Estimated and true hinge axis: a comparison of condylar displacements

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Mounting dental casts on an articulator has been recommended as an important diagnostic tool in routine clinical orthodontic practice.[1,2,3] Mounted casts enable the clinician to simulate the mandibular position in centric relation and they allow a certain degree of simulation of mandibular movements and occlusal contacts without the influence of the patient's neuromuscular input.[4,5] The initial detection of large centric slides that mounted casts may facilitate has been helpful in defending litigation involving temporomandibular joint dysfunction.[6] (The term "centric slide" is used throughout this study for its brevity and universal acceptance. Preferred terms include "slide from centric relation to maximum intercuspation" or "slide to maximum intercuspation.)

Treating orthodontic cases to centric relation may increase the efficiency of the patient's masticatory neuromuscular system compared to treating to maximum intercuspation.[1] In addition, cases treated to centric relation may be more stable[5] and are possibly less likely to develop temporomandibular dysfunction than cases treated without regard for this mandibular relationship.[4]

Although a centric slide occurs at the level of the occlusion, the condyles may be distracted and/or deflected when the mandible moves from centric relation to maximum intercuspation. With the use of new instruments such as the Mandibular Position Indicator (MPI), movement of the condyles is believed to be converted numerically into three different planes of space.

If the putative condylar distractions and deflections are large, lateral cephalograms taken in maxi-

Abstract

The purposes of the investigation were: i) to compare the condylar displacements from centric slides for 74 sets of casts mounted with an estimated versus a true hinge axis; ii) to determine the error in hinge axes location on the recording of condylar displacements from centric slides; and iii) to define the reproducibility of the Mandibular Position Indicator (MPI), a method of measuring condylar (in vitro) displacements from centric relation position.

The findings revealed that routine use of the true hinge axis to obtain MPI readings for analysis of diagnostic casts is not warranted. The mean standard error of MPI double readings attributed to both hinge axes location was 0.4 mm for each component in the sagittal plane. Of the 0.4 mm of mean standard error, 0.2 mm was contributed by the lack of reproducibility of the MPI. The centric relation bite registration technique outlined in this study always captured a superior articulator position of the condylar mechanism. The condylar distractions and deflections from centric relation to maximum intercuspation were primarily in an inferior direction with a smaller posterior component.

This manuscript was submitted February 1991. It was revised and accepted for publication August 1991.

Key Words

Hinge axis • Articulator • Condylar displacement • Centric relation

mum intercuspation are "converted", by using the MPI values, to centric relation cephalograms from which a treatment plan is devised. If the goals of orthodontic treatment are to place teeth in harmony with condylar guidance, then most often a case mounted in centric relation may call for a different orthodontic treatment plan than the same case diagnosed from maximum intercuspation.

To mount study casts on an articulator, the location of the kinematic hinge axis must be determined. Lucia[7] defines the hinge axis as "an imaginary line connecting the center of rotation of one condyle to the center of rotation of the other condyle". The kinematic hinge axis of the mandible is determined when the mandible is in centric relation.[8,9]

A face-bow oriented to the hinge axis transfers the position of the maxillary cast to the articulator in practically the same relationship as in the patient. The mandibular cast can then be mounted to the fixed maxillary cast with a centric relation bite registration. When the kinematic hinge axis has not been exactly duplicated, inaccuracies can be produced when the teeth are allowed to contact because the arc of closure is not the same.[10]

The procedure for the precise location of the kinematic hinge axis (true hinge axis) has been described previously.[7,11,12] A clutch and assembly which has two adjustable pins near the condyle are secured to the mandibular teeth. The patient is manipulated to open and close in the terminal hinge arc of closure. As long as the motion of the mandible (observed in the sagittal plane) is in a circle (the condyles do not translate), the pins can be adjusted horizontally and vertically until they only rotate. These points define the hinge axis[7,11] and if recorded properly, also locate the kinematic axis.

The routine location and use of the true hinge axis has been questioned for over 60 years.[13,14] Recent technology has not simplified the procedure. Contemporary equipment is expensive and similar in design to the original devices. As a result, the routine use of the hinge axis remains uncommon today.

