Cone-beam tomography assessment of condylar position discrepancy between centric relation and maximal intercuspation

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Abstract: The magnitude of occasional discrepancies between the centric relation and maximal intercuspation positions remains a controversial subject. This study quantitatively evaluated the possible discrepancies in the condyle/mandibular fossa relationship between these positions using cone-beam computed tomography. Twenty young and asymptomatic volunteers were distributed equally into normal occlusion and Angle Class I, II and III malocclusion groups. They were submitted to one tomographic scan in maximal intercuspation and one in centric relation. Measurements were performed on lateral and frontal cuts of the patients' temporomandibular joints, and the data collected were compared using Student's t test at a significance level of 5%. The results showed that there were no statistically significant differences between the centric relation and maximal intercuspation positions in young and asymptomatic patients with practically intact dentitions using cone-beam computed tomography.

Descriptors: Temporomandibular Joint; Malocclusion; Cone-Beam Computed Tomography.

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Introduction

Discrepancies between the centric relation (CR) and the maximal intercuspation (MI) positions and their therapeutic implications have been extensively debated.[1-3] Opinions diverge greatly with regard to the clinical use of these maxillomandibular positions. Systematic literature reviews include authors in favor of an extensive use of CR in the planning of occlusal rehabilitation therapy and orthodontics,[1,3] alongside others who suggest an individual analysis of each clinical situation when determining which maxillomandibular relationship should be considered correct.[4,5] Despite the different opinions about how and when to use either of these two maxillomandibular positions, one point of relative acceptance among scientists is that most individuals in the population have discrepancies between CR and MI,[4] mainly symptomatic individuals and those with Class II and III malocclusions.[6-11] Among the methodological resources most widely used in studies comparing variations between maxillomandibular relations are articulator casts and conventional radiography.[1,2,10] These studies, in several cases, have established statistically significant differences between the two positions. In other studies, however, the differences found between the two positions showed little statistical significance.[11] The goal of the present study was to take advantage of the precision of cone-beam computed tomography technology to measure the condylar variations found between the CR and MI positions in young, asymptomatic patients with full dentitions, who present different occlusion patterns.

Methodology

Twenty young adult volunteers took part in this study after approval by the Ethics Committee of the Federal University of Uberlândia (n. 127). The criteria for inclusion in the research were as follows:

- age 18 to 25,
- both sexes,
- all healthy teeth,
- no symptoms and
- no previous orthodontic treatment or occlusal adjustments.

The twenty patients were divided equally into four groups of five participants each. One group consisted of individuals with normal occlusion, whereas the other three groups consisted of individuals with Angle Classes I, II, and III malocclusions, respectively. The research procedures were divided into two main sections.

Section 1

Initially, a clinical survey was carried out to identify the occlusal features of each patient. Manipulation of the mandible was performed and an anterior deprogramming device (JIG)[12] was used to record the centric relation position. This device was fabricated using chemically activated acrylic resin (CAAR) (Duralay Reliance; Dental Mfg. Co., Chicago, USA). The first contact between the maxillary and mandibular arches corresponding to the temporomandibular joint in CR was identified for the purpose of maintaining a CR position during the tomographic examination. Next, the palatal acclivity of the JIG was ground carefully until this first occlusal contact was obtained. A standardized channel leading to the CR position was made with CAAR to be used as a stable and safe reference for the patient's occlusion during the CR tomography.

Section 2

This section was conducted by the same radiologist and operator. Each of the 20 patients underwent two cone-beam computed tomographic examinations of the temporomandibular joints (TMJs), the first in MI and the second in CR. Lateral and vertical cone beam scans were obtained with a NewTom 3G gantry tomographer (Quantitative Radiology, Verona, Italy). Ball-point pen marks standardized the patient's head position during the two scans. For the first scan, the patient was instructed to stabilize his/her occlusion in the maximal intercuspal position, whereas, for the second scan, the patient was instructed to open his/her mouth so that the operator could adjust the JIG in the upper central incisors. Primary reconstructions of the images were immediately performed by QRNNT software version 2.00, coupled to the NewTom 3G device.

Image selection and measurements

Following the same methodological sequence as that followed for the CR and MI scanning of the right and left TMJs, the radiologist acquired lateral and frontal cuts to obtain secondary reconstructions. Four lateral cuts and four frontal cuts were placed side by side and received specific file names to be used during the CR/MI comparison performed for each patient. The cuts in each patient file were named as follows:

- Right Lateral MI/Right Lateral CR,
- Left Lateral MI/Left Lateral CR,
- Right Frontal MI/Right Frontal CR, and
- Left Frontal MI/Left Frontal CR.

