Measurement of the influence of the degree of applied force on the resulting retruded border position of the mandible established that the position varied significantly in all three dimensions according to variation in the amount of force. On the basis of the analysis of the t-test (sampling error of 8%), it can be concluded that increasing the manipulative force on the mandible in the general male population will result in a significant three-dimensional increase in the distance from centric occlusion to centric relation. The measurement data document the variability of the retruded centric relation position according to the different amounts of applied retrusive force. The data question the choice of the retruded border position on the basis of its clinical repetitiveness.

Effect of variation in manipulative force on the repetitiveness of centric relation registration: a computer-based study

Bernard Jankelson, DMD
Fray Adib, BSEE

The maxillomandibular relationship between centric occlusion and centric relation has been a controversial subject. The *Glossary of Prosthodontic Terms* defines centric relation as "the most retruded physiological relation of the mandible to the maxilla when the condyles are in the most posterior unstrained position in the glenoid fossae from which lateral movement can be made, at any degree of jaw separation.[1] Centric occlusion is defined as the existing position of maximum intercuspation. The rationale for positioning intercuspation of the dentition (centric occlusion) at the retruded border position of the mandible has been the widespread reliance on the repetitiveness[2-4] with which the position can be registered.

Because of the many variables inherent in current registration techniques, precise quantitative data are needed to assess the reality of repetitiveness. One of several questions that arises is whether and to what degree variations in the amount of manipulated force affect the repetitiveness of centric relation. Procedures advocated for the accomplishment of mandibular retrusion are commonly described in quantitatively vague empirical terms such as "jiggling" the mandible, "light centric relation closure," and "firmly seat the condyles in their most posterior positions in the glenoid fossae." The specific question, "how much force, expressed in pounds, is applied to retrude the mandible?," is not quantitatively answered by such descriptions.

Several studies have been conducted to determine the relationship between centric occlusion and centric relation and various methods were used to measure the three-dimensional distance between centric relation and centric occlusion. The check bite method,[3,5,6] graphic method,[7-9] and electronic method[10-13] have been used in these studies.

Few studies have analyzed the effect of quantitative manipulation force on the position of centric relation. Frederick and others[14] studied the applied force necessary to retrude the mandible to the centric relation position. No studies have been conducted that lead to measurements of three-dimensional movements of the mandible as a function of a specific applied force.

This report is limited specifically to the occurrence of three-dimensional quantitative changes in centric relation positioning of the mandible in response to various degrees of applied manipulative force. Other possible variables, such as the effect of existing muscle tension and the individual subject's muscle resistance to the application of external pressure, are recognized but are not within the scope of this report.

Methods and materials

For the purpose of this study, a gnathoretrusive positioner (Fig 1) was designed to provide measurement of the amount of force being applied to retrude the subject's mandible. The device consists of a molded cup that comfortably fits the chin, a spring-loaded rod and sleeve, a poundage indicator, and pistol grip. The

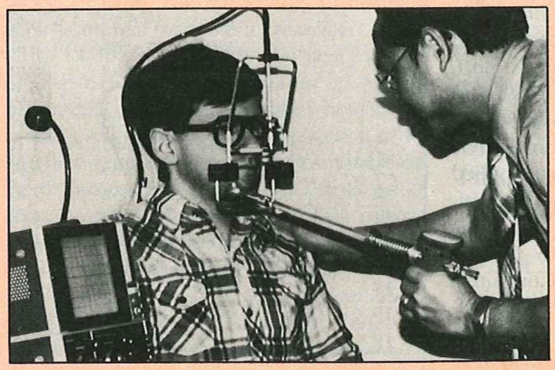

Fig 1 ■ Application of gnathoretrusive positioner.

force applied by the operator acts on the spring that is calibrated to 5, 10, and 15 lb of pressure.

The data presented in this report were derived from 16 asymptomatic males ranging in age from 20 to 47 years. The subjects were volunteers, selected randomly from the general population, who had no TMJ pain, no muscle pain, and no joint noise symptoms and, thus, were categorized as asymptomatic. The subjects did not have an awareness of the study's intent. [An equal number of female subjects initially were included in this study; however, these subjects had considerable discomfort when the application of force to the mandible was increased beyond 5 lb. Consequently, this group was eliminated from this study. This lesser toleration of increased pressure suggests that there could be a genetic difference between the genders that might cause the greater incidence of musculoskeletal disturbance of the head and neck (TMJ) in females.]

Movement of the mandible from centric occlusion to centric relation was electronically tracked and recorded on the Model K5AR Mandibular Kinesiograph (MKG).[11] Calibrated against test instrumentation,[12] the worst measurement error value resulting from the instrumentation for the dimensional parameters of this investigation was less than 5% of measured value.

To investigate precisely the biophysical and physiological aspects of mandibular movement and its relationship to the centric relation position, a computer data collection system was developed. All related information for this study was categorized and stored.