Other methods for simply estimating the "area" of the hinge axis have been proposed.[15] These include using a point about 13 mm anterior to the tragus of the ear on a line from the tragus to the outer canthus of the eye.[16] More recent equipment employs an ear face-bow which has adjustable components to relate the maxillary teeth to an estimated hinge axis in proximity to the external auditory meatus. Teteruck and Lundeen[16] modified a commercially available ear face-bow and found that it increased the accuracy of estimating the location of the hinge axis.

When casts are mounted on an adjustable articulator, upon removal of the centric relation record, the articulator closely simulates the hinge axis border arc of the mandible and the initial centric relation contact. The mandibular cast is then deflected to the maximum intercuspation position, revealing the centric slide.[17] If diagnostic casts are mounted with an estimated hinge axis that greatly differs from the true hinge axis, there will be differences in the centric slides recorded at the level of the occlusion. To date, no one has estimated what these differences might be in condylar distractions and deflections.

The present study had three purposes. One was to determine, using the SAM articulator system, whether condylar distractions and deflections are different for casts mounted with an estimated hinge axis versus those using a so-called true hinge axis. The second purpose was to determine the amount of error in hinge axes location on the recording of condylar distractions and deflections. The third purpose was to define the reproducibility of the MPI instrumentation.

Materials and methods

Thirty-nine (39) undergraduate dental students at the University of Western Ontario volunteered for the study. Two sets of maxillary and mandibular impressions were taken using an irreversible hydrocolloid material in non perforated rimlock trays. A maximum intercuspation (MI) bite registration was taken with one thickness of pink dental wax (10 X wax, Moyco Industries Inc., Philadelphia, Penn.). Participants were instructed to bite completely through the warm water-softened wax into their maximum intercuspation position. A centric relation (CR) bite registration was taken by first warming a wafer of blue wax (Bite registration wax, DeLar Corp., Lake Oswego, Ore.) in a heated water bath (60 degrees C) and folding it in two. A strip of the two-thickness wax the width of maxillary intercanine distance, was folded over the incisor region to offer anterior resistance and to ensure a "bracing" position of the condyles.[7]

The centric relation bite was cut to the shape of the maxilla with scissors to allow very little horizontal overlap that the cheeks could distort. The posterior part of the wax (two thicknesses) was heated to be very soft. The anterior portion (6 thicknesses) remained very rigid after heating and was carried back far enough lingually to capture the mandibular incisors in the most retruded position of the mandible for those participants with large overjets. The differentially heated CR wax bite was placed against the maxillary teeth. The participants were instructed to retrude their mandibles as far back as possible with their mouths closed but not touching the wax. After practicing prior to placing the wax in the mouth, the participants were instructed to close into the anterior portion of the wax once the mandible had been retruded. The lower lip was retracted to observe gingival blanching while closing into the very stiff anterior portion. The subjects were instructed to close until the cusp tips just indented the still soft part of the posterior portion of the wax. The participants held this position until the wax hardened sufficiently to allow removal without distortion. The above method is a "hands off" technique that allows the subject's own musculature to "seat the condyles".

The four impressions were immediately poured in type IV high-strength dental stone (Vel-Mix, Kerr Manufacturing Co., Romulus, Mich.). and separated after initial set. The casts were inspected for detail and any unwanted artifacts were removed. The casts were trimmed for ease of mounting. The centric relation bite registration was carefully trimmed with a scalpel blade so that only indentations for the cusp tips remained.

To reduce instrumentation variables, only one SAM2 articulator (Great Lakes Orthodontics Ltd., Tonawanda, NY) was used for the entire study. All casts were mounted on the articulator using fast-set mounting stone. One maxillary cast was mounted on the SAM2 articulator using the ear face-bow transfer provided to locate the estimated hinge axis. Manufacturers' recommendations for all clinical and laboratory procedures were followed.[18]

The second maxillary cast was mounted on the SAM2 articulator by a face-bow transfer after locating the so-called true hinge axis with the Axiograph (Great Lakes Orthodontics Ltd., Tonawanda, NY). The procedure described by the manufacturer was closely followed.[19] The terminal hinge position was located with the subject in a supine position. The operator gently guided the subject's mandible in the terminal hinge arc of closure. Once the "true" hinge axis was located, the skin was marked with the subject sitting upright, head out of the head rest and facial musculature clinically relaxed.

Mandibular casts were mounted on the articulator, one to the "true" axis cast and the other to the estimated axis cast, using the same centric relation bite registration from each subject.