The measurements were made using Basic 3G software, coupled to the NewTom 3G device. The same trained operator performed all the measurements, starting with the Right Lateral CR cut. Reference line 1 was traced tangentially to the lowest posterior and anterior extremities of the mandibular fossa. Reference line segment 2 was then traced on a segment of line 1 overlapping the condylar process, and its value was recorded. Reference line segment 3 was traced overlapping exactly half of line segment 2, and its value was also recorded. An angle tool was then used to form a 90° angle, which was then placed at a 45° angle to reference line 1. The angle's vertex met the end of line segment 3 at a point named the middle point of reference. For future reference, the distance between the middle point of reference and the uppermost point of the condylar process was measured along reference line 4, which coincided with the vertical arrow of the angle tool. The distance between the uppermost point of the condyle and the closest internal point of the mandibular fossa overlapping the vertical arrow of the angle tool was then measured. This measurement was named "superior". Another measurement, named "anterior," was obtained in a similar fashion, except for an anterior variation of 45° in relation to the vertical arrow, and a final measurement, named "posterior," was obtained in the same way, except for a posterior variation of 45° in relation to the vertical arrow (Figure 1). After these three measurements of the Right Lateral CR were recorded, the Right Lateral MI cut was performed for comparison. For this purpose, the operator identified the same points and traced the same reference lines accurately to confirm that the same measurements were obtained as those obtained in the previous comparable cut. Next, the same three condyle-to-fossa measurements – superior, anterior, and posterior – were recorded. The entire measuring process was conducted identically on the lateral cuts of the left side.

Measuring of the frontal cuts started with the Right Frontal CR cut. Initially, the most medial and lateral points of the condylar head were identified. The line measuring tool was used to connect these points to produce an alpha line. A segment line was then traced overlapping the alpha line up to exactly half of its length, and this line was termed the beta line segment. A point at the end of the beta line segment was named the middle point of reference for the frontal cut. Again, the angle tool was used to form a 90° angle, which was then placed at a 45° angle to the alpha line. The angle's vertex was adjusted to meet the middle point of reference, and then the "superior," "medial," and "lateral" measurements were obtained in the same manner as the "superior," "anterior," and "posterior" measurements were obtained in the lateral cuts, as described previously. The distance between the middle point of reference and the uppermost point of the condyle head along the vertical arrow of the angle tool po-

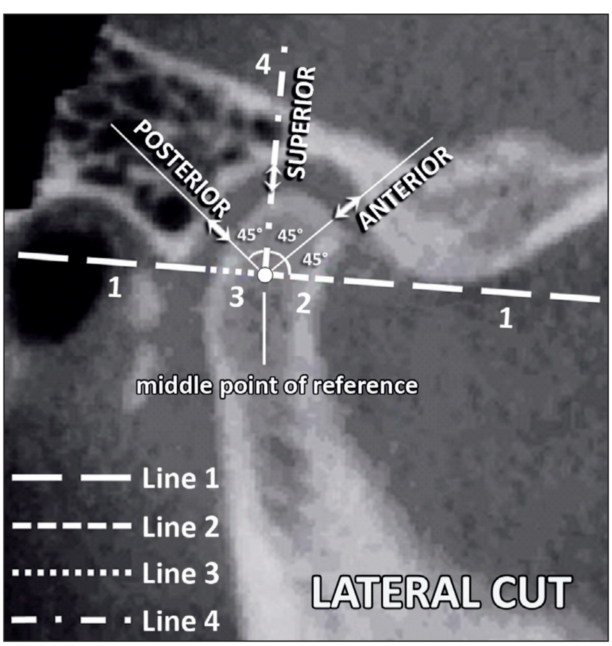

Figure 1 - Lateral view of the posterior, superior and anterior distances used to assess the condyle/mandibular fossa relationship.

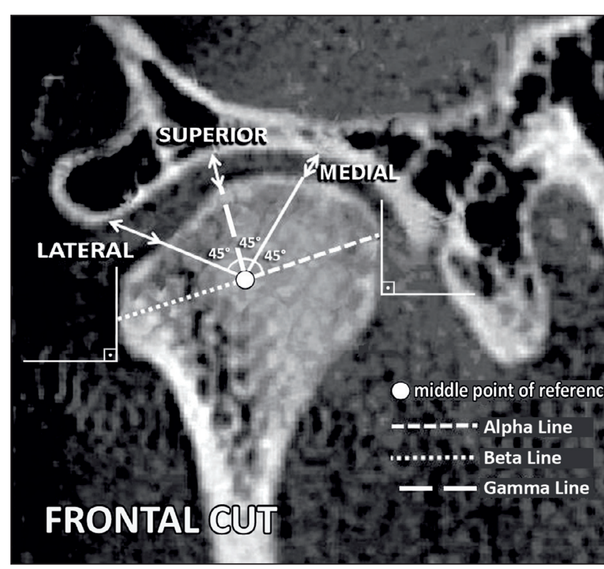

Figure 2 - Frontal view of the lateral, superior and medial distances used to assess the condyle/mandibular fossa relationship.

