EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org
VOL. 71, 1111:1120, APRIL, 2025
PRINT ISSN 0070-9484 • ONLINE ISSN 2090-2360
ORTHODONTICS, PEDIATRIC AND PREVENTIVE DENTISTRY
Submit Date : 23-01-2025 • Accept Date : 23-02-2025 • Available online: 01-04-2025 • DOI : 10.21608/edj.2025.354303.3349

CHANGES OF POSTERIOR CROSSBITE REPRESENTATION IN CENTRIC OCCLUSION IN CONTRAST TO MAXIMUM INTERCUSPATION IN ADULT ORTHODONTIC PATIENTS USING DIGITAL MODELS: A CROSS-SECTIONAL STUDY

Ghada El-Zanaty [*], Ahmed Kotb [**], Amr El-Beialy [***], Nouran Seif El-Din [****] *and* Mohamed Abd-El-Ghafour [****]

ABSTRACT

Introduction: Aim of the current study was to reveal the effect of centric relation(CR)/ maximum intercuspation (MI) discrepancy on changing the posterior crossbite diagnosis in adult orthodontic patients.

Material and method: One hundred and one patients were recruited in the current study. For each patient both MI and CR were recorded using digital workflow. The presence or absence of unilateral and bilateral posterior crossbite was identified in each occlusion.

Results: Mandibular displacement from CR to MI affected the clinical presentation of posterior crossbite. There was a statistically significant difference between incidence of bilateral posterior crossbite in centric relation records versus maximum intercuspation with less significant difference in the incidence of unilateral posterior cross bite while evaluating the 2 occlusion patterns.

Conclusion: Based on the reached results, there is increased incidence of posterior crossbite development in centric occlusion in comparison to the maximum intercuspation. Recording the centric occlusion in orthodontic patients might be of diagnostic value regarding the development of posterior crossbite.

KEYWORDS: Centric relation; Maximum intercuspation, cross bite.

* Resident, Department of Orthodontics, Faculty of Dentistry, Cairo University, Cairo, Egypt.
** Lecturer, Department of Prosthodontics, Faculty of Dentistry, Cairo University, Cairo, Egypt.
*** Professor, Department of Pediatric Plastic Surgery, Faculty of Medicine, Cairo University, Cairo, Egypt.
**** Lecturer, Department of Orthodontics, Faculty of Dentistry, Cairo University, Cairo, Egypt.

INTRODUCTION

Upon diagnosing the orthodontic patients, there are 2 patterns of static occlusion maximum intercuspation and the occlusion pattern existing when condyles are in centric relation. Centric relation (CR) is an anatomically determined position, therefore it is repeatable and reproducible. (Ash & Ramfjord, 1995) It is defined as the relationship of the mandible to the maxilla when the condyles are seated against the intermediate thin avascular portion of the articular disc in their most superoanterior position in the glenoid fossa and centered transversely, regardless of the tooth contact pattern.(Dawson, 1996; Okeson, 1993)

The maximum intercuspation (MI) is defined as the full intercuspation of opposing teeth, regardless of condylar position, therefore usually considered a tooth-determined position. (Capp & Clayton, 1985; Kovaleski & De Boever, 1975) It was generally agreed that a difference exists between the pattern of occlusion that is present in the maximum intercuspation compared to that in centric relation (Capp & Clayton, 1985; Kovaleski & De Boever, 1975; Proffit et al., 2013). This is defined as dental arch displacement which is also known as a mandibular functional shift, centric slide or dual bite.

Moreover, repetitive closure in the intercuspal position develops muscle engram (muscle splinting), causing the proprioceptive neuromuscular system to become patterned to the deviated closure. The resultant muscle function becomes so dominant and the apparent pattern of occlusion is often mistaken by most clinicians as the seated condylar position. (Gaikwad & Tamore, 2019)

Mandibular displacement (functional shift) can affect the transverse interarch relationship according to the magnitude and direction of the shift. It can be the cause and the effect of inter-arch transverse discrepancy (posterior crossbite). This functional shift, if left untreated for a prolonged period, can lead to a true posterior crossbite. Unilateral posterior crossbites are commonly a result of bilateral maxillary constriction with a lateral mandibular functional shift into intercuspation, resulting in normal buccal-lingual intercuspation unilaterally and a cross bite on the opposing side.