Centric slides were assessed in the sagittal plane at the articulator condyles for each mounting procedure using a MPI (mandibular position indicator) (Great Lakes Orthodontics Ltd., Tonawanda, NY). This device can measure the three-dimensional change in the position of the articulator condyles between centric relation and maximum intercuspation.

This study was concerned only with the horizontal (i.e. anteroposterior) and vertical changes in the sagittal plane at each articulator condyle. The horizontal and vertical changes correspond to the Δx and Δz changes respectively on the adhesive grids affixed to the sliding blocks on the MPI. The procedure described by the manufacturer[20] and by Slavicek[1] was followed except for one modification. In order to further stabilize the maximum intercuspation position and prevent damage to the stone casts, the MI wax record was interposed between the mounted models before the grids were marked with articulating paper.

The MPI procedure was performed twice for each subject: once for casts mounted with the true hinge axis and the other for the estimated hinge axis casts using the same maximum intercuspation record. Four numbers thus describe the articulator condylar distractions and displacements for the MPI procedures: a horizontal change (antero-posterior) or Δx at the left and right condylar mechanism; and a vertical change or Δz at the left and right condylar mechanism. All MPI values were recorded in multiples of 0.5 mm.

The "true" hinge axis (THA) mean MPI values were compared to their estimated hinge axis (EHA) counterparts, e.g. Δx left THA versus Δx left EHA by way of a paired t-test. Correlation coefficients were calculated for the counterparts. Statistical significance was set at the 5% level.

Error study 1. The effect of reproducibility of hinge axes location on the recording of sagittal centric slides was determined by relocating the "true" and estimated hinge axes on 10 randomly chosen subjects 3 months after the initial experiment. The same maxillary and mandibular casts were used. The same centric relation and maximum intercuspation bite registrations were used for each subject to remount the mandibular casts and repeat the MPI readings. The MPI values derived from the two determinations of the estimated and true hinge axes were compared by correlation coefficients and standard errors of double measurement within each hinge axis. The standard error of double measurement was calculated according to the formula[21]:

$$S.E. = \sqrt{\frac{\Sigma d^2}{2n}}$$

where Σd^2 is the sum of the squared differences between the two mountings, and n is the number of subjects.

Error study 2. The reproducibility of the measurements made by the MPI instrument was determined by having the same operator perform the MPI procedure twice for the same set of mounted casts. Therefore, in contrast to error study 1, no

Table 1
Mean articulator condylar displacements and standard deviations (in parentheses). Values are for the four components with the two hinge axes mounting (in mm, n=37)

	Hinge Axis	
Component	Estimated	True
ΔzR	+1.24 (0.98)	+1.15 (0.91)
ΔzL	+1.13 (1.01)	+1.27 (0.93)
ΔxR	-0.32 (1.07)	-0.65 (0.86)
ΔxL	+0.31 (0.79)	-0.16 (0.74)

Key:
Δz = vertical change R=right
Δx = horizontal change L=left

Table II
Mean differences and standard deviations of MPI component values between casts mounted with estimated (EHA) and "true" (THA) hinge axes (in mm, n=37). Statistical analysis by paired t-test.

Component	Mean Difference	S.D.
EHA ΔzR - THA ΔzR	0.09	±0.92
EHA ΔzL - THA ΔzL	-0.14	±0.85
EHA ΔxR - THA ΔxR	0.32*	±0.84
EHA ΔzL - THA ΔzL	0.47**	±0.88

* p<0.05
**p<0.01

Key:
Δz = vertical change R = right
Δx = horizontal change L = left

difference existed in the location of the hinge axes. The standard error of double measurement was calculated using the same formula above.

Results

Of the 39 subjects who volunteered for the study, two were excluded from the statistical calculations. In both cases, difficulty was encountered in trying to locate the terminal hinge axis with the axiograph. One subject displayed a loud reciprocal click upon jaw manipulation and the other had significant muscular resistance to jaw manipulation.

The nature of articulator condylar displacements

Close inspection of the raw data of MPI values reveals that the MI (maximum intercuspation) position of the articulator condyle as expected and by definition was always inferior to the CR (centric relation) position. Therefore, in this study, the so-called condylar displacements from CR to MI were in an anterior-inferior, posterior-inferior or straight inferior direction for both hinge axes.