Table 1 - Comparison of mean measurements (mm) obtained for all groups in the MI and CR positions (n = 20). Student's t-test (p > 0.05).

Measurement	Position	Mean	Standard Deviation	Student's t-test	p-value
Right Lat POST	MI	1.87	0.512	−0.105	0.917
	CR	1.89	0.684		
Right Lat ANT	MI	1.915	0.9354	−0.235	0.815
	CR	1.980	0.8082		
Right Lat SUP	MI	2.315	0.7869	−0.208	0.836
	CR	2.365	0.7315		
Right Fron LAT	MI	2.090	0.9002	−0.225	0.823
	CR	2.155	0.9254		
Right Fron SUP	MI	2.47	0.838	−0.125	0.901
	CR	2.51	0.930		
Right Fron MED	MI	2.520	0.9860	−0.515	0.609
	CR	2.690	1.0978		
Left Lat POST	MI	1.980	0.6296	0.464	0.645
	CR	1.890	0.5973		
Left Lat ANT	MI	2.015	0.9304	0.227	0.822
	CR	1.950	0.8829		
Left Lat SUP	MI	2.565	0.8113	0.039	0.969
	CR	2.555	0.8056		
Left Fron LAT	MI	2.26	0.741	0.127	0.899
	CR	2.23	0.749		
Left Fron SUP	MI	2.82	0.827	0.073	0.942
	CR	2.80	0.899		
Left Fron MED	MI	2.84	0.915	−0.017	0.987
	CR	2.84	0.956		

Table 2 - Comparison of the mean measurements (mm) obtained for patients with normal occlusion in the MI and CR positions. Student's t-test (p > 0.05).

Measurement	Position	Mean	Standard Deviation	Student's t-test	p-value
Right Lat POST	MI	1.940	0.5413	1.332	0.219
	CR	1.580	0.2683		
Right Lat ANT	MI	1.840	0.9017	−0.499	0.631
	CR	2.140	0.9965		
Right Lat SUP	MI	2.460	0.9607	0.349	0.736
	CR	2.280	0.6380		
Right Fron LAT	MI	2.560	0.7861	−0.313	0.763
	CR	2.720	0.8319		
Right Fron SUP	MI	2.960	0.9263	0.068	0.947
	CR	2.920	0.9338		
Right Fron MED	MI	2.64	1.036	0.097	0.925
	CR	2.58	0.915		
Left Lat POST	MI	1.82	0.492	1.412	0.196
	CR	1.46	0.288		
Left Lat ANT	MI	2.220	0.4025	0.300	0.772
	CR	2.140	0.4393		
Left Lat SUP	MI	2.54	0.979	0.476	0.647
	CR	2.26	0.879		
Left Fron LAT	MI	2.380	0.8468	0.000	1.000
	CR	2.380	0.8672		
Left Fron SUP	MI	2.960	0.8678	0.068	0.948
	CR	2.920	0.9910		
Left Fron MED	MI	2.820	0.5891	0.213	0.837
	CR	2.720	0.8701		

sitioned at 90° was measured to serve as future reference for measurement checking, just as reference line segment 3 served as a reference in the lateral cut measuring procedure. This measurement was named the gamma line segment (Figure 2). All measurement values were duly recorded. Assessment of the Right Frontal MI cut was then performed by the same examiner in the same way as previously performed for the CR cut, to allow direct comparison of the corresponding measurements. In order to validate the comparison, the alpha, beta, and gamma line measurements should necessarily present the same values in the two cuts, thus confirming the correct identification of the same middle points of reference in both procedures. Twenty days after the first measurement session and before the statistical analysis was performed, an intra-examiner methodological error test was conducted by selecting and repeating two measurements in five randomly selected patients. This test confirmed the reliability of the results using Student's t-test set at p > 0.05 (measurement 1: p = 0.0374 / measurement 2: p = 1.000). Finally, the data were submitted to statistical analysis using Student's t-test (p > 0.05).

