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Guided and unguided mandibular reference positions in asymptomatic individuals

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Structured Abstract
Objectives – To determine the difference between guided and unguided mandibular reference positions assessed by articulator simulation.
Setting and Sample Population – This study was carried out at the Division of Orthodontics at Vienna Medical University. The sample population consisted of 19 men and 18 women aged 23–32 years and without temporomandibular disorder.
Materials and Methods – Three examiners used bimanual operator guidance and unguided mandibular stationary hinging at final jaw closure before occlusal contact and made occlusal wax recordings. The examiners repeated both techniques after 8 and 17 days on the same subjects. Condylar positions were assessed using articulator-mounted casts and a three-dimensional electronic condylar position indicator.
Results – Bimanual guidance positioned the condylar spheres, on average, 0.1 mm more right and 0.6 mm more posterior and superior to unguided hinging ($p < 0.04$). The repeatability of bimanual guidance by three operators and on 3 days resulted in inter-repetition standard deviations ranging from 0.19 to 0.4 mm and from 0.41 to 0.76 mm for unguided hinging. The highest fraction of the total variance came from the individuals, followed by days, then intra-operator and interoperator variability. Both methods showed considerable overlap of condylar sphere positions at the 95% confidence level.
Conclusion – Within the limits of an articulator study, the spatial variability of condylar sphere positions suggested a statistically but not clinically relevant methodological difference between bimanual guidance and unguided stationary hinging.

Key words: bimanual manipulation; condylar position indicator; guidance; unguided mandibular reference position

Introduction

The comprehension of maxillomandibular relationships represents an integral part of clinical decision-making in orofacial medicine (1). A diagnostic jaw relationship should represent sound occlusal conditions and identify discrepancies that may be masked by hand-articulated models (2). If initial occlusal contacts force the mandible towards a sagittally or laterally deviated position, the jaw relationship may look different in a reference position that does not coincide with complete jaw closure but indicates the first occlusal contact without mandibular slide. In this situation, the jaw relationship and the extent of malocclusion differ from that shown by full intercuspation (ICP).

Because full ICP is usually lost during initial orthodontic treatment, diagnostic reference positions may help assess the oncoming jaw relationship before the onset of treatment, provided that muscles and joints primarily determine the relationship. Furthermore, at the end of the orthodontic treatment cycle, reference positions will help establish a finishing position.

Two key concepts concur in the location of a diagnostic jaw relationship: operator guidance and unguided patient-determined positions. Without a gold standard, it is debatable which method will ensure physiology, reproducibility and operator independence. Operator guidance has been recommended over unguided techniques (3–6), but different ways of guidance, small samples and lack of neuromuscular conditioning before the testing of unguided methods limit the significance of several previous reports. Bimanual guidance of the mandible was described as being the most consistent method (3, 7–10) but was not considered physiological (11). Upward guidance may cause head extension and more posterior mandibular positions (12). Because the jaw will return to the unguided posture after operator guidance, Bumann and Lotzmann (13) recommended Brill and Tryde's (14) unguided technique of terminal jaw closure immediately before occlusion.

The aim of the present study was to evaluate these controversial issues regarding the registration of the jaw relationship in asymptomatic individuals. The comparison of bimanual operator guidance and unguided jaw closure included the 1) spatial relationship of articulator condylar sphere positions, 2) the influence of three different operators on positioning the mandible and 3) the repeatability over time.

Materials and methods

Subjects

The authors invited dental school students in the pre-clinical terms to participate in this study. These volunteers showed complete dentitions except third molars and had no history of temporomandibular disorder. The sample comprised 19 men and 18 women aged 23–32 years (mean 26.6 ± 2.7). Twenty-five students showed a bilateral Angle Class I relationship; four students, a bilateral Class II from ¼ to 1 premolar width; and one student a bilateral Class III of ¼ premolar width. Another six individuals had a unilateral Class I and Class II (¼–1 premolar width), and one subject, a Class I on the left but a ¼ Class III on the right. Informed consent was obtained from all participants. The university ethical board approved the project in accordance with the Helsinki Declaration (#610/2010).