Table I lists the mean values of the articulator condylar displacements divided into components and hinge axes. For the vertical component, both the estimated and "true" hinge axes have condylar displacements slightly greater than 1mm. The horizontal changes are smaller and slightly different between the hinge axes. It should be noted that large variances are associated with all of the component mean values.

Estimated versus "true" hinge axis: comparison of articulator condylar displacements

Comparative statistics between the estimated and "true" hinge axes mountings for the four components are summarized in Tables II and III. Table II lists the mean differences between the estimated versus "true" hinge axis for each component. Very little difference exists for the vertical changes between the hinge axes. However, both sides show larger and significant differences between the estimated and "true" hinge axes for the horizontal components.

Table III lists the linear correlation coefficients for the four components between the estimated and "true" hinge axes. Three of four are highly significant with a moderate to good relationship between MPI values derived from estimated and "true" hinge axes mountings. However, the correlation for the horizontal component on the left side is only fair. None of the r values are higher than 0.64.

The effect of reproducibility of hinge axes location on the recording of articulator condylar displacement

Table IV lists the linear correlation coefficients between MPI values derived from the initial mounted casts and the error study casts. The magnitude of the coefficients in Tables III and IV were compared. Smaller coefficients in Table III indicates that the discrepancies of MPI values between casts mounted with the estimated versus the "true" hinge axis cannot be explained by measurement error alone. This suggests that while the two sets of values are statistically related, they are not interchangeable.

In general, all the correlation coefficients in Table IV are very good to excellent, indicating that record-

Table III
Linear correlation coefficients (r) of MPI readings between casts mounted with estimated and true hinge axes (n=37).

Component	r
ΔzR	.53***
ΔzL	.62***
ΔxR	.64***
ΔxL	.34*

* p<0.05
***p<0.001

Key:
Δz = vertical change R = right
Δx = horizontal change L = left

Table IV
Error study 1
Linear correlation coefficients (r) describing the effect of reproducibility of hinge axes location on MPI readings. Values related component articulator condylar displacements between two separate mountings (initial casts and error study casts, n=10).

	Hinge Axis	
Component	Estimated	True
ΔzR	.92	.90
ΔzL	.84	.64
ΔxR	.89	.86
ΔxL	.82	.92

Key:
Δz = vertical change R = right
Δx = horizontal change L = left

ing articulator condylar displacements with the MPI device using both the estimated and true hinge axes seems to be highly reproducible.

The results of determining the effect of error in hinge axes location on the recording of sagittal articulator condylar displacements measured with the MPI are found in Table V. The variability is listed for all components for both the estimated and true hinge axes. The range of standard error for the component displacements is from 0.30 - 0.66 mm. The mean standard error for the estimated axis was ±0.36 mm per component, while for the true hinge, the mean standard error was ±0.49 mm. The mean standard error for both axes and all components was ±0.4 mm per component. For each component, the standard error is slightly larger for the "true" hinge MPI readings. However, differences in the standard errors for the estimated and "true" hinge axes fell short of statistical significance.

Instrument error

Part of the error involved in the reproducibility of hinge axes location consists of instrument error of the MPI. Table VI lists these standard errors for all components for both the estimated and "true" hinge axes. As expected, the values are comparable between the hinge axes. The mean standard error for all the components for both the estimated and true hinge axes was ±0.2 mm per component.

Discussion

The nature of articulator condylar displacements

For every centric slide recorded, the position of the articulator condyle at maximum intercuspation as expected and by definition was always inferior to its position at centric relation. It would seem that the method described for taking the centric relation bite registration promotes capturing a more superior position of the condyle. This emphasis on capturing a superior position would be in agreement with Roth[2] and Dawson.[10] Studies by Hoffman et al.,[22] Rosner,[23] and Rosner and Goldberg[24] found from 9% to about 50% of the slides featured the condyle more superior in maximum intercuspation. The difference appears to be in the method of recording centric relation which, in the previous studies,[22-24] was done by chin guidance in the retruded arc of closure.

