Reproducibility of the Condylar Reference Position

The reproducibility of the condylar reference position was examined at the point of unstrained hinging movement of the mandible in subjects with TMJ symptoms and in asymptomatic subjects. Three different operators performed the procedure to detect inter-operator variability. Each operator made five registrations using computerized axiography in the electronic mandibular position indicator mode. Data were evaluated by an analysis of variance using three factors: (1) repetitions of the single operator, (2) data from symptomatic versus asymptomatic patients, and (3) values of different operators. The results showed that none of these factors had a significant influence on reproducibility of the condylar reference position. High reproducibility was obtained in both symptomatic and asymptomatic groups. Measured values remained within ±0.1 mm in 58.6% and within ±0.2 mm in 24.3% of the registrations.

J OROFACIAL PAIN 1993;7:68–75

E. Piehslinger, MD, DDS

A. Celar, MD, DDS

R. Celar, MD, DDS

Department of Removable and Fixed Prosthodontics

W. Jäger, PhD, DDS
Institute for Pharmaceutic Chemistry

R. Slavicek, MD, DDS
Department of Removable and Fixed Prosthodontics

University of Vienna
School of Dentistry
Vienna, Austria

Correspondence to:
Dr E. Piehslinger
Department of Fixed and Removable Prosthodontics
University of Vienna
School of Dentistry
Währingerstrasse 25a
1090 Vienna, Austria

Centric relation and the principle of hinge axis have been matters of discussion and even points of contention for several decades. Changing definitions in the literature outline the existence of the controversy. Centric relation has been interpreted so variously that it implies more meanings than few definitions can convey. Its meaning is no longer definite. It has become a term in transition to obsolescence.[1]

McCollum and Stuart[2] and Beard and Clayton[3] stated that there was only one reproducible hinge axis, and it corresponded to centric relation. They described the terminal hinge as an imaginary line between two condylar centers of rotation.[1] Lucia[4] termed centric relation "a specific relationship of the centers of rotation of the mandible to the maxillae in the most posterior terminal position."

Centric relation has also been defined as a physiologic relationship of the mandible to the skull.[5–8] Definitions of centric condylar position in the literature vary considerably: "posteriorly and cranially in the glenoid cavity"[5]; "a posterior terminal position but as far up and as far back as the patient will ever place them when teeth or restorations are in use"[4]; "most posterior, most cranial, and without transversal shift"[7]; "most anterior and superior and related to the articular eminence."[7] Long[5] termed centric relation the most retruded, physiologic relation to allow lateral excursions and reproducibility (the patient being able to get into this position by himself).

Definitions state that "osseous and intra-articular tissue structures as well as capsular ligaments were in harmony"; "the central bearing area of the disc has to be in contact with condyle and articular eminence"[10]; "both condyles must be articulated with the thinnest, avascular portion of their respective discs." The condyle-disc assemblies must be placed with anterosuperior force against

the articular eminences of the glenoid fossae. At this point the condyles are activated by muscles in a braced position that is clinically discernible by the ability of pure rotary motion about a transverse horizontal axis.

Gilboe[10] describes centric relation as a functional position, as do Bauer and Gutowski[9]: "Terminal hinge axis is a reproducible border position and the origin of all kinematic mandibular movements." Opposing statements are also found in the literature: "Hinge axis position was mainly not a position of normal function but reference for anatomically correct mounting of maxillary casts in the articulator. Mostly retral contact position (RCP) did not coincide with intercuspation position (ICP)."[6] Centric relation is also considered by some authors to be a therapeutic position.[7,10,11]

Slavicek[8] defines RP as the diagnostic reference position of the TMJ (also known as physiologic reference position). The mandible is in physiologic retral border position. All structures of the joint are unloaded, ie, the ligaments are not in tension in any direction. There is only minimum muscle activity and no pressure on cartilaginous structures. Deranged reference position is stated to be a diagnostic reference position, but the TMJ is luxated with the condyles in unstrained retral border position.

