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Registration of the Seated Condylar Position (SCP/CR): Part I: Rationale

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Abstract

The purpose of this paper is to present the rationale for registration of the Seated Condylar Position (SCP)/Centric Relation (CR) position of the condyles.

Keywords

Dental Arch Displacement (DAD), Condylar Displacement (CD), Seated Condylar Position (SCP), Maximum Intercuspation (MIC), Intercuspal Position (ICP), Musculo-Skeletal Dysfunction, Temporo-Mandibular Dysfunction (TMD), Common Muscle Contraction Headache (CMCH)

1. Introduction

From the introduction to Samuel J. Higdon's text on the TM joint [1]:

> "It is the hope of this author that (this information) will foster further appreciation of the critical relationships between structure (form) and function regarding the role of the TM joints in the harmonious, physiologic function of the masticatory system. When considering what has traditionally been referred to as 'dental occlusion' we are now more aware than ever before that the study of dental occlusion must take into account the role of both normal and dysfunctional TM joint anatomy as related to the static and dynamic relationships of the teeth, as well as their equally important

role in muscle function."

In Pete Dawson's last text [2], he specified that, "The ultimate goal for every patient and the goal of complete dentistry is long term maintainable health of the total masticatory system. Achieving functional harmony in an environment of optimally healthy teeth, joints, periodontium, and musculature, in combination with the best possible esthetic result, is the essence of complete dentistry. Neuromuscular harmony depends on structural harmony between the occlusion and the TM joints." He further identified the goals for complete dentistry:

1) Freedom from disease in all masticatory structures;
2) The ability to maintain a healthy periodontium;
3) Stable TM joints and mandibular position;
4) Stable occlusion;
5) The ability to maintain healthy teeth;
6) Comfortable function;
7) Optimal esthetics;
8) Nasal breathing with relaxed lip posture.

Adding physiologic/functional treatment goals to traditional anatomic (static) goals changes virtually every aspect of dental correction. Kazumi Ikeda [3] [4] states, "(Orthodontic/dental) treatment is not only about improving form but also about promoting the development and maintenance of stomatognathic function, thereby improving quality of life." A systems approach to dental correction attempts to answer the following questions: What influence do the teeth have on the health and function of the gnathic system? and What influence does the health and function of the gnathic system have on the teeth? Thus, if one of the stated goals of dental and orthodontic correction is "Ideal Occlusal Function," then it is of paramount importance to have an understanding of what the Seated Condylar Position (SCP)/Centric Relation (CR) is and how to register it.

"There is a reason why masticatory muscles get tender, why TMJ's hurt, why teeth get sensitive, and why certain occlusions remain stable and others do not. There is extensive clinical evidence to support the relationship between deflective occlusal contacts and masticatory muscle symptoms." [2]. Deflective occlusal contacts/interferences that require condylar displacement (CD) to achieve the IP/MIC/CO are a primary etiologic factor of occluso-muscle pain/common muscle contraction headache (CMCH), the most common type of TMD [2] [5] [6] [7].

2. Three-Dimensional Determination of Condylar Position

The seated condylar position (SCP) or Centric Relation (CR) is anatomically determined; thus it is repeatable and reproducible [8] [9] [10]. It is defined as the relationship of the mandible to the maxilla when the condyles are seated against the thinnest avascular portion of the articular disc in their most superoanterior position in the glenoid fossae and are centered transversely, regardless of tooth contact [10] [11]. Okeson [10] describes this as the most orthopedically and musculoskeletally stable position of the mandible, while Sicher, [12] Hylander, [13] and Gibbs and Lundeen [14] consider this position to be the essence of optimal TMJ form and function. It is considered to be the most reliable and reproducible reference point for accurately recording the relationship of the mandible to the maxilla [9] [10] [15]-[20]. The seated condylar position implies that no further movement superiorly, anteriorly, or medially is possible and implies a healthy disc position and morphology. Therefore, a determination of the SCP/CR is a reasonable prerequisite for analyses of dental inter-arch, condylar position, and skeletal (maxillo-mandibular) relationships [8]-[13] [15]-[26] and is an important topic for further study and greater understanding.

The SCP/CR is a desirable treatment goal for reorganization of the occlusion. Howat *et al.* [9] state that the discrepancy between the seated and unseated condylar position should be identified and eliminated when the operator reorganizes the occlusion. The occlusion is reorganized when:

Restoring posterior occlusal stability by occlusal adjustment or tooth restoration.

Treating mandibular dysfunction.

Restoring the dentition with multiunit restorations.

Restoring patients with complete denture prosthetics.

Treating patients orthodontically.

Positioning the condyle during orthognathic surgery.

Thus, treatment success in each of these areas is completely dependent upon the operator's ability to attain a comfortable, stable, repeatable seated condylar position as a reference point for treatment.

A definitive description of occlusion includes an assessment of not only models articulated accurately in the SCP/CR but also an assessment of condylar position resulting from intercuspation of the teeth. "Significant joint displacements are routinely missed if condylar position is not accurately determined before analyzing the maxilla to mandible relationship." [2].

The intercuspal position/maximum intercuspation/centric occlusion (IP/MIC/CO) is defined as the most closed position that the mandible can assume, determined by full intercuspation of opposing teeth, regardless of condylar position [22] [27] [28] [29] [30]. The SCP/CR defines a condylar-determined position of the mandible, whereas the IP/MIC/CO defines a tooth-determined position. It is generally agreed that a difference exists between the three-dimensional dental inter-arch relationships in the IP/MIC/CO and the SCP/CR [25] [27] [28] [29] [30]. This is defined as dental arch displacement (DAD). Previously, DAD has been referred to as a mandiblular functional shift, hit-and-slide, or dual bite (**Figure 1**).

