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The lateral leeway in the habitual intercuspation: experimental studies and literature review

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SUMMARY The habitual intercuspation is used ubiquitous for manufacturing small dental restorations. However, a little is known on its precision. The aim of the present study was therefore to investigate the unambiguity and accuracy of the habitual occlusion in mounted plaster casts from fully dentate persons. Eighty-one fully dentate volunteers, 36 women and 45 men aged 26.8 ± 6.2 years (18–55 years), with minor fillings and no signs or symptoms of TMD took part in the experiments. Silicone impressions were taken, poured with stone plaster and the obtained casts mounted into Dentatus ARL® – articulators using an individual face bow transfer. Subsequently, the models were transferred to a custom-made measuring articulator where the lateral leeway and the accuracy of the hand-held habitual intercuspation were quantified in the condylar area. Measurements were repeated seven times with the upper cast pushed either to the maximum right or the maximum left intercuspation.

The hand-held habitual intercuspation of upper and lower cast proved ambiguous in 57% of pairs of casts. The average lateral leeway of the habitual intercuspation in the condylar area was 0.10 ± 0.05 mm (0–0.51 mm; median 0.07 mm) between the maximum right and left occlusal positions. The average accuracy of three repeated measurements was 0.22 ± 0.09 mm (0.02–1.17 mm; median 0.16 mm). Natural occlusal surfaces in a full dentition do not guarantee an unambiguous habitual intercuspation of the plaster casts. The described leeway and technical limits might be possible causes for occlusal adjustments that are sometimes necessary when inserting restorations manufactured in habitual intercuspation.

KEYWORDS: habitual intercuspation, maximum intercuspation, habitual occlusion, lateral leeway, accuracy, bite registration, mandibular position

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Introduction

The seemingly good accuracy at which the clinical habitual occlusion can be transferred to the articulator requires only minimal clinical adjustments and thus reduces chair-side time at insertion of restorative dental work. The number and distribution of occlusal contacts is known to be smaller than previously assumed (1–5). A literature review is listed in Tables 1–4.

Therefore, the clinically important question arises whether casts with a seemingly ‘stable’ habitual occlusion are more precisely mounted with or without

registration. If registrations are used, A-Silicone materials or polyether products proved more precise than wax or resins wafers (6–17). Inaccuracies might also be attributed to the impression technique and the meticulousness of its execution (11–13).

The accuracy of the transfer of a purely tooth supported habitual intercuspation into the articulator may further be determined by a ‘lateral leeway’ when hand-holding the plaster casts in occlusion. Comprehensive electronic and hand search until March 2006 revealed that such lateral leeway has to our knowledge only once been described in the literature (18).

Table 1. Literature review on the number of occlusal contacts in natural dentitions (intraoral evaluation by occlusal or Shimstock® foil)

Authors	<i>n</i>	Number per type of tooth							
		Number of occlusal contacts per jaw		Front teeth		Premolars		Molars	
		Light closing	Clenching	Light closing	Clenching	Light closing	Clenching	Light closing	Clenching
Riise (31)									
Young adults	30	10.6 ± 4.2	18.0 ± 4.8						
Elderly adults	61	7.4 ± 4.6	18.3 ± 6.4						
Riise <i>et al.</i> (32)									
Young adults	30			3	4.8	3.2	5.2	4	8.4
Elderly adults	61			1.2	4.2	3.2	6	3.2	8
Reiber <i>et al.</i> (33)	49	17	24 (15–36)						
McDevitt <i>et al.</i> (34)	38	11.5 ± 4.2 (9–13)		2.3 ± 2.2		3.6 ± 2.1		5.7 ± 3.2	
DeLong <i>et al.</i> (35)	10	14 ± 6							
Ferrario <i>et al.</i> (36)	23	10.2		1.9		4.2		4.1	

Table 2. Literature review on the number of occlusal contacts in dentate subjects. Measurements were taken from registrations.

