A three-dimensional comparison of condylar position changes between centric relation and centric occlusion using the mandibular position indicator

Thomas W. Utt, DDS,[a] Charles E. Meyers Jr., DDS,[b] Thomas F. Wierzba, MS, MPH,[c] and Steven O. Hondrum, DDS, MS[d]
Stuttgart, Germany

The mandibular position indicator (MPI) was used to compare condylar position between centric relation (CR) and centric occlusion (CO) for 107 patients before orthodontic treatment. The MPI data were examined to determine frequency, direction, and magnitude of CO-CR difference; and data were analyzed for possible correlation to the patient's Angle classification, ANB angular measurement, age, or gender. Only one patient (0.9%) had no measurable CO-CR difference in all three spatial planes. Six subjects (5.6%) showed a shift in condylar position in the transverse plane without a measurable difference in the sagittal plane. Twenty patients (18.7%) experienced a superoinferior (SI) or anteroposterior (AP) condylar displacement of at least 2.0 mm on one or both sides; 17 (15.9%) displayed a transverse shift at the level of the condyles of 0.5 mm or greater. No statistical difference was found between the 31 patients with Class I malocclusions and 72 patients with Class II malocclusions when comparing the amount or direction of CO-CR change. The amount of CO-CR difference was nearly identical for right and left sides with the amount of SI displacement ($\bar{x}$ = 0.84 mm) consistently greater than AP displacement ($\bar{x}$ = 0.61 mm). Only weak correlations were found between movements of right and left condyles. The average transverse CO-CR difference was 0.27 mm. Patient age, ANB angle, gender, or Angle classification cannot be used to predict frequency, magnitude, or direction of CO-CR changes at the level of the condyles. (AM J ORTHOD DENTOFAC ORTHOP 1995;107:298-308.)

An understanding of the mandibular condyle-glenoid fossa relationship continues to be of great interest and controversy.[1] Although tomographs have traditionally been used to attempt visualization of condylar structure and the condyle-fossa relation, different methods may be used to produce and interpret the images obtained.[2-19] Some investigators have advocated the use of radiographs to determine condyle position,[7-14] whereas others question the reliability of joint imaging to make such a determination.[15-19] These contradictory findings are one reason a consensus group in 1983 stated there was insufficient evidence that condyle-fossa eccentricity is a diagnostic sign of TMJ disorders.[20] The American Dental Association[21] and the American Academy of Craniomandibular Disorders[22] have concluded that radiographs are contraindicated to assess condylar position for diagnostic purposes.

Techniques such as computed tomography (CT), magnetic resonance imaging (MRI), arthrography, and arthroscopy may improve diagnostic capability; however, they are not without disadvantages and limitations.[21-25]

Previous attempts that use mounted models to examine changes in condylar position have been reported. In 1952 Sears[26] studied sagittal, vertical, and horizontal changes of the condyles with the condyle migration recorder. The extent of lateral shift of the condyles was an unexpected discovery. Posselt[27] used the gnatho-thesiometer for analysis of contact positions, Bennett movement, and observation of condylar path variation. Long[28] used the Buhnergraph to locate hinge axis, to verify the terminal hinge axis location, and to verify centric jaw registrations. The Buhnergraph, however, did not quantify a change of condylar location in the transverse plane.

A 1973 study by Hoffman, Silverman, and Garfinkel[29] used a modified articulator to measure differences in condyle position between centric

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[a]Major, U.S. Army Dental Corps; Chief, Orthodontics, Stuttgart, Germany.
[b]Colonel, U.S. Army Dental Corps; Director, U.S. Army Orthodontic Residency Program.
[c]Epidemiologist, Henry M. Jackson Foundation.
[d]Colonel, U.S. Army Dental Corps, Dental Materials, U.S. Army Institute of Dental Research.

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relation (CR) and centric occlusion (CO) in anteroposterior (A-P), superoinferior (S-I), and mediolateral (M-L) dimensions. They found CR does not coincide with CO in the majority of cases. Other authors[30,31] have used the Veri-Check (Denar Corp., Anaheim, Calif.) to analyze variability of centric relation records or to compare the mandibular condyle position in the glenoid fossa by using different types of interocclusal records. Rosner and Goldberg[32] used a method similar to the Veri-Check for a three-dimensional comparison of condylar position in the intercuspal position relative to what was described as the retruded contact position.

Slavicek[33] described the use of the SAM articulator with the mandibular position indicator (MPI) (Great Lakes Orthodontics, Ltd., Tonawanda, N.Y.) to quantify differences between the joint-dominated recorded condylar position and the tooth-dominated position of maximum intercuspal position.

Girardot[19] evaluated the nature of condylar displacement in pain dysfunction patients. Condylar position changes were measured with the SAM and MPI instrumentation, oriented tomograms, and analysis of articulator mounted casts. He compared the methods of measurement and evaluated the correlation between elimination of condylar displacement and relief of clinical symptoms. He found limited correlation between MPI readings and tomographic position, but MPI readings correlated highly with the mounted casts.

The SAM articulator and the MPI, or similar instrumentation such as the Panadent Condyle Position Indicator (Panadent Corp., Grand Terrace, Calif.), enable the clinician to determine, record, and compare the positional changes of the condyle between CR and CO in all three spatial planes.

The purposes of this study were (1) to make a three-dimensional comparison of condylar position in CO relative to the clinically captured CR on patients before initiation of orthodontic treatment, (2) to report the frequency and magnitude of the differences between CO and CR positions at the level of the condyles, and (3) to examine the relationship of condylar position changes to other factors routinely available and traditionally considered by orthodontists before treatment.

MATERIALS AND METHODS

The records of 107 patients accepted for orthodontic treatment at the U. S. Army Orthodontic Residency Program, Fort George G. Meade, Md., were used as the sample for this investigation. There were 48 male subjects and 59 female subjects. The average age was 13.53 years, with a range of 7.75 to 38.17 years. There were 31 Class I, 72 Class II, and 4 Class III malocclusions. The mean ANB angular measurement was 4.38° with a range of −1° to 10.5°. Pretreatment records included CO (maximum intercuspation) bite registration, CR registration, SAM anatomic face-bow, CR mounting of the models on the SAM articulator, and MPI recordings.

All participating orthodontists received similar instruction for CR interocclusal records technique and the use of the MPI.[33,34] A "power centric" wax interocclusal registration was taken to obtain the clinically captured CR position. The power centric registration refers to the use of the patient's power closure muscles (masseters, medial pterygoids, and superior heads of the lateral pterygoids) to seat the condyles as closely as possible to CR with condyles centered transversely and seated against the articular disks at the posterior slope of the articular eminences without dental interferences.

The power centric registration was taken with Delar Bite registration wax (Delar Corp., Lake Oswego, Ore.) and constructed in two sections. The anterior section extends from canine to canine, is four or five layers thick, and the anteroposterior dimension depends on the amount of overjet. The posterior section is one or two layers thick and depends on the curve of Spee, overbite, and the amount of mandibular closure. The posterior section is wide enough to extend across the arch and end slightly buccal to the buccal surfaces of the molars and premolars. A controlled water bath, 140° F, is used to soften the wax, which must be "dead soft" when used.

The patient is seated in the dental chair, and the chair is reclined to a 45° angle. The anterior section is placed on the upper anterior teeth. The operator guides the mandible, applying chin point pressure at pogonion to prevent protrusion, supporting the angles of the mandible in a superior direction, and asking the patient to relax and close slowly. The patient continues to close slowly until the lower anterior teeth are indexed and there is a 2-mm posterior interarch vertical separation at the probable first contact. The wax section is cooled with the air syringe, removed, and placed in cold water to harden.

The dead-soft posterior section is then placed across the upper posterior teeth, and the hardened anterior section is replaced over the upper anterior teeth. There should be no contact between the two wax sections. As the patient closes into the hardened anterior section, he is asked to close firmly. The hardened anterior stop allows the patient's power closure muscles to seat the condyles. The posterior section captures the posterior tooth indexing. It is then cooled and hardened in cold water.

The registration is inspected to ensure no cusp penetration through the wax. The wax registration is trimmed with a sharp scalpel to remove undercuts, soft tissue contacts, interproximal areas, and occlusal surfaces, while maintaining indexing of cusp tips and incisal

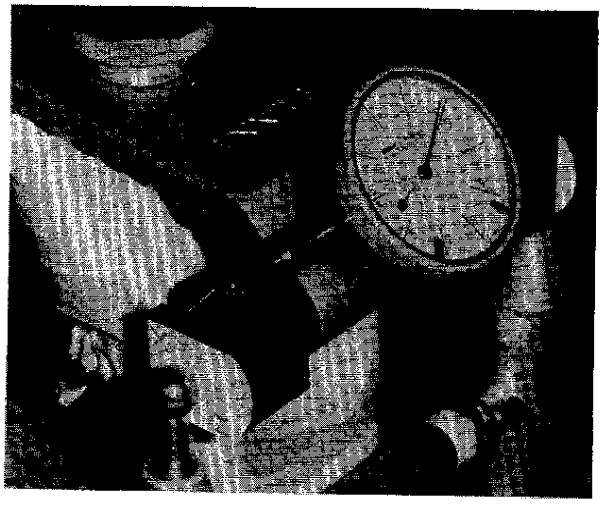

Fig. 1. MPI instrumentation: self-adhesive flags attached to lateral aspect of right and left sliding blocks are used to make registrations in sagittal plane. Dial gauge measures changes in transverse plane.

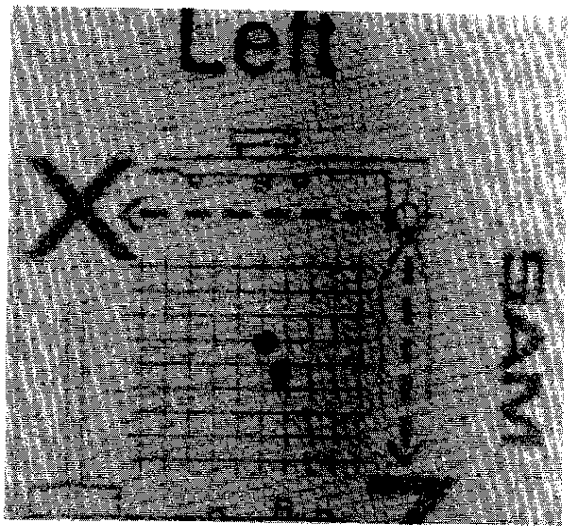

Fig. 2. MPI registration flag with CR mark anterosuperior to CO mark.

edges. A second habitual occlusion (CO) wax bite registration was made with a single layer of dead-soft pink bite registration wax.