From research conducted with dental instrumentation, it is apparent that most DAD's are NOT detectable intra-orally [3] [4] [5] [6] [9] [14] [15]-[25] [27] [31]-[48]. If a DAD is detected intra-orally, the magnitude of the DAD is increased exponentially in all three planes when it is visualized on dental casts articulated in the SCP/CR [3] [4] [5] [6] [17] [21] [36] [39] [40] [43].

It is also generally agreed that a difference exists between the three-dimensional condylar position in the IP/MIC/CO (the occlusion-dictated condylar position) and in the SCP/CR (the three-dimensional condyle position when the condyles are seated) [19] [21] [23] [27] [28] [29] [33] [34] [36] [37] [38] [39] [43]-[49]. In the naturally occurring dentition, the SCP/CR does not usually coincide with the position the mandible assumes when the teeth are in intercuspation/MIC/CO [2] [8] [9] [10] [11] [15]-[23] [27] [28] [29] [30] [33] [34] [36] [37] [38] [39] [43]-[52]. This positional difference is known as condylar displacement (CD) [16] [17] [21] [23] [24] [30] [33] [39] [43] [44] [45] [49] (**Figure 2**).

Various clinical methods have been proposed to assess condylar displacement as it relates to the dentition.

Condylar displacement (CD) can be:

1) Inferred via intra-oral observation of DAD;

2) Visualized with dental imaging (lateral cephalogram, corrected tomogram, MRI);

3) Measured via CBCT joint space imaging data and condylar graph measurement data through utilization of common dental instrumentation.

2.1. Inferring CD

Previous investigators have attempted to observe a mandibular functional

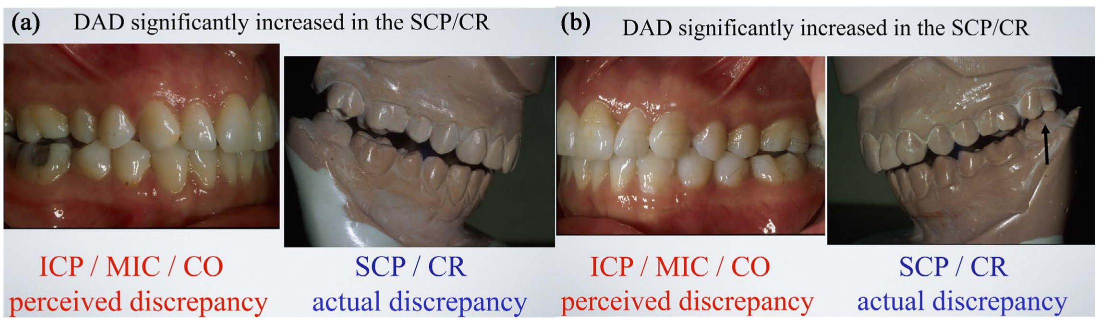

Figure 1. DAD: the difference between the three-dimensional dental inter-arch relationship in the IP/MIC/CO and the SCP/CR.

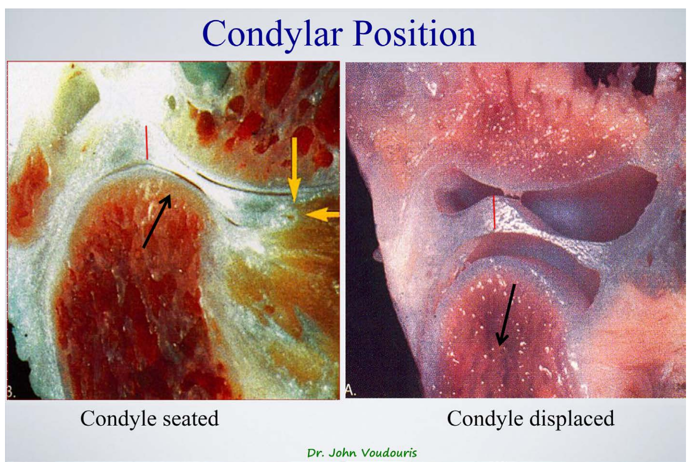

Figure 2. CD: the difference between the three-dimensional condylar position in the IP/MIC/CO and the SCP/CR.

shift/hit and slide/dual bite intra-orally through mandibular manipulation and chairside visualization of DAD at the level of the occlusion in an attempt to infer CD from DAD. Various clinical methods have been proposed to assess condylar displacement as it relates to the dentition. One popular method is a chairside assessment through intraoral visual estimation, using mandibular manipulation to attempt to seat the condyles and locate the initial occlusal contact [53]. In this method, utilized previously in large TMD population studies as a substitue for instrumentation [54]-[63], the operator attempts to estimate the degree/direction/magnitude of condylar displacement by measuring the hit-and-slide (DAD) at the occlusal level. However, investigators have concluded that it is diffucult and uncommon to observe a mandibular functional shift (DAD) in the mouth/intra-orally.and to quantitatively assess a discrepancy between the SCP/CR and the IP/MIC/CO clinically at the level of the occlusion [3] [4] [5] [6] [9] [14] [15]-[25] [27] [31]-[48]. If a DAD is detected intra-orally, the magnitude of the DAD is increased exponentially in all three planes when it is visualized on dental casts articulated in the SCP/CR [3] [4] [5] [6] [17] [21] [36] [39] [40] [43].