Fox[12] quantifies the occlusal error caused by the difference between true hinge axis and the one transferred to the articulator. Negligible occlusal inaccuracies occur (0.075 mm at maximum) whenever the localization of hinge axis is accurate to within 1 mm. He established a guideline for prosthetic restoration. Consequently, the reproducibility of condylar hinge axis should lie within an area of 1 mm.

The replicability of reference positions has been reported. Körber[13] discusses several millimeters for reproducibility of hinge axis. Bosman[14] reproduced kinematic determination of the hinge axis on the articulator in a range of 0.4 × 0.4 mm and obtained its reproducibility within 1.7 × 1.7 mm on patients. Sindledecker[15] found centric relation within an area ranging from 0.11 to 0.21 mm, depending on the material used (wax, zinc oxide–eugenol, acrylic resin).

Shafagh and Amirloo[16] found replicability of retruded contact position in 40% of patients at an average variability ranging from 0.10 to 0.20 mm. Rosner and Goldberg[17] researched retruded contact position and noted reproducibility within an area of 0.16 mm. These two investigations refer to a reference established by tooth contact.

Schubert[18] tattooed terminal hinge axes and researched its reproducibility in intervals of 3 months. The results showed differences of up to 1.5 mm in asymptomatic patients. Temporomandibular disorders caused variability in hinge axis position of up to 4 mm after 12 months. Seiler and Hupfauf[19] found reproducibility within 0.7 mm in asymptomatic individuals without functional symptoms after 2, 6, and 8 weeks.

Lundeen[20] compared centric records obtained by different techniques and materials. The greatest number of superior condylar positions were achieved by using Aluwax; zinc oxide–eugenol impression paste recordings were inferior to Aluwax (0.5 mm). Myo-Monitor resin records were least consistent (inferior to Aluwax, 2.27 mm).

Kantor et al.[21] researched replicability and spatial patterning of centric relation records by using four techniques: (1) swallowing, (2) chin-point guidance, (3) chin-point guidance with anterior jig, and (4) bilateral manipulation. Bilateral manipulation allowed the greatest reproducibility, followed by chin-point guidance. Swallowing was the least consistent.

Gerber[22] warned against pushing the condyles posteriorly and inferiorly to the most retruded position. In taking the mandible to the reference position, one should allow tactile sensitivity to lightly monitor an uninhibited hinging, patient-activated, retruded mandibular posture. The dentist should not guide or push[11]: iatrogenic TMD may occur if the therapist places the mandible too far posteriorly.[10]

This study evaluated the reproducibility of reference position by means of computerized axiography by using the electronic mandibular position indicator (EMPI) mode. In addition, its purpose was to determine differences between operators, the effects of TMD on reproducibility, and whether repeatedly placing the mandible in RP has an influence upon replicability.

Materials and Methods

The study group comprised 44 subjects who ranged in age from 16 to 62 years (average = 33 years). There were 30 women and 14 men. The subjects were examined with computerized axiography and EMPI mode.[23] This noninvasive method offers three-dimensional imaging of condylar paths by recording movements of the hinge axis. The double-stylus system enables recording of rotational components during movement.

The patients were selected at random and divided into two equal groups. Group 1 comprised per-

sons without signs or symptoms of TMD (12 men, 10 women). Group 2 consisted of symptomatic patients (2 men, 20 women) who had functional disturbances. Symptoms of TMD included limitation of mandibular movement, asymmetry of condylar paths, clicking phenomena, hypermobility, displacement of the disc, and luxation, as well as subjective complaints: pain in wide mouth opening and mastication; clicking; pain radiating to ear, head, and neck. The patients were instructed how to perform the movements and were advised to move easily, avoiding any tooth contact. Patients practiced making the movements (protrusion-retrusion, opening-closing, mediotrusion right and left) before the facebows were mounted.

The upper facebow carried resistance plates that were placed sagittally and covered the TMJ area. A paraocclusal functional clutch was cemented to the mandibular teeth in such a manner as to assure mandibular movements without interference between the clutch and the maxillary teeth. The mandibular clutch was attached to the lower facebow with left and right double-tipped styli. The styli were adjusted to the hinge axis by computer calculation, which also recorded all condylar motion, including rotation.

