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Review Article

Dentistry Section

Is Centric Relation and Centric Occlusion Discrepancy an Enigma? An Orthodontic Perspective

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ABSTRACT

Centric Relation (CR) and Centric Occlusion (CO) are commonly used references in clinical dentistry. CR represents bone-to-bone contact independent of teeth contact, while CO refers to occlusal contact between the maxillary and mandibular teeth. The coincidence or discrepancy between CR and CO has been the subject of many challenging debates. These reference positions of the mandible typically do not align in natural dentition. When a discrepancy exists, the mandible slides from CR to CO to stabilise the occlusion. Such functional interferences can result in occlusal wear, excessive tooth mobility, poor periodontal health, temporomandibular joint dysfunction, and myofascial pain. Orthodontists who follow gnathologic occlusion recommend using study models mounted on articulators in the CR position to coincide with the treatment of CR-ICP (Maximal Intercuspal Position - ICP). Generally, a discrepancy of 1.5 mm in the vertical and horizontal planes and 0.5 mm in the transverse plane is considered acceptable as it does not cause significant pathology. In the present article authors, we discuss the discrepancy between CR and CO, the dentofacial characteristics of patients with CR-CO discrepancy, its relationship with TMJ dysfunction, and its impact on cephalometric analysis and deprogramming. A clear understanding of CO and CR allows clinicians to approach treatment planning in an organised manner.

Keywords: Cephalometric, Deprogramming, Maxillomandibular relation, Occlusion, Temporomandibular disorder

INTRODUCTION

The knowledge of mandibular movements during mastication greatly influences various clinical procedures in dentistry. Initially, understanding mandibular movement was deemed important for removable prosthodontics, denture design, and articulator development. However, its significance has expanded to fixed prosthodontics, periodontics, orthodontics, and the diagnosis and treatment of masticatory system pain disorders [1,2]. The quest for optimal dynamic and static occlusions has sparked debates surrounding Centric Relation (CR), including its definition, measurement, recording, and its relationship with oral health and diseases. Currently, CR is defined as the anterior and superior position of the condyle relative to the glenoid fossa, based on magnetic resonance imaging data that revealed distal condylar displacement and anterio-medial displacement of disks in patients with internal derangements [3]. The Glossary of Prosthodontic Terms defines CR as "a maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks within the complex, in the anterior superior position against the slopes of the articular eminence" [3]. Presently, there are approximately 26 definitions of CR, necessitating a clinically oriented definition for effective communication among dental specialties [3,4]. It is evident that the position of the condyle in the fossa can vary within a range of normal positions, rather than a single ideal position [4,5]. In general, practitioners agree that CR is the most comfortable posterior position of the mandible when gently manipulated backward and upward into a retrusive position [3].

CO is another crucial factor in relation to occlusion and is defined as "The occlusion of upper and lower teeth with the mandible in CR, and this position may or may not match with the maximal intercuspal position" [6].

CR-CO Relationship

CR represents bone-to-bone contact, independent of teeth contact, while CO refers to occlusal contact between the maxillary and mandibular teeth [3]. Typically, these two reference positions of the mandible do not coincide in natural dentition [7]. In CR, the mandible exhibits rotary movement along the transverse horizontal axis. When there is a discrepancy between CR and CO, the mandible slides from CR to CO to stabilise the occlusion. This may result in a change in the condylar position in the glenoid fossa, commonly in a downward and backward direction, but also in other directions [8]. After repositioning, the mandible and the lower dental arch assume an anterior position. According to gnathologists, a significant slide may lead to stomatognathic system breakdown. These functional interferences can cause occlusal wear, excessive tooth mobility, weakened periodontium, temporomandibular joint dysfunction, and myofascial pain [8,9].

In orthodontics, the most common method for classifying the static state of the dentition is Angle's molar relationship. This classification, along with clinical findings, is still widely used by orthodontists for initial diagnosis and treatment planning. However, once CR occlusion is analysed using articulator-mounted models, further investigations of TMJ, skeletal, and dental occlusal interferences become essential to develop a comprehensive treatment plan [9-11]. Orthodontists who follow a gnathological approach recommend using study models articulated in CR to address CR-CP discrepancies. Minor discrepancies of 1.5 mm in the vertical and horizontal planes and 0.5 mm in the transverse plane are considered acceptable [12].

Methods of Recording Maxillomandibular Relations

To determine the CR before analysing condylar position, interarch relationships, and skeletal relationships, several methods can be used:

1. **Direct check bite recordings of inter-occlusal region:** This is the oldest type of CR record, involving a direct record of the interocclusal region. A common technique in orthodontics is the Roth power centric bite, which uses a two-part blue wax called delar wax. This technique, also known as the physiologic method, takes into account the dentist's visual acuity and tactile sensibility. It involves placing small amounts of plaster, wax, impression

compound, or zinc oxide eugenol impression paste on the occlusal rims, and then guiding the patient to close their jaw into CR [13].