One investigator validated the asymptomatic state by medical and dental histories and manual structural analysis of the craniomandibular system (13). Exclusion criteria encompassed facial pain, recurrent headache, head or neck trauma, temporomandibular joint crepitus, clicking, locking, capsulitis or synovitis, disc displacement, maximum jaw opening <40 mm, maximum protrusion and lateral excursions <8 mm, anxiety, depression, tranquillizer or muscle relaxant medication, pain on muscle palpation (anterior–medial–posterior temporal, superficial and deep masseter, medial and lateral pterygoid muscles, anterior and posterior digastric, suprahyoid and infrahyoid muscles), pain or loss of muscle force during 20 s of isometric closure against cotton rolls and pain or loss of muscle force during isometric maintenance of 4 mm left and 4 mm right lateral mandibular positions over 20 s, while the examiner exerted medially directed pressure against the subject's mandible, as well as pain, clicking, or crepitus during upward guidance of the moving mandible (dynamic compression) or during medial pressure against the subject's mandible in protrusion-open-close-retrusion movements (dynamic translation to left, dynamic translation to right), plus hypodontia, oligodontia and orthodontic or prosthetic treatment. The sample did not present a mandibular side shift.

Maxillary and mandibular casts (GC Fuji Rock; GC Europe, Leuven, Belgium) were obtained from irreversible hydrocolloid impressions (Tetrachrom; Kaniedenta, Herford, Germany). Plaster artefacts on occlusal surfaces were removed for unambiguous ICP. One operator mounted the casts in a SAM2P articulator (SAM Präzisionstechnik GmbH, Gauting, Germany) using an arbitrary face-bow referenced to Porion and aligned parallel to the bipupillary line (15). He positioned the mandibular casts manually into the best-fit maximum ICP. Split-cast controls verified the mountings.

The same operator instructed each subject for neuromuscular relaxation, bimanual guidance (16) and unguided mandibular stationary hinging. Then three right-handed operators recorded the jaw relationships on the same day. The operators had combined clinical experience of at least 12 years and were calibrated in performing both recording techniques. A random chart gave the sequence of operators and methods. The recordings were repeated after 8 days ($t_0 - t_1$) and another 9 days ($t_1 - t_2$) at similar times of day.

Bimanual guidance method

The subjects sat in a dental chair reclined at 20°. A headrest supported the occiput. After two initial maximum mouth-openings, a cotton roll was placed between the antagonist second premolars and first molars. The cotton roll avoided the ICP and was held with light pressure from the teeth for 5 min. After this conditioning, the operator stood behind the subject, placed the fifth fingers behind the subject's mandibular angles, fingers 2–4 in front of the angle to the inferior mandibular border and the thumbs laterally to the chin. Easy guidance of jaw-open-and-almost-close movements was mandatory; otherwise, muscular relaxation was continued. Antagonist tooth contacts were avoided throughout the procedure. The operator trimmed a double-layered Beauty Pink X Hard wax plate (Miltex Inc., York, PA, USA) to the size of the maxillary dental arch and placed the softened wax onto dried maxillary teeth. The bimanual guidance method (BM) position was recorded during strong upward pressure at the posterior body of the mandible and simultaneous downward pressure of the chin. The record was taken at 1–2 mm vertical jaw separation at the first molars. When wax impressions of the teeth were deeper than 0.5 mm, the margins of the impressions were cut with a sharp knife for precise fit between wax and dental cast.

Non-manipulated method

Subjects were seated as for BM. They performed two initial maximum mouth-openings, followed by repetitive open-and-almost-close movements (40–50/min, including two 5-s breaks) with a maximum interincisal distance of 15 mm. The subjects avoided antagonist tooth contacts and mandibular protrusion. After 3 min, the operator placed a single-layered softened Beauty Pink X Hard wax plate on the maxillary dentition. Stationary hinging produced first contacts of mandibular teeth with the wax. The wax was removed, and the subject continued small open–close movements with breaks. The operator added Aluwax (Aluwax Dental Products Co., Allendale, MI, USA), where impressions of mandibular canines or first molars were missing, and recorded further impressions. The registration was removed again. While the subject continued stationary hinging, the operator covered the wax impressions with a thin layer of mixed zinc oxide and eugenol (Temp bond, Kerr, Salerno, Italy). After repositioning of the record, the non-manipulated method (NM) position was registered definitely at 1–2 mm jaw separation with the same thickness of the wax as in BM. Impressions >0.5 mm were trimmed.

Measurements

One operator used an electronic condylar position indicator (CPI) (Condymeter; Vamed, Graz, Austria), which measured the position of the condylar spheres with six measuring gauges (measuring accuracy <0.01 mm; Mitutoyo, Kawasaki, Japan) at an intercondylar distance of 110 mm (Fig. 1). The gauges displayed xyz spatial coordinates of the left and right condylar positions. The zero of the coordinate system represented ICP; x, the anterior direction; y, inferior; and z, left. One operator made all CPI measurements. All BM and NM wax records and ICP were measured thrice after careful repositioning of maxillary and mandibular casts. A 5 N weight stabilized the upper part of the CPI. Before the next record was measured, all gauges were zeroed in the CPI mechanically locked position.