Orthopedic standard movements were recorded while the patients' teeth were not in contact. The orthopedic functional analysis is a standardized procedure and consists of the following movements: protrusion/retrusion, mediotrusion right, mediotrusion left, and opening-closing, each of which were repeated with and without guidance. The patient also performed the functional movements of bruxism, speech, and mastication. The quality of the axiographic tracings helped to confirm the accuracy of patient evaluations with regard to their assignment to groups 1 or 2.

The reproducibility of RP was researched in the EMPI mode by using three different operators. Each operator made five recordings of the following procedure. The mandible was placed into RP by unforced chin-point guidance (RP denotes pure hinging movement achieved without strain during guidance). The vertical component was determined by the position approximating tooth contact. Any contact of teeth might have activated proprioceptive engrams, thus preventing perfect hinge closure.[4] Each of these records was then stored in the computer. The patient was asked to protrude and retrude the mandible. RP was then established in the same manner as before and registered again. The difference in condylar position between both RPs was calculated by computer and displayed on the screen. The differences of positions are represented by the codes dXR, dXL, dZR, and dZL, with X denoting the anteroposterior direction, and Z denoting the vertical direction; R and L indicate right or left side, respectively. The difference in laterolateral direction (horizontal plane in the direction of the hinge axis) is represented by dY (Fig 1). The calculated three-dimensional differences of incisal pin positions at the articulator incisal guidance table were represented by dW (laterolateral), dL (anteroposterior), and dH (change of incisal pin height). Gamma (γ) was defined as the amount of rotation of the hinge axis between two positions.

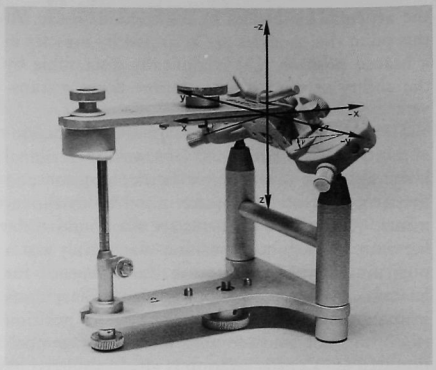

Fig 1 The coordinate system in all three dimensions. The z-axis lies in the vertical plane, y-axis in the horizontal plane, and x-axis in the sagittal plane. Deviations represented as follows: (+Z) caudal; (−Z) cranial; (+Y) right side; (−Y) left side; (+X) anterior; (−X) posterior. This coordinate system is used in the articulator as well as in the mechanical and electronic MPI.

These data were calculated and displayed in 0.01 mm in hundredths of degrees (γ). The axis-orbitale plane served as the reference plane.

Results

Figures 2 and 3 show the distribution of values of hinge axis points in RP related to three different ranges: .0 to 0.1 mm, 0.1 to 0.2 mm, and >0.2 mm. Ranges of .0 to 0.5 degrees, 0.5 to 1 degrees and >1 degree were selected for γ (Fig 4). The data for groups 1 and 2 are given separately. Reproducibility of all parameters was higher in the asymptomatic group than in the symptomatic group (Figs 2 and 3).

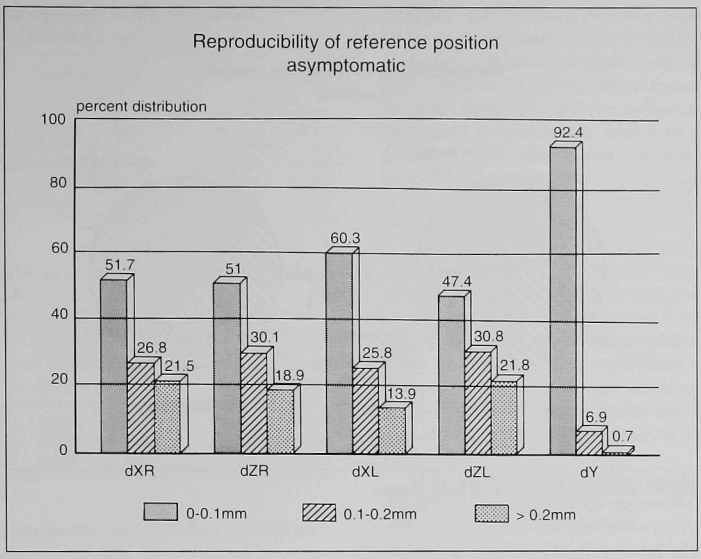

Fig 2 Distribution of data for the asymptomatic group.