Clinical mandibular manipulation is unreliable in determining the seated condylar position because of the effects of the neuromusculature, which is consistent with Calagna [27] who stated "…there is no known scientific method available to determine which patients require neuromuscular conditioning."

The Neuromuscular Protective Mechanism/Proprioceptive Guidance

It has been demonstrated that the neuromusculature positions the mandible to achieve maximum intercuspation in the IP/MIC/CO, overriding condylar seating [19] [21] [23] [27] [28] [29] [33] [34] [36] [37] [38] [39] [43]-[49]. Attempts to assess dental arch displacement (DAD) in the general population through intraoral visual estimation are unpredictable, because the muscles of mastication and neuromuscular reflexes protect the teeth by superseding the guidance of the joint [9] [15] [21] [27] [28] [29] [36] [39] [64]-[69]. The neuromusculature may change the arc of closure of the mandible in the presence of occlusal interferences, in order to protect the interfering teeth from absorbing the entire force of the closing musculature [9] [10] [15] [22] [24] [36] [39] [64] [70].

Engrams (muscle splinting) develop due to repetitive closure in the intercuspal position, causing the proprioceptive neuromuscular system to become patterned to the deviated closure. The resultant muscle function becomes so dominant that the acquired mandibular position (the perceived discrepancy) as a result of the occlusion dictated condylar position will often be mistaken by the clinician as the mandibular position in the seated condylar position (the actual discrepancy) (**Figure 3**). As Lerman states, "The engram (the masticatory "muscle memory") is a conditioned reflex reinforced and stored in the masticatory muscles at every swallow, adjusting masticatory muscle activity to guide the mandible and lower dental arch unerringly into its ICP. These muscle adjustments compensate for the continually changing internal and external factors that affect the mandible's entry into the ICP," masking the DAD between the IP and

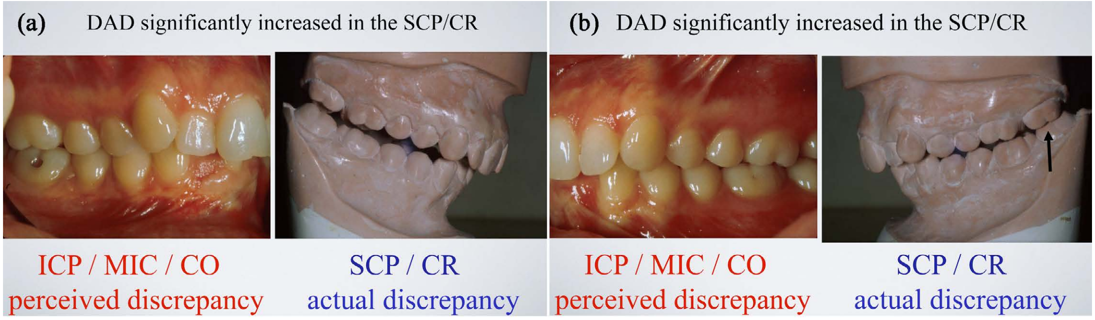

Figure 3. The perceived discrepancy in the IP/MIC/CO v. the actual discrepancy in the SCP/CR.

the SCP [71].

The neuromuscular response to the habitual occlusion has been described in the occlusion literature as the neuromuscular protective mechanism by Hannam [72] and proprioceptive guidance by Roth [22] [25] [73] [74]. Condylar position is determined by the dentition at the IP as a result of deflective contacts. Thus tooth position and the occlusal surfaces of the teeth dictate condylar position at the end of closure. Deflective occlusal contacts result in condylar displacement. Slavicek [17] described the use of the SAM articulator with the MPI instrument (Great Lakes Orthodontics, Ltd., Tonawanda, New York) to quantify differences between the tooth-determined position of maximum intercuspation (the IP/MIC/CO) and the joint-determined position (SCP/CR). Thus the occlusal position observed intra-orally (the IP/MIC/CO) is an accomodated mandibular position with condylar displacement.

Furthermore, studies have shown that observation of a slide or shift at the level of the occlusion (DAD) does not accurately represent the three-dimensional change in position of the condylar axis [16] [17] [21] [23] [24] [33] [36] [39] [43]-[46] [49]. Hodge and Mahan showed that only a small part of the AP component of a DAD (SCP/CR-to-IP/MIC/CO occlusal slide) as seen at the incisal level is due to AP translational displacement of the condyles. The majority of the AP component of the DAD ("slide") seen at the incisal level is due to "the mandible swinging posteriorly (inferiorly) when it opens and anteriorly (superiorly) when it closes, as it rotates around the horizontal axis in the terminal hinge closing arc (and initial occlusal contact)." [75].

Rosner [33] [34] used the modified Buhnergraph for a three-dimensional assessment of condylar position in the RCP and the ICP for 49 and 75 subjects respectively and found a remarkable lack of symmetry for right and left condylar displacement between the two positions. As Rosner states, "(One) cannot determine CD by observation of… (DAD)." [34]. Thus from these seminal studies it is evident that condylar displacement (CD) can not be determined clinically. What is observed intra-orally is dental arch displacement (DAD), previously referred to as a hit-and-slide/functional shift/dual bite.