Posterior crossbite is defined as an inadequate transversal relationship of maxillary and mandibular posterior teeth. (Gabriel de Silva Fo et al., 1991) Faulty transverse arch relationship is especially critical because of the limited growth, as it is the first dimension to stop growing.(O'Grady et al., 2006) This malocclusion does not show spontaneous correction, and should be treated as early as possible. (Gabriel de Silva Fo et al., 1991) Therefore, an accurate diagnosis and treatment planning must be accomplished with the condyle in a centric relation. (O'Grady et al., 2006)

In order to guide the mandible to its fully seated position in centric relation, lots of methods and techniques can be used. The leaf gauge, introduced by Dr.Long many years ago, is one of the most popular aids for determining centric relation. (Long, 1973, Dawson, 2007)

Since 1977 Williamson, used leaf gauge deprogramming and condylar position instrumentation, he outlined the rationale for articulating diagnostic study models in the CR. He also analyzed the variability between different CR records.(Williamson, 1977; Williamson et al., 1980)

Till now leaf guage is a commonly used method for relocating condyle in centric relation.Its is also considered as the most cost effective and the easiest of all methods.

In 2020 Radu used leaf gauge to record centric relation digitally at the desired vertical dimension of occlusion.Using leaf guage he was able to seat the condyle in centric relation and then the relation was recorded using intraoral scanner at the desired vertical dimension that have sufficient occlusal clearance for the design of the fixed prostheses (Radu et al., 2020)

Based on the previously mentioned facts, the aim of the current study was to identify the change in transverse dental relation between maximum intercuspation and centric relation using a digital workflow in orthodontic patients.

MATERIALS AND METHODS

Setting:

A total of 101 patients were recruited for this study from the outpatient clinic of the department of orthodontics, Cairo university, Egypt. Patients were informed about the study procedure and written consents were obtained. Patients' recruitment started in July 2023 and lasted for 6 months. For each patient, digital scans were taken and MI and CR were recorded digitally.

Participates:

Eligibility criteria:

Inclusion criteria:

Orthodontic patients having full permanent dentition including Class I malocclusion, Class II division 1 or division 2 and class II subdivision cases in addition to Class III malocclusion , Class III subdivision, deep bite cases, open bite cases, crowding and spacing cases.

Exclusion criteria:

Patients who had undergone previous orthodontic treatment, syndromic patients and patients with craniofacial anomalies as patients with cleft lip and palate were excluded from the study.

Additionally patients with severe skeletal discrepancy, patients with symptomatic temporomandibular disorders and patients who cannot accept firm loading (positive load test) and patients having teeth mobility were also excluded.

Centric relation registration:

I - TMJ examination:

Dental status examination was performed together with patient examination according to the DC-TMD protocol to identify eventual temporomandibular joint (TMJ) and muscle-related complaints.

II- Muscle fatigue (muscle deactivation):

With the help of the leaf gauge, muscle fatigue was achieved by continuous back and forth movement in a sliding pattern on the leaf.

III-Positioning the condyles in centric relation

Positioning the condyles in CR with the leaf gauge method and verified using tongue retrusion method and bimanual manipulation technique methods with help of the leaf gauge.

Leaf gauge method:

After muscle fatigue, the patient with the instructed to move in a forward slide on the leaf gauge followed by a backward movement and tap on the leaf gauge.

Centric relation position verification using tongue retrusion technique:

The patient was then instructed to retrude his tongue along the palate as a physiologic method of obtaining CR. (De Moraes Melo Neto et al., 2022).

Centric relation position verification using bilateral manipulation (Dawson's technique) was done as follow:

Step one: The patient was reclined all the way back. After the head was stabilized, the patient's chin was lifted to slightly stretch the neck.

Step two: The four fingers of each hand were gently positioned on the lower border of the mandible and the thumbs were fit in the notch above the symphysis.

Step three: With a very gentle touch, the jaw was manipulated so it slowly hinged (opened and closed).

After the mandible was felt like it is hinging freely and the condyles seemed to be fully seated up in their fossae, it was assumed that the condyle was in centric relation. The position and alignment of each condyle was tested by applying firm pressure up with the fingers on the back half of the mandible and down with thumb pressure in the notch above the symphysis (load testing).

VI-MI and CR registration using digital technique

Digital scanning for both arches was done using TRIOS 4 intraoral scanner.