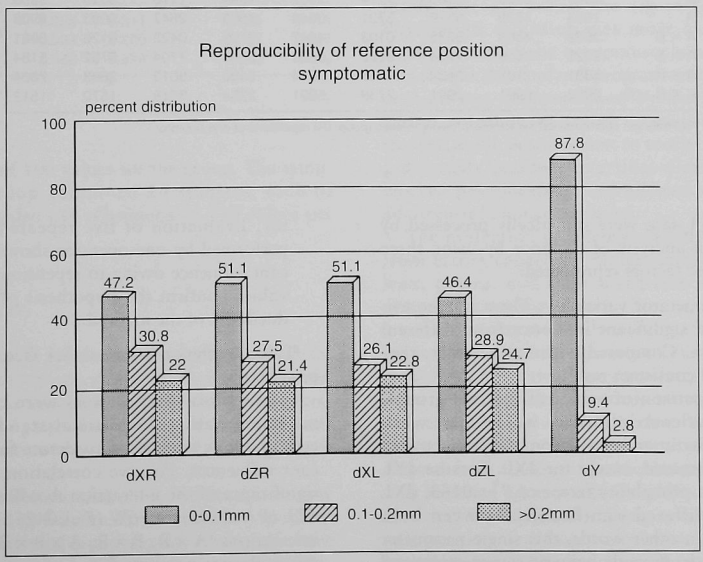

Fig 3 Distribution of data for the symptomatic group.

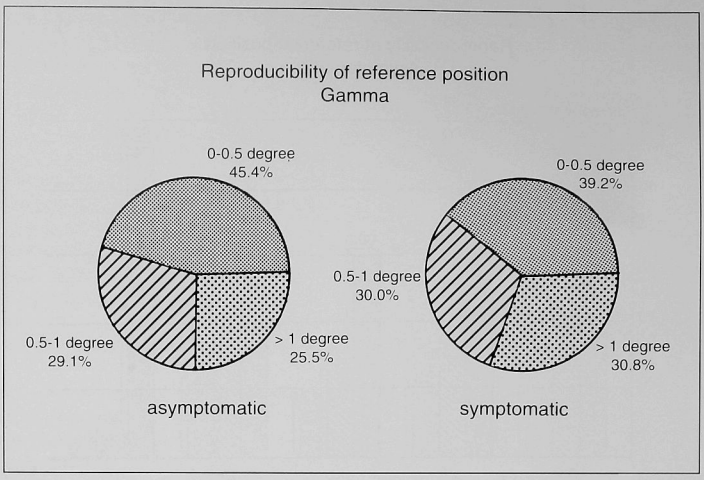

Fig 4 Gamma — rotation in both groups.

Table 1 Probability Factors (*P*) for A, B, and R Parameters*

	dXR	dZR	dXL	dZL	dY	dH	dW	dL	γ
A	.1540	.5037	.4048	.5031	.6696	.9369	.9141	.8240	.8281
B	.3967	.2909	.0163	.2174	.2202	.4509	.1170	.5335	.3356
R	.1034	.1538	.3379	.3721	.0649	.8663	.2547	.9093	.8908
A × B	.2989	.4508	.5235	.0103	.4047	.8799	.0425	.9126	.8961
A × R	.2229	.3516	.1234	.3222	.0624	.5031	.7704	.5762	.5184
B × R	.6981	.7195	.5422	.3455	.7674	.5400	.5618	.2693	.2664
A × B × R	.0672	.6961	.0991	.7738	.5991	.2754	.3718	.1570	.1512

*(A) different operators; (B) symptomatic/asymptomatic group; (R) repetitions of one operator.