However, two malocclusions that routinely present with DADs/mandibular functional shifts that may be observed intra-orally are:

1) Unilateral posterior cross bite: Unilateral posterior cross bites are commonly a result of bilateral maxillary constriction (hypoplasia) with a lateral mandibular functional shift into intercuspation, resulting in normal buccal-lingual intercuspation unilaterally and a cross bite on the opposing side. Often a midline shift is observed intra-orally between the intercuspal postion (IP/MIC/CO) and the seated position (SCP/CR). Correction of the maxillary constriction (with palatal expansion and/or surgery) results in arch coordination in which the maxillary arch width is normalized with respect to the mandibular arch width, normal lateral intercuspation is restored, and the mandible centers upon closure. Thus dental midline correction is improved/achieved through skeletal maxillary expansion. Clinically, a DAD resulting in a unilateral posterior cross bite is frequently accompanied by common muscle contraction headache (CMCH), the symptoms of which are often eliminated with maxillary width correction and concomitant centering of the mandible, allowing more vertical opening and closing patterns (**Figure 4**).

2) Anterior cross bite: It is common for dental clinicians to attempt to determine through mandibular manipulation if an end-on or Class 3 anterior occlusion is a result of an anterior mandibular functional shift or a horizontal (AP) skeletal discrepancy (**Figure 5**).

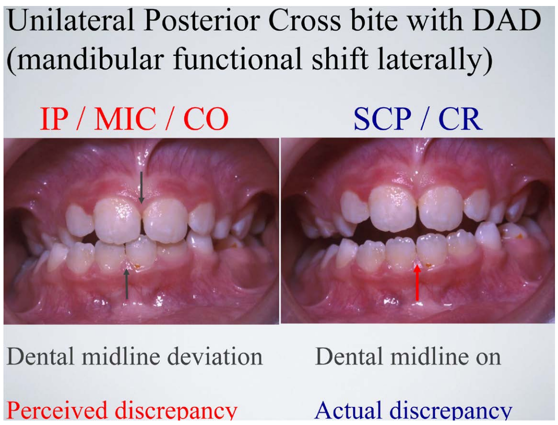

Figure 4. Unilateral posterior cross bite with DAD (mandibular functional shift laterally).

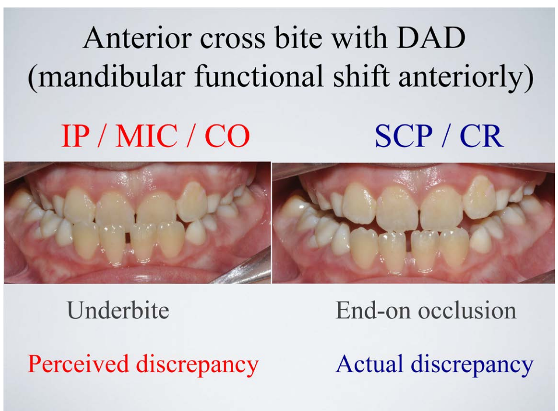

Figure 5. Anterior cross bite with DAD (mandibular functional shift anteriorly).

2.2. Visualizing CD

CD is infrequently visualized with dental imaging (lateral cephalogram, corrected tomogram, MRI).

1) Lateral cephalogram: CD can be visualizd on a lateral ceph, but it requires highly accurate imaging and its observance is rare. Tamimi and Hatcher state, "TM joints can not be adequately visualized on a lateral ceph due to superimposition of bilateral structures on a 2D film." [76]. Typically the condylar outline is not evident on a lateral ceph (**Figure 6**). However, severe vertical displacement of the condyles can result in a significant observable joint space superior-anterior to the condyle (**Figure 7**).

2) Corrected (oriented) tomogram: From a submental vertex image the condylar angle and center of the condylar head can be determined, providing the settings for a center cut image of the condyle and thus improved accuracy and reproducibilityof the position of the condyle in the fossa [77] [78]. According to

Figure 6. Lateral cephalogram: Condylar outline unclear due to superimposition of skeletal structures.

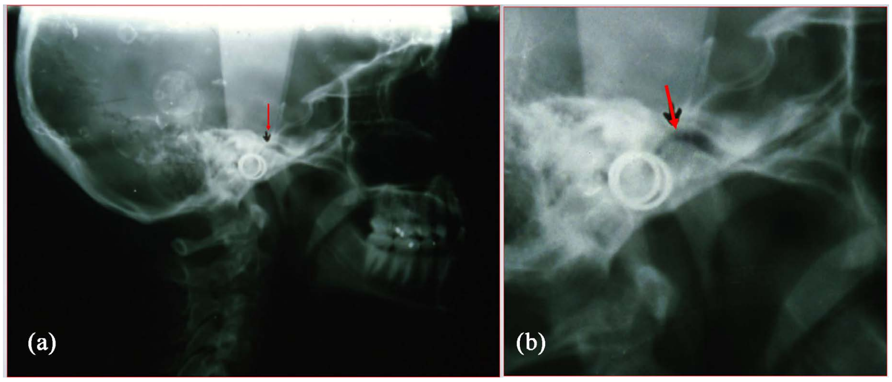

Figure 7. Joint space visible on lateral ceph due to vertical condylar displacement (CD).

Tamimi and Hatcher corrected/oriented tomograms are the best plain film technique for visualization and interpretation of condylar shape and position [76] (**Figure 8**).

3) Proton density and T2 weighted MRI images also provide accurate TM joint imaging with visualization of both hard tissue (condyle and eminence) and soft tissue (disc/meniscus) [3] [4] (**Figure 9**).

