search for other treatment modalities.

A review of other disciplines can provide insight into condylar position. Study of trabeculation of the femur bone by the mathematician D’Autremont in 1817 showed it is subject to tension and compression. Venous structures in bones have no valves. Lacunae and canaliculae of the Haversian system and Volkmann canals allow movement of blood, but they need intermittent application of force to create a flow. Physiologic tension, compression, and hysteresis are intermittently required to prevent pooling of blood.

Blood flow in vivo might provide a mechanism for dissipating energy to help protect against fracture. The temporomandibular joint veins and sinusoids that lack elastic connective tissue have considerable capacity to drain blood. With their absence of valves, the temporomandibular joint veins enable blood to flow back into the condyles and fossae to restore their mechanical properties. Thus, the temporomandibular joint veins and sinusoids together serve as both a shock absorber and a pump. To consider the meniscus as solely a shock absorber would ignore its effectiveness in providing the intermittent pressure-pumping action of trabeculae.
The study of bone structure demonstrates that the inner structure and external form of human bone are closely adapted to the mechanical conditions existing at every point in the bone. Additionally, the inner architecture of normal bone is determined by definite and exact requirements of mathematical and mechanical laws to produce a maximum of strength with a minimum of material.

The trabeculation of the condyle is composed of cancellous bone that radiates from its neck to the cortex at right angles. The compressive stress is at the anterior portion of the condyle (Fig 3). The most superior portion of the glenoid fossa consists of compact bone, the pterygopatympanic fissure, or in some cases, no bone.

The trabeculation of the anterior tubercle receives the force of the condyle (Fig 4). Its position is graphically shown and duplicated with polarized light studies (Fig 5). Stresses are communicated through a frictionless joint only in a direction perpendicular to the joint surface. This position requires the meniscus to act as a condylar positioner, a force transmitter, a shock absorber, and a friction-free pad during the physiological bending and twisting of the mandible and during mandibular movement. The two layers of the masseter muscle and the three layers of the temporalis muscle, as well as the inward pull of the pterygoid muscles, help maintain proper positioning of upper and lower anterior teeth by the flexing of the mandible and maxilla while in function. This flexion is aided by the midline palatal suture of the maxilla and the palatine foramen, and is confirmed by polarized model stress studies.

In the past when pantograph tracings were made with the Stewart recorder, practitioners were instructed to support the lower border of the mandible with two forefingers. The thumb was placed to guide the mandible. If not done properly, "pig tails" would appear at the ends of the tracings (Fig 6). And also, at times, their confluence or "centric" was exposed. Many times as the patient was in repose, the pointer would move straight down slowly. Sir Astley Cooper in 1901 described a condition he called "subluxation." "It occurs principally in delicate women and is believed by some to be due to the relaxation of the ligaments permitting the
condyle, and possible displacement of the fibro-cartilage. The term "subluxation" is vague. The Latin prefix "sub" means "under and along." It would be more precise to use the term "cado-luxation" to describe condylar movement, as this incorporates the prefix "cado," which means "to drop." A second glass slide recording (Fig 7) shows a drop of 7 mm at the centric portion while at rest, with a confluence of the lines. It is written, "... the temporomandibular joint is the only one in the body to dislocate." Yet the literature also states "muscle tension, or the ligaments, hold the condyle in contact with the anterior tubercle at all times. So much so, it does not seem to warrant investiga-
It is also recorded, "Regardless of any potential importance of the reliability and diagnostic validity of occlusal facets are equivocal and cannot be taken as diagnostic of temporomandibular joint." Also stated, "The position of the condyle in the fossa and its use as a diagnostic criterion or a specific therapeutic objective is not warranted." These authors suggest that perhaps pain must be the benchmark of temporomandibular joint syndrome.

**Experimental device**

A theory corroborated by reproducible quantitative evidence is needed. Removable clutches for both the upper and lower arch were constructed of aluminium and adapted only to buccal and labial surfaces of the teeth. The occlusal, lingual, and incisal aspects were devoid of metal so the teeth could occlude without interference of metal in any movement or closure (Fig 8). The clutches were attached to each respective arch with cold-cure acrylic resin and could be removed easily by loosening the assembly screws on each side. A stud was attached to each clutch by a bolt and key system as in the regular manner for pantograph tracings (Fig 9). A vertical recording flag and cross arm were attached to the stud of the upper clutch and positioned over the area of the temporomandibular joint next to the integument (Fig 10). The hinge axis locator with its needle pointer was then attached to the lower stud of the mandibular clutch. The experiment was conducted and data recorded (Fig 11).