Authors	<i>n</i>	Number per jaw	Number per type of tooth			Method
			Front teeth	Premolars	Molars	
McNamara <i>et al.</i> (1974) [cited from (31)]	15	19.7				Occlusal wax, clenching
Ehrlich & Taicher (37)	29			9.1	24.7	Occlusal wax light box
Durbin & Sadowsky (38)						
After orthodontic tx	38	10.1 ± 3.4	1.4 ± 1.7	8.7 ± 3.2		Registration with Polyether
After orthodontic retention tx	38	11.5 ± 3.4	1.4 ± 1.7	10.1 ± 3.2		
Woda <i>et al.</i> (39)	22	14.8	3.1 in lower jaw 3.9 in upper jaw	4.3 in lower jaw 4.5 in upper jaw	7.4 in lower jaw 6.5 in upper jaw	Registration with silicone
Razdolsky (40)						
after orthodontic tx	40	19.1	2.9	4.1	12.1	Registration with polyether
21 months of retention	40	28.2	3.5	5.8	18.9	whilst clenching
Korioth (41)	45	14.8 (4–29) (except for front teeth)				Registration with alginate (analysis by light transparency)
Sullivan <i>et al.</i> (42)						
Check-up	18	16.8	3.3	13.5		Registration with silicone
After orthodontic tx	19	15.0	2.9	12.1		
Ciancaglini <i>et al.</i> (43)						
Healthy subjects	25	37 ± 6	5.8 ± 5.7	8.9 ± 12	16.8 ± 29.5	Occlusal wax
CMD patients	25	38 ± 6	6.6 ± 5.8	8.5 ± 12.5	17.2 ± 28.8	

The aim of the present study was therefore to investigate the lateral leeway and accuracy of the hand-held habitual intercuspation in plaster casts from fully dentate subjects. Measurements were taken in the condylar area which allows the comparison with previously reported data on the accuracy of the centric condylar position (19).

Material and method

Patient sample

Thirty-six female and 45 male volunteers with an average age of 26.8 ± 6.2 years (18–55 years) were recruited from the students and staff of the Dental

Table 3. Literature review on the number of occlusal contacts in dentate subjects. Measurements were taken by Photocclusion or T-Scan

Authors	<i>n</i>	Number per jaw	Number per type of tooth			Method
			Front teeth	Premolars	Molars	
Athanasίου <i>et al.</i> (44)	20	23.8 ± 4.7 (15–34)				Photocclusion
Gianniri <i>et al.</i> (45)						
Healthy subjects	28	21 ± 2	4 ± 1	17 ± 1		Photocclusion
CMD patients	28	18 ± 3	3 ± 2	14 ± 2		
Cartagena <i>et al.</i> (46)						
Force-method	31	12.5 ± 2.7	2.1 ± 1.6	10.4 ± 3.7		T-Scan
Time-method	31	16.8 ± 3.6	4.5 ± 2.2	12.4 ± 5.0		
Garcia <i>et al.</i> (47) + Sequeros <i>et al.</i> (48)	18	19.4 ± 6.1 (8–31)	4.1 ± 1.0	4.4 ± 1.1	10.9 ± 2.2	T-Scan

Table 4. Literature review on the number of occlusal contacts in dentate subjects. Measurements were taken from the articulator

Authors	<i>n</i>	Number occlusal contacts per jaw	Method
Aoki <i>et al.</i> (1970) [after (31)]	20	9.6 (3–14)	Unknown
Ziebert & Donegan (49)			
Before orthodontic tx	10	12.4	Shimstock®-foil registration with silicone
After orthodontic tx	10	13.3	
2 weeks after occlusal adjustment	10	14.6	
Riise (31)	61	Light closing: 7.4 ± 4.6	Occlusal foil
		Articulator: 6.4 ± 3.4	
	35	Clenching: 17.8 ± 6.4	
		Occlusion adjusted in articulator: 15.8 ± 5.2	
Reiber & Trbola (14) no registration	49	18	KKD-holder, KKD registration paste
With registration	49	13	

School of the University of Bonn. They had a full dentition including third molars and no signs of temporo-mandibular dysfunction. The volunteers had full dentitions, the average number of occlusal fillings or individual crowns was 7.4 ± 5.9 (from 0 to 26); 11 subjects had no restorations at all. Fifty-four subjects had undergone orthodontic treatment, none of them had currently been under treatment. Prior to the experiments informed consent was obtained.

Measuring articulator

Spatial differences in the condylar area were evaluated by means of a custom-made measuring articulator, a Kondymeter®-like device based on the Dentatus ARL® Articulator (20). The detached upper part of the device was equipped with three electronical gauges (Mitutoyo* IDC 1012 B) in both condylar areas. They recorded the spatial position of the upper

cast in three dimensions with an accuracy below 0.01 mm (21).