Statistical methods

To investigate statistical differences between BM and NM, a mixed model was calculated for the left and right xyz values, accounting for method, age and gender as fixed factors, and subject, operator, day within subject and operator, repetition within subject, operator and day as random factors.

To quantify the sources of variability of the xyz values separately for BM and NM, analyses of variance components were used to determine intraclass correlation coefficients (ICC) and interoperator standard deviations (SD), *that is*, within subject and operator between days, interoperator SD, that is, within subject between operators, and inter-repetition SD of three CPI measurements of the same record. The ICC was calculated as the ratio of the intersubject component of variance to the total variance, and the intersubject SD, as the square root of the intersubject component in the analysis. Intra- and interoperator SDs were calculated as the square root of the corresponding variance component determined from the analysis. All statistics were performed using SAS 9.1 (SAS Institute Inc., Cary, NC, USA).

Fig. 1. Condylar position indicator with measuring gauges for left and right xyz condylar data, mounted casts and interposed occlusal wax record.

Results

All data were normally distributed. Descriptive statistics are given in Table 1. Gender and age did not show statistically significant interaction with the values.

Repeatability of measurements

The accuracy in measurement with the CPI was deduced from three repeated measurements of each BM, NM and ICP position. The xyz data of the condylar spheres yielded inter-repetition SDs from 0.01 to 0.12 mm.

Overall relationships for three operators and 3 days

In the sagittal plane, the left average BM position was located 0.74 mm posterior and 0.28 mm inferior to ICP. The left average NM position was 0.28 mm posterior and 0.8 mm inferior to ICP. On the right, the average BM position was located 0.3 mm posterior and 0.45 mm inferior to ICP, with the average NM position 0.15 mm anterior and 0.86 mm inferior to ICP (Fig. 2).

In the frontal plane, BM positioned the condylar spheres, on average, 0.22 mm more right than ICP, and NM, 0.12 mm more right. BM and NM differed significantly in all directions ($p < 0.04$).

Table 1. **Results of bimanual operator manipulation (BM) and non-manipulated stationary hinging (NM) in millimetres: means and standard deviations (SD) of three operators at t_0, t_1, t_2, upper and lower levels of 95% confidence intervals (CI) for the mean, intraclass correlation coefficients (ICC, 1 describing best consistency) for repeated BM and NM, SD between subjects (intersubject), days (intra-operator) and operators at same time point (inter-operator)**

				Variance components		
	Mean ± SD	95% CI	ICC	Intersubject SD	Intra-operator SD	Interoperator SD
BM						
rx	−0.3 ± 0.77	0.25; 0.34	0.64	0.62	0.31	0.14
ry	0.45 ± 0.81	0.4; 0.5	0.73	0.7	0.35	0.16
rz	−0.21 ± 0.46	−0.24; −0.19	0.77	0.41	0.21	0.06
lx	−0.74 ± 0.75	−0.79; −0.7	0.71	0.64	0.34	0.18
ly	0.28 ± 0.64	0.24; 0.32	0.51	0.46	0.4	0.1
lz	0.23 ± 0.46	0.2; 0.26	0.77	0.41	0.19	0.05
NM						
rx	0.15 ± 1.09	0.08; 0.21	0.51	0.78	0.61	0.2
ry	0.86 ± 1.21	0.79; 0.94	0.56	0.91	0.76	0.18
rz	−0.12 ± 0.63	−0.16; −0.08	0.55	0.47	0.41	<0.01
lx	−0.28 ± 1.12	−0.35; −0.21	0.51	0.8	0.76	<0.01
ly	0.8 ± 1.1	0.73; 0.87	0.5	0.78	0.71	0.2
lz	0.13 ± 0.62	0.09; 0.17	0.56	0.47	0.41	<0.01

r, right condylar ball; l, left condylar ball; x, anterior; y, inferior; z, to the left.

Single-operator relationships

The NM–ICP relationships for a single operator at t_0 showed that NM was significantly more caudal than ICP ($p < 0.0001$). Sagittal and transverse NM–ICP differences were not significant. BM and ICP differed significantly on both sides in the left–right direction but antero-posteriorly only on the left ($p < 0.022$). Vertically, BM was not significantly different from ICP. BM and NM differed significantly ($p < 0.024$) in all directions except antero-posteriorly on the right.