The EMPI data were statistically processed by means of an analysis of variance by using three factors. These factors represented:

1. A: Interoperator variability. There was no evidence of significant influence from different operators. Compared with one another, they achieved consistent results.
2. B: Comparison of values of the two groups. No significant influences were found when symptomatic and asymptomatic subject data were compared, except for dXL. Because dXL offered a probability factor of $P = .0163$, dXL values differed significantly between both groups. In other words, this single parameter differed significantly between symptomatic and asymptomatic subjects.
3. R: Repetitions of the procedure by one operator. Evaluation of five repeated procedures performed by one operator showed no significant influence owing to repetitions. Consistent values confirm the hypothesis of high reproducibility of the method.

Table 1 offers the probability factors (*P*) for all parameters.

Interactions of all factors were calculated to meet international statistical standards. These combinations were used to detect further significant influences. Positive correlation to statistical significance in the interaction A × B was shown in dZL ($P = .0103$) and dW ($P = .0425$). For all other interactions (A × R, B × R, A × B × R), no significant influence was revealed.

The mean values correspond to the 20 asymptomatic subjects, each of whom provided five values,

Table 2 Intraoperator Mean Values and Standard Deviations for dXL in B

	Asymptomatic group		Symptomatic group	
Operator	Mean	SD	Mean	SD
1	−0.002	0.182	−0.066	0.256
2	−0.016	0.118	−0.099	0.266
3	−0.010	0.165	−0.030	0.225

Table 3 Intraoperator Mean Values and SD for dZL in A × B

	Asymptomatic group		Symptomatic group	
Operator	Mean	SD	Mean	SD
1	0.083	0.348	0.011	0.211
2	0.065	0.199	−0.033	0.201
3	0.009	0.162	0.086	0.219

Table 4 Intraoperator Mean Values and SD for dW in A × B

	Asymptomatic group		Symptomatic group	
Operator	Mean	SD	Mean	SD
1	−0.068	0.311	0.103	0.414
2	−0.029	0.280	0.053	0.387
3	−0.066	0.374	−0.003	0.405

for a total of 100 values for the group. The symptomatic group contained 24 subjects, each of whom provided five repetitions — 120 values per operator.

Discussion

To comply with international statistical standards, $P = .05$ was chosen as the level of significance. This value is very low and critical for measurements in vivo. Significant influence owing to those factors mentioned was observed in three cases only.

The significance of dXL in B ($P = .0163$) may be explained as follows. Mean value and standard deviation differed significantly among all three operators compared with the symptomatic collective. There was evident difference between both groups in left anteroposterior positioning of the condyles. The standard deviation was significantly larger in symptomatic subjects (Table 2).

Table 3 explains the significance of dZL in A × B ($P = .0103$). The distribution of mean values and standard deviations did not follow a single trend that could be definitively related to either subject group. Puzzling distribution did not create correspondence between operator and asymptomatic-symptomatic on the other hand. The constellation of data caused low P values in the interaction.

If all three values of "asymptomatic" were smaller or larger than those of "symptomatic," P would be above .05. If single operators find different values in both groups, then P must be small (eg, operator 1 attains higher values in asymptomatic subjects than in symptomatic ones, but the values attained by operator 2 are reversed).

The significance in dW referring to A × B ($P = .0425$) shows relation analogous to the case before (Table 4).

Most patients have a reflex closure (an engram) determined and guided by occlusion. The proprioceptive reflex must be blocked out to ensure a perfect hinge closure, and this is done by making the record at an increased vertical dimension. Adjustment of a jig helps to break the reflex pattern of closure by training the neuromusculature. The patient must be instructed not to bring the teeth together when the jig is removed.[4,21] Physiologic retrusion was more assured after deprogramming the neuromusculature.[11] No jig was used in this study: deprogramming of proprioception was accomplished by instructing the patient not to achieve tooth contact. The patients stopped at the position next to tooth contact, ie, a judiciously increased vertical dimension that blocked proprioception and allowed reproducible adjustment of hinging motion.