Step 1: Scanning upper and lower models was done according to manufacturer's instructions. (figure 1a,b)

Step 2: Recording MI relation was done first. (figure 2)

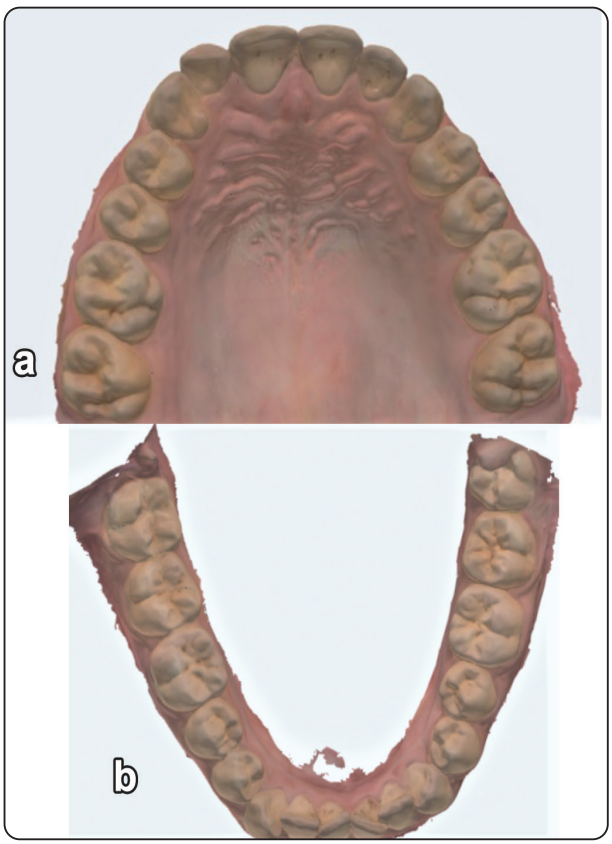


Fig (1) a) Scan for upper arch. b) Scan for the lower arch

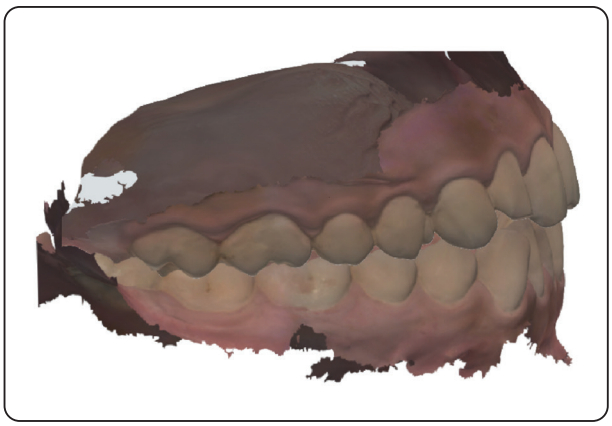


Fig. (2) Digitally recorded MI

Step 3: Then seating the condyle in CR was done, as mentioned before, and registered. The leaf gauge was used to hold the bite in centric relation hanging on first point of contact, some bite registration material was added to prevent any slide during digital acquisition of the bite relation. (Figure 2)

For each patient, 2 digital models were collected with one articulated in MI and the other in CR.

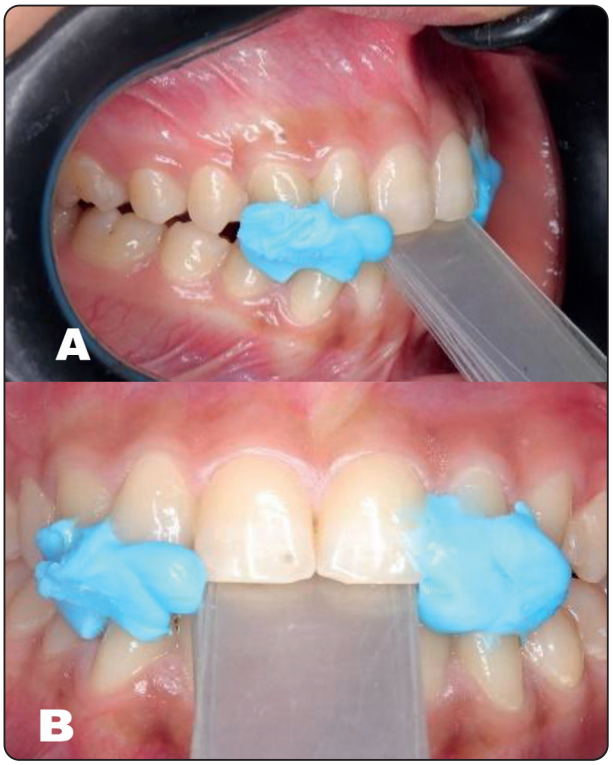


Fig. (3) A and B show leaf gauge in place with bite registration material added to prevent any slide during digital acquisition of the bite relation

Fig. (4) Showing bite after registration with digital method at the first point of contact.