Variability of data

The Table 1 shows the results of the variance component analyses separately for both methods, calculated for three operators and three recording dates. Higher ICCs for BM indicated more consistency than that of NM. The variance between operators and repetitions was lower for BM than NM. There was more variability between days for both methods but with larger intra-operator SDs of NM. In both methods, the highest fraction of the total variance came from the variation between subjects.

Discussion

A diagnostic record of the jaw relationship, in addition to judging the ICP, has been considered indispensible for occlusal analysis and treatment (16). Orthodontists may also require a method for establishing a maxillomandibular relationship in the finishing state of treatment when full ICP of the teeth has not yet been accomplished.

The relatively small difference in condylar position between the BM and NM methods indicated that the mandible tended to go back towards posterior positions, whether guided or induced by a neuromuscular exercise. BM aims at placing the condyles in a superior–anterior border position but requires operator training for its proper use. In the present investigation, BM resulted in slightly more posterior and superior condylar sphere positions than NM. However, for an unguided technique, the NM condylar positions came

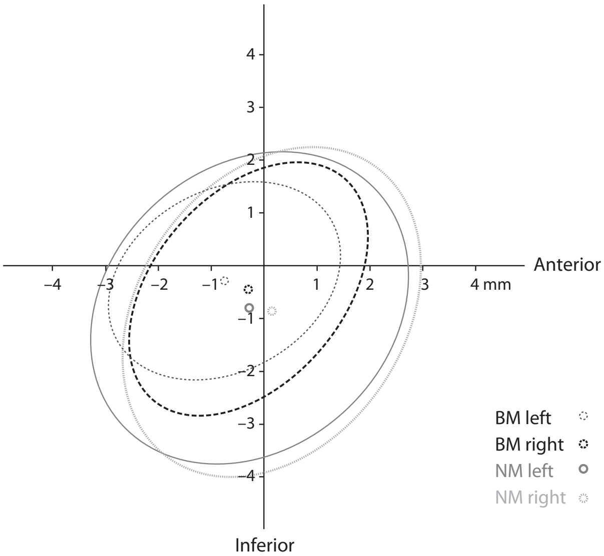

Fig. 2. Superimposition of left and right average condylar positions resulting from bimanual manipulation (BM) and non-manipulated hinging (NM), 95% confidence ellipses for three operators and three recording dates in the sagittal plane. Intercuspal position is the origin of coordinate system; outliers were not eliminated.

remarkably close to the BM positions. This suggests NM, which does not yield a border position, as an alternative reference for clinicians and students without experience in jaw guidance. The 0.6-mm difference between the average BM and NM condylar positions might reflect the tolerance of a biological system for occlusal and craniomandibular relationships. These speculations agree with the idea of a mandibular reference area (17). In addition, most individuals show retruded contact position–ICP differences of 0.5–1.5 mm (18). We hypothesize that a 1.5-mm difference also indicates a tolerance of the masticatory system. The quantification of individual tolerance requires further studies to shed more light on this complex question.

Positional consistency and less variability favoured BM over NM, in agreement with Tripodakis et al. (8), who reported that the repeatability of BM and NM improved significantly after the incorporation of a bite plane for 2 weeks, whereupon NM approached BM to a discrepancy of 0.6 mm sagitally and 0.12 mm laterally. The present study found similar results without the bite plane. It may be speculated that orthotics or meticulous occlusal adjustment will shift NM even closer to BM, but both positions will hardly be identical, because of the techniques used in determining them.

Contrary to Tripodakis et al. (8) and McKee (9), the three operators of the present study did not repeat BM within 0.1 mm^2 or 0.11 mm. The SDs indicated considerable overlap of BM and NM condylar sphere positions. Non-significant sagittal differences in the single-operator statistics and the superimposition of the 95% confidence ellipses (Fig. 2) support this observation. Although the 95% confidence intervals are small, this representation is projected along the single coordinate axes and has geometric properties different from those of the 2D confidence ellipses. The ellipses have a directed overlap and indicate that several BM and NM positions are alike.