The centric occlusion-center relation data were collected in the following manner. Because a previous investigation[15] established that mastication and deglutition occur at the position of centric occlusion, the subject was asked to tap lightly several times into occlusion of the posterior teeth to ensure closure into a stable centric occlusion. The operator then applied the positioner to the chin. The subject was instructed to keep the teeth lightly together as the mandible was being retruded with 5 lb of applied force. The operator avoided any introduction of laterally directed force while retruding the mandible. With rest intervals of 5 minutes, subsequent forces of 10 and the 15 lb were applied, respectively, using the same procedure. Every subject was subjected to 5-, 10-, and 15-lb forces in the same order. The tracings, magnified to a gain of 12 times, were recorded and stored on the Kinesiograph screen and photographed to obtain a permanent record (Fig 2).

A study of the repeatability of centric relation, as a result of the application of gnathoretrusive force on the same subject by the same operator, was conducted on three male subjects, randomly selected from the study population. The operator consecutively applied 5-, 10-, and 15-lb retrusive forces in three trials with 10-minute intervals between the trials. Centric relation positions corresponding to the three trials were recorded on the Kinesiograph and photographed. Variations from the average centric relation position determined by the three trials for the anteroposterior, vertical, and lateral directions were calculated. The maximum variation from the mean of trials in any direction was 22% for subject no. 1, 24% for subject no. 2, and 11% for subject no. 3. The minimum variation was 4% for subject no. 1, 5% for subject no. 2, and 1% for subject no. 3. The typical variation was 11% for subject no. 1, 10% for subject no. 2, and 4% for subject no. 3. The typical error resulting from experimental variabilities for the three subjects was approximately 8% of the measured data.

A study of the variability of centric relation attributable to operator difference was conducted on five of the 16 subjects by two different operators. The maximum variability between operators in the vertical, anteroposterior, and lateral component of the centric relation distance from centric occlusion was 9% of the distance with typical variability of 6%. Therefore, the maximum clinical error in the measurement of centric relation position, because of the variability of operators, did not exceed 9%. The maximum total measurement error resulting from clinical error (9%) and instrumentation error (5%) was less than 14%. The typical measurement error, however, was less than 10%.

A high resolution digitizer was used as part of the computer system to digitize the data that were then stored in the computer's memory. Thus, all parameters associated with the tracing were entered into the data bank for future recall and analysis. The results of the analysis were plotted.

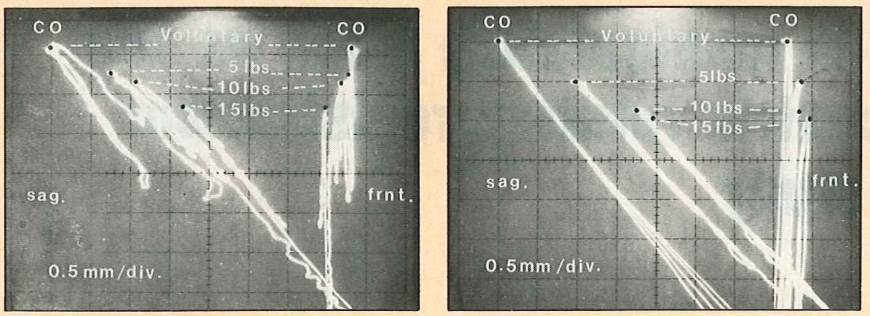

Fig 2, left and right ■ Two cases showing the effect of force on the position of centric occlusion.

Results

Presentation of data

Representative (typical) tracings for two typical subjects are shown in Figure 2. Table 1 presents the change in the position of centric relation in the vertical, anteroposterior, and lateral direction when subjected to 5, 10, and 15 lb, respectively, of gnathoretrusive force. The statistical parameters associated with the results of Table 1 are shown in Table 2. Standard deviation/mean that correlates to the randomness of centric relation and centric occlusion retrusive distance values in each direction is also tabulated in Table 2. Figures 3 and 4 represent the bar graph plots of the statistical data from Table 2.

Table 1 ■ The distance from the centric occlusion to the centric relation in millimeters as a function of force in pounds.

Subject no.	Anteroposterior direction (lb)			Vertical direction (lb)			Lateral direction (lb)		
	5	10	15	5	10	15	5	10	15
1	0.55	0.73	0.91	0.72	0.92	1.42	0.19	0.31	0.15
2	0.97	1.75	1.96	0.51	0.87	0.96	0.20	0.19	0.29
3	0.35	0.57	0.65	0.24	0.43	0.56	0.30	0.45	0.56
4	0.52	0.63	0.65	0.65	0.73	0.73	0.20	0.33	0.33
5	0.71	0.80	0.88	0.46	0.52	0.63	0.91	1.05	1.19
6	0.29	0.47	0.67	0.45	0.75	1.06	0.04	0.08	0.13
7	0.67	0.93	1.03	1.38	1.86	2.06	0.09	0.09	0.09
8	1.34	1.52	1.72	0.73	0.82	0.88	0.21	0.19	0.19
9	0.64	0.85	0.92	0.22	0.30	0.33	0.00	0.02	0.04
10	0.51	0.82	1.07	0.19	0.46	0.66	0.06	0.14	0.21
11	0.80	1.02	1.06	0.45	0.45	0.41	0.07	0.22	0.30
12	0.74	1.06	1.68	0.32	0.42	0.74	0.03	0.11	0.31
13	1.09	1.55	1.94	1.37	1.75	2.04	0.16	0.20	0.17
14	0.12	0.34	0.45	0.05	0.11	0.12	0.06	0.12	0.11
15	1.94	2.18	2.27	1.40	1.30	0.96	0.11	0.17	0.15
16	0.16	0.64	0.69	0.07	0.62	0.81	0.03	0.26	0.25

Table 2 ■ The statistical summary of the results.