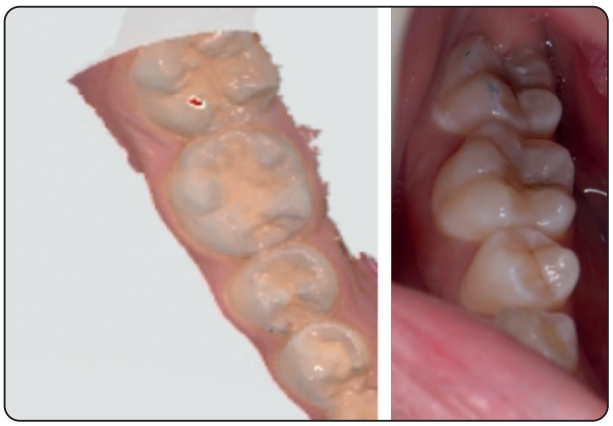


Fig. (5):A) Showing first point of contact when determining position of teeth contact with scanning software B) First point of contact marked by an articulating paper.

VII-Measuring Outcomes:

Posterior crossbite whether unilateral or bilateral was identified in maximum intercuspal position and recorded CR. If lower buccal cusps were not aligned with upper central fossae it was considered as crossbite on this side. Outcome was reported as binary data according to the presence or absence of posterior crossbite (Yes / No).

VIII-Statistical methods :

All tests were run at the 95% confidence level (CI). McNemar test was used which determined if there were differences on a dichotomous dependent variable between two related groups. The level of significance was set to be at p value <o.o5.

RESULTS

The total number of subjects was 101 recruited in this study. The descriptive analysis of the collected data is presented in the following tables:

TABLE (1) MI x CR Cross Tabulation

			CR		Total
			no cross bite	crossbite exist	
MI	**No cross bite**	**Count**	30	39	69
		% of Total	29.7%	38.6%	68.3%
	Crossbite exist	**Count**	1	31	32
		% of Total	1.0%	30.7%	31.7%
Total		**Count**	31	70	101
		% of Total	30.7%	69.3%	100.0%

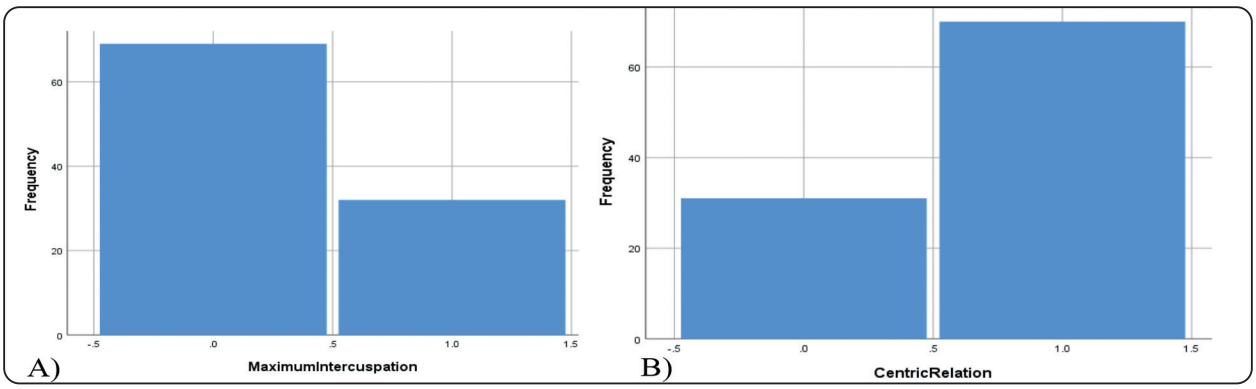


Fig. (6) A)Bar chart showing proportion of posterior crosbite in MI B)Bar chart showing proportion of posterior crosbite in CR

Descriptive statistics:

A total of 30 (29.7%) patients did not have a crossbite in MI , and also in centric relation. Thirty nine (38.6 %) did not have crossbite either unilateral or bilateral in MI, yet appeared to have crossbite in centric relation and 1 (1%) patient had a posterior crossbite in MI and no crossbite in centric relation. Thirty one patients (30.7%) had a posterior crossbite in both MI and CR.

Sixty four subjects had no unilateral posterior crossbite either in CR or MI. Eighteen subjects who appeared to have no unilateral posterior crossbite in maximum intercuspation, showed unilateral posterior crossbite in centric relation. Eight subjects who appeared to have a unilateral posterior crossbite in maximum intercuspation, showed no unilateral posterior crossbite in centric relation. Eleven subjects had unilateral posterior crossbite in both CR and MI.