If a condylar displacement is suspected by visualization of a DAD intra-orally or on a lateral ceph, corrected tomogram, or MRI it would be pertinent to determine the full extent of the condylar displacement by deprogramming the patient and articulating the dental casts in the SCP/CR. For example, in orthodontics, an argument can be made in most cases for either a non-extraction or extraction treatment plan, depending on a number of factors, one of which is the magnitude (mm) of the horizontal, vertical, and transverse inter-arch discrepancy (DAD) present, which is precisely (to the mm) revealed by dental casts articulated in the SCP/CR.

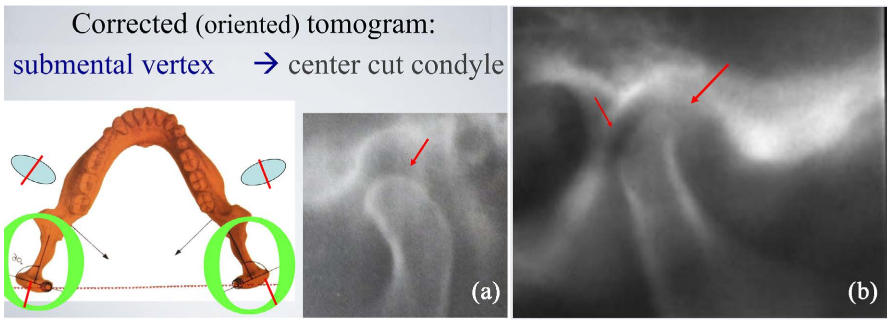

Figure 8. Condylar displacement as visualized on corrected/oriented tomogram of the condyle.

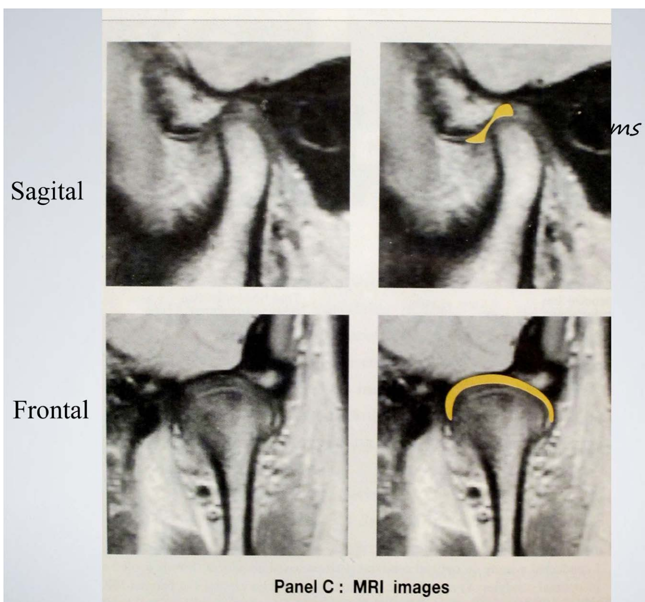

Figure 9. Proton density and T2 weighted sagital and frontal MRI images of the condyle-disc assembly.

2.3. Measuring CD

CD can be measured via both highly specific imaging, such as limited CBCT joint space imaging and condylar graph measurement through utilization of common dental instrumentation.

1) Limited CBCT joint space measurement data.

The clarity of the limited CBCT image allows for precise measurement of the joint space between the condyle and fossa due to its ability to clearly delineate osseous structures. Ikeda and Kawamura [79] [80] assessed optimal condylar position with limited cone-beam computerized tomography. Joints included in this study had:

a) Normal disc position;

b) Minimal SCP-MIC discrepancy by CPI data from articulated models mounted in the SCP/CR;

c) Normal condylar movement on Axiograph tracings;

d) Asymptomatic.

Using limited CBCT of the TM joint, they determined the optimal condylar position in 3 planes (AP (horiz), SI (vert), ML (transv) in both the sagital and frontal planes (**Figure 10**).

2) The use of study models articulator mounted in the SCP/CR in conjunction with condylar position instrumentation is another method of assessing three-dimensionally both the dental inter-arch relationship and position of the condyles. Dental instrumentation (an articulator mounting in the SCP/CR and condylar graph measurements) has proven to be valid, reproducible, accessible, cost-effective, noninvasive, and highly accurate [3] [4] [5] [6] [16] [17] [21] [24] [33] [34] [43]. The magnitude and direction of any discrepancy between the SCP/CR and MIC/CO is determined with condylar position instrumentation, designed to record, measure, quantify, and compare the positional changes of the condylar axis between the SCP/CR and IP/MIC/CO in all three spatial planes. Specifically, this means that this instrumentation is capable of recording mm. measurements of condylar position in the horizontal (AP), vertical (SI), and transverse (ML) planes (**Figure 11**).