The maxillary stone cast was mounted on the upper member of the SAM articulator with the anatomic facebow transfer. The mandibular cast was related to the upper cast with the CR bite registration. The CR and CO MPI markings were made[33,34] on self-adhesive grid paper flags (Figs. 1 and 2). The flags were maintained as part of the permanent patient record of differences in condylar position between CR and CO in the sagittal plane.

The pretreatment records were reviewed. Anonymity of the patients was maintained. All MPI registrations were measured to the nearest 0.25 mm by visual inspection (T.W.U.). The magnitude and direction between the CR and CO markings were measured and recorded for both sides. The transverse shift was measured with the dial gauge on the MPI assembly. This measurement was made and recorded at the time the models were mounted by the examining orthodontist who obtained the pretreatment records.

A pretest was performed to determine the reliability of measuring by visual inspection for changes in the sagittal plane. Fifteen patients' records were selected at random. The MPI flags were measured for A-P and S-I changes to the nearest 0.25 mm with a Ultra-cal II electronic micrometer (Fred V. Fowler Co., Inc., Newton, Mass.) by T.W.U. Approximately 2 weeks later, the same records were remeasured to the nearest 0.25 mm by visual inspection. From the total of 60 measurements (four measurements from each record), 22 measurements varied by 0.25 mm and two measurements differed by 0.5 mm. No measurements differed more than 0.5 mm. When the A-P and S-I measurements were averaged for the 15 patients for each side, no difference existed between the two measurement methods. Measurement of changes in the sagittal plane (A-P and S-I) by visual inspection was selected as the method of choice.

In addition to the MPI registrations, the age, gender, Angle classification, and ANB angle were recorded for each patient. The data were plotted to assess normality of distribution. A statistical report (SAS Software, Cary, N.C.) was created from the MPI data and used to determine the percentage of the sample population with a measurable difference in any direction between CR and CO; to quantify the average difference between CR and CO at the level of the condyles; to determine what percentage of the sample population has a "significant" discrepancy in any direction between CR and CO; and to identify possible correlation between MPI measurements and patient age, gender, Angle classification, or ANB angle.

The Student's *t* test was performed for comparison of magnitude of MPI measurements between Angle Classes I and II. The Chi-square test was used to test association of directional changes between the right and left sides, and the Pearson correlation coefficient was used to assess correlation between the continuous variables recorded. The mean values for each subgroup of patients were compared, and an analysis of variance (ANOVA) was performed to examine interoperator differences found for the patients examined by each of the four orthodontists whose patients were used for this study.

Dr. Brian Wong (personal communication) has previously conducted research with the MPI. He examined 250 pretreatment patients and found the difference between clinically captured CR and the patients' CO to average 0.7 mm A-P, 1.0 mm S-I, and 0.3 mm transversely. For purposes of this study, a discrepancy of approximately twice the amount normally found—that is, 2 mm or greater in the sagittal plane or 0.5 mm or

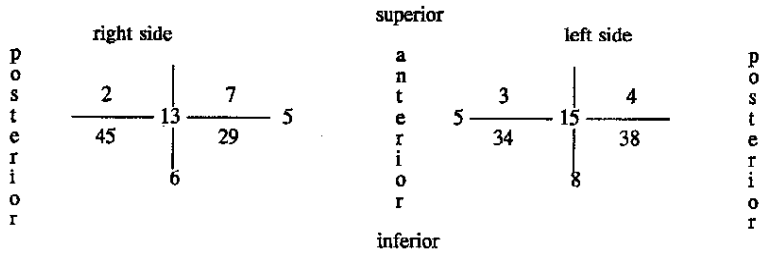

Fig. 3. Individual MPI quadrant distribution (N = 107 per side). (Intersection of vertical and horizontal axes = CR.)

greater in the transverse or frontal plane—was considered clinically significant.

RESULTS

The frequency and range of CO-CR differences as determined from the MPI are summarized in Table I. Distribution of MPI data by quadrant is displayed in Fig. 3. Twenty subjects (18.7%) were found to have at least a 2.0 mm A-P or S-I change in condylar position from CO to CR on at least one side. Six individuals (5.6%) were found to have a significant sagittal discrepancy bilaterally. Five individuals (4.6%) experienced a significant CO-CR difference in both the transverse and sagittal planes.

When viewed in the sagittal plane, condylar position in CO relative to CR was located inferiorly 74% and superiorly 8%, 5% anterosuperior and 3% posterosuperior. Eighteen percent had no vertical displacement of the condyles from CR to CO. There was a slight tendency for posterior displacement with 39% posteroinferiorly displaced, 29% anteroinferiorly displaced, and 6% displaced directly downward to CO.

The mean and standard deviations of MPI registrations for Angle Class I and Class II subgroups are shown in Table II. Four patients with Class III malocclusions were studied; this small number prevented any statistical analysis or comparison with Class III as a separate subgroup. Distribution of MPI data by quadrant is displayed for each Angle classification in Figs. 4 to 8. Five patients with Class I malocclusions and 15 patients with Class II malocclusions showed a significant sagittal difference, representing 16.1% and 20.8%, respectively. Four (12.9%) subjects with Class I malocclusions and seven (11.3%) subjects with Class II malocclusions displayed a significant transverse shift. Only two (6.5%) subjects with Class I malocclusions and three (4.8%) subjects with Class II malocclusions exhibited significant CO-CR differences in the transverse and sagittal planes simultaneously. No significant difference was observed between Angle Class I and II groups of patients when compared for magnitude of MPI measurements (Table III).

Table I. Frequency and range of CO-CR difference

	Doctor				
	1	*2*	*3*	*4*	*Total*
Number	30	31	22	24	107
MPI = "0"		1			1 0.9%
AP and SI = "0"	1	2	1	2	6 5.6%
≥2.0 mm AP or SI	8	5	6	1	20 18.7%
≥0.5 mm transverse	6	2	5	4	17 15.9%

The overall average CO-CR discrepancy was nearly identical when the right and left sides were compared (Table IV). Although 62% agreement was noted between right AP and left AP and 76% agreement between right SI and left SI, the right and left sides were statistically significantly different (Table V). The amount of vertical (S-I) displacement was consistently greater than the amount of horizontal (A-P) displacement in the sagittal plane.

Eight (7.5%) of the 107 persons studied had no measured difference transversely between CO and CR condylar position. Seventeen (15.9%) displayed a transverse shift of 0.5 mm or more. The mean transverse displacement was 0.27 ± 0.23 mm. Fifty-eight (55%) patients displayed a shift to the left, and 41 (38%) patients a shift to the right.

No statistically significant correlation was found between the magnitude of CO-CR difference and the Angle classification, ANB angular measurement, age of the patient, or patient gender. Only a

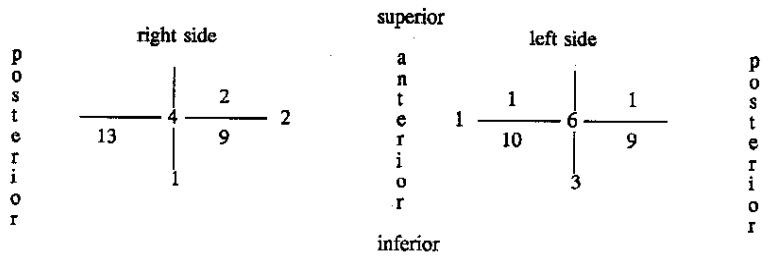

Fig. 4. Class I MPI quadrant distribution (n = 31).

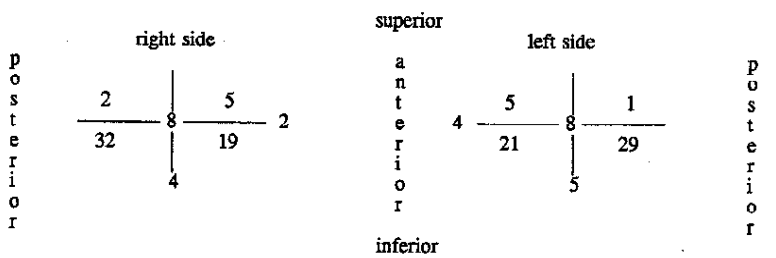

Fig. 5. Class II MPI quadrant distribution (n = 72).

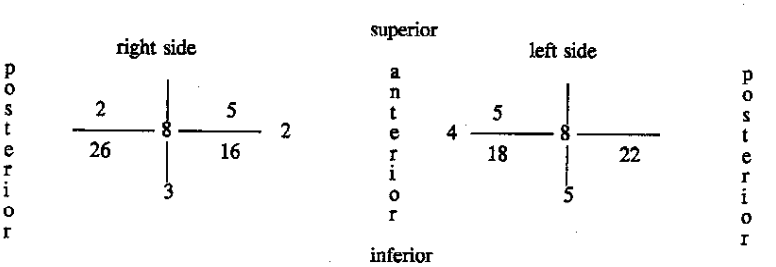

Fig. 6. Class II, Division 1 MPI quadrant distribution (n = 62).

Table II. MPI data for patients with Class I and Class II malocclusions

	Rt A-P	*Rt S-I*	*Transv*	*Lt A-P*	*Lt S-I*
Class I $\bar{x}$	0.59 mm	0.75 mm	0.26 mm	0.59 mm	0.75 mm
n = 31 σ	0.47	0.68	0.19	0.58	0.75
Class II $\bar{x}$	0.63	0.91	0.27	0.64	0.88
n = 72 σ	0.57	0.81	0.22	0.54	0.73
Cl II, d 1 $\bar{x}$	0.62	0.87	0.27	0.62	0.85
n = 62 σ	0.55	0.86	0.22	0.58	0.75
Cl II, d 2 $\bar{x}$	0.70	1.16	0.25	0.75	1.10
n = 10 σ	0.42	0.35	0.14	0.22	0.45

weak correlation was found between magnitude of A-P displacement and the amount of S-I displacement. A mild correlation was noted to exist between the right A-P and left A-P displacement. Moderate correlation existed between magnitude of left S-I and right S-I displacement (Table VI).

No statistically significant difference was found between male and female patients or the magnitude of CO-CR discrepancy. The MPI data for each gender are summarized in Table VII and Figs. 9 and 10. Both genders exhibited the full range of possible condylar positions.