Where blue color represents no unilateral posterior crossbite and red color represents that unilateral posterior crossbites do exist.

Fifty nine patients had no bilateral posterior crossbite in both MI and CR. Twenty eight subjects who appeared to have no bilateral posterior crossbite in maximum intercuspation, showed bilateral posterior crossbite in centric relation. One subject who appeared to have a posterior crossbite in maximum intercuspation, showed no bilateral posterior crossbite in centric relation.Thirteen subjects had bilateral posterior crossbite in both MI and CR.

TABLE (2) Unilateral posterior crossbite in MI (uniMI) * unilateral crossbite in CR Crosstabulation (uniCRD)

			uniCRD		Total
			No cross bite	Crossbite exist	
uniMI	**no cross bite**	**Count**	64	18	82
		% of Total	63.4%	17.8%	81.2%
	crossbite exist	**Count**	8	11	19
		% of Total	7.9%	10.9%	18.8%
	Total	**Count**	72	29	101
		% of Total	71.3%	28.7%	100.0%

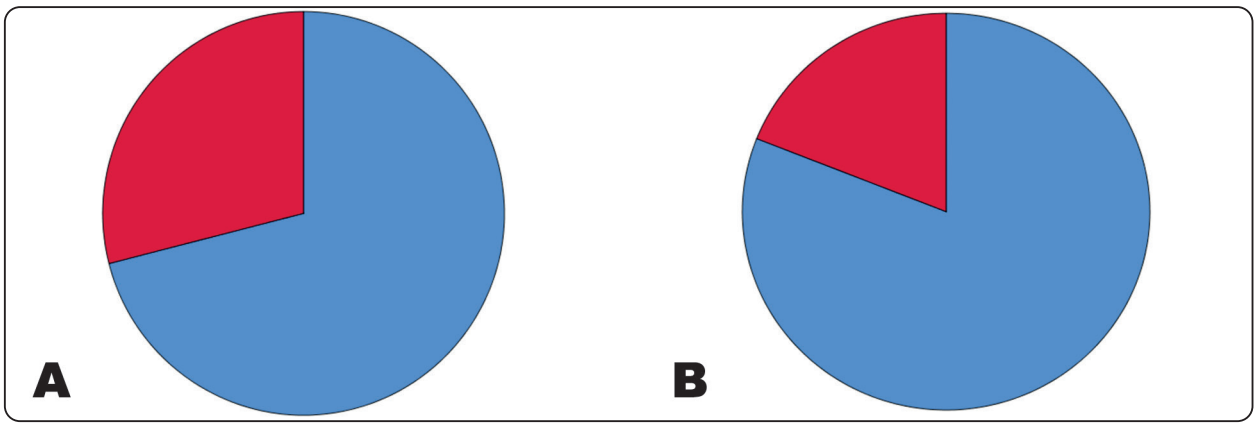
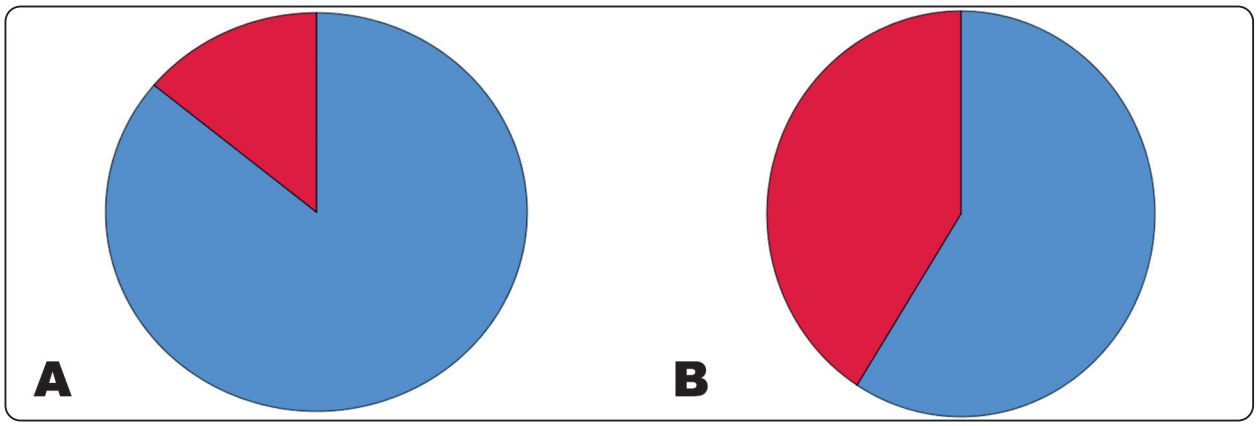