The evaluation of reference position was free from errors caused by materials such as casts, wax, pastes, and their distortion when being removed from the mouth. Zinc oxide-eugenol impression paste required several minutes to harden; it is difficult for a patient to maintain steady muscle contraction for this length of time. Materials for making records must be handled very carefully. The occlusal surfaces of stone casts must be reproduced accurately. Conclusions derived from findings of articulator analysis can only be based upon trends or significant clustering of dots.[20] Opening and closing in terminal hinge axis position is the only movement that may be reproduced at 100% in an articulator.[9] Initial jaw motion takes place at the hinge axis and allows transfer of the patient's jaw relations to an instru-

ment. Reference position is used for occlusal rehabilitation. Appropriate determination of the maxillomandibular relation becomes important in functional analysis and therapy. Therefore, reproducibility of RP implies utmost importance.

The question arose as to how large the area can be in which the hinge axis points of reference position are recorded. Data derived from this study (Figs 1 and 2) indicate that axis points are positioned in an area 0.2 mm in diameter. This finding occurred in approximately 60% of all recordings. It implies very small spatial extension, particularly in a biologic system.

Muscle action causes different condylar positions to be explained by the magnitude of muscle contraction. Heavy muscular contraction and anterior stop seated the condyles most superiorly. Light muscular contraction and use of an anterior jig resulted in a condylar position inferior to the above record by 0.5 mm.[20] Not only muscles play a role in positioning the condyles; operators may influence mandibular movement in establishing reference position. This study indicates that interoperator variability is not significant. Basic operator's influence is encountered with every patient but can be minimized in symptomatic and asymptomatic subjects.

The term *centric in point* cannot be maintained in a biologic system. It has to be relativized and adapted to possibilities of biologic tissues. Therefore, the term, *reference position area* makes more sense. Celenza[24] described an area in which all centric relation records, established by different techniques, were located. Eganhouse (personal communication, 1990) suggested the term *area* for condylar reference positions in general. Even a single method should follow this hypothesis with regard to Celenza's statement.

Conclusion

Diagnostic, restorative, and therapeutic procedures require a reliable reference position. The applied method displayed data at 0.01 mm. It was free from errors caused by the use of casts and wax or plaster registrations.

No significant influence could be detected in repeated establishment of condylar reference position in symptomatic and asymptomatic subjects. Different operators did not significantly influence values. Reproducibility in both the symptomatic and asymptomatic groups was high. These findings elaborated fundamental characters of the investigated method. Data showed only minimal dispersion for a biologic system. The majority of reproduced condylar positions were located within 0.2 mm of each other, indicating a physiologic area of reference position.

Chin-point guidance incorporates a clinically applicable method that is easy to use and offers exact establishment of a reference point.

References

1. Bauer A, Gutowski A. Gnathologie—Einführung in Theorie und Praxis. Berlin: Quintessenz, 1975.
2. McCollum BB, Stuart CE. A research project. South Pasadena, Calif: Scientific Press, 1955.
3. Beard CC, Clayton JA. Studies on the validity of the terminal hinge axis. J Prosthet Dent 1981:46,185–191.
4. Lucia VO. A technique for recording centric relation. J Prosthet Dent 1964;14:492–505.
5. Long JH. Locating centric relation with a leaf gauge. J Prosthet Dent 1973;29:608–610.
6. Phillips RW. Report of Committee on Scientific Investigation of the American Academy of Restorative Dentistry. J Prosthet Dent 1986;55:736–772.
7. Hupfauf L (ed). Funktionsstörungen des Kauorgans. Praxis der Zahnheilkunde 8. 2. München: Aufl. Urban & Schwarzenberg, 1989.
8. Slavicek R. Functions and dysfunctions of the masticatory organ. Diagnosis and therapy. Presented to Vienna Group IV, 28 Jul to 5 Aug, 1990.
9. Guichet NF. Innere Kiefergelenkstörungen und die Bedeutung einer richtigen Diagnose. Phillip J 1985; 6.
10. Gilboe DB. Centric relation as the treatment position. J Prosthet Dent 1983;50:685–689.
11. Wood GN. Centric relation and the treatment position in rehabilitating occlusions: A physiologic approach. Part 1: Developing an optimum mandibular posture. J Prosthet Dent 1988;59:647–651.
12. Fox SS. The significance of errors in hinge axis location. J Am Dent Assoc 1967;74:1268–1272.
13. Körber E, Landt H. Untersuchungen über die. Reproduzierbarkeit von Registrierungen. Dtsch Zahnärztl Z 1979;34:202.
14. Bosman AE. Hinge Axis Determination of the Mandible [thesis]. The Netherlands, University of Utrecht, 1974.
15. Sindledecker L. Effect of different centric relation registrations on the pantographic representation of centric relation. J Prosthet Dent 1981;46:271–279.
16. Shafagh I, Amirloo R. Replicability of chinpoint guidance and anterior programmer for recording centric relation. J Prosthet Dent 1979;42:402–404.
17. Rosner D, Goldberg GF. Condylar retruded contact position and intercuspal position correlation in dentulous patients. Part 1: Three-dimensional analysis of condylar registrations. J Prosthet Dent 1986;56:230–237.
18. Schubert R. Zur Frage der Reproduzierbarkeit der terminalen Scharnierachsenposition. Dtsch Zahnärztl Z 1985;40:96–99.
19. Seiler F, Hupfauf L. Untersuchungen über die Reproduzierbarkeit der terminalen Scharnierachsenpunkte. Dtsch Zahnärztl Z 1973;28:775.
20. Lundeen HC. Centric relation records: The effects of muscle action. J Prosthet Dent 1974;31:244–251.