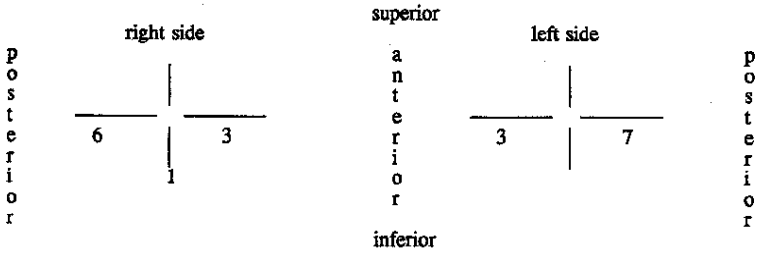

Fig. 7. Class II, Division 2 MPI quadrant distribution (n = 10).

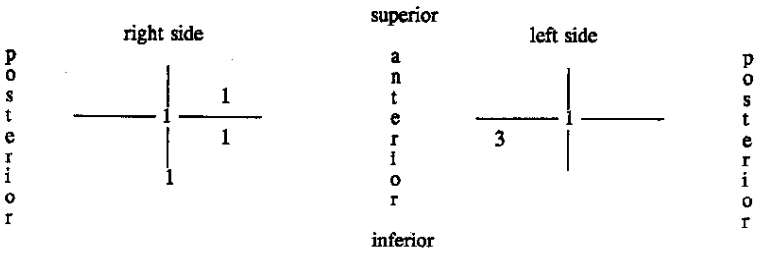

Fig. 8. Class III MPI quadrant distribution (n = 4).

Table III. The t test. Comparison of Angle Class I and Class II MPI measurements

	Rt A-P	*Rt S-I*	*Transv*	*Lt A-P*	*Lt S-I*
F^9 value	0.2401	0.2320	0.3448	0.2147	0.8320

Table IV. Condylar displacement between CO and CR

	Doctor				
	1	*2*	*3*	*4*	*Total*
Number	30	31	22	24	107
Right AP $\bar{x}$	0.62 mm	0.62 mm	0.72 mm	0.46 mm	0.60 mm
σ	0.57	0.52	0.57	0.46	0.54
Right SI $\bar{x}$	0.90	0.87	0.90	0.67	0.84
σ	0.94	0.71	0.73	0.60	0.77
Left AP $\bar{x}$	0.64	0.63	0.68	0.54	0.62
σ	0.60	0.59	0.52	0.48	0.56
Left SI $\bar{x}$	0.88	0.91	0.89	0.59	0.83
σ	0.68	0.82	0.78	0.55	0.73
Transverse $\bar{x}$	0.29	0.20	0.33	0.28	0.27
σ	0.20	0.18	0.23	0.30	0.23
Range AP	0-3.0	0-2.0	0-2.0	0-1.75	0-3.0
Range SI	0-4.75	0-3.5	0-3.0	0-2.5	0-4.75
Range transv	0-.75	0-.8	0-.6	0-1.4	0-1.4

When considered for interoperator differences, no significant difference in amount of CO-CR discrepancy was found between the four subgroups of patients (Table VIII).

DISCUSSION

Almost all subjects studied displayed a CO-CR difference in condylar location. A wide range of condylar positions was noted during this investiga-

Table V. Chi-square test

Association between RtAP and LtAP	
DF = 4 χ^2 = 31.089	Prob = 0
Association between RtSI and LtSI	
DF = 4 χ^2 = 29.031	Prob = 0

tion. Previous authors have noted various ranges of condylar positions with instrumentation similar to the MPI.[26-29,32] Efforts to assess condylar position and positional changes with radiography have been contradictory.[3,7-18] This may be due to the diversity of techniques employed to obtain joint radiographs, the interpretation of the images, the inability to assess condylar position in the transverse plane, and the cut depth differences in tomography. This may also be due to the fact that since CR is a three-dimensional relationship, it must be assessed with a three-dimensional measuring device, not two-dimensional x-ray films.

Girardot[19] observed that measurements obtained with the MPI were different from those obtained with oriented tomograms even though the same condyles were being measured. He concluded the MPI instrumentation is a more reliable method to assess changes in condylar position than tracings of oriented tomograms, and he questioned the validity of using tomographic x-ray tracings to measure small changes in condylar position.

The infrequent finding of CO located superior to CR may result from an internal joint derangement that allows the condyle to become positioned superior to the desired CR condylar position, centered transversely and seated against the articular disks at the posterior superior slope of the articular eminences without dental interferences. Slavicek[33] attributes such findings to a compression phenomenon. Dawson[35] explains that, from a mechanical standpoint, the condyle must move downward when it moves forward or backward from centric rotation. Okeson[36] states the condyle may maintain its most superior position in an anteroposterior range if the temporomandibular ligament has been loosened or elongated.

There is very little, if any, correlation between right and left sides for magnitude or direction of CO-CR differences. The highest correlation was found between the magnitude of CO-CR difference of left S-I and right S-I. But this correlation was moderate at best. An observation of sidedness or asymmetry has been noted by previous authors.[9,10,26,29,32,37]

Hoffman, Silverman, and Garfinkel[29] noted A-P asymmetry (skew) of at least 0.1 mm in 77% and S-I asymmetry (tilt) of 0.1 mm or greater in 75% of the subjects studied. No relationship was found between the amount of skew and the amount of tilt. Rosner and Goldberg[32] found a remarkable absence of symmetrical condylar movement between CR and CO; only one of the 75 persons studied showed equal movement in the anterior posterior direction. One might expect a higher correlation because of expected morphologic similarity with the rigid mandible connecting the condyles; however, flexure of the mandible has been described by Butler.[38] It should be considered that the joints are at the ends of the mandible with similar but separate, and perhaps, asymmetric environments.

A transverse shift is difficult to detect by clinical examination only and cannot be observed with joint imaging in the sagittal plane. The magnitude and incidence of transverse displacement reported were similar to previous reports. Rosner and Goldberg[32] reported nearly half of those studied had less than 0.3 mm medial lateral displacement, 38% were displaced 0.3 to 0.6 mm, and 12% displaced more than 0.6 mm. They reported a mean medial lateral displacement of 0.34 ± 0.239 mm. They further stated the complex movements transmitted by skew, tilt, and medial lateral displacement to the condylar centers of rotation make it difficult to determine asymmetric condylar movement by measuring dental midline displacement.[39]

The goal of centric occlusion in accord with centric relation is not new to dentistry, especially in the realm of prosthodontics. Previous authors[1,32,33,35,36,40-48] have advocated use of diagnostic study models mounted in centric relation to make a complete diagnosis. They have concluded it is difficult, if not impossible, to quantitatively assess a CO-CR discrepancy clinically. Dawson[35] considers it "... a mistake to neglect the kind of careful analysis that is possible only when casts are mounted in centric relation with a facebow transfer." Okeson[36] advocates the use of mounted casts since the protective reflexes of the neuromuscular system may prevent detection of interferences clinically.

Orthodontists have not completely ignored this goal. Parker[40] suggested that for many patients study casts be placed on an adjustable articulator in centric relation to see if it coincides with centric occlusion. Perry[49] urged orthodontists to consider more than the static result and be aware of the functioning relation of cusps, inclines, condyles, and fossae. Roth[50] has long been a proponent of

Table VI. Pearson Correlation Coefficients

	Rt A-P	*Rt S-I*	*Transv*	*Lt A-P*	*Lt S-I*
ANB	0.003	0.047	−0.001	−0.086	0.171
Age	−0.062	0.119	−0.073	0.073	0.062
RtAP	–	0.272*	0.009	0.467**	237*
RtSI	0.272*	–	0.044	0.216*	0.581**
Trans	0.009	0.044	–	0.085	0.142
LtAP	0.467**	0.216*	0.085	–	0.410**
LtSI	0.237*	0.581**	0.142	0.410**	–

*$p < 0.05$; **$p < 0.005$.

Table VII. MPI data for female and male subgroups

	Rt A-P	*Rt S-I*	*Transv*	*Lt A-P*	*Lt S-I*
Female $\bar{x}$	0.60 mm	0.75 mm	0.25 mm	0.66 mm	0.81 mm
σ	0.50	0.63	0.25	0.56	0.75
Male $\bar{x}$	0.61	0.95	0.29	0.58	0.85
σ	0.58	0.90	0.21	0.55	0.71

Table VIII. Analysis of variance. Compare registrations for interoperator differences

	Rt A-P	*Rt S-I*	*Transv*	*Lt A-P*	*Lt S-I*
F =	0.77	0.36	2.11	0.22	0.83
p =	0.515	0.783	0.104	0.880	0.482

centric occlusion in harmony with centric relation as a treatment goal.[41-43,50] Ackerman and Proffit[51] recommended "... if there is a shift of more than 1 to 2 mm between the point of initial tooth contact in terminal hinge closure and maximum intercuspation, the point of initial contact should be used." Proffit further stated[52] that lateral shifts of any magnitude or forward shifts of 2 or 3 mm should be considered significant and would require an articulator mounting. Williamson et al.[53] concluded that all cases should be assessed in centric relation before treatment and Class II cases should be articulated (mounted).

Instruments such as the MPI are valuable adjuncts to diagnostic casts mounted on an articulator that provides information concerning changes between CO and CR at the level of the condyles. It has been the experience of the orthodontists whose patients were studied during this research that evaluation of magnitude and direction of CO-CR discrepancy, or "slide," is difficult to determine clinically. Further, the observation of a slide or shift at the level of the occlusion may not accurately represent the three-dimensional changes in position of the condylar axis.[37,39]

Few orthodontists reported using an articulator to aid in the diagnosis and treatment planning of their patients. Only 13.3% of the orthodontists responding to a 1986 survey reported the use of pretreatment study models mounted on an articulator.[54] The same survey found 3.9% used progress models and 6.5% posttreatment models mounted on an articulator.

This study accepted the validity of centric relation as a reference point for occlusal evaluation and makes no attempt to debate this concept, for the dental literature is replete with such discussions.[35,36,40-50,55-57] If treatment goals include condyles seated in the fossa and an occlusion that will not interfere with condylar border movement, then there is a need to assess the occlusion with condyles in centric relation position. One cannot assume the condyle is in the correct position before treatment just because the patient is asymptomatic. It would also seem beneficial to use available instrumentation, such as the MPI, to assess pretreatment and posttreatment models.