Fig. (7) A) Pie chart presentation for the proportion unilateral crossbite in MI B)Pie chart presentation for the prorotion unilateral crossbite in CR

TABLE (3) Bilateral posterior crossbite in MI (BiMI) * Bilateral posterior crossbite in centric relation(BiCRD) Cross Tabulation

			BiCRD		Total
			no cross bite	crossbite exist	
BiMI	No cross bite	Count	59	28	87
		% of Total	58.4%	27.7%	86.1%
	Crossbite exist	Count	1	13	14
		% of Total	1.0%	12.9%	13.9%
Total		Count	60	41	101
		% of Total	59.4%	40.6%	100.0%



A) Pie chart presentation for the proportion bilateral crossbite in MI. B) Pie chart presentation for the proportion bilateral crossbite in CR

Where blue represents no bilateral posterior crossbite and red color represents that bilateral posterior crossbite does exist.

Inferential statistics:

TABLE (4) McNemar Test comparing the incidence of posterior crossbite in MI vs CR

	Value	Exact Sig. (2-sided)
McNemar Test		.000[a]
N of Valid Cases	101	

a. Binomial distribution used.

McNemar Tests showed that there was a highly statistically significant difference between the incidence of posterior crossbite (unilateral and bilateral) with change in mandibular position from maximum intercuspation to centric relation with a p value of 0.00.

TABLE (5) McNemar Tests comparing the incidence of unilateral posterior crossbite in MI vs CR

	Value	Exact Sig. (2-sided)
McNemar Test		.076[a]
N of Valid Cases	101	

a. Binomial distribution used.

McNemar Test shows that there was no statistically significant difference between presence of unilateral posterior crossbite with the change in mandibular position from maximum intercuspation to centric relation with a p value of 0.076.

TABLE (6) McNemar Tests Comparing the incidence of bilateral posterior crossbite in MI vs CR

	Value	Exact Sig. (2-sided)
McNemar Test		.000[a]
N of Valid Cases	101	

a. Binomial distribution used.

McNemar test shows that there was a highly statistically significant difference between presence of bilateral posterior crossbite with change in mandibular position from maximum intercuspation to centric relation with a p value of 0.00.

DISCUSSION

Accurate diagnosis of patients with malocclusion and their abnormal occlusal relationships will lead to correct treatment decisions and subsequently, satisfying treatment outcomes. Functional examination (represented in the current article as detection of functional shift) is always a challenging diagnostic measure. At the same time, it can significantly change the presented occlusal relationships and the required treatment decisions. For that reason, the aim of the current article was to quantify that occlusal change (represented in the change of posterior crossbite relations) to identify its clinical significance.

Being in the digital era, digital methods were chosen for both recording maximum intercuspation and centric relation .

Centric relation recording strategy depended on using leaf gauge as a method for posterior occlusal separation. After using leaf gauge to perform fatigue exercise and deprograming, seating of the condyles in centric relation was further checked by 2 methods. In order to make sure that condyle was in centric position tongue retrusion maneuver and bimanual manipulation with load testing were both used while keeping the leaf guage in place. Using the leaf gauge, the number of leaflets was adjusted till the first point of touch. This allowed recording the reaction without a lot of posterior separation and hence there was no need to record the arc of closure using a face bow. This static relation with the first point of contact recorded represents the pattern of occlusion that exists in centric relation also known as centric occlusion according to the grocery of prothodontic terms 8th edition. (The Glossary of Prosthodontic Terms 2005 (GPT 8°)) This was also the relation upon which the diagnosis was determined.

The above mentioned methodology permitted recording the centric relation digitally with much less sophisticated appliances and in minimal time duration using an intraoral scanner. Bearing in mind the great advantages of using digital records over physical ones like virtual treatment planning, enhanced communication and ease of data storage. (Akdeniz et al., 2022)

Analyzing models in centric relation uncover the relationship between the jaws while in seated condylar position. In some patients this brings clinically significant occlusal modifications.

The incidence of posterior crossbite significantly increased with seating of the condyle in centric relation. Although the increase in unilateral crossbite is statistically insignificant, the change in diagnosis of crossbite presence occurred in 25% of the current sample. The diagnosis of bilateral posterior crossbite has been significantly changed in 28 % of the cases.