Protocol

Experiments were carried out by four different operators (L, *n* = 19; N, *n* = 18; S, *n* = 19; U, *n* = 25). Firstly impressions were taken of the upper and lower jaw by means of Schreinemakers[†] impression trays and medium viscosity silicone (Panaseal® K[‡]). Stone plaster casts were poured and checked for occlusal plaster pearls.[§] A fifth independent operator analysed if upper and lower casts could be assembled in habitual intercuspation with or without rocking. Therefore, upper and lower plaster casts were loaded alternating on the second molar and the contralateral canine using thumbs and middle fingers. Rocking movements were only analysed in this

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[†]Clan Dental Products, Maarheeze, the Netherlands.

[‡]Kettenbach GmbH & Co. KG, Eschenburg, Germany.

[§]Fuji Rock® plaster; GC Europe N.V., Head Office, Leuven, Belgium.



Fig. 1. Measuring device with relocatable load of 10 N on the upper part which records the habitual occlusion in the condylar area in three dimensions.

diagonal manner, neither unilaterally nor purely anterior or posterior. Further rotation in the habitual intercuspation was verified by turning the assembled upper and lower plaster casts in occlusion.

In a second session the individual hinge axes were determined using the SAM Axiograph® No. 2[¶] and marked on the skin for a face-bow transfer (Dentatus AEK®**). The casts were then mounted into freshly adjusted Dentatus ARL®-articulators which were equipped with an Adesso® Magnet-Quick-Split-System^{††} to allow an accurate transfer into the measuring articulator (19, 21). For the evaluation of the lateral leeway the upper casts were positioned in habitual occlusion on the corresponding lower casts under central load from the index finger which was then replaced by a 10 N weight on the upper part of the measuring device (Fig. 1). Each set of casts was assembled twice in habitual occlusion, with 'felt resistance' on the right (A) and on the left side (B) under continuous vertical load. The casts were removed and replaced in the measuring articulator before each of the seven repetitions of the A and B measurements.

Data analysis

The eight measurements in the A and B positions were used to calculate both, the lateral leeway and the

accuracy when assembling the casts in habitual intercuspation. The lateral leeway was calculated as median and mean value of the eight differences between the A and B values:

1. absolute difference $|1A-1B| = D1$,
2. absolute difference $|2A-2B| = D2$,
3. absolute difference $|3A-3B| = D3$,
and so on until
4. absolute difference $|8A-8B| = D8$.

Subsequently the average differences were calculated as follows:

$$[D1 + D2 + D3 + D4 + D5 + D6 + D7 + D8]/8 = \text{lateral leeway.}$$

The accuracy was calculated as median and mean value of the averaged A and B values from the last three of the eight performed recordings. At first the average values of A and B values were calculated.

1. $(6A + 6B)/2 = C1$,
2. $(7A + 7B)/2 = C2$,
3. $(8A + 8B)/2 = C3$.

These values were used to calculate the average distance between these condylar positions.

$$[|(C1 - C2)| + |(C2 - C3)| + |(C3 - C1)|]/3 = \text{accuracy.}$$

The spatial displacement in the condylar area was calculated from the three individual room directions as $\sqrt{\text{sagittal}^2 + \text{vertikal}^2 + \text{transversal}^2}$.

Statistical analysis was performed using custom made software (E.F.). Differences were considered significant at or below the 5% level. Differences between operators and the subject's gender, number of fillings and previous orthodontic treatment were analysed by means of the Wilcoxon U-test and the H-test adapted from Kruskal-Wallis(22).

Results

In 57% of the pairs of plaster casts a rocking movement of varying extent could be produced in hand-held habitual intercuspation. Rotational movements were equally possible in 57% of the cases. Despite a considerable coincidence, both movements occurred individually in some cases.

Lateral leeway

The median values of the lateral leeway in habitual occlusion were in the right condylar area 0.04 mm in the sagittal as well as 0.03 mm in the vertical and transversal plane. In the left condylar area, the median

[¶]SAM Präzisionstechnik GmbH, Gauting, Germany.

^{**}Dentatus AEK® and Dentatus ARL®; Dentatus AB, Hägersten, Sweden.

^{††}Mälzer Dental, Wunstorf, Germany.

lateral leeway was 0.05 mm in the sagittal and 0.03 mm in the vertical and transversal plane. The median spatial displacement in the condylar area between the A and B positions of the habitual occlusion was calculated as 0.07 mm (mean value 0.10 ± 0.05 ; 0–0.51 mm) (Table 5).