Figure 12 is a mock-up to show the results of the procedures and numbered positions as explanation. The hinge axis locator point of epicenter of rotation was located. This location was marked (Fig 12-1) and confirmed by moiré patterns. The equipment was tightened securely to prevent joint slippage. The patient was asked to occlude all teeth in habitual closure. The new position of the pointer was marked on the flag (Fig 12-2). The patient was then asked to move the mandible forward in protrusion and the flag was marked at the terminus of movement (Fig 12-3).

A spring system was placed between the upper and lower stud (Fig 13). The spring system had a gimbal to allow the patient to move the mandible in any direction. The threaded tube through the center of the springs acts as a stiffener to prevent the spring from buckling, and has a threaded nut to increase or decrease spring force. The nut was rotated so that the upper and lower arches were held apart by increased compression on the spring. If it was found that the dental arches would come together when loaded, the spring pressure was increased by rotating the nut to separate upper and lower teeth and allow the hinge axis pointer to elevate to its fundus or the so-called "braced" position of the condyle.

Several successive stages of the hinge axis migrating positions were marked (Figs 12-8-10). After 6 to 13 minutes the hinge axis pointer moved (Fig 12-4) and then remained fixed for 17 minutes. Empirically, it was found that proprioception of mandibular or habitual closure position was lost as was vertical positioning. Many times the patient stated, "I did not know where to close; my jaw just closed." Repetitively the subject closed to the first prematurity, and with exactitude.

To continue with the experiment the spring tension was increased, and with strong muscular force by the subject, the pointer moved (Fig 12-5). Note the direction of the pointer during forced closure. This could be indicative of muscle direction, osseous bending, meniscus rim compression, and displacement, which are all supported by trabeculation patterns, polarized light studies, hysteresis, and moiré patterns.

When the intense spring tension was released and the musculature allowed to abate, the hinge axis needle returned to the braced hinge axis location (see Fig 12-4). The spring system between the studs was removed and the subject was allowed to rest. It was noted that the hinge axis pointer slowly descended (Fig 12-6).

The patient was then asked to occlude her teeth, bearing in mind the occlusal surfaces where free of cover. A forefinger was then placed under her gnathion and she was asked to open against this upward force. The hinge axis needle immediately dropped a distance of slightly over 11 mm (Fig 12-7).
1. NORMAL HINGE AXIS LOCATION
2. HABITUAL CENTRIC CLOSURE
3. PROTRUSIVE TERMINUS
4. FULLY SEATED CONDYLE
5. VERY HARD CLOSING PRESSURE
6. REST POSITION – SPRINGS REMOVED
7. OPENING AGAINST RESISTANCE
8. Cadoluxation – OPENING AGAINST LIGHT RESISTANCE
9. ONE SHIM BETWEEN INCISOR TEETH
10. SECOND SHIM ADDED
11. THIRD SHIM
12. FOURTH SHIM – 13 MINUTES
13. COTTON ROLL BETWEEN POSTERIOR TEETH
14. COTTON ROLL BETWEEN BICUSPIDS ONLY
15. COTTON ROLL END BETWEEN INCISORS ONLY
16. COTTON ROLL END BETWEEN 3RD MOLARS
17. CENTER BEARING PIN AGAINST PALATE
18. ANTERIOR BEARING PIN
19. POSTERIOR PALATAL BEARING PIN
20. ANTERIOR PIN AGAINST STEEP INCLINE
21. HARD PRESSURE AGAINST STEEP SLOPE
22. SWALLOW WITH TEETH APART
23. SWALLOW WITH TEETH TOGETHER AND IN BRACED POSITION
24. BRACED POSITION AGAINST SPRINGS WITH LIMITED OPENING AND CLOSING AND CHECKED WITH MOIRE PATTERNS AND SPLIT CAST
The spring system was replaced but with the spring below the lower stud to close the mandible (Fig 16). To activate the springs, only the submandibular muscles would be needed to depress the mandible. The unaltered ligamentous hinge axis needle immediately dropped (Fig 12-7).

At this time only the spring was removed and a cotton roll was placed between the anterior teeth. When the subject was asked to close, the needle moved (see Fig 12-4). The cotton roll was placed between the premolars and the patient was asked to close with force. The pointer moved (Fig 12-12). With the cotton roll end placed between the second and third molars, the pointer moved (Fig 12-13). When the cotton roll was placed lengthwise between the posterior teeth, ie the premolars and molars, the needle moved (Fig 12-11).