Results

The four lateral cuts provided 12 measurements, and the four frontal cuts also provided 12 mea-

Table 3 - Comparison of the mean measurements (mm) obtained for Angle Class I patients, in the MI and CR positions. Student's t-test ($p > 0.05$).

Measurement	Position	Mean	Standard Deviation	Student's t-test	p-value
Right Lat POST	MI	1.820	0.5718	0.524	0.614
	CR	1.640	0.5128		
Right Lat ANT	MI	1.680	0.6458	–0.762	0.468
	CR	2.000	0.6819		
Right Lat SUP	MI	2.360	0.7403	–0.269	0.795
	CR	2.480	0.6686		
Right Fron LAT	MI	2.080	0.7981	–0.121	0.907
	CR	2.140	0.7701		
Right Fron SUP	MI	2.660	0.5505	0.367	0.723
	CR	2.540	0.4827		
Right Fron MED	MI	2.860	0.9397	0.155	0.881
	CR	2.760	1.0922		
Left Lat POST	MI	1.960	0.6269	0.202	0.845
	CR	1.880	0.6261		
Left Lat ANT	MI	1.540	0.8473	–0.128	0.902
	CR	1.600	0.6205		
Left Lat SUP	MI	2.84	0.727	0.581	0.577
	CR	2.60	0.570		
Left Fron LAT	MI	2.56	0.456	0.553	0.595
	CR	2.42	0.335		
Left Fron SUP	MI	3.060	0.6427	0.414	0.690
	CR	2.880	0.7294		
Left Fron MED	MI	2.880	1.2215	0.026	0.980
	CR	2.860	1.1929		

Table 4 - Comparison of the mean measurements (mm) obtained for Angle Class II patients, in the MI and CR positions. Student's t-test ($p > 0.05$).

Measurement	Position	Mean	Standard Deviation	Student's t-test	p-value
Right Lat POST	MI	1.94	0.568	–1.720	0.124
	CR	2.66	0.744		
Right Lat ANT	MI	2.020	1.1389	0.121	0.906
	CR	1.940	0.9343		
Right Lat SUP	MI	2.720	0.7887	–0.799	0.447
	CR	3.060	0.5320		
Right Fron LAT	MI	2.640	0.7956	–0.39	0.970
	CR	2.660	0.8112		
Right Fron SUP	MI	2.66	0.737	–0.663	0.526
	CR	3.02	0.965		
Right Fron MED	MI	2.840	1.0922	–0.917	0.386
	CR	3.500	1.1811		
Left Lat POST	MI	2.140	0.9450	–0.333	0.748
	CR	2.320	0.7530		
Left Lat ANT	MI	1.800	0.9055	0.667	0.524
	CR	1.480	0.5762		
Left Lat SUP	MI	2.680	0.6834	–0.646	0.536
	CR	3.000	0.8718		
Left Fron LAT	MI	2.14	0.508	–1.004	0.345
	CR	2.44	0.434		
Left Fron SUP	MI	2.78	0.572	–0.284	0.784
	CR	2.92	0.942		
Left Fron MED	MI	3.04	0.750	–0.034	0.973
	CR	3,06	1,060		

surements, for a total of 24 measurements for each patient. The results show that 95.4% of the 240 pairs of measurements used for direct comparison between MI and CR were different. The means observed for the left and right sides of the TMJ in the entire research sample and also in each individual group (MI or CR) were compared using Student's t-test. There were no statistically significant differences between the two positions ($p > 0.05$) (Tables 1 through 5).

Discussion

Much of the investigative work aiming at determining the quantitative discrepancies between the CR and MI maxillomandibular positions was based on different conceptions of centric relation, registration techniques and methodologies used to estimate the reproducibility of the condyle/glenoid fossa relationship, either through articulators that do not take into account neither the presence of TMJ soft tissue nor its anatomical variability, or by means of radiographs obtained under varying degrees of magnification and restricted to the two-dimensional plane. The limitations of these methods used to examine TMJ anatomy are subject to much controversy and debate in scientific circles, warranting further clarification.[1,2,4]

The introduction of cone-beam computerized

Table 5 - Comparison of the mean measurement (mm) obtained for Angle Class III patients, in the MI and CR positions. Student's t-test ($p > 0.05$).