The MPI allows a simple and noninvasive technique for comparing clinically captured CR and CO positions through displacement of the opening

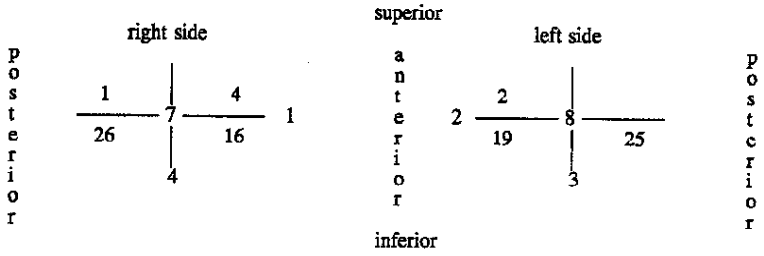

Fig. 9. Female MPI quadrant distribution (n = 59).

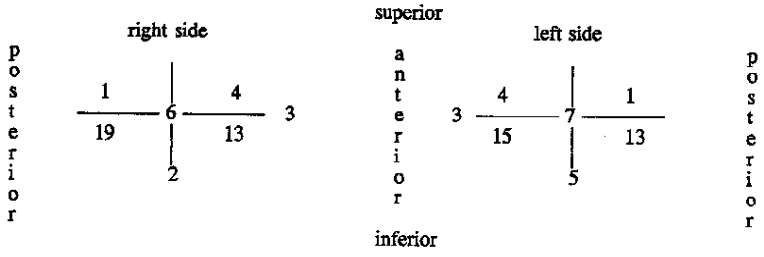

Fig. 10. Male MPI quadrant distribution (n = 48).

and closing axis position of the patient. The MPI represents the opening and closing axis of the mandible that passes through both condyles; therefore movement of the dots and the axis represents movement of the condyles. Such a comparison is a useful screening procedure and provides information needed for a more complete diagnosis.

Typically, if a CO-CR discrepancy exists, the sagittal interarch discrepancy increases as the vertical relationship changes with premature occlusal contacts on the incline planes of posterior teeth, overbite decreases, and lack of transverse arch coordination is seen as the condyle seats superiorly to CR.[52] Although this is a simplification, it can be stated that viewing diagnostic models mounted in centric relation yields information not available from conventionally trimmed study models.

This information may be used to convert the lateral cephalometric head film taken in CO.[33,43,52,58-60] It is recommended to convert the head film when a vertical or horizontal difference of 2 mm or more is noted. An amount less than this yields little, if any, change in traditional cephalometric measurements. Nearly 19% of the patients studied had a large enough discrepancy that the cephalometric lateral head film should be converted to reflect the CR relationship seen with the mounted casts.

CONCLUSIONS

Nearly 19% of patients studied showed a CO-CR sagittal discrepancy greater than 2 mm in at least one direction at the level of the condyles.

Almost 17% of patients with Class I malocclusions and 21% of the patients with Class II malocclusions displayed a significant CO-CR difference.

Of the 107 patients studied, 15.9% showed a transverse CO-CR difference of 0.5 mm or more at the level of the condyle.

Only weak correlations were found to exist with magnitude or direction of CO-CR differences between the right and left sides.

None of the factors studied enable the clinician to identify which patients have a significant CO-CR discrepancy.

Discrepancies greater than twice the amount of normal displacement from clinically captured CR are probably of clinical significance in diagnosis and treatment planning of the orthodontic patient. It is advised that diagnostic study casts of all patients be mounted on an articulator in centric relation as part of the records procedure and as a screening procedure to find those with significant discrepancies.

Further study is needed to compare pretreatment and posttreatment MPI measurements, MPI recordings of patients with and without symptoms,

and MPI measurements to joint imaging techniques.

NOTE: The discussions in the *Point/Counterpoint* (pp. 315-8) and *Counterpoint* (pp. 319-28) should be read in conjunction with this article.

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Reprint requests to:
Dr. Thomas W. Utt
Major, U.S. Army Dental Corps
89th MED DET
Unit 30401, Box 2545
APO AE 09131

CORRECTION

In the articles by Cook, Selke, and BeGole titled "Control of the Vertical Dimension in Class II Correction Using a Cervical Headgear and Lower Utility Arch in Growing Patients. Part I" and "The Variability and Reliability of Two Maxillary and Mandibular Superimposition Techniques. Part II" (AM J ORTHOD DENTOFAC ORTHOP 1994;107:376-88 and 463-71), Figs. 3 and 4 of Part I were switched with Figs. 3 and 4 of Part II.

POINT/COUNTERPOINT

It is interesting that I even have to write this "Point/Counterpoint" to get Dr. Utt's article published in the AMERICAN JOURNAL OF ORTHODONTICS AND DENTOFACIAL ORTHOPEDICS.

It is an article on occlusion and condylar position that was accepted for a Master's degree and Certificate of Specialty in Orthodontics by a department that has been accredited by the ADA, the AADS, and the AAO. That alone should suffice for the article to be accepted for publication in the JOURNAL with perhaps some editorial changes.

The issue that prompted this *Point/Counterpoint* is the relevance of Dr. Utt's article and whether it is of sufficient interest and importance to orthodontists to be published in the AJO/DO.

I think the first point to be covered is whether condylar position is important to orthodontists.

Condylar position is of importance if one believes that the condyles belong in the sockets when teeth come into occlusion. Without a concept of condylar position, diagnosis of interdental and jaw relationships becomes impossible. For example, how large is a Class II malocclusion? Without knowing where the condyles belong, this question cannot be answered.

Orthodontics has assumed, by its method of diagnosis in habitual occlusion, that when the patient bites into occlusion the condyles are approximately in the correct position. The question is, how do we know this? Is this a fact or are there instances in which the condyles are out of "normal" or "ideal" position?

Dr. Utt's article is the first step in dealing with these issues.

If condylar position is not important in orthodontics, how did the term "Sunday Bite" ever arise? And why do orthodontists even worry whether cases are Class II or not? We might as well instruct all of our patients with Class II malocclusions to just "bite" into Class I after we align the teeth, if condylar position is unimportant!

Dr. Utt's article deals with an issue that I think should be considered extremely important by the specialty of orthodontics. Granted, anything that has to do with occlusion, articulators, temporomandibular joints is not a very popular topic in the eyes of orthodontists at this time. However, if we are to serve the public properly, we must know something about joint function and occlusion and have some parameters and some functional occlusion goals that can be measured objectively!

It seems that in the rush to absolve ourselves from "blame" and legal remedies involving post-orthodontic temporomandibular disorder (TMD) problems, we have forgotten our obligation to the patient. That obligation is what should separate us into "professional health care providers" as opposed to cosmetologists and/or business men or women.

In the recent literature, a series of articles by Seligman and Pullinger, Mohl, Greene, and others[1-15] have lead to position articles by orthodontists stating that occlusion has nothing to do with TMD, which in itself is a gigantic leap to an incorrect clinical conclusion and is totally unjustified in light of the facts. Not having "scientific proof" that occlusion is one of the factors in TMD does not mean that it has nothing to do with TMD. Isn't it interesting that although many of these people who believe that occlusion has nothing to do with TMD, use occlusal splints in the treatment of TMD! Indeed, if occlusion has nothing to do with TMD, why don't they put the splint on their patient's elbows??

The fact is the main thrust of these studies has been that there was no correlation found between "TMD/head and neck pain" and the x-ray film of the location of the condyle.[3-11] However, there is an equal number of studies that do show correlation of occlusion and TMD signs and symptoms.[16-31]

I would like to have the opportunity of placing a "high molar restoration with balancing interferences" in the mouths of all who believe that occlusion has nothing to do with TMD. I think that under those circumstances we would have no problem finding some correlations between occlusion and TMD!

The problems of TMD and head and neck pain is multifaceted and there are many causes. So if one is to properly research occlusion as a factor, differential diagnosis of pain is a "must" in selection of a sample.

Second, a better method must be used to measure condylar position than x-ray films and tracings. Anyone who has had experience with corrected temporomandibular joint (TMJ) tomography knows that just varying the depth of the cut or repositioning of the patient in the machine will many times yield what appears to be a difference in condylar position.

Although x-ray films have historically been used, they are still a two-dimensional medium. In my opinion, it is not possible to express a three-dimensional relationship of a three-dimensional object accurately in a two-dimensional medium.

Third, excursions must be studied, not just closure position. In any study of occlusion, the subject must be adequately deprogrammed from his/her occlusion to capture a "seated condylar position" as a reference. To do this and to be able to study the data, the neuromuscular response to the occlusion must be eliminated, thus one must use appropriate instrumentation—a repositioning splint and an articulator.

And last, but not least, one must be aware that occlusal interferences may produce signs or symptoms other than muscle pain and joint sounds (e.g., occlusal wear, pulpitis, shifting of teeth, and aggravation of periodontal disease). Properly designed studies should take this into account.

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The recent rash of literature that has been misconstrued in regard to occlusion and TMD has shown only one thing. That these studies have found no correlation in random samples between location of the *condyles on an x-ray film* and *TMD symptoms*. This still does not prove that occlusion has nothing to do with TMD!

Traditionally in dentistry the "gold standard" for evaluating condylar position has been corrected tomography. As helpful as corrected tomography may be in comparing bony parts of the TMJ at different points in time, and gross condylar position change, it is not accurate enough to assess condylar position in three planes of space to the millimeter. I have personally compared tracking of condylar position with corrected tomograms and Mandibular Position Indicator (MPI) readings (as in Utt's study) and find the MPI method to be much more accurate in recording small position changes. This has been verified in a study by Girardot in 1989.[29]

A difference in depth of cut alone will make the condyle appear to occupy a different position on an immobile patient who is not removed from the machine between exposures!

It was the studies of Mohl, Greene and Pullinger, and *his own conclusions* that lead one reviewer to deem Dr. Utt's article as unnecessary for publication in our JOURNAL.

Aside from the faulty conclusion that these studies have precipitated, this still does not mean that the orthodontist should not have an occlusion goal from the standpoint of function that is ideal and measurable and that follows the concepts of joint position and joint-guided movement. It is surprising that a referee would even suggest that an article on occlusion and joint position using an articulator is not of sufficient interest to orthodontists to be published in the AMERICAN JOURNAL OF ORTHODONTICS AND DENTOFACIAL ORTHOPEDICS!

From my standpoint, quoting only the literature that supports one's viewpoint to reject an article for publication is well out of line ethically and scientifically! Beside which, it is not a review of the article itself.

The literature is replete with references and research regarding the techniques that Dr. Utt used in his article and these techniques have been a mainstay in restorative dentistry and prosthetics for years. Because concepts are "old" does not make them wrong. In fact, an old concept that has remained in clinical use for years and years may bear witness to its validity!