The spring system was carefully replaced between the clutch studs, leaving the original hinge axis location undisturbed (Fig 12-1). The spring was activated to separate the teeth, and the patient was asked to move the mandible up and down unaided. This action was performed to determine whether musculature alone could produce a braced hinge axis location. The needle moved (Fig 12-4). This position was checked with moiré patterns and with a split cast mounting on an articulator later, again leaving the original hinge axis location undisturbed. It is often stated that overbite will force the condyles back and away from the anterior tubercle. A metal piece fashioned with an overbite was placed on the upper stud, and a rounded rod was placed on the lower stud to simulate an actual case (Fig 15).

When the patient closed with a modicum of force, the hinge axis pointer moved (Fig 12-4) and when the patient was asked to close with strong force, the pointer moved (Fig 12-16). This movement was checked by other dentists and always elicited surprise when the pointer failed to move distally. The fabricated mechanical overbite was then removed. To check the original setting of the hinge axis pointer, the thumb and forefinger were used to locate the center of ligamentous rotation (Fig 12-1). The joints had not moved.

To continue the experiment, sticky waxed shims of pure tin 0.8 mm thick were press contoured to the anterior teeth (Fig 12-16), again taking care not to disturb the original hinge axis location (Fig 12-1). As the shims were added, a “teeter-totter” effect was observed and recorded. The needle, starting
(Fig 12-2) with the teeth in habitual occlusion, gradually rose by incremental amounts (Figs 12-8 and 12-4). At this point successive shims were added until the teeth were no longer in contact and could no longer hold the red tape with the flag and hinge axis needle still in place.

A wax wafer bite was then taken using muscular pressure to overcome the balancing act of the mandible to equalize pressure on the posterior teeth as shown (Fig 12-11). The addition of three more shims opened the bite beyond the tactile sense of the teeth on the wax wafer. Diegrad was then placed in the wax indentations of the teeth and the wafer seated in the mouth. The patient was asked to close firmly against the back teeth, which were not in contact. When set, the wafer was retrieved. Two bites were taken.

Using an arbitrary bite fork setting and being careful to leave the hinge axis needle and the flag undisturbed, the upper split cast model was mounted on an articulator. The lower cast was mounted using the wafer bite. The mounting was tested and checked on the split cast with both bite wafers. The condylar elements of the articulator were then locked with the ball to the stop, in centric occlusion.

The models were allowed to come together and the first maturity marked with red tape and recorded. With the removal of four shims from the patient red tape was used in the mouth and its first prematurity noted and compared to the articulated model’s first prematurity.

Next, with the condylar inclination set to zero, the upper member of the Stewart articulator was tilted so all teeth of the models occluded. The opening on the condyles denoted the drop of the condyle in the fossa and was measured and recorded (Fig 17). On the semi adjustable instruments, this procedure was accomplished by setting the condylar elements to zero and loosening the condylar post locks to allow the assembly to rise. The resultant space was measured and recorded.

When the spring system was again placed between the clutch studs, spring tension was increased to activate the levators of the mandible to the braced position of the condyle in the fossa (Fig 12-4). The subject was asked to close firmly until the first prematurity was contacted. This spot was registered with red silk tape. It was equilibrated and recorded. Closure in braced position, red tape marking, equilibration, and recording were repeated until the
pointer moved by increments (Figs 12-8 through 12-10). The pointer was at position 4 (Fig 12-4). At this point all posterior teeth must contact at the same instant. The canines should be in contact causing immediate disocclusion in lateral excursions or balancing action.

The right canine protects the left bank of posterior teeth in balance, and the left bank of teeth in centric occlusion in turn protects the position of the right premolar. The malocclusion off centric is relieved by canine rise on the opposite portion of the arch, and can eventually move the cuspids out of contact.

Practical Methods

With the preponderance of malocclusion, not every patient can be required, or can afford, to have gnathological armentarium to diagnose malocclusion and to equilibrate the teeth. The leaf gauge is a pioneering example of a method of practical application in an office as shown by Huffman and Regenos.

Pure tin shims 24 mm long by 8 mm wide by 0.8 mm thick were made, as were aluminium shims 24 mm long by 8 mm wide by 0.3 mm thick. To one side of each shim soft sticky wax was applied. The shim with sticky side to the tooth was finger-pressure contoured over 8 and 9 (Fig 18).