Previous studies showed that, when a discrepancy exists between the CR and MIC this can change the orthodontic diagnostic relation with overjet increases and overbite decreases. (Hoffman et al., 1973; Shildkraut, 1994)

Many studies attempted to reveal the effect of the change in mandibular position from MI to CR on the diagnosis of orthodontic case but none had identified the effect on posterior crossbite.In a study by Cordray, 21.3% of the subjects (127), dental

midlines were different in the CR when compared with MI/CR. This reflects a lateral mandibular shift from the CR to accommodate the MI bite. (Cordray, 2006b)

Neuromuscular deprogramming is the key for reproducibility and evading dual bite. Splint therapy can be effective in neuromuscular deprogramming. (Dawson, 1989; Williamson, 1977) But it is not practical in a busy orthodontic practice.(Beard & Clayton, 1980; Karl & Foley, 1999; Lundeen, 1974)

It was shown in this study that 5 to 10 minutes of chair-side neuromuscular deprogramming with the help of muscular fatigue exercise and using a relatively rigid leaf gauge can be effective for initial deprogramming.

Muscle deprogramming eliminates muscle engram that consistently keeps the mandible in maximum intercuspation every time the patient occludes. As a result, the acquired mandibular position (the occlusion-dictated condylar position) will often be mistaken by the clinician for the centric relation. (Cordray, 2006b)

The results of this study demonstrate that models, taken from a neuromuscular deprogrammed asymptomatic patient population can reveal a masked posterior crossbite that has to be taken into consideration during treatment planning.

CONCLUSION

Initial deprogramming and centric relation recording can reveal the masked posterior crossbite that should be taken into consideration during treatment planning.

Although the difference between the incidence of unilateral posterior crossbite in CR and MI is statistically insignificant , in 25% of the sample of the sample the crossbite diagnosis changed from MI to CR

The digitally registered CR with neuromuscular deprogramming, represents a reproducible method to show discrepancies between a subject's occlusion when the condyles are seated and when the occlusion is dictated by the intercuspation of the teeth.

Neuromuscular deprogramming using leaf gauge is a helpful adjunct for registration of the CR. It is an easy procedure that can be accomplished with little chair-side time, little expenses, and no compliance problems.

REFERENCES

- Ash, Major M., 1921-2007 Occlusion : https://archive.org/details/occlusion0000ashm
- Akdeniz, B. S., Aykaç, V., Turgut, M., & Çetin, S. (2022). Digital dental models in orthodontics: A review. Journal of Experimental and Clinical Medicine (Turkey), 39(1), 250–255.
- Beard, C. C., & Clayton, J. A. (1980). Effects of occlusal splint therapy on TMJ dysfunction. The Journal of Prosthetic Dentistry, 44(3), 324–335. https://doi.org/10.1016/0022-3913(80)90021-9
- Capp, N. J., & Clayton, J. A. (1985). A technique for evaluation of centric relation tooth contacts. Part II: Following use of an occlusal splint for treatment of temporomandibular joint dysfunction. The Journal of Prosthetic Dentistry, 54(5), 697–705. https://doi.org/10.1016/0022-3913(85)90254-9
- Cordray, F. E. (2006a). Three-dimensional analysis of models articulated in the seated condylar position from a deprogrammed asymptomatic population: a prospective study. Part 1. Am J Orthod Dentofacial Orthop, 129(1), 619–630. https://doi.org/10.1016/j.ajodo.2004.10.015
- Cordray, F. E. (2006b). Three-dimensional analysis of models articulated in the seated condylar position from a deprogrammed asymptomatic population: a prospective study. Part 1. American Journal of Orthodontics and Dentofacial Orthopedics : Official Publication of the American Association of Orthodontists, Its Constituent Societies, and the American Board of Orthodontics, 129(5), 619–630. https://doi.org/10.1016/J.AJODO.2004.10.015
- Cordray, F. E. (2016). Articulated dental cast analysis of asymptomatic and symptomatic populations. International Journal of Oral Science 2016 8:2, 8(2), 126–132. https://doi.org/10.1038/ijos.2015.44
- Dawson, P. E. (1996). A classification system for occlusions that relates maximal intercuspation to the position and

condition of the temporomandibular joints. The Journal of Prosthetic Dentistry, 75(1), 60–66. https://doi.org/10.1016/S0022-3913(96)90419-9