In this study, the replicability of the centric relation position is not a factor as the same interocclusal records were used for comparing the slides between the estimated and "true" hinge axes mountings and for the error study. In clinical practice, however, the replicability of the CR position will influence the MPI readings of the CR-MI "condylar" displacement. Investigators have alluded to a wide variation in centric relation positions.[25,26]

The magnitude of articulator condylar displacements, both vertically and horizontally, was often dissimilar for the right and left sides. For this to happen a rotation of the condyle must have occurred. The MPI is sensitive only to vertical and horizontal articulator condyle movements in the sagittal plane and transverse movements in the frontal plane. To learn more about what occurs during condylar distractions and deflections, more

Table V
Error study 1
Standard errors of double measurement* describing the effect of reproducibility of hinge axes location on MPI readings. Values reflect differences in component articulator condylar displacements between two separate mountings (initial casts and error study casts, in mm, n=10).

Component	Hinge Axes Estimated	True
ΔzR	.30	.42
ΔzL	.43	.66
ΔxR	.30	.46
ΔxL	.39	.40

$$*S.E. = \sqrt{\frac{\Sigma d^2}{2n}}$$

Key:
Δz = vertical change R = right
Δx = horizontal change L = left

Table VI
Error study 2
MPI instrument error. Standard errors of double measurement* for two separate MPI readings on the same set of mounted casts (in mm, n=10).

Component	Hinge Axes Estimated	True
ΔzR	.25	.25
ΔzL	.16	.22
ΔxR	.19	.19
ΔxL	.19	.22

$$*S.E. = \sqrt{\frac{\Sigma d^2}{2n}}$$

Key:
Δz = vertical change R = right
Δx = horizontal change L = left

sophisticated equipment is needed in order to study the rotations and transverse movement of the condyles in a three dimensional model.

According to the magnitude of the articulator condylar displacements recorded, the putative displacement of the condyle from CR to MI was more vertical than horizontal. The values found in this study for the vertical component of the condylar displacement were greater than those reported elsewhere.[22-24]

In fact, if the sample consisted of adolescent patients rather than adults, the condylar displacements might have been much larger than reported in this study. The horizontal component of the condylar displacement indicated a posterior displacement from CR to MI. Previous studies all found the average MI position of the condyle was anterior to the CR position, from 0.26 - 0.40 mm.[22-24] These discrepancies must be understood in the light of differing concepts of centric relation and the means for recording it. In this study, the condyle appeared to be in a more superior position when in centric relation.

Estimated vs. "true" hinge axis: comparison of articulator condylar displacements

If the component "condylar" displacements for the two hinge axes were identical, then the estimated face bow would have recorded the kinematic axis points on each subject. This was not found or expected. However, the comparative analysis of the "condylar" displacement (Tables II and III) for casts mounted with the estimated versus the "true" hinge axis revealed similar but not identical results. There appeared to be a relationship between the component displacements for the two hinge axes, although the strength of the relationship differed for the four components. What the results do show is that the estimated face bow of the SAM articulator system locates an axis fairly close to the kinematic axis. Also, the estimated axis is related to the kinematic axis in such a fashion that no statistical differences were found between condylar distraction in the vertical plane. However, the horizontal component, especially on the left side, gave evidence of systematic differences for "condylar" displacements between the two hinge axes. Even in the vertical components, the correlation coefficients between estimated and "true" hinge axes (Table III) were much smaller than those within the same hinge axis determined from the error study (Table VI). As such, the MPI values attained with one hinge axis recording were not interchangeable with the values derived from the other hinge axis recording, especially in the horizontal component.

The effect of reproducibility of hinge axis location on the recording of articulator condylar displacements

From the magnitude of the correlation coefficients for MPI values from casts mounted with two hinge axes determinations (Table IV), it appears that the recording of condylar displacements with the MPI is highly reproducible, regardless of the hinge axis used.

The error in estimated versus "true" hinge axis location (Tables IV and V) on the recording of "condylar" displacements was determined. In this study, there was less variability in locating the same axis points from the estimated face bow than from the axiograph.

Location and transfer of the estimated hinge axis depends only on securing the estimated face-bow to relatively stable landmarks of the cranium (i.e. the external auditory meati and soft-tissue nasion), whereas location and transfer of the true hinge axis includes two steps that are prone to error where the "true" hinge axis points can differ from the kinematic axis points. Firstly, location of the "true" axis depends on guiding the patient's jaw into a pure rotation at the terminal hinge position. Difficulty in obtaining a pure rotation of the mandible arises if the patient has any masticatory muscle "trismus or fatigue". Secondly, transfer of the "true" hinge axis involves marking the subject's skin at the hinge axis points. Should the skin be deflected through facial expression or even head positioning when the face-bow is being positioned, the "true" hinge axis points are erroneously transferred.