The use of articulators to study occlusion is nothing new and the use of the MPI is a validated method in the prosthetic literature for studying condylar distractions from a seated condylar position, as caused by the intercuspation of the teeth. I doubt that there would have been any problem getting this article published in the *Journal of Prosthetic Dentistry*.

The general misconception in orthodontics currently, that condylar position is irrelevant and that occlusal changes do not change condylar position is erroneous. Change in condylar position due to a change in occlusion can be demonstrated readily on patients using the method that was used in Dr. Utt's study. The erroneous idea that occlusal change causes no change in joint position was arrived at by studying radiograms of joint position rather than by using an appropriate measuring device, like an articulator and the MPI. Measuring condylar position on an x-ray film is just not accurate enough when studying the effects of occlusion on condylar position.

Is condylar position important to the orthodontist? Some orthodontists tend to think not. However, ask a prosthodontist or an oral surgeon that does orthognathic surgery. It is very important to them because incorrect condylar position spells instant failure!

Isn't it odd that orthodontists think that they operate under a different set of rules just because their failure takes longer to surface when the condyle is out of position.

Symptoms due to incorrect condylar position can result in occlusal wear, TMD, aggravation of periodontal disease, pulpitis, tooth movement or orthodontic relapse. I have spent 30 years in clinical practice using the concepts of functional occlusion that were developed by McCollum and Stuart[32-34] to consistently solve many of the vexing problems that face posttreatment orthodontic patients who have occlusal related symptoms. Those of us who have used these methods find them to be highly successful clinically on a consistent basis. If not, I for one, would have quit using these principles long ago.

With a variety of symptoms that can occur once the patient's tolerance level and adaptive capacity is exceeded, it is no wonder that there was no correlation found between x-ray pictures of the condyles and TMD symptoms.

The orthodontist is doing a "full mouth reconstruction" in enamel whenever he undertakes orthodontic treatment. To approach treatment with no objective goal for condylar position and no idea of where condyles are before treatment is at best, a risky proposition, and at worst a disaster looking for a place to happen. Orthodontists have been able to seemingly get away with this approach for a number of years because most orthodontic patients were children with a great adaptive capacity and because the problems take a long time to surface. However, with the recent increase in adult treatment, problems are showing up sooner, and patients are not so forgiving as they once were. These problems have surfaced and continue to surface in the medicolegal arena.

Rather than dealing with the problems and learning something about occlusion, and establishing goals for good function, many in the specialty of orthodontics have chosen to ignore the problem and cover themselves medicolegally with "self-serving research," in an attempt to prove that occlusion has no bearing on the neuromuscular mechanism and the temporomandibular joints.

We must respond with what is in the best interest of the patient and research that will objectively help us do this must be published in our journals.

It is time that we return to listening a bit to seasoned clinicians. Too many "career academicians" are doing research in clinical areas they know little about and are making quantum leaps to clinical conclusions that are incorrect. Once published in the journal, these are then quoted by students and young orthodontists and become "law" even though the conclusions may be incorrect.

Bruce Epker, at a recent AAMOS meeting discussed a case in which a LeFort I osteotomy failed to produce a satisfactory occlusion because, as he termed it, "the patient was real good at biting into her false bite occlusion before surgery and we just didn't recognize it." Aren't we all good at biting where the teeth fit?! So what else is new! That's why the effect of the neuromuscular protective mechanism must be eliminated to study the occlusion properly. To do this, the articulator was invented.

Dr. Utt's article deals with trying to uncover false bites before treatment. His findings corroborate those of our practice in which he (Utt) *found 19% of a sample of more than 100 patients to be 100% or more out of the range of normal.* That sounds quite significant to me! That would put these patients well outside of the normal population.

Utt then tried to correlate his findings with the things that orthodontists normally look at, such as age, race, sex, Angle's classification, and cephalometric measurements and could find no correlation. He concluded that to find the 19% with significant condylar displacement before treatment it required the use of the articular mounting and an operator "skilled" in taking centric interocclusal registrations, using a technique that would adequately seat the condyles. He also found that it was impossible to find and to study the discrepancies by intraoral examination and mandibular manipulation at the chair.

I would think that Dr. Utt's findings would be very significant for the orthodontist because with such a large error as he found in the initial condylar position in 19% of his sample, the treatment plans must change if one is to treat to a "normal" condylar position.

What Utt found in 81% of the patients is the "normal" discrepancy in condylar position from a seated position. So he also established the "normal" centric relation to centric occlusion range. Anteroposteriorly it is plus or minus 1 mm, vertically, slightly more than 1 mm, and transversely less than 0.5 mm.

The importance of this study is obvious to anyone who has an appreciation of occlusion. To not print this study in the JOURNAL would, in my opinion, be unthinkable.

If one looks at the work of Gibbs and Lundeen at the University of Florida on human chewing with the gnathic replicator,[31] it is evident that it is important for the condyles to be able to get to a "seated position" during mastication and for the condyle-disk assembly to be able to traverse the eminence on the balancing side during the chewing stroke. If the teeth do not permit this to happen, then masticatory function is impaired. In addition to this, the interferences tend to trigger parafunctional habits. Ideal chewing function is impossible if the condyles are significantly displaced from the fossae.

Studying a population to find out what is "normal" does not necessarily establish what is most desirable. Just because most people in our society have occlusal interferences does not make that a desirable goal. If we averaged periodontal pocket depth in the United States and came up with the average and one standard deviation either side of the average of 3 mm pocketing plus or minus 1 mm, I doubt the periodontists would accept this as their goal! In our case the goal should be "ideal" occlusion or no interferences—not just "What can we get away with?"

In Cyril Sadowsky's[12, 13] studies of posttreatment orthodontic cases compared with an untreated general population in a long-term comparison for TMJ symptoms and periodontal disease, he found no statistically significant differences between the treated and untreated groups. When this was presented, orthodontists breathed a sigh of relief—"off the hook", so to speak. However, the question we should ask ourselves is "If we treated the patients shouldn't they be better off in the long run?!" If not, it is hard to justify orthodontic treatment as health care!

It is about time we accepted some tangible and measurable goals in orthodontics regarding function of the occlusion and the joints and condylar position. Our goal should be a higher one than just "the patient isn't complaining." It seems to me that a lot of time and effort is going into avoiding what we need to learn about occlusion while attempting to clutch tightly to what we have always done in the past.

Dr. Utt's article is very important as it points out that a fair percentage of patients may be started in orthodontics with a significant false or "Sunday" bite. To not publish this study because one does not like the conclusions or the methods (articulators) is certainly not in the best interests of either the patients or the specialty.

Dr. Utt proposes methods to find these hidden discrepancies before treatment. It would seem to me that this should spark a lot of interest from practicing clinicians and leaders in our specialty and especially educators if our primary concern is for better treatment for our patients. I personally would find it very distressing if organized orthodontics deliberately turned its back on this kind of information!

Ronald H. Roth, DDS, MS
San Mateo, Calif.

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Reprint requests to:
Dr. Ronald H. Roth
Clinical Professor of Orthodontics
University of California San Francisco
University of Detroit/Mercy
320 N. San Mateo Dr.
San Mateo, CA 94401

COUNTERPOINT

A three-dimensional comparison of condylar change between centric relation and centric occlusion using the mandibular position indicator

Donald J. Rinchuse, DMD, MS, MDS, PhD[a]
Pittsburgh, Pa.

Those who fall in love
with practice without
science are like a sailor
who enters a ship without
a helm or compass, and
who never can be certain
whither he is going.

- Leonardo da Vinci

I am grateful for the opportunity to evaluate the article entitled, "A Three-Dimensional Comparison of Condylar Position Changes Between Centric Relation and Centric Occlusion Using the Mandibular Position Indicator" by Utt et al. It is certainly a challenge to debate the efficacy of this article with Ron Roth. Surely the specialty will benefit from a consideration of two divergent views and this novel approach to the AJO-DO format. Plato said "wisdom emerges from the clash of contending views."

Dr. Thomas Utt should be given credit for providing the materials for this educational exercise and for allowing me to evaluate his article in a critical way. As Teddy Roosevelt once said, "The credit belongs to the man who is actually in the arena . . . who at best knows in the end the triumph of high achievement; and at the worst, if he fails, at least fails while daring greatly. . . ."

I have been requested to provide a detailed, critical review of Dr. Utt's article and not merely a commentary. I hope Dr. Utt and the readers will understand and appreciate the nature of my role.

The article by Dr. Utt has many limitations and shortcomings. The methodology of the study is faulty, and the reliability questionable. More importantly, the validity of the study is tenuous, and the article, once read, becomes one of those that you ask, "So what!"

I have divided my remarks about the article into two parts. Part I deals with those aspects of my critique that need little or no discussion. Several of the points I will make in Part I will be listings of errors in the article. Part II addresses issues involving "centric relation," as it specifically relates to Dr. Utt's article, as well as to the more general topic of orthodontics. Part II also considers the general topic of "articulators" and their use (misuse) in research and dentistry.

[a]Diplomate of the American Board of Orthodontics; Fellow of the American College of Dentists; Manuscript Review Consultant, *The American Journal of Orthodontics and Dentofacial Orthopedics;* private practice, Greensburg, Mount Pleasant, Apollo, Youngwood, and Westmoreland Hospital - Pennsylvania; Associate Professor of Orthodontics and Pharmacology-Physiology, University of Pittsburgh School of Dental Medicine.

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PART I

1. Title

The title of the article is misleading and ambiguous. It purports to address the topic of "condylar position," however, nowhere in the study are subjects' condylar positions recorded or measured. What has been recorded and measured is an "articulator generated mandibular position(s)"—or is it maxillary position, since the mandibular component of the articulator is fixed! Data about mandibular position are then extrapolated to the "SAM articulator" condyles. Furthermore, the reader is not certain from an examination of the article's title, or reading the text, the definition the author has chosen for "centric relation" and "centric occlusion."

2. Definition of CR and CO?

The "Glossary of Prosthodontic Terms," published in the *Journal of Prosthetic Dentistry,* has had six editions. The Glossary has served as the dictionary "standard" for terms used in dentistry, particularly prosthodontics, since 1956, when the first edition was published.

The definitions for CR and CO in the first,[1] third,[2] fifth,[3] and sixth[4] editions of the Glossary are as follows:
First edition (1956); page 11

Centric Relation—The most retruded relation of the mandible to the maxilla when the condyles are in the most posterior unrestrained position in the glenoid fossa from which lateral movements can be made, at any given degree of jaw separation.

Centric Occlusion—Not defined.