	Anteroposterior direction (lb)			Vertical direction (lb)			Lateral direction (lb)		
Measurements	5	10	15	5	10	15	5	10	15
Mean (mm)	0.71	0.99	1.16	0.58	0.77	0.90	0.17	0.25	0.28
SD (mm)	0.45	0.49	0.55	0.43	0.48	0.53	0.21	0.23	0.26
SD/mean	0.63	0.50	0.47	0.76	0.62	0.58	1.26	0.95	0.94

Table 3 and Table 4 respectively display the correlation coefficients r and the t ratios.

To determine whether the variation in manipulative forces of 5, 10, and 15 lb resulted in a significant change in the position of centric relation, a correlation analysis and a standard t-test were performed on the experimental data listed in Table 1.

Correlation analysis

For the correlation analysis, the correlation coefficients or r between pairs of measurement data resulting from the application of 5 versus 10 lb, 5 versus 15 lb, and 10 versus 15 lb were calculated in the anteroposterior, vertical, and lateral directions. The correlation coefficients of r listed in Table 3 indicate a strong positive correlation between pairs of measurements with any variation of force in all directions (anteroposterior, vertical, and lateral). At df (degrees of freedom) of 15 ($df = N - 1 = 15$), the nine coefficients listed in Table 3 are significant at the 1% level of significance. There was a strong tendency in this experiment for subjects who had a large displacement to centric relation, as a result of the application of a 5-lb manipulative force, to have a larger increase in the displacement to centric relation as the manipulative force was increased. Additionally, the subjects with a small displacement to centric relation as a result of the application of a 5-lb manipulative force had a smaller increase in the displacement to centric relation as the manipulative force was subsequently increased to 10 and 15 lb.

Analysis of t-test

The t ratios between pairs of measurement data resulting from the application of 5 versus 10 lb, 5 versus 15 lb, and 10 versus 15 lb were calculated and are displayed in Table 4. It can be concluded that the differential treatment of the subjects (increasing the manipulative force) produced significant differences in the position of centric relation for at least 92% of the subjects in the experiment. Thus, with a sampling error of 8%, it would be expected that the general male population will have a significant change in the three-dimensional components of their centric relation when subjected to increasing manipulative forces. Large standard deviation/mean values in Table 2 point to the extreme randomness of the centric occlusion-centric relation displacement obtained from subject to subject under controlled experimental conditions. This is consistent with previous findings.[15]

Anteroposterior direction

All subjects showed significant changes in their centric relation position as applied force was increased from 5 to 10 and 15 lb, respectively. The mean value of the centric occlusion to centric relation distance that resulted from the 5-lb force increased by 39% and 62%, respectively, as the 10- and 15-lb forces were subsequently applied. The t ratios attributed to the increase in the anteroposterior exceeded the 1% level of significance.

Vertical direction

All subjects showed significant vertical change on retrusion from centric occlusion to centric relation as applied force was increased from 5 to 10 and 15 lb, respectively. Subject no. 11 showed a 0.45-mm vertical change in centric occlusion-centric relation distance when 5 lb of force was applied. Subsequent application of 10 and 15 lb did not result in a significant increase in the 0.45-mm vertical distance. For all other subjects, however, the mean value of the centric occlusion to centric relation vertical change that resulted from the 5-lb force increased by 34% and 56%, respectively, as the 10- and 15-lb forces were applied. The t ratios attributed to the above increases in the vertical mean values exceeded the 3% level of significance.

Lateral direction

The increase in the gnathoretrusive force did not result in as great a magnitude of change in the lateral direction of the centric relation position. However, the relative lateral changes were significant. There was a 48% and a 69% increase, respectively, in the mean value of centric occlusion-centric relation distance as 10- and 15-lb forces were applied. The t ratios attributed to the foregoing increase in the lateral mean values exceeded the 8% level of significance.

Discussion

It is significant that with variation in the amount of retrusive force all subjects showed substantial three-dimensional change in their centric relation position, which is a spatial point with coordinates of anteroposterior, vertical, and lateral components. Only in the case of subject no. 4 did the gnathoretrusive forces greater than 10 lb not result in a further change in the position of centric relation. On the basis of the analysis of the t-tests, with a sampling error of 8%, it can be concluded that increasing the manipulative force on the mandible will produce a significant increase in the distance of centric occlusion to centric relation in the male population. The data establish that the retruded centric relation position varies significantly in all three dimensions according to the degree of applied force.

The overall analysis of the results substantiates the conclusion that the position of centric relation varies according to the amount of applied gnathoretrusive force.