The patient was asked to close firmly to adapt the shim to the lingual of the maxillary anterior teeth. Red tape was placed on the occlusal surface of the posterior teeth and the patient was instructed to close. As the patient tries to keep the mandible closed with moderate force, the condyle will slowly seat in the fossa and may eventually hold the tape. If it does, succeeding shims are added until the teeth no longer occlude to hold the tape. After 7 minutes, the tape was no longer being held, presumably indicating the condyle was braced to the anterior tubercle. With successive removal of each shim, the prematurities appeared and were marked, equilibrated, and recorded until the pointer reached braced centric simultaneously with the contact of all posterior teeth.

The purpose of the sticky wax shims is to prevent the teeter-totter effect of the habitual occlusion to drop the condyle from the fossa, when the patient may close his or her teeth inadvertently upon removal of the leaf gauge. The subsequent wait time of 6 to 13 minutes to reach the braced position, is time consuming.

When equilibrating to the tactile tolerance and feel of the patient, the relief of temporomandibular joint syndrome can be dramatic. In 16 years, over 600 cases of varied idiopathic and iatrogenic pain symptoms have been relieved.

Further Experiments and Study of Movement

Custom pantograph equipment was fabricated that would record in three directory deviations exhibited by a changing axis or condyle.

A vertical plate with a vertical recording needle was placed next to the integument in the area of the temporomandibular joint. It was held by an arm attached to the maxillary clutch stud. A separate horizontal flag was held in place by an arm that attaches to the mandibular clutch stud. A tube that held a sliding hinge axis pointer was soldered beneath the movable flag. As the mandible moved the pointer would record on the vertical stationary flag. The hinge axis pointer was set to the original ligamentous position (Fig 12-1).

This equipment was fabricated to learn if condylar position at the fossa has any effect on the lateral and protrusive movements. Also, as the needle moves in conjunction with braced or habitual position, a fresh recording surface area can be positioned by moving the lower flag in or out as needed while still preserving the ligamentous hinge axis position.

The first recording was made with the ordinary method using a center bearing pin on a plastic palatal plate. The tracing scribed is the middle of three on the horizontal and vertical plates (Fig 19). Next, the spring system was inserted between the clutch studs, and the fresh recording surface was
positioned by moving the lower flag outward along the original ligamentous hinge axis. Muscular closure of 10 minutes raised the hinge axis pointers to braced position. Tracings on the plate were inscribed by protrusive and balancing movement (third inscription from the bottom). There was no sign of a Bennett angle or shift.

Cotton rolls were substituted in place of the springs between the studs, and were placed between the posterior teeth. The needle denoting the ligamentous hinge axis immediately dropped and scribbled the lowest of the three upper tracings on the vertical plate. On the lower flag the lowest inscription showed an immediate and large Bennett shift. As shown all recordings are at variance. Again, the ligamentous hinge axis pointer was not been re-adjusted, only the condyle position in the fossa changed. The recordings were performed on the same patient at the same sitting.

The next experiment was to determine the effect of a balancing prematurity on the condylar path during movement of the mandible when in habitual occlusion. A recording was made with the same subject with all 32 teeth in braced centric occlusion, which had immediate canine protection on the opposite side (Fig 20). The occlusion of the right maxillary (tooth no. 1) and mandibular (tooth no. 32) third molars was such that in centric occlusion the #1 lingual cusp posited in the fossa of #32, but the buccal cusps of #1 were in supraversion with its accompanying space. A removable casting with clasps was made to create a heavy balancing tip on the distal buccal of #32 that did not interfere with centric occlusion of #1 and #32. It was placed on #32 and snapped into place. Centric occlusion was checked. The hinge axis pointer was lowered so the subsequent experiment would not superimpose on the results of this experiment.
The patient was asked to move to the left. While being recorded and after several tries, the patient succeeded in moving to the left and a recording was made. The space between the buccal tips of the mandibular teeth to the lingual tips of the maxillary teeth was increased by 2.5 mm. The excursion without the pseudo-removable balancing prematurity, the cusp tips passed within 0.5 mm of each other. Cado-luxation was obvious.