Third edition (1968); page 452

Centric Jaw Relation—(1) The most retruded physiologic relation of the mandible to the maxilla to and from which the individual can make lateral movements. It is a condition which can exist at various

degrees of jaw separation. It occurs around the terminal hinge axis. (2) The most posterior relation of the mandible to the maxilla at the established vertical relation.

Centric Occlusion – The centered contact position of the lower occlusal surfaces against the upper ones; a reference position from which all other horizontal positions are eccentric.

Fifth edition (1987); pages 724-725

Centric Occlusion – The occlusion of opposing teeth when the mandible is in centric relation. This may or may not coincide with the maximum intercuspation position. This is a term in transition to obsolescence. (See also *intercuspation, maximum.*)

Centric Relation – A maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks with the complex in the anterior-superior position against the slopes of the articular eminences. This position is independent of tooth contact. This position is clinically discernible when the mandible is directed superiorly and anteriorly and restricted to a purely rotary movement about a transverse horizontal axis. This term is in transition to obsolescence.

Centric Relation Interocclusal Record. See *centric relations record.*

Centric Relation Occlusion. (Objectionable.) See *centric occlusion.*

Sixth edition (1994); pages 59 and 84

Centric Occlusion – (same as fifth edition)

Maximum Intercuspation – The complete intercuspation of opposing teeth independent of condylar position.

Centric Relation – (same as fifth edition)

As can be seen, the definition of CR has changed over the years from a posterior, superior position to an anterior, superior position. Parenthetically, there are some in the specialty who believe the condyles should be centered, or concentric, to the glenoid fossa. Furthermore, CR has always been a "condylar position," whereas CO has always been an interocclusal position. Therefore CR is not a comparable term to CO, because the former denotes condyle position and the latter denotes an interocclusal dental position. Dr. Utt's usage of CR and CO in his article is totally incorrect.

Nevertheless, how does Dr. Utt define CR and CO in his article? He does not! The only place in the article that the reader can even indirectly deduce a definition for CR is in the *Methods and Materials* section, second paragraph:

> Power centric registration refers to the use of the patient's power closure muscles (masseter, medial pterygoids, and superior heads of the lateral pterygoids) to rest the condyles as closely as possible to CR with the condyles centered transversely and seated against the articular discs of the slope of the articular eminences without dental interference.

From the previously mentioned paragraph, one is not certain, but assumes Dr. Utt's definition of CR is the current sixth edition version of the Glossary, i.e., anterior and superior. Dr. Utt does not define CO per se. He states that CO equals "maximum intercuspation" at one point in the article and then later equates it to "habitual occlusion." If we assume that he also subscribes to the sixth edition of the Glossary for this term, then CO is the interocclusal position of the teeth when the mandible, or condyles, are in centric relation. Once again, what is Dr. Utt attempting to compare and also record and measure? What is not defined cannot be recorded and measured.

Interestingly, Dr. Utt cites many references (some of which are Roth's) that attempt to demonstrate the importance and validity for his study. However, he fails to point out that Dr. Roth,[5-9] in the 1970s and 1980s, asserted the virtues of "building" orthodontic occlusions to the then accepted CR position of *posterior, superior.* Incidentally, Dr. Roth now accepts an anterior, superior CR position. Later we learned that the same addlepated thinking that led some of the less thoughtful orthodontists to "treat" to the then posterior CR position in the 1970s and 1980s went full circle and in the mid-1980s and 1990s a new philosophy emerged and claimed that a posterior, or distal, position of the condyles predisposes to temporomandibular disorder (TMD). How much creditability can one give to a view and philosophy that changes directions so often? In this respect, Dr. Utt should have made it clear in his literature review which centric position and condyle position each of his cited authors assumed to be correct, i.e., the posterior and superior, the anterior and superior, or somewhere between.

3. Comparison to Dr. Wong's data – a validity issue

There is great adaptability and variability in the human species. If one looks at the variable, "stature" (i.e., adult height), one finds diversity with regard to race and gender. Disregarding the effects of pathologic conditions and genetic defects, stature per se has never been demonstrated to be related to health/disease. That is, no one can say that a white male subject of 6 feet 1 inch in height is more or less healthy than one who is 5 feet 6 inches.

Unless Dr. Utt can relate his data to specific aspects of disease or health, such as TMD or periodontal disease, one has no way of knowing whether the variable that Dr. Utt is studying has anything whatsoever to do with health/disease. He may only be substantiating the endless morphologic variation in nature.

To somehow validate his descriptive study, Dr. Utt was compelled to compare his data with a certain baseline or gold standard. He chose to use the unpublished data of Brian Wong. As stated earlier, the ideal comparison data would be that which relates to health/disease. Parenthetically, an experimental (prospective and longitudinal) or observational (retrospective and cross-sectional) study would have been preferred to the choice of a descriptive study. Since we assume that Dr. Wong's

data are also "normative" and have no relationship to health or disease, the comparison of Dr. Utt's data with Dr. Wong's is somewhat meaningless.

Further, the only information Dr. Utt offers in regard to Dr. Wong's data is that it came from 250 pretreatment subjects. The reader is not provided information on how these 250 subjects were selected (i.e., inclusion/exclusion criteria) nor any other characteristics of this group (i.e., age, gender, or race). If the aim of the studies by Drs. Wong and Utt was to provide normative data, did they rule out disease?

The sample of Dr. Utt contained both male and female subjects and the average age was 13.53 years. What was the gender/age mix of Dr. Wong's sample? Furthermore, how can the data of Drs. Utt and Wong be compared since we do not know if the same methodology was used. That is, we can only assume from the information provided in Dr. Utt's article that the same instrumentation was used, but Dr. Utt used four different observers. In summary, the discrepancy between the data could be due solely to differences in samples and methods.

The author's arbitrary choice of using 2 mm or greater CO-CR discrepancies in the sagittal and 0.5 mm or greater in the transverse dimension is arbitrary. Why would he consider these parameters as being "clinically significant"?

4. SAM articulator and MPI

Dr. Utt provides no useful information regarding the reliability and validity of the SAM articulator with the MPI; and, as research instruments, the SAM articulator and MPI have questionable merit.

Dr. Utt makes several unsupported claims about the use of the SAM-MPI. He states in the seventh paragraph:

> The SAM articulator and MPI or similar instrumentation, such as the Paradent Condylar Position Indicator, enable the clinician to determine, record, and compare the positional changes of the condyle between CR and CO in all three spatial planes.

However, he provides no data, or reference to data, that in any way substantiates any of the aforecited claims. In this regard, he merely offers several "viewpoint/anecdotal" reports on the use of the SAM articulator/MPI, i.e., Slavicek,[10] published in the JOURNAL OF CLINICAL ORTHODONTICS and Girardiot,[11] published in *Orthodontic Review*. Both articles were published in what are considered *clinical* journals versus *scientific* journals, with neither article providing experimental evidence for the efficacy of the instrument(s). Where then is the documented research to support the author's choice of "research instrumentation"?

There are several other considerations in regard to the SAM articulator/MPI. Dr. Utt gives no information regarding the precision/error of the instrument system and the procedure(s) involved in the articulator set-up. The measurement and discrimination capabilities of the instrument were not determined. Furthermore, the error in determining and/or recording the clinical (jaw manipulation/determination) and laboratory (cast mountings) variables were not considered as part of the overall "instrumentation" error. Instrumentation error was not compared with and calculated against the derived numerical data. Since the Utt article places emphasis on millimeter and fraction of millimeter differences, a consideration of the instrument(s) error is essential. Finally, critics of articulators claim: (1) The anatomy of both hard and soft TMJ tissues and joint function vary grossly between persons and cannot be "copied" by an articulator. (2) The function of an articulator is based on average mandibular slope and average condyle structure and therefore can only provide an estimation of the individual condylar position(s). (3) Articulators are designed on the basis of perhaps the faulty terminal hinge axis theory and do not incorporate any initial translatory movement of the condyles during jaw opening or the terminal phase of jaw closing. (These points will be discussed further in Part II.)

The interocclusal registrations for the articulator set-up were made by four orthodontists. However, there was no interjudge evaluation. And, although the four orthodontists were given similar instructions before their recordings, they were not calibrated before the study. The only pretest information was directed at determining the reliability of "visual inspection" (i.e., visual estimation of MPI changes). The MPI registrations from 15 randomly selected patients were measured with a micrometer and were also visually inspected. Sixty measurements were made, which presumably correspond to one measurement per examining orthodontist. No double registrations and determinations of intrajudge error were made, and there is uncertainty as to whether the variation of between 0.25 mm and 0.5 mm noted in approximately a third of the measurements refers to intrajudge error and/or interjudge error, or if it reflects a difference in mandibular position. In addition, the mean values for each subgroup of patients treated by the four orthodontists are compared, and it is concluded that the results do not significantly differ. However, this is not valid since the four orthodontists examined different patients. Finally, the pretest was made only on the sagittal measurements. The reliability of measurements for the transverse dimension would have been of greater interest since as little as 0.5 mm in transverse shift of the mandible is stated to influence mandibular position "significantly."

6. Reliability and validity of the "power centric" wax registration

No evidence is provided for the reliability and validity of the power centric wax registration "to obtain the clinically captured CR position." Dr. Utt does not provide data or references that demonstrate that by using the power centric registration the condyles will be seated "as closely as possible to CR with condyles centered transversely and seated against the articular disks at the

posterior slope of the articular eminences without dental interferences." And, the reliability and validity of the power centric registration is the essence of Dr. Utt's article.

Furthermore, he does not discuss the difference between a manipulated CR and an unmanipulated CR. Manipulated CR, or passively recorded CR, is made by the examiner without conscious cooperation of the subject/patient. Unmanipulated CR, or actively recorded CR, is assumed by the subject without the aid of the examiner.[12] Manipulated, "retruded" (i.e., posterior-superior) CR is thought to be more precise and reproducible than unmanipulated, retruded CR. That is, retruded CR records made with passive manipulation yield a smaller range of mandibular positions than do active methods.[12-20] Nevertheless, active, retruded CR records are believed to be more natural and physiologic. Incidentally, the repeatability of determining the "retruded" CR position, rather than the position itself, appears to be the prime criterion for using a technique for recording CR.[21] Passively recorded retruded CR is thought to be a range of mandibular positions. One of the better investigations demonstrated the average range of "shift" for repeated recordings of "retruded" CR to be 0.302 mm mediolaterally and 0.278 mm anteroposteriorly.[22] It should be pointed out and made clear that the previously mentioned information, as well as most of the data concerning CR recordings, are based on recording the posterior-superior, or retruded, CR rather than the currently accepted CR position of anterior-superior. Little, or no, objective data exists regarding the reliability of recording the anterior-superior CR position. Dr. Utt does not provide data or citation of literature that demonstrated the reliability of recording anterior-superior CR by the use of power centric wax registrations.