While the average condylar sphere position produced by BM was more posterior than ICP on both sides, the average NM was anterior to ICP on the right but posterior on the left. In the frontal plane, NM positioned the mandible, on average, 0.1 mm more left than BM. This finding agrees with the results obtained in other studies (8, 19, 20), which described transverse differences of 0.2–0.3 mm between guided and unguided methods. Weffort and de Fantini (2) stated that anterior condylar movement from centric to ICP was significantly more pronounced on the right side. The tendency of the mandible towards the left indicates directional asymmetry (21) and corresponds with the kinematic laterality during jaw opening, *that is,* the mandible moved significantly more often to the left (22). As a characteristic of a normal population, asymmetry involved condylar position (23), chewing side preference, bite force and occlusal contacts (24).

The suitability of both BM and NM can be deduced from the variance component analysis. The highest fraction of the total variance came from the variation between individuals, and the least, from the operators. However, reproducibility *per se* is not necessarily indicative of physiology (1). Patient-governed positions may represent each person's unique neuromuscular function (25), including asymmetry. The lack of consensus on correct mandibular positions limits the validation of different methods. The extra exercises to prepare the subject for the task may well have resulted in the almost similar reproducibility with regard to the guided method. Similar reproducibility may be the result of the conditioning procedure rather than the technique used, which differs from results of other studies. In clinical practice and in a given patient, both guided and unguided techniques should be used to assess the existing occlusion, before and after treatment, for diagnosis and evaluation of the therapy.

One of the aspects eligible for the validation of reference positions pertains to the condyle–disc assembly, preferably evaluated by MRI (26). Further studies should evaluate BM and NM positions by MRI. Our study used a mechanistic approach for the comparison of two controversial concepts. In the literature, unguided positions were thought to be less precise and reproducible than guided retruded positions, which yielded a smaller range of mandibular positions (3, 4, 27, 28). These assertions relied on the accuracy of articulator and CPI instruments. Their simulation of condylar movement may not completely reflect real changes that are occurring anatomically (29). This claim refers to a study (30), which used a mandibular position indicator (MPI) and MRIs, and mentioned that MPI data failed to correlate statistically with MRI data. The authors (30) attributed this difference most likely to a lack of sharp demarcation of cortical bone on the MRI and a measuring accuracy of their MPI of only 0.5 mm in the sagittal plane. The lack of MRI-controlled condyle position may limit the present study's results. However, for the comparison of two methods, the articulator or face-bow errors were considered to affect the BM and NM methods to the same extent, that is, still allowing for integration of the experiment and its data into the patients' biological temporomandibular joint framework.

The absence of electromyography (EMG) may represent a limitation of this study. Although EMG might have increased the validity of the data, we wanted to adhere with the clinical routine and avoid operator and patient irritations from electrodes or cables. Intramuscular needle and fine-wire EMG was considered too invasive. Surface EMG monitors the sum of motor unit action potentials of superficial muscles only and will not investigate deep muscles. The operator's sensation of slow hinging without muscular resistance during BM was the clinically based rationale.

Another limitation could be attributed to using dental students from the pre-clinical semesters. In spite of theoretical knowledge, their exercises appeared equivalent to those that are observed in lay people. The students' candour and understanding for the significance of the medical history predisposed to using empathic questions on anxiety, depression and potential medication. However, potentially more useful tools as the Hospital Anxiety and Depression Scale or the Beck Anxiety Inventory could have been used.

Conclusions

Within the limitations of an articulator study, individuals without temporomandibular disorder showed considerable variability of CPI positions for records obtained by BM and NM and substantial overlap of these positions. The intersubject differences represented the main source for the scattering of individual condylar points. The influence of three different operators on positioning the mandible was the component with least variance, followed by the variability over time.

In the sagittal plane, the NM technique, which does not spot a border position, placed the CPI condylar spheres, on average, 0.6 mm anterior and inferior to the points obtained by the BM border position. Clinically, the difference between BM and NM condylar sphere positions can be expected to lie within the tolerance of a biological system. Protagonists of border positions may select BM, rely on their manual skills, and expect reproducibility within 1 mm. Clinicians who consider operator guidance or border positions as non-physiological, are not trained in jaw guidance, or favour patient-governed positions may apply NM and accept reproducibility within 2 mm in asymptomatic individuals.

Clinical relevance

The controversy regarding whether or not to use operator guidance in determining a reference position of the mandible initiated a comparison of bimanual jaw guidance and an unguided mandibular exercise. The effects of both techniques on the position of the mandibular condyles were assessed by articulator condylar sphere measurements. While operator guidance has been recommended in the literature, the present results did not demonstrate a practical difference between the two methods. Both techniques can be used to establish a reasonable position for initial diagnosis and orthodontic finishing.

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