- Dawson, P. E. (2007). Functional occlusion : from TMJ to smile design. 630.
- Dawson, P. E. . (1989). Evaluation, diagnosis, and treatment of occlusal problems. 633. https://search.worldcat.org/title/981275552
- De Moraes Melo Neto, C. L., Dos Santos, D. M., De Magalhães Bertoz, A. P., Moreno, A. L. D. M., & Goiato, M. C. (2022). Comparison of Techniques for Obtaining Centric Relation Based on the Reproducibility of the Condylar Positions in Centric Relation-A Systematic Review. European Journal of Dentistry, 16(2), 251–257. https://doi.org/10.1055/S-0041-1735903/ID/JR2151582-27/BIB
- EH Williamson, D. E. W. B. (1977). The effect of bite plane use on terminal hinge axis location. Angle Orthod, 47(1), 25–33.
- Gabriel de Silva Fo, O., Boas, C. V., & Capelozza, L. F. O. (1991). Rapid maxillary expansion in the primary and mixed dentitions: a cephalometric evaluation. American Journal of Orthodontics and Dentofacial Orthopedics : Official Publication of the American Association of Orthodontists, Its Constituent Societies, and the American Board of Orthodontics, 100(2), 171–179. https://doi.org/10.1016/S0889-5406(05)81524-0
- Gaikwad, A. M., & Tamore, S. (2019). Fabricating an inexpensive leaf gauge deprogrammer from panoramic radiographic film. Journal of Prosthetic Dentistry, 122(3), 339–340. https://doi.org/10.1016/j.prosdent.2019.04.027
- Hoffman, P. J., Silverman, S., & Garfinkel, L. (1973). Comparison of condylar position in centric relation and in centric occlusion in dentulous subjects. The Journal of Prosthetic Dentistry.
- Huffman, R., & Regenos, J. (1978). Principles of occlusion. Columbus: Hand R Press.
- Karl, P.J. and Foley, T.F. (1999) The Use of a Deprogramming Appliance to Obtain Centric Relation Records. Angle Orthodontist, 69, 117-125. - References - Scientific Research Publishing. (n.d.). Retrieved November 22, 2024, from https://www.scirp.org/reference/referencespapers?referenceid=1951148
- Kovaleski, W. C., & De Boever, J. (1975). Influence of occlusal splints on jaw position and musculature in patients with temporomandibular joint dysfunction. The Journal of Prosthetic Dentistry, 33(3), 321–327. https://doi.org/10.1016/S0022-3913(75)80090-4
- Long, J. H. (1973). Locating centric relation with a leaf gauge. The Journal of Prosthetic Dentistry, 29(6), 608–610. https://doi.org/10.1016/0022-3913(73)90267-9
- Lundeen, H. C. (1974). Centric relation records: the effect of muscle action. The Journal of Prosthetic Dentistry, 31(3), 244–253. https://doi.org/10.1016/0022-3913(74)90191-7
- M Shildkraut, D. W. W. H. (1994). The CR-CO discrepancy and its effect on cephalometric measurements. Angle Orthod, 64(5), 333–342.
- O'Grady, P. W., McNamara, J. A., Baccetti, T., & Franchi, L. (2006). A long-term evaluation of the mandibular Schwarz appliance and the acrylic splint expander in early mixed dentition patients. American Journal of Orthodontics and Dentofacial Orthopedics, 130(2), 202–213. https://doi.org/10.1016/J.AJODO.2004.12.023
- Okeson, J. (1993). Management of TM disorders and occlusion. St Louis: CV Mosby.
- Richard W. Huffman.Principles of Occlusion: Laboratory and Clinical Teaching Manual, by Richard, Richard W. Huffman. Retrieved December 5, 2024, from Radu, M., Radu, D., & Abboud, M. (2020). Digital recording of a conventionally determined centric relation: A technique using an intraoral scanner. Journal of Prosthetic Dentistry, 123(2), 228–231.
- Roth, R. (1973). Temporomandibular pain-dysfunction and occlusal relationships. Angle Orthod, 43(2), 136–153.
- Tiwari, B., Ladha, K., Lalit, A., & Dwarakananda Naik, B. (2014). Occlusal Concepts in Full Mouth Rehabilitation: An Overview. The Journal of the Indian Prosthodontic Society, 14(4), 344.
- William R Proffit, D. P. D., Henry Fields, D. M. S. M., Larson, B., & David M Sarver, D. M. D. M. S. (2013). Contemporary Orthodontics, 6e: South Asia Edition-E-Book. 33–36.
- Williamson, E. H., Steinke, R. M., Morse, P. K., & Swift, T. R. (1980). Centric relation: a comparison of muscle-determined position and operator guidance. Am J Orthod, 77(1), 133–145.