Measurement	Position	Mean	Standard Deviation	Student's t-test	p-value
Right Lat POST	MI	1.760	0.5225	0.288	0.780
	CR	1.660	0.5727		
Right Lat ANT	MI	2.120	1.2194	0.422	0.684
	CR	1.840	0.8444		
Right Lat SUP	MI	1.720	0.4147	0.332	0.748
	CR	1.640	0.3435		
Right Front LAT	MI	1.080	0.1789	–0.206	0.842
	CR	1.100	0.1225		
Right Front SUP	MI	1.60	0.543	0.165	0.873
	CR	1.54	0.602		
Right Front MED	MI	1.740	0.6465	–0.378	0.715
	CR	1.920	0.8468		
Left Lat POST	MI	2.000	0.5385	0.323	0.755
	CR	1.900	0.4359		
Left Lat ANT	MI	2.500	1.3134	–0.095	0.927
	CR	2.580	1.3498		
Left Lat SUP	MI	2.200	0.9460	–0.273	0.792
	CR	2.360	0.9044		
Left Front LAT	MI	1.940	1.0714	0.420	0.686
	CR	1.660	1.0383		
Left Front SUP	MI	2.460	1.2239	0.000	1.000
	CR	2.460	1.1194		
Left Front MED	MI	2.600	1.2042	–0.173	0.867
	CR	2.720	0.9706		

tomography, a reliable and affordable three-dimensional diagnostic tool, created the possibility of faithfully reproducing any anatomical condition of the craniofacial complex.[11] It is well known that spatial variations in the position of the condyle relative to the mandibular fossa in the RC and MI maxillomandibular positions are mostly very small – on the order of millimeters – and occur in approximately 90% of the entire population.[4,5]

Even though we used one of the most advanced imaging methods available for application in Dentistry, the Ethics Committee of the Federal University of Uberlândia determined that our sample be reduced to 20 individuals because of the exposure of human subjects to X radiation.

In the present study, we compared each measurement mean found in the MI and RC positions, considering the whole sample and individual groups. In most cases (95.4%), the mean measurement values were different (Tables 1 through 5). These results agree with those of several authors who recognize the existence of discrepancies between the two positions (MI and RC)[4,6-11] in more than 90% of individuals.[4] However, these differences were not statistically significant, in either the lateral or the frontal cuts. This may have occurred because the differences between MI and CR are generally very small.[4,5] In our study these differences may have been even smaller owing to the relatively higher accuracy of the imaging method we used, as compared to those used in several other studies, namely the methods of conventional radiographic examination and models mounted on articulators.[1,2] Some of these studies found statistically significant differences between the MI and RC positions.[6-11]

Other factors may also have contributed to the divergence observed between our results and those found in the literature.[4,5]. Our research sample consisted of young asymptomatic adults having all permanent teeth (except third molars) and no periodontal disease, whereas other research was conducted with older patients displaying symptoms of TMD and missing teeth.

The clinical applicability of these maxillomandibular positions is also subject to widely differing opinions because of the existence of contradictory results in the literature.[3-5]

Many authors support the use of CR in occlusal rehabilitation therapy,[3,11] since they consider it an easily reproducible reference position, and also in orthodontics,[1,3] strongly advocating the need to plan any treatment by mounting study models on an articulator and performing diagnostic teleradiography, both using CR.

Several other authors are opposed to using CR in various oral rehabilitation procedures, on account of the conceptual differences observed throughout history regarding a true CR position, varied reproducibility rates, nearly negligible discrepancies between the RC and MI positions, the lack of scientific evidence supporting the assumption that condylar position and orthodontic treatment may be related to TMDs, and the limitations of articulators to reproduce TMJ anatomy and function.[3-5]

Some authors, however, have reported more balanced views, admitting that both RC and MI may be used in oral rehabilitation according to each patient's specific situation. According to this view, extensive prosthetic restorations, occlusal adjustments, parafunction management, rehabilitation after orthognathic surgery, unsatisfactory MI, TMD management, and orthodontic therapy of greater complexity would be indications for using CR. In contrast, less extensive oral rehabilitations, a stable MI position, the absence of signs and symptoms, and less complex orthodontic therapy would be indications for using MI.[3-5]

Based on the results of the present study, the latter approach seems to be a more logical choice. Despite the limitations previously discussed, the absence of symptoms and the relative similarity of results in our study sample suggest the existence of a relative balance capable of preventing pathologic changes in the condyle/fossa relationship, a balance which could be maintained after low-complexity procedures.

Conclusions

Within the limitations of this study, it can be concluded that there were no significant condyle/mandibular fossa relationship discrepancies between the centric relation and the maximum intercuspation positions in asymptomatic patients with practically intact dentitions, using cone-beam computed tomography.

This study also found a high rate of variation in condyle position in both CR and MI, even though the measurement differences were statistically insignificant. The fact that our sample consisted of young, asymptomatic individuals with intact dentition suggests the existence of a range of adaptive possibilities for the condyle/articular fossa relationship compatible with a balanced condition and normal function in these patients.

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