Besides the issues concerning the reliability of the power centric wax registrations, manipulated versus unmanipulated CR, and posterior-superior CR records versus anterior-superior CR records, there is the equally important issue related to the validity of the power centric registration. Where in Dr. Utt's article does he demonstrate that subjects' condyles are actually in the anterior-superior CR position he ascribes to, i.e., the condyles seated "closely as possible to CR with condyles centered transversely and seated against the articular disks at the posterior slope of the articular eminence"? Dr. Utt does not provide TMJ "imaging" data to support this view. Furthermore, Dr. Utt does not even provide one reference to data that supports this view. What validates the power centric registration?

How did the author standardize the pressure the examining orthodontists used to manipulate the mandible, e.g., *Materials and Methods,* fourth paragraph, "The operator guides the mandible applying chin point pressure at pogonion to prevent protrusion, supporting the angles of the mandible in a superior direction, and asking the patient to relax and close slowly"? Incidentally, there are several reports that have demonstrated that many of the "clinically" derived data in medicine[23] and dentistry[24-32] are unreliable.

In addition, Dr. Utt uses several times the term *dead soft.* He should define exactly what this means. Further, he does not discuss or determine the influence the thickness of the wax index has on the CO and CR registrations. The thickness of CR registrations influence condylar position.[33] Also, the depth of tooth penetration into the wax index will influence the MPI recording among subjects and within the same subject.

7. Angle's classes

Comparison of CR and CO data for the Angle's classes was not practical in this study. Because there were only four subjects with Class III malocclusions, the Angle Class IIIs were excluded. Further, since this study was descriptive with poststratification of the data, the Angle Class I, Class II, Division 1, and Class II, Division 2 malocclusions could not be matched for size or gender.

8. Tables

There are many errors in the tables and some figures. Often the information presented in the text does not match that provided in the tables/figures and vice versa. The legends and descriptions of most of the tables and figures are inaccurate and/or inappropriate. A summary of my remarks for the tables are as follows:

a. *Table I.*
The text and Table I do not correspond. In the *Results,* first paragraph, Dr. Utt writes, "The frequency and range of CO-CR differences as determined from MPI are summarized in Table I." However, although Table I is indeed titled "Frequency and range of CO-CR differences," what is actually reported in the table is the number and percent of subjects with and without CO-CR differences, as recorded by four orthodontic judges, and the average of the four orthodontists' recordings. Parenthetically, because the interjudge error for the orthodontists is unknown, the individual judges' recordings are unnecessary.

b. *Table II.*
Because the standard deviation is high, "median values" or "transformation of the data" would provide more, or additional, information than the "mean values."

c. *Table III.*
The table is titled, "T-test. . .," but the table reports "F-values." Table III also needs p-levels/values.

d. *Table IV.*
The article's text, *Results* (fourth paragraph) reads, "The overall average CO-CR discrepancy was nearly identical when the right and left sides were compared (Table IV)." However, Table IV reports only mean and standard deviation values. Because only descriptive statistics were reported in the text and no inferential statistics used, how can the author make the "inference/conclusion" previously stated? Is this conclusion based on visual inspection of the data? Also, as with Table I, there are

large standard deviations (e.g., in two instances the standard deviation is greater than the mean); "median values" would be more appropriate.

e. *Table V.*
Table V reports 4 df. Therefore there must be five "levels" of agreement in the study. I can easily determine four: right SI, left SI, right AP, and left AP. Where is the fifth "level"?

f. *Table VI.*
The table is titled, "Pearson Correlation Coefficients (R^2)." However, R^2 is the *Coefficient of Determination; R* is the *Correlation Coefficient.*

g. *Table VII.*
In the second to last paragraph of the *Results,* the author writes, "No statistically significant difference was found between male and female patients or the magnitude of CO-CR discrepancy. The MPI data for each gender is summarized in Table VII and Figs. 9 and 10." However, no inferential statistical test was reported in Table VII to substantiate the author's statement. Table VII contains only mean and standard deviation values.

h. *Fig. 3*
The second paragraph of the *Results* reports percentages for subjects with inferior, superior, anterior-posterior, and posterior-superior condylar positions when CO is compared with CR. However, Fig. 3 reports only absolute numbers. Where do the percentages come from? I suspect the author used the numbers in Fig. 3 to calculate them, but I do not know for sure.

9. Consideration of several statements made in the Results/Discussion

In the last sentence of the fourth paragraph of the *Results,* Dr. Utt states, "The amount of vertical (S-I) displacement was consistently greater than the amount of horizontal (A-P) displacement in the sagittal plane." He does not refer the reader to any table, figure, or statistic that would support this statement. The point I make here is not to challenge the author's statement, but to question where this conclusion comes from.

How does the author explain the finding of CO being located posterior to CR? This can possibly be explained by the fact that Dr. Utt is using the anterior-superior condylar position for CR. If this is so, how does he explain the finding of CO being located anterior to CR? Dr. Utt accepts CR as the position where the "condyles are centered transversely and seated against the articular disks at the posterior slope of the articular eminences without dental interferences." How can a patient's teeth be in occlusion (CO) and the condyles be more anterior than they could be when they rest against the posterior slope of the articular eminences?

The author even recognizes the confusion of his findings because he states in the *Discussion,* paragraph three: "Most likely the infrequent findings of CO superior to CR are the result of technique or operator error or an internal joint derangement that allows the condyle to become positioned superior to desired CR position of condyles, centered transversely, and seated against the articular disk at the posterior superior slope of the articular eminences without dental interference." If he admits to operator error, why did he not measure or account for it in his methodology? If the author conjectures that the patients have internal derangement, why did he not screen for this in his sample selection? Was the sample supposed to be homogenous and normative (i.e., free of TMD symptoms)? Was it a heterogenous population composed of patients with TMD?

Dr. Utt compares study findings at the beginning of his article and in the *Discussion* that are not comparable since different definitions of CR and CO were used. It is the proverbial comparison of apples to oranges. For example, the author states in the *Discussion,* first paragraph: "Almost all subjects studied displaced a CO-CR difference in condylar location. A wide range of condylar positions was noted during this investigation. Previous authors have noted various ranges of condylar positions with instrumentation similar to the MPI."[26-29,32] If one looks at the author's references (26-29, 32), one finds two of the papers published in the 1950s, two published in the 1970s, and one published in the mid-1980s. The five cited references surely had different definitions of CR and CO. Further, if one accepts the previously cited statement of Dr. Utt, perhaps all his study has demonstrated is the "normal," morphologic variation in the position of the human condyles and teeth. In addition, I reiterate again what I mentioned earlier in this critique, Dr. Utt is "looking at" two different variables when comparing CR to CO, since by definition CR refers to a position of the condyles, whereas CO is an interocclusal position of the teeth.

Perhaps the most logical information provided by Dr. Utt, and he was too biased by his "gnathological philosophy" to "see" it, was his statement in the *Discussion,* paragraph 10: "Only 13.3% of the orthodontists responding to a 1986 survey reported the use of pretreatment study models mounted on an articulator."[53] This statement could be considered in several ways. One way (and the way Dr. Utt would view it) is that there are 86.7% of the orthodontists not keeping up with the "standard of care," because they do not use articulators in their practice. Perhaps another view may be, 86.7% of the orthodontists are intelligent enough not to easily accept the scientifically unfounded claims of the "gnathologists/occlusionists."

PART II

1. Introduction

Arguably, the basic premise of the Utt article is flawed because it is at least 20 years old. Instead of arguing that a posterior, superior position of the mandibular condyles is virtuous, the gnathologists today argue for an anterior, superior position of the condyles. Perhaps the clinical significance of orthodontic patients' condylar position is exaggerated.

Certainly, Brodie,[34,35] Perry,[36,37] Moyer,[38] Thompson,[39-44] Ricketts,[45-47] and Roth,[5-9] were pioneers in the effort to motivate orthodontists to look beyond the mere

static, morphologic relationship of the dentition. And, there is little doubt that the dynamic, "functional" aspects of occlusion and the supporting temporomandibular structures are important considerations of mastication, deglutition, and parafunction. Some in the specialty, however, have taken a rather "mechanistic" versus "biologic/physiologic" approach to the issue(s) of "function." Science took a backseat to many feeble-minded notions. Even the more noble and intuitively appealing ideas of the "mechanistic" orthodontists were found to have no scientific merit.

Gnathology became the buzzword of the 1970s and 1980s. Canine Protected Occlusion, centric relation, and articulator mounted casts became the presumed criteria for "the standard of care."

However, research over the past 20 years has shed some doubt about the credibility of "gnathology." In the 1970s and 1980s centric relation meant a posterior, superior position of the condyles. How many orthodontists treated patients to this position? A decade or so later, centric relation migrated to an anterior, superior position along the posterior slope of the articular eminence. The change of CR to the anterior position was motivated mainly from unenlightened dentists who claimed that distal pressure and location of the condyles can cause internal derangement of the TMJ, i.e., anterior displacement of the TMJ disk.[48-50] Consistent with this view was the notion that Class II, Division 2 malocclusions, missing posterior teeth with bite collapse, any occlusal contacts that may deflect the condyle(s) posteriorly, and such orthodontic procedures as Class II elastics, headgear, chincup, and certain retainers were causes of TMD.[51-53]

Few questioned the logic of many of the ideas and concepts of the gnathologist and occlusionist. More became followers and ignored the scientific data that were emerging.

Today the compelling evidence makes one question some of the ideas of the gnathologist and occlusionist. Condylar position[54-58] and occlusion[54,55,59-64] have been demonstrated to have little or no relationship to TMD. Further, gnathologists were surprised to learn that studies aimed at comparing the "functional occlusions" of orthodontically treated subjects with those of nonorthodontically treated subjects found that, for the most part, both groups possessed "balanced occlusion."[59,60,65-67] Parenthetically, the gnathologist expected to find orthodontically treated subject with balancing contacts because orthodontists supposedly ignore function. Interestingly, Canine Protected Occlusion was found to be essentially absent in orthodontically treated and untreated subjects. Further, orthodontics per se was not found to be causative of TMD.[56,59,60,68-72]

2. CR and condylar position

Centric relation was defined some years ago as the most posterior, superior, unrestrained, position of the mandible to the maxilla at the established vertical dimension. The condyles were said to be located as far posterior in the glenoid fossa as the ligaments and musculator of the TMJ permitted. Because this position is governed mainly by the TMJ ligaments, it has been called the *ligamentous position.* Centric relation occlusion (CRO) became known as the interocclusal position of the teeth while the mandible and condyles were in centric relation. According to the early definition, centric occlusion was defined as the position of the teeth when they are maximally and habitually intercuspated.