Several movements elicited a popping sound. Upon close examination, the sound was emitted as soon as the subject passed over the tip of the gold balancing cusp as the condyle tried to seat. It was apparent that muscular tension of the levator muscles forcibly brought the condyle to braced position on the eminence as indicated on the hinge axis pointer resulting in the accompanying "pop." With removal of the pseudo-balancing gold cusp, the sound quickly disappeared. When the cusp tip was replaced for 15 minutes, muscle soreness was reported. With removal of the false buccal cusp the relief was almost immediate. This finding suggests a spatio temporal dynamic pattern of motion is stored and can be retrieved with the use of vestibular and somesthetic cues.\(^5,9\)

### Application

After prolonged or major therapy and dental procedures, patients often complain of teeth not meeting properly. Often it is found that their teeth originally did not meet in normal intercuspation. After equilibration of succeeding prematurities exposed by the removal of successive shims and elimination of the teeter-totter of the mandible, all posterior teeth and canines will occlude evenly and at the same instant.

This system of equilibration using successive shim removal has been applied to over 600 cases of temporomandibular joint conditions in a general practice. The principles of treatment include:

1. The posterior teeth and the canines should all occlude simultaneously and evenly.

2. Slight contact between anterior teeth in centric braced position is optional.

3. Posterior teeth protect the anterior teeth in centric braced position.

4. Anterior teeth protect posterior teeth, especially the canines, during excursive movement.

5. Canines protect posterior teeth on the opposite side in excursion as well as habitual closure, and prevent lateral forces on posterior teeth.

6. Swallowing with posterior teeth together gives ease of function and intermittent stimulation of bone (shown by polarized study of mandibular trabeculation patterns), and prevents tongue thrust between teeth.

7. The head stays erect in muscular tension.

When one considers the enormous strength of the mandible and the masticatory system, its tactile sense and its function and resiliency, practitioners are faced with great responsibilities. After many years of study and practice, any deviations, accidents, or treatment of the most minute amount can initiate or aggravate a long insidious road to tooth loss or surgical intervention. Uneven wear or dissimilar restorative materials are suspect, and with the accompanying loss of centric braced hinge axis position, cado-luxation will allow the mandible to quickly compensate for high restorations.

Before involving surgery of the joint we must try to reduce errors in occlusion. In everyday practice, the condition of broad subtle occlusal dysfunction leading to temporomandibular joint problems is easily diagnosed.

1. Place a cotton roll between incisor for 6 minutes; remove, then close on posterior teeth to determine which teeth contact first.

2. Ask the patient to occlude rapidly and hard. The sound must be clean and sharp.

3. All canines must be in contact in centric closure.

4. Posterior teeth must immediately separate in excursion.

Function and structure are but one. My recommendation is that patients suffering from temporomandibular joint syndrome be examined for cado-luxation before surgical procedures are performed.
In practice, the following procedure is recommended to assess occlusion.

1. Successive shims should be added until tape is no longer held. This procedure usually takes 6 to 13 minutes and can be completed by an assistant.
2. Two bites should be made and recorded.
3. Arbitrary facebow.
4. Three upper and lower impressions should be taken.
5. Mount models on articulators:
   a) Model set 1, for diagnosis and future record;
   b) Model set 2, for working, equilibration, and recording;
   c) Model set 3, to fabricate bite planes.
6. At a subsequent appointment, equilibration of contacting teeth can be recorded as shims are removed, and canine rises can be fabricated. Subsequent follow-up at 1 to 2 weeks, and long term adjustments should be performed at 3 to 60 months or 1 year, as needed.

In 50 years of practice, examination of occlusion has become as important as periodic examination and x-rays, particularly in relation to reconstruction procedures, periodontal procedures, accidents, surgical procedures, and before and after root canal therapy. It was found in many cases, that the teeth and the bite plane should both be in centric—either alone may not suffice.

The help of plain cotton rolls between the posterior teeth, even at night in severe cases, can be of immediate diagnostic value. The cotton rolls are easy to use especially when the patient is far away, or after restorations, orthodontia, root canals, or surgery. Use of cotton rolls can also be a test of patient cooperation. Many times the patient is asked to close with moderate force on cotton rolls on anterior teeth for 10 minutes. The cotton is removed and the patient is asked to slowly close on the back teeth, point to the first tooth to touch, close the teeth together and point to where it slides, and finally to report on pain. The cotton roll, as such, can be of great diagnostic value.

Conclusion

Many years ago it was reported that 75% of tooth loss was due to causes other than decay. Dental practice today is mostly in the area of malocclusion and its sequelae. Rigorous studies are needed to address malocclusion and its corrections.

References

Note
The Paper has been published posthumously. The text was altered slightly by normal editorial practices to improve grammar and reduce redundancy. The author's son, Dr. Marsh J. Youngbluth, read, revised and recommended the final version. Reprints will be available on request.