Table 1 indicates the magnitude of condylar displacement in three planes (mm) as measured with dental instrumentation from asymptomatic and symptomatic populations. These studies were conducted over a 43 year period. The larger discrepancies reported by Karl and Foley [39], Padala [81], and Cordray [5] [6] are most likely due to methodology. These investigators utilized deprogramming with a hard anterior stop prior to registration of the SCP/CR, which results in more complete condylar seating and more accurate measurement of condylar displacement than are found in those studies which have utilized traditional chin-point guidance alone (without deprogramming) in an attempt to clinically capture the SCP/CR. Girardot [37] found larger horizontal and vertical condylar displacements in dolichofacial (open-bite) skeletal patterns than in

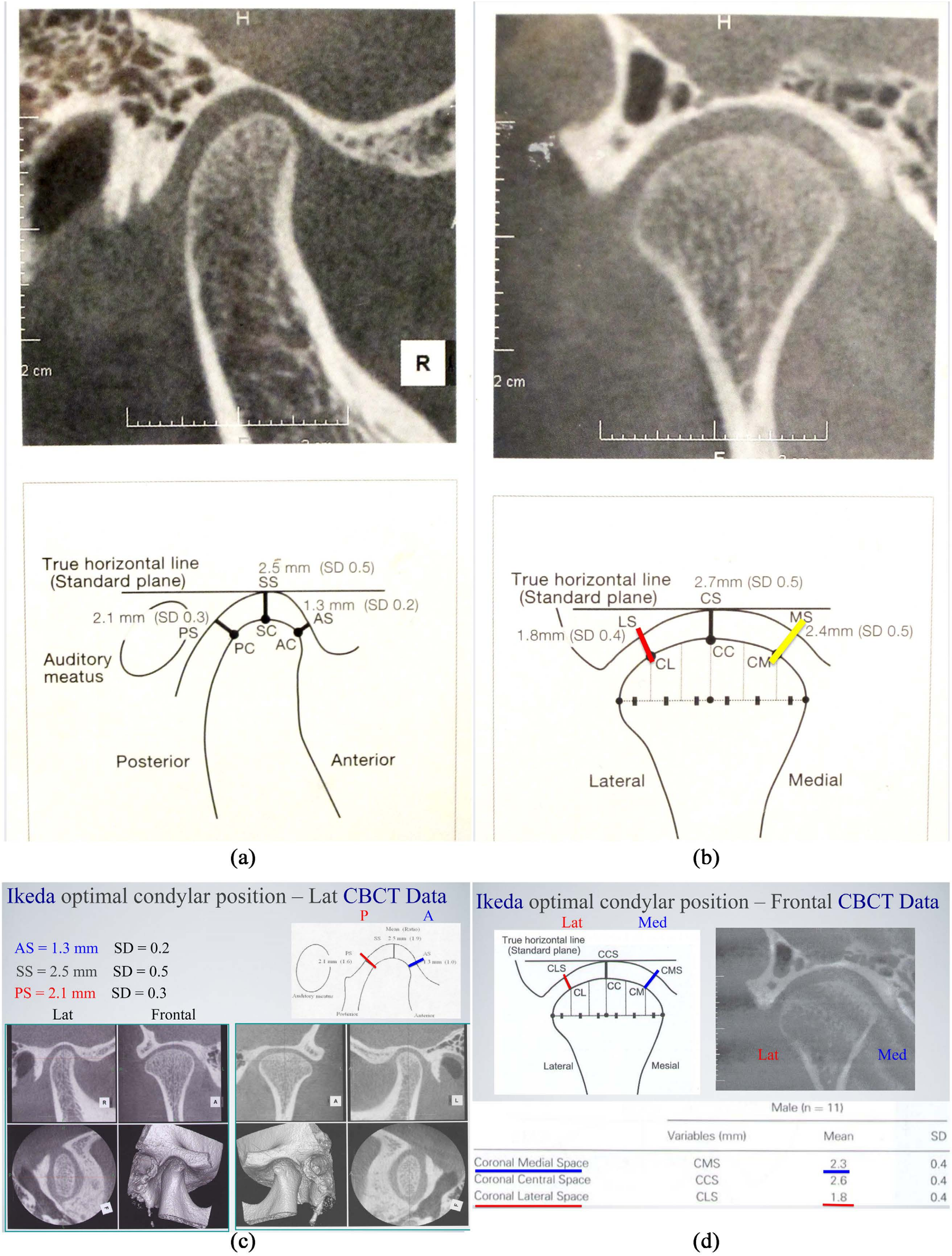

Figure 10. The clarity of the limited CBCT image allows for precise measurement of the joint space between the condyle and fossa due to its ability to clearly delineate osseous structures.