21. Kantor ME, Silverman SI, Garfinkel L. Centric relation recording techniques — a comparative investigation. J Prosthet Dent 1972;28:593–600.
22. Gerber A. Kiefergelenk und Zahnokklusion. Dtsch Zahnäztl Z 1971;26:119–141.
23. Slavicek R. Clinical and instrumental functional analysis for diagnosis and treatment planning. Part 7: Computer-aided axiography. J Clin Orthod 1988;22:776–787.
24. Celenza FV. The centric position: Replacement and character. J Prosthet Dent 1973;30:591-598.

Resumen

La reproducibilidad de la posición condilar de referencia

La reproducibilidad de la posición condilar de referencia fue examinada en el punto del movimiento de bisagra no forzado de la mandíbula en sujetos con síntomas de la articulación temporomandibular (ATM), y en personas asintomáticas. El procedimiento fue efectuado por tres operadores diferentes, para detectar la variabilidad entre los mismos. Cada operador ejecutó cinco registros utilizando axografía computarizada en el punto electrónico indicador de la posición mandibular. La información fue evaluada por medio de un análisis de varianza utilizando tres factores: (1) repeticiones de un solo operador, (2) la información de los pacientes sintomáticos y asintomáticos, y (3) los valores de los diferentes operadores. Los resultados demonstraron que ninguno de estos factores tenía una influencia significativa en la reproducibilidad de la posición condilar de referencia. Se obtuvo una gran reproducibilidad tanto en el grupo sintomático como en el asintomático. Los valores registrados permanencieron entre ± 0.2 mm en el 24.3% de los registros.

Zusammenfassung

Die Reproduzierbarkeit der kondylären Referenzposition

Die Reproduzierbarkeit der kondylären Referenzposition wurde bei unforcierter Scharnierachsbewegung der Mandibula in Patienten mit TMJ Symptomen und in asymptomatischen Probanden untersucht. Drei verschiedene Behandler führten die Untersuchung durch, um auch einen eventuellen Einfluß von Seiten des Behandlers festzusteller. Jeder Behandler wiederholte den Vorgang fünf mal Die Registrierung erfolgte im elektronischen Mandibularpositionsindikator (EMPI) im Rahmen der elektronischen Axiographie. Die Meßwerte wurden der trifaktoriellen Varianzanalyse unterworfen, um somit eine Abhängingkeit von den drei Faktoren: (1) Behandler, (2) Symptomatische beziehungsweise asymptomatische Gruppe und (3) Wiederholungen — nachzuweisen. Die Ergebnisse zeigten, daß keiner der Faktoren einen signifikanten Einfluß auf die Reproduzierbarkeit der kondylären Referenzposition ausübte. Hohe Reproduzierbarkeit wurde sowohl im der symptomatischen als auch in der asymptomatischen Gruppe erlangt. Gemessene Werte blieben innerhalb von ±0.1 mm in 58.6% und innerhalb ±0.2 mm in 24.3% der Registrierungen.