2. **The graphic method:** This method involves tracing mandibular movements in the horizontal plane. A pointer is placed on one occlusal rim, and a tracing plate is placed over the opposite rim to create a tracing pattern. This method is also known as "Arrow point tracing" or "Gothic arch tracing". The apex of the tracing indicates the CR position. Depending on whether the tracing plate is placed intraorally or extraorally, the tracing can be intraoral or extraoral [14].
3. **Cephalometrics:** Cephalometrics can also be used to determine CR and the vertical dimension of occlusion. However, this method is impractical and has not gained widespread use [14].

Various devices have been used to assist in recording CR, including the Thielmann spiegelkinometer (1939), Sears condyle migrator (1952), Posselt gnathothesiometer (1957), Buhnergraph, Long leaf gauge (1973), shims made of acetate or plastic, Williamson vericheck (1980), Slavicek Semi-Adjustable Articulator (SAM) articulator (1988), and Mandibular Positioning Device (MPI).

Discrepancy between CR and Centric Occlusion (CO)

Numerous studies have reported that most patients with natural dentitions have discrepancies between CR and CO [15-17]. Posselt U found that the anteroposterior distance between the retruded mandible and ICP in adults was 1.25 mm (±1.00 mm), while in children it was 0.85 mm (±0.6 mm), and this distance remained constant even after successful orthodontic treatment [15]. Hodge LC and Mahan PE conducted a study on mandibular movement between CR and CO and found that 50% of the subjects showed no vertical or anteroposterior movement of the mandible from CR to CO, with only a few showing lateral movements [16].

Glickman I et al., studied a completely reconstructed, natural dentition to determine which occlusion the patient used during chewing and swallowing. Telemetric testing was performed during swallowing and chewing, and the pattern of tooth contact was recorded before and after the preparation of restorations. They found that there was no change in the tendency for tooth contacts to occur in the patient's CO after the prosthesis with intercuspation in CR was placed. They concluded that using CR as a reference point is not advisable due to the distance between variable and unpredictable CO and CR positions [17].

Rieder CE conducted a study on 323 adult patients to determine the prevalence and percentage of mandibular displacement from CR to CO. They found that 86% of the sample population displaced their mandible to CO from the CR position during vertical, anterior, and lateral movement [18].

Rosner D and Goldberg GE conducted a study on the three-dimensional differences between CR and CO in 75 patients. They used a custom-made Buhnergraph on a Whip-Mix articulator to identify the differences. They found that 60% of the records of CO were anterior and inferior to CR [19,20].

Shildkraut M et al., designed a study to determine significant differences between 24 cephalometric measurements on CO-derived mandibular position compared with tracings converted to CR. They concluded that the existing differences between CR and CO were statistically significant [21].

Utt TW et al., conducted a similar study to Shildkraut but excluded radiographic assessments. They measured the CR-CO discrepancy in 107 patients and analysed the association with age, gender, occlusal type, and ANB angle. They found that the mandibular shifts from CR to CO were 0.16 mm, 0.84 mm, and 0.27 mm anteroposteriorly, superoinferiorly, and laterally, respectively. Their conclusion emphasised the differences between CR and CO, and they also found poor correlation between the left and right TMJs in terms of the magnitude and direction of the CR-CO discrepancy [7].

Rinchuse DJ opposed both the studies by Shildraut M et al., and Utt TW et al., arguing that the right and left positions in their study were not comparable and that the basis of the study was flawed [22,23].

Padala S et al., correlated Temporomandibular Disorder (TMD) and the position of condyles in 40 symptomatic and asymptomatic patients. They concluded that symptomatic patients had significantly larger average vertical and horizontal condylar displacements, and both symptomatic and asymptomatic patients had significant deviations at the level of occlusion [24].

Dentofacial Characteristics in Orthodontic Patients with CR-CO Discrepancy

The most desirable post-orthodontic occlusion is a mutually protected occlusion. In patients with a large CR-CO discrepancy, the position of the mandible and associated musculature determine the specific dentofacial characteristics of the patient. Shildkraut M et al., found that in patients with a large discrepancy and an increased ANB angle, what appears to be skeletal Class I could actually be Class II in CR. During sliding from CR to CO, the condyles moved vertically with a slight distal component. An increase in the mandibular plane angle and a decrease in the facial axis in CR revealed a vertical growth pattern, which should be considered in the treatment plan as vertical pattern is more challenging than horizontal growth patterns. A reduced SNB and facial angle in CO might actually be severely reduced in CR. Their tracings in CR showed a larger angle of convexity, increased ANB angle, and a reduced facial angle, similar to a study by Williamson EH using Wood's "centric-ceph" technique. They concluded that lateral cephalograms should be traced in CR to minimise errors in treatment plans [21].