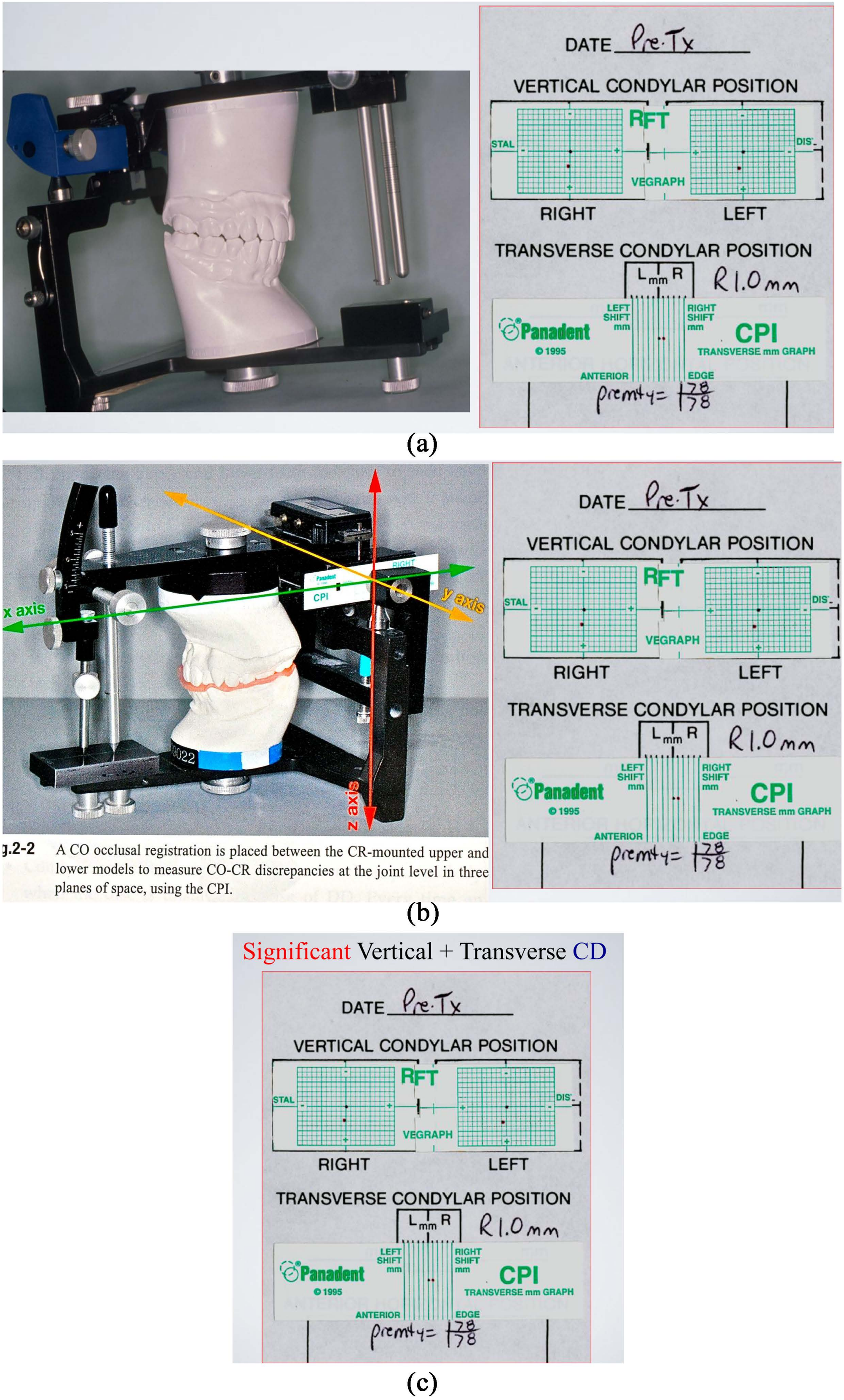

Figure 11. 3-D assessment of condylar position: study models articulated in the SCP/CR in conjunction with condylar position instrumentation.

Table 1. Magnitude of condylar displacement in three planes (mm) as measured with dental instrumentation from asymptomatic and symptomatic populations. Studies conducted over a 43 year period.

INVESTIGATOR (YR)	COMPONENT (mm)			
	AP (HORIZ)	SI (VERT)	ML (TRANS)	n
HOFFMAN (1973)	0.28	0.25	0.10	52
ROSNER (1986)	0.56	0.84	0.34	75
WONG (Unpub)	0.70	1.00	0.30	250
WOOD + KORNE (1992)	--	1.20	--	39
ALEXANDER (1993)	0.25	0.30	0.30	28
UTT (1995)	0.61	0.84	0.27	107
ESMAY (1995) (MS)	0.63	1.53	0.37	46
HICKS + WOOD (1996)	--	1.20	0.27	37
GIRARDOT (2001) brachyfacial	0.66	1.20	--	19
GIRARDOT (2001) dolichofacial	1.21	1.70	--	19
HIDAKA (2002)	--	1.00	0.00	150
KARL + FOLEY (1999)**	1.54	1.76	0.51	40
WEFFORT (2010) ASYMPT	0.63	1.26	0.23	35
WEFFORT (2010) SYMPT	0.64	1.60	0.41	35
PADALA (2012) ASYMPT**	0.82	0.70	0.61	20
PADALA (2012) SYMPT**	1.51	1.18	0.96	20
CORDRAY (2006) ASYMPT**	0.86	1.80	0.26	596
CORDRAY (2016) SYMPT**	1.02	2.20	0.82	596

--: magnitude either not measured or averaged using. − and + values instead of absolute values. **neuromuscular deprogramming utilized prior to registration of SCP/CR. Note: 1. Displacement values for deprogrammed subjects larger than for non-deprogrammed subjects; 2. Displacement values for symptomatic subjects larger than for asymptomatic subjects; 3. Displacement values for dolichofacial patterns larger than brachyfacial patterns.

brachyfacial (deep bite) skeletal patterns. Larger condylar displacements were observed in all dimensions for symptomatic subjects, especially in the transverse (medial-lateral) plane [6] [81] [82].

3. Reproducibility of the Registration Technique

The accuracy, reproducibility, and reliability of condylar position instrumentation have been confirmed [5] [6] [16] [17] [21] [23] [36] [37] [38] [39] [40] [43] [44] [45] [46]. A number of articulator systems incorporate this type of condylar position measurement instrumentation. They include the Cranio-Mandibular Positioner (CMP) (formerly Veri-check), by Denar Corporation, Anaheim, California, the SAM Mandibular Position Indicator (MPI), by Great Lakes Orthodontics, Ltd., Tonawanda, New York, the Modified Buhnergraph, by Whip-Mix Corportion, Louisville, Kentucky, the Condylar Position Indicator (CPI), by Panadent Corporation, Grand Terrace, California, and the Measure of Condylar Displacement (MCD), by AD2 (Advanced Dental Designs), Riverside, California. The seated condylar position is a three-dimensional entity that is most accurately assessed with a three-dimensional measuring device, such as those listed here.