Early studies demonstrated that CO was usually found 0.1 to 1.8 mm anterior to CRO[73-75] depending on the population studied and the subjects' ages.

Centric relation became a position used to reproduce mandibular position during the construction of dentures. The popularity of CR grew and was adapted for the natural dentition as applied to fixed prosthodontics.

Consideration of the early literature on CR would provide a useful framework to contrast with today's knowledge. When reviewing the earlier work, the definition of CR for that time period will be used, i.e., posterior, superior. CRO is considered in the following context as the interocclusal antilog of CR. Centric occlusion is considered the interocclusal position of the teeth when they are maximally and habitually intercuspated.

Support for the usefulness of "retruded" CR came mainly from electromyogram (EMG) studies. It was hypothesized that EMG activity of the masticatory muscles could be extrapolated to conditions, or positions, of the occlusion or condyle.[76,77] The EMG recordings have been criticized for several reasons such as the EMG method produces muscle activity that distorts the natural functional pattern.[78] Another shortcoming of EMG investigations has been the lack of a proper description of what abnormal muscle activity or high EMG activity means, particularly when no adequate control groups were used. Because of the lack of controls in EMG studies, there is no means for calculating sensitivity values, and the analysis of specificity scores indicate that the EMG method is strongly biased toward a false positive diagnosis.[79-83] A final argument is that there is a lack of convincing evidence to support the use of EMG because of insufficient data on age, gender, occlusal structure, and facial pattern.[81,82]

Although there is some variation in the findings from intraoral telemetric studies, the preponderance of evidence suggests that, although CRO contacts have been found to occur during swallowing, most swallowing and all chewing contacts occur in CO.[84-86] And, lateral functional occlusal contacts originate from CO and not from CRO. Furthermore, telemetry research has indicated that even when patients' entire dentitions were reconstructed with maximal intercuspation in CRO, patients persisted in using CO.[87]

Although the posterior-superior concept for CR was generally accepted by the dental profession for some time, Sicher[88] was one of the first to claim that "retruded" CR was an extreme position, and that a joint habitually postured in such a position was contrary to

principles of biologic structures. Silverman[89] even suggested that adjustment of the occlusion of patients to the retruded mandibular position may be iatrogenic. Further, Sheppard[90-92] believed that manipulation of the mandible in "retruded" centric relation by forcing, guiding, or tracing and the use of clutches and attached face-bows used in the hinge-axis technique, do not simulate normal functional movements but initiate those associated with pathologic conditions. Graber [personal communication] called *manipulated CR* "arbitrary and unphysiologic in contrast to postural rest position."

Parenthetically, Jankelson[93] supported the view that neither CRO nor CO were physiologic centric positions, but advocated what he termed the "myocentric," or muscle (i.e., masticatory) generated centric. He believed the myocentric was usually located between CRO and CO and was determined through the use of the "myomonitor." On the other hand, Schulyer[94,95] advocated a "long centric," in which occlusal prematuries, or interferences, were eliminated to and from CRO and CO. In the Schulyer scheme, functional occlusions were developed in patients so that they had "freedom" to use both CRO and CO and all positions in between without inhibition from occlusal interferences.

Williamson[77] recently advocated a CR position with the condyles located superiorly on the posterior slope of the articular eminence, i.e., anterior-superior condylar position. Williamson's philosophy was based on the belief that subjects' EMG patterns were better when the condyles were so placed. Okeson[96] also advocated an anterior-superior condylar position and believed it to be the "most stable joint position and is also the musculoskeletally stable position." Gelb's concept for the preferred CR position was one in which the condyles translated approximately halfway down the posterior slope of the articular eminence,[96] i.e., anterior-midcondylar position.

The concept of CR and condyle/jaw position has been challenged by recent research. The preponderance of evidence supports the view that there is no one ideal position of the condyles in the glenoid fossa, but a range of "normal" condylar positions. The American Dental Association, in conference reports of 1983[54] and again in 1990,[55] endorsed the view, "... there is insufficient evidence that eccentricity of the condyle in the fossa is a diagnostic sign of a temporomandibular disorder." There is no suggestion by the above that "condylar position per se is unimportant, but rather to suggest that there is no good reason to assume that any of the many centric relations is optimal."[97]

A recent study by Alexander et al.,[98] sought to compare and evaluate the reliability of three occlusal and/or jaw positions: (1) Retruded centric (RE) (i.e., the "old" posterior-superior centric relation), (2) centric occlusion (CO) (i.e., maximal intercuspation/habitual centric) and (3) centric relation (CR) (i.e., the "contemporary" anterior-superior centric relation through Williamson and the use of a "leaf gauge"). Their sample consisted of TMD symptom free men ($N = 28$). Their methodology consisted of (1) the Sam articulator with MPI, (2) interocclusal zinc oxide and eugenol records, (3) axiographs face-bow to located RE, and (4) MRI with acrylic interocclusal registrations. Their findings and conclusions were provocative: (1) CO has a distinct jaw position, (2) CO-condyles are positioned inferior and anterior to RE and CR, (3) CO is not coincident to CR, (4) the data did not support distinct condylar positions for RE and CR, and (5) the clinical concept of treating to CR as a preventive measure to improve disk-to-condyle relationships was not supported.

Lysle Johnson[98] offered this critique of many of the notions related to CR. He writes:

> The specialty of orthodontics has for years been badgered by a variegated assortment of gnathologists, "occlusionists," and the like who argue, among other things, that orthodontic treatment should produce a so-called "centric relation occlusion." Indeed, if one accepts this major premise, a reasonable case can be made for much of the instrumentation, manipulation, and irradiation that are advocated in the literature. Unfortunately, I know of no convincing evidence that condyles of patients with intact dentitions "should" be placed in centric relation or that once having been placed there, the resulting improvement on nature will be stable. . . . Instead of demanding a rational theoretical basis and convincing proof, we took "how-to" courses and bought big articulators, apparently in hope that this demonstration of Right Thinking would keep us out of court and our waiting rooms full of referrals. We were mistaken. (page 84)

Furthermore, Dr. Johnston added this note of sarcasm, "... it could be argued that the progressive modifications in the definition of centric relation have done more to eliminate centric slides than 20 years of grudging acquiescence to the precepts of gnathology."[97] He made a plea to orthodontists for "... attention to existing research, a respect for basic theory, and a healthy skepticism can serve to bridge the gap between mindless chaos and unobtainable certainty."[97]

3. Articulators

Articulators have shown their usefulness for many aspects of dentistry. For "gross" prosthodontics such as complete and partial dentures and also for certain "fixed" procedures, the benefits of articulators are well known. An occlusal examination with articulator-mounted dental casts can facilitate the detailed examination of static and functional relationships of the dentition. Articulated casts may provide information concerning the possible deleterious effects of bruxism and other oral habits. In a way, articulators perhaps provide the "art" in dentistry's claim of a profession that encompasses both "art" and "science."

However, one must also be cognizant of the fact that there is poor diagnostic sensitivity and specificity of occlusal factors in relationship to TMD, and the analysis of occlusion with articulated casts will in no way be diagnostic of TMD per se.[61] Interestingly, when articulators were initially used, the role of occlusion in the cause of TMD was considered primary. Occlusion, then, was even thought to be significantly involved in periodontal disease. Contemporary views on "occlusion" have shown that, at best, it has no role, or a secondary role, in the cause of TMD.[54,55,61] Further, the "centricity" of the condyles in the glenoid fossa, irrespective of where that position may be, has not been demonstrated to be consequential in the presence or absences of signs/symptoms of TMD.[54,55] With "occlusion" and "condylar position" having been demonstrated to be less importance than once thought, the usefulness of articulators has been questioned.

As a research "tool," articulators, even fully adjustable ones that also incorporate a MPI component, have their pitfalls. First, even the most elaborate and sophisticated mechanism can never exactly and precisely duplicate all the bony relations of the condyles, glenoid fossa, and eminentia, let alone simulate the influences of such biologic elements as the TMJ disk, TMJ ligaments, muscles, which obviously affect mandibular condylar movements. Second, it is the maxillary cast that is movable with articulators, whereas in nature the mandible moves. Next, certain average values are used in the articulator set-up procedures that do not address the biologic variability of each person. Pantographs were introduced to reduce some of this error. Further, there is error in the use and the procedures involved with the intraoral "occlusal/jaw" registrations needed to set the articulator. Incidentally, some critics of articulators even make an issue out of the notion that the intraoral "occlusal/jaw" registrations require conscious, voluntary acts on the part of the subject, whereas, for the most part, mastication, deglutition, and parafunctional jaw movements are preconscious and involuntary.[99] In addition, articulators are based on the perhaps mistaken notion that human jaw opening is a hinge-like motion in its initial stage. There is compelling evidence, however, that even in the initial phase of opening and the final phase of closing, both rotation and translation occur. Finally, Shanahan and Alexander[100,101] offered this critique:

1. . . . condylar paths vary with the nature of the mandibular movements and the type of occlusal guidance, which would therefore challenge the attempted registration of condylar pathways used for setting an articulator.

2. The natural opening and closing excursions do not coincide with those of a hinge axis articulator. The natural protrusive movement does not coincide with the straight line protrusive movement of the adjustable articulator, and the differences between the quality of the cycles and the excursions are not reproducible on an adjustable instrument.

CONCLUSIONS

Because the study by Dr. Utt is descriptive rather than experimental (longitudinal/prospective) or observational (cross-sectional/retrospective), it must have a "sound" theoretical basis. I find the basic premise for this study faulty. Further, the methodology of this study is tenuous. In addition, I am still not certain what Dr. Utt's study was about. Since he did not directly define CR and CO, I do not know for sure what was actually recorded and measured in the study. If one accepts the latest "Glossary of Prosthodontic Terms" definition of CR and CO, the concept of the article is absurd. That is, CR is a condylar position and cannot be compared with CO, which is an interocclusal position of the teeth. In addition, by current definition CO is the interocclusal position when the condyles/mandible is in CR. So, again, what is Dr. Utt studying? Finally, the significance of the results of this study are not obvious because the validity of the study is questionable.

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Reprint requests to:
Dr. Donald J. Rinchuse
Villawood Professional Center
Pellis Rd.
Greensburg, PA 15601