Accuracy

The accuracy in the right condylar area showed median values in the sagittal plane of 0.1 mm and in the vertical and transversal plane of 0.08 and 0.07 mm respectively. In the left condylar area, the accuracy had a median value of 0.09 mm in the sagittal, 0.06 mm in the vertical and 0.07 mm in the transversal plane. From these data a spatial displacement of 0.16 mm (mean 0.22 ± 0.09 ; 0.02–1.17 mm) was calculated (Table 6).

Differences in the lateral leeway of the habitual occlusion or in the accuracy of assembling the plaster casts were not verified between the individual operators as the results and their variation were in a similar

range. The results proved likewise independent from the subjects' gender, their number of fillings or a previous orthodontic treatment.

Discussion

Critique of method

The experimental design included all clinical parameters that are relevant for a jaw registration. These include biological parameters such as tooth mobility, mandibular distortion at mouth opening and different operators as well as biotechnical parameters like impression trays, impression material, delays of procedures, type of plaster as well as the mounting technique. Repeated measurements by several operators would have allowed to calculate kappa-values for the inter-operator reliability. Further some features of the measuring device itself might have influenced the results.

Although it is likely that an instable habitual intercuspation leads to an instability of the plaster casts, such

Table 5. Lateral leeway of plaster casts in habitual occlusion (81 subjects, 2×8 independent measurements per pair of casts)

<i>n</i> = 81 subjects	Right side			Left side			Spatial displacement	
	Sagittal (mm)	Vertical (mm)	Transversal (mm)	Sagittal (mm)	Vertical (mm)	Transversal (mm)	Right side (mm)	Left side (mm)
Median	0.04	0.03	0.03	0.05	0.03	0.03	0.07	0.07
Mean value	0.06	0.04	0.04	0.07	0.05	0.04	0.09	0.11
SD	± 0.06	± 0.04	± 0.06	± 0.07	± 0.05	± 0.04	± 0.06	± 0.04
90% Quantil	0.10	0.09	0.08	0.14	0.10	0.08	0.17	0.22
Maximum 1	0.35	0.19	0.38	0.40	0.32	0.29	0.49	0.51
Maximum 2	0.29	0.14	0.29	0.33	0.23	0.21	0.43	0.49
Maximum 3	0.21	0.12	0.14	0.32	0.21	0.14	0.41	0.34
Minimum	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01

Table 6. Accuracy of habitual occlusion in the articulator (81 subjects, 2×3 independent measurements per pair of casts)

<i>n</i> = 81 subjects	Right side			Left side			Spatial displacement	
	Sagittal (mm)	Vertical (mm)	Transversal (mm)	Sagittal (mm)	Vertical (mm)	Transversal (mm)	Right side (mm)	Left side (mm)
Median	0.10	0.08	0.07	0.09	0.06	0.07	0.16	0.15
Mean value	0.13	0.10	0.09	0.14	0.11	0.08	0.21	0.22
SD	± 0.13	± 0.09	± 0.10	± 0.16	± 0.13	± 0.08	± 0.10	± 0.08
90% Quantil	0.22	0.22	0.16	0.27	0.21	0.16	0.44	0.53
Maximum 1	0.80	0.46	0.69	0.93	0.72	0.42	0.98	1.17
Maximum 2	0.68	0.42	0.40	0.65	0.60	0.40	0.90	0.77
Maximum 3	0.43	0.37	0.32	0.61	0.52	0.31	0.61	0.74
Minimum	0.01	0.01	0.00	0.01	0.01	0.00	0.04	0.02

conclusion cannot be drawn from the present experiments, because the intraoral contacts have not been verified with Shimstock®-foil. In retrospect, this would have been an interesting complement to the study. A further interesting finding would have been if a large lateral leeway corresponded to a flat occlusal relief. However, predicting parameters for an instable habitual occlusion of the plaster casts, like for example the number of occlusal restorations, could not be confirmed.

The use of a face bow in reference to the Frankfort plane lead in several cases to an anterior inclination of the occlusal plane in the articulator. This rendered not only the mounting of the upper cast difficult, it might have also influenced the positioning of the relocatable 10 N weight on the upper part of the articulator which stabilized the hand-held intercuspation during the A and B measurements.

Nevertheless the results from this study have a sound foundation: lateral leeway values were averaged from eight repeated measurements per pair of plaster casts and each reading was taken after re-mounting the casts into the Adesso®-Split-System and re-assembly of the habitual intercuspation. The sample size of 81 subjects allows for extrapolation of the findings.

Lateral leeway and accuracy of habitual intercuspation

The differences in calculating the lateral leeway or the accuracy are mathematical, whereas the lateral leeway indicates the 'occlusal stability' once the casts are hand-held in habitual intercuspation. This leeway is likely to represent the biological situation once methodological bias is subtracted.

The accuracy was calculated exactly like in a previous study on the same group of patients to allow directly for comparison (19). The last three of the eight recordings were chosen because they were closely time-related to the calibration of measuring device.

The difficulties of transferring the habitual intercuspation into the articulator have been known for a long-time and have been discussed in the literature within the context of bite registration and impression techniques (23, 24) (Tables 1–4).

Although it is the first choice for dental restorations the accuracy of the habitual intercuspation in the articulator has to our knowledge only once been investigated by an Austrian research group (18). Twenty casts of fully dentate subjects were assembled in maximum intercuspation by three dentists and subsequently

measured at least five times in an electronic Kondymer. The results in the three planes were sagittal: 0.42 ± 0.22 mm (0.12–0.69 mm), vertical: 0.56 ± 0.31 mm (0.21–1.11 mm), frontal: 0.41 ± 0.22 mm (0.16–0.78 mm) with differences between the three dentists. Although the method of calculating the accuracy was not specified it can be assumed that it was calculated like the accuracy in the present study, thus it has to be compared with the results from Table 6. The substantially lower accuracy of the handheld occlusion reported in the Austrian study may be caused either by a smaller sample size or/and the number of fillings or/and different mathematic analyses.

The habitual intercuspation has been measured clinically using the electronic SAS® registration system with paraocclusal fixation of the lower face bow. The reported accuracy was approximately 0.04 mm ($n = 49$) in asymptomatic and 0.047 mm in CMD subjects ($n = 74$) (25). Although such small differences are difficult to measure in a clinical setting they correspond well to the bench values of 0.07 mm for the lateral leeway and 0.16 mm for the accuracy evaluated in the present study.

Interpretation of results

Despite numerous attempts the scientific definition of a 'healthy habitual intercuspation' remains difficult. However, the dental practitioner needs to know if the existing habitual intercuspation could be used for restorative works. In the absence of CMD symptoms the distance between centric relation and habitual intercuspation as well as a symmetrical occlusion with a sufficient number of antagonistic tooth contacts may play a role in this decision (26).

Using the same sample of volunteers, we previously reported for the accuracy of the centric condylar position a median value of 0.32 mm (mean 0.4 ± 0.1 ; 0.01–2.13 mm) (19). Thus, the habitual intercuspation is twice as accurate (median 0.16 mm; mean 0.20 ± 0.1 ; 0.02–1.17 mm). Clinically this might be expected as the habitual intercuspation is determined by dental enamel, whereas the centric condylar position is determined by less rigid tissues like bone, ligaments and cartilage. In addition to its acknowledged biological advantages the habitual intercuspation is also easier to use for restorative works, especially concerning the verification of premature contacts given the adjacent natural dentition.

The interocclusal tactile sensibility of natural teeth of 0.02 mm is in a similar range to the reported accuracy of the habitual intercuspation (27–29). Thus ideally no occlusal adjustments should be necessary when inserting restorative work made in habitual intercuspation. It is not surprising that a registration is more precise in patients with a natural dentition than in complete denture wearers where an accuracy of 0.56 ± 0.35 mm was found for the central bearing point technique and 0.72 ± 0.43 mm for a manually guided check-bite registration (30). In addition to the age-related loosening of the TMJ ligaments these differences might also be attributed to the resiliency of the denture bearing tissues.

Conclusions and practical recommendations

The results of the present study show that in 57% of patients the plaster models obtained by an open mouth impression technique cannot be assembled in an unambiguous occlusal position. Therefore, we suggest the following clinical steps for reconstructions in habitual occlusion:

- (1) Take interocclusal registration in habitual intercuspation using A-silicone or polyether materials and trim any excess.
- (2) Check in the laboratory if plaster casts can be assembled unambiguously and if yes, discard registration.
- (3) Perform occlusal adjustments using a scalpel on the plaster models until antagonistic contacts correspond to the clinical situation (verify using Shimstock®-foil and an 'occlusal protocol').

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