Condylar graph measurement with condylar position instrumentation has many advantages, especially over imaging technics. It is simple and easy to perform; it is widely available in a dental practice setting; it is inexpensive and noninvasive; it is suitable for screening large numbers of patients; and it is highly accurate. In fact it is the most accurate method for determining condylar position in all three planes (to within 0.2 mm horizontal and vertical and 0.1 mm transverse) [5] [6] [16] [17] [21] [23] [36] [37] [38] [39] [40] [43] [44] [45] [46].

Williamson, using leaf gauge deprogramming and condylar position instrumentation (Veri-Check, Denar Corporation, Anaheim, California), outlined the rationale for articulating diagnostic study models in the SCP/CR and demonstrated how to measure occlusion-dictated condylar position and condylar displacement in three spatial planes. He also analyzed the variability of CR records [24] [47]. Wood and Elliott found that the two-piece power SCP/CR wax registration technique is highly reproducible [16]. Alexander [49] studied condylar position, comparing MPI instrumentation to MRI imaging. He concluded that the IP/MIC/CO and SCP/CR are distinctly different condylar positions, with the IP/MIC/CO being inferior to the SCP/CR. He further concluded that the articulator analysis of MIC/CO and SCP/CR is statistically replicable, thus confirming that the MPI system accurately represents condylar position in three planes. Shafagh [31] [83], using deprogramming and the Veri-Check to compare condylar position produced by different interocclusal records, determined that the condylar RCP (retruded contact position/SCP/CR) has a variability in any three planes of space of ±0.2 mm. The accuracy and repeatability of the MPI instrument was proven by Wood and Korne [41], who found the instrument error of the MPI system to be ±0.2 mm for each component in the horizontal and vertical planes. Rosner established the condylar position measurements of the Whip-mix Buhnergraph to be accurate to 0.15 mm. [33] [34] [35], while Hicks and Wood demonstrated that the condylar registrations produced by the SAM MPI and Panadent CPI condylar instrumentation systems are reproducible on the same patient [42].

Measurement error for each directional component of the graphic recordings for condylar position are given in **Table 2**, which presents eight previous investigations of this type conducted over a 27-year period, all of which reported measurement error of ≤0.3 mm. This includes the possible distortion of the impression material, the stone, and the registration material, as well as the technic

Table 2. Reliability of the registration and laboratory technique: error measurements of condylar position in 3 planes: 8 studies conducted over a 27 year period. SEOM < 0.3 mm.

INVESTIGATOR YR	COMPONENT and ERROR (mm)		
	AP (HORIZ)	SI (VERT)	ML (TRANS)
SHAFAGH '79	0.15		
ROSNER '86	0.16	0.16	0.23
WOOD + KORNE '92	0.19	0.21	
WOOD + ELLIOTT '94	0.27	0.3	
UTT '95	0.25	0.25	0.1
KARL + FOLEY '99	0.17	0.19	0.19
GIRARDOT '01	0.25	0.25	
CORDRAY '06	0.15	0.16	0.08

error of impression taking, registration, and articulating/mounting of the dental casts. Thus the extremely small SEOM found in these studies implies reproducibility of the method described and that certain observations of mandibular condyle displacement can be made if carefully interpreted.

4. Conclusions

Measuring DAD at the occlusal level, either intra-orally or with hand-articulated study models or scans conducted in the IP/MIC/CO, provides no information about what is occurring at the condylar level.

The majority of DAD's and CD's are only detectable by registering the SCP/CR and articulating the dental casts. A definitive three-dimensional diagnostic description of occlusion includes not only an assessment of DAD from dental casts articulated accurately in the SCP/CR, but also an assessment of CD resulting from intercuspation of the teeth.

A consequence of undetected condylar displacement (CD) is that the perceived DAD in the intercuspal position (IP/MIC /CO) is often significantly different fron the actual DAD with the condyles in the seated position, which can lead to diagnostic errors and subsequent treatment planning errors. Measurement of the skeletal and dental arch discrepancies in the seated position allows for the formation of an accurate and definitive three-dimensional treatment plan in pursuit of achieving a normalized occlusion. Thus a tangible result of registering complete condylar seating is that the clinician is provided with a more accurate representation of the three-dimensional dental inter-arch, condylar position, and maxillo-mandibular skeletal spatial relationships. Condylar seating and stabilization clearly reveals the discrepancy between the SCP/CR and IP/MIC/CO at both the level of the TM joints (CD) and at the level of the occlusion (DAD), which in turn allows for the visualization of the actual 3D position of the mandible relative to the maxilla.

Occlusal analysis of the presenting/perceived occlusion must answer the following questions. Does the maximum intercuspation of teeth allow the condyles to remain seated? Is the occlusion-dictated condylar position (the position of the condyles in IP/MIC/CO) coincident with the SCP/CR? Or are the condyles displaced as the teeth are brought into the IP/MIC/CO? If the condyles are displaced, what is the magnitude and direction of the both the DAD and CD in three planes? It is of paramount importance to answer these questions when attempting to determine the actual dental arch displacement (DAD), condylar displacement (CD), and the consequent maxillo-mandibular skeletal displacement/discrepancy present.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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