Williamson EH observed that cases of Angle's Class II malocclusion had larger discrepancies between CO and CR compared to Angle's Class I cases. They further suggested that TMJ problems, muscle and joint pain, and headaches could occur if discrepancies persist after orthodontic treatment [25].

Kleinrok M used a function graph to classify CR-CO discrepancy into Class I and Class II:

Class I: CO disturbances without lateral displacement of CO to CR.

Class II: CO disturbances with lateral displacement of CO to CR [26].

Lim WH et al., found that when CR-CO discrepancies are large, the mandible retrudes, and the skeletal pattern is hyperdivergent in the CR position. The CR position showed a steeper mandibular plane and ramus inclination than the MI position, as well as a greater ANB and overjet than the MI position. There was backward positioning and rotation of the mandible in the Maximum Intercuspation (MIP) position, and there was more clockwise rotation during the CR to CO change. Premature contact during closure in CR might result in parafunctional activities such as clenching or bruxism [27].

CR-CO Discrepancy and TMJ Dysfunction

TMD refers to a group of conditions affecting the musculoskeletal and neuromuscular aspects of masticatory muscles and the temporomandibular joint. The etiology is multifactorial, including occlusal factors, trauma, stress, and parafunctional activities.

Some signs and symptoms associated with TMJ dysfunction include muscle contraction headaches, pain upon movement, parafunction (clenching, grinding), occlusal attrition, muscular pain, displacement of the disc, joint pain, joint noise, crepitus, osteoarthrosis, and osteoarthritis [28].

Lim WH et al., found that patients with a large CR-MI discrepancy had reduced SNB, Nasion perpendicular to pogonion, and height of the ramus, while they showed an increase in ANB angle and inclination of the ramus in both CO and CR positions. They attributed these features to altered morphologies associated with TMJ dysfunction [27].

A study by Costea CM et al., concluded that the displacement of the condyle was more frequently inferior and posterior when teeth

were touching in maximal intercuspal position [29]. The average value of vertical condylar displacement was 1.3 times higher than the horizontal displacement. A CR-CO discrepancy greater than 2.0 mm may strain the ligaments of the disc and increase the risk of intracapsular disorders.

Mounting the cast prior to treatment is generally recommended to observe the difference in the position of the condyle between CR and CO. A CR bite is necessary to determine the presence of a discrepancy and unmask the neuromuscular feedback. Class-II patients may have larger CR-CO discrepancies due to the luxation of the condyle from the glenoid fossa during CO [30].

Carvalho EM et al., conducted a study to investigate the influence of Class-II elastics on CR-CO discrepancy and found no significant influence [30].

He SS et al., found a significant correlation between CR-CO discrepancy and TMJ dysfunction problems (TMD) like masticatory muscle pain or tenderness, joint pain, joint sounds, restricted mouth opening, fatigue or spasm of masticatory muscle, and deviation of the mandible on closing/opening of the jaws [31]. The severity of TMJ dysfunction depended on the degree of discrepancy between CR and CO.

While occlusal discrepancies have been considered a reason for TMJ dysfunction, a recent study showed minimal association between malocclusion and TMJ dysfunction, as people without malocclusion can have TMJ problems and vice versa [32].

A systematic review by Silva AJ et al., concluded that establishing definitive conclusions on the topic is challenging due to limited evidence, low study quality, and heterogeneous designs and methods. More prospective studies with higher levels of evidence are needed to determine a causal relationship between CR-ICP discrepancy and TMD [28].

Roth described the necessary criteria to achieve a functional occlusion and believed in a significant relationship between TMJ dysfunction and occlusal interferences [13]. Ahn SJ et al., reported that TMJ Disc Displacement (DD) may be associated with reduced height of the ramus and posterior facial length, indicating a hyperdivergent pattern in skeletal Class-II malocclusion [33].

Utt TW et al., found an average discrepancy of 2.0 mm in the horizontal and vertical planes and 0.5 mm in the transverse plane, while Crawford SD found 1.0 mm in the horizontal and vertical planes and 0.5 mm in the transverse plane [7,34]. Studies showed that a discrepancy of less than 1 mm in the vertical or horizontal plane was considered normal and may not be associated with TMD [5,35-36]. Symptomatic individuals often had an inferior and distal condylar displacement in a greater amount. When the CR-Maximal ICP discrepancy exceeded the average values significantly, more subjects were found to be suffering from TMD. Weak or no correlation was found between occlusion and TMD, possibly due to poor indicators of the condyle's position provided by dental examinations [37].

Aubrey RB believed that removing functional interferences was key to achieving a functional occlusion in CR and advocated adapting the teeth to the joint, not vice versa [37].