Slight difficulty was encountered in recording the "true" hinge axis on a number of subjects in the study. In fact, two subjects were not used because of obvious dysfunction during the clinical procedures. Although the rest of the subjects appeared free of dysfunction, the increased variability of the "true" versus estimated hinge axis recording may have been due, in part, to muscle splinting in some patients. Because the sample comprised undergraduate dental students, muscle splinting was a problem. If adolescent subjects were used, the hinge axis would have been easier to locate since muscles in the younger patients tend to be more relaxed. In patients with signs and symptoms of temporomandibular joint dysfunction, a mandibular repositioning splint is recommended for some time prior to "true" hinge axis location.[27,28] Supposedly, the splint normalizes the neuromuscular pattern and facilitates manipulation of the mandible in the retruded arc of closure.[4,17,28] Although not suffering from obvious TMJ dysfunction, the "true" hinge axis would have been easier to locate and therefore replicate the kinematic axis in some patients had they worn a mandibular repositioning splint for some time prior to the clinical procedures.[27] Also, in this study the "true" hinge axis was not checked by split cast verification using different centric relation wax records of varying thicknesses. Many of the "true" hinge axis recordings may not have been identical to the kinematic axes.

Recommendations

The SAM axiograph, if used on a deprogrammed patient with split cast verification can repeatably locate the kinematic axis. In this study, some of the "true" hinge axis recordings were not identical to the kinematic axis due to the increased variability of the error study and the fact that splints and split cast validations were not performed. However, in an exhaustive review of hinge axis by Winstanley,[29] an axis located by using clutches ("true" hinge axis) was always closer to the kinematic center of rotation than any arbitrary (estimated) axis used.

What we are looking at here is the arc of closure of the mandible on a located axis from an opening the thickness of the CR wax bite to the first tooth contact. Closing the mandible the thickness of the CR wax bite on a different axis will give a different first tooth contact position (centric relation estimated axis and centric relation "true" axis). Closing the mandible from the two first tooth contact positions (determined by the two axes located) to maximum intercuspation results in two different but similar condylar distractions and deflections.

Since the condylar displacements in the sagittal plane were similar with the greatest difference being only 0.5mm in the horizontal component, it would appear that the estimated face bow can place the mandible very close to the "true" hinge axis placement.

When using MPI values to convert lateral cephalograms (taken in maximum intercuspation) to centric relation lateral cephalograms then the estimated axis is recommended for its practicality. Also, when looking at mounted orthodontic casts to assess mandibular position, then use of the estimated axis is recommended. However, for research purposes, for the study of mandibular movements, and for the equilibration of casts where the mandible will be closing on a different arc, only the "true" hinge axis is recommended.

Conclusions

From the findings of this study, the following conclusions can be reached:

1. Condyle displacements determined from MPI values for casts mounted with an estimated hinge axis are related to the values obtained using the "true" hinge axis. Because of its practicality and reliability, use of the estimated hinge axis is recommended for examining the mandibular position of mounted orthodontic casts and for using MPI values with which to convert lateral cephalograms to centric relation cephalograms.
2. Recording condylar displacements with the MPI device, using either the estimated or "true" hinge axis to mount the maxillary cast is highly reproducible.
3. The effect of reproducibility of hinge axes location on the recording of condylar displacements was determined to be $\pm$0.4mm (standard error of measurement) for each component in the sagittal

plane. In clinical practice, this figure is probably slightly larger when the variability of the centric relation bite is considered. Therefore, orthodontists should be aware of the existing error and the decisions based on MPI values should take this into consideration.

4. The variability of the condylar displacements determined from the estimated hinge axis is less, although not significantly so, compared to the "true" hinge axis. The increased variability is due to the technical errors inherent in recording the true hinge axis. The sample consisted of adults where splints and split cast validations were not used.

5. Part of the standard error of measurement due to the reproducibility of hinge axes location is composed of instrument error of the MPI. It is precise to $\pm$0.2mm for each component in the sagittal plane.

6. Use of centric relation bite technique with a modified wax record as described in this study produced a superior condylar position 100% of the time. The wax record features a very stiff anterior portion and a dead soft posterior portion.

7. The mean condylar displacement from centric relation to maximum intercuspation in 37 dental students was slightly larger than 1mm in an inferior direction, with a smaller posterior component.

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