Under neuromuscular influence, the jaw is placed on the site with the most occlusal contacts without considering the final position of the condyle [38]. Mobilio N et al., studied the effect of muscle pain on dental occlusion by inducing pain with 5% hypertonic saline injected into the right masseter muscle. They explained that the position of the mandible and occlusal contacts change in the presence of pain, which can be attributed to an adaptation-protection mechanism [39].

Effect of CR CO Discrepancy and Cephalometrics

Wood CR studied "centrically related cephalometrics" with 30 patients. The casts of these patients were mounted on Whip-Mix articulators. Although the statistical analysis indicated that the shadowgraph was accurate, Wood believed it was not clinically useful [40].

Williamson EH conducted a study on 46 patients using the "centric ceph" technique and divided the patients into two groups: Angle Class-I and Class-II malocclusions. They found a significant difference in mandibular position with cephalometric measurements [25].

Shildkraut M et al., conducted a study using cephalometric tracing and found a significant difference between a CO tracing and a CR tracing [21]. This difference appeared to apply equally to men and women, as well as, skeletal Class-I and Class-II groups.

Ferreira RP et al., studied if cephalometric measurements performed in CR and MIP were significantly different and analysed if those differences could impact orthodontic diagnosis and planning. In patients with less than 2 mm CR-MIP discrepancy, the low significant difference between the two methods was considered of limited clinical importance. In those patients, cephalometric analysis can be carried out in MIP due to its ease and cost-effectiveness. They further suggested that in Class-II patients presenting with a large CR-MIP discrepancy, the Class-II condition may be exacerbated, and hence cephalometric values can be registered in CR for better treatment planning [41].

Lim WH et al., showed that in both CR and MI positions, patients with large CR-MI discrepancies exhibited specific dentofacial characteristics, such as a greater ANB angle and ramus inclination and a decreased SNB angle and Nasion perpendicular to pogonion angle. Hence, patients with large CR-MI discrepancies had a backward positioning as well as rotation of the mandible and ramus [27].

Deprogramming

The TMJ positioned in CR can withstand the highest load from the muscles of mastication without any signs of discomfort, whereas a discrepancy in CR-CO might lead to occlusal wear, excessive tooth mobility, TMJ sounds, limited opening or closing movement of jaws, myofascial pain, and contracture of mandibular musculature [3]. A Neuromuscular Deprogramming Appliance (NDA) is an occlusal splint that ensures anatomically and orthopaedically stable condyles while providing a functional occlusion. It is recommended in patients with CR-CO discrepancy presenting with muscular pain, occlusal dysfunction, and TMD.

Dawson classified splints into three categories: 1) Permissive (muscle deprogrammer); 2) Non-permissive (directive splints); 3) Pseudo-permissive.

Deprogramming a muscle helps reduce or relax its activity levels and relieves pain, tension, and discomfort. These appliances remove the faulty muscle engram and allow the mandible to achieve a proper CR. The appropriate seating of the condyle in its position is prohibited unless a deprogramming splint is used before CR registration. With the muscles relaxed and the condyles in a fully seated position, this procedure can be used to examine the relationship between the maxilla and the mandible with accuracy. It can be achieved by placing a bite plane in the anterior area, which will eliminate occlusal contact in the posterior region (e.g., Lucia jig, leaf gauge, bite plane, etc.) [42].

This will help the lateral pterygoid muscle to relax, reducing its workload in holding the mandible in an anterior position. Splints that are permissive include bite planes (anterior jig, Lucia jig, anterior deprogrammer) and stabilisation splints (flat plane, Tanner, and superior repositioning occlusal splint). Karl PJ and Foley TF used a "lucia type anterior deprogramming jig" (anterior tooth contact without contact in the posteriors) in 40 patients with TMJ problems. They found that there was only a fraction of a millimeter change in centric registration when the splint was used [43]. Types of deprogramming splints used in different conditions have been mentioned in [Table/Fig-1] [44-46].

Deprogramming therapy requires continued wear of the appliance until centric occlusal stability is achieved. It is followed by a second

Clinical condition	Type of deprogramming splint [46-48]
Bruxism, headaches, but no TMJ disorder	Full-coverage splint at night
Muscle soreness (due to muscle in coordination/muscle hyperactivity) associated with TMJ disorder	Bite plane (Lucia Jig, anterior deprogrammer) Full-coverage stabilisation splints- (CR appliance, flat plane)
Advanced disc pathology (jaw locking and/or noises, painful joints)	Stabilisation splint

[Table/Fig-1]: Types of deprogramming splints used in different conditions.

phase involving orthodontic treatment, prosthetic rehabilitation, surgical corrections, or a combination of any of these methods [46].

CONCLUSION(S)

Understanding the concept of CO and CR very clearly will allow the clinician to have an organised approach to plan the treatment. Diagnosing the pathology behind the CR-CO discrepancy simplifies the treatment and enhances patient comfort. A deprogrammer might be helpful in the analysis of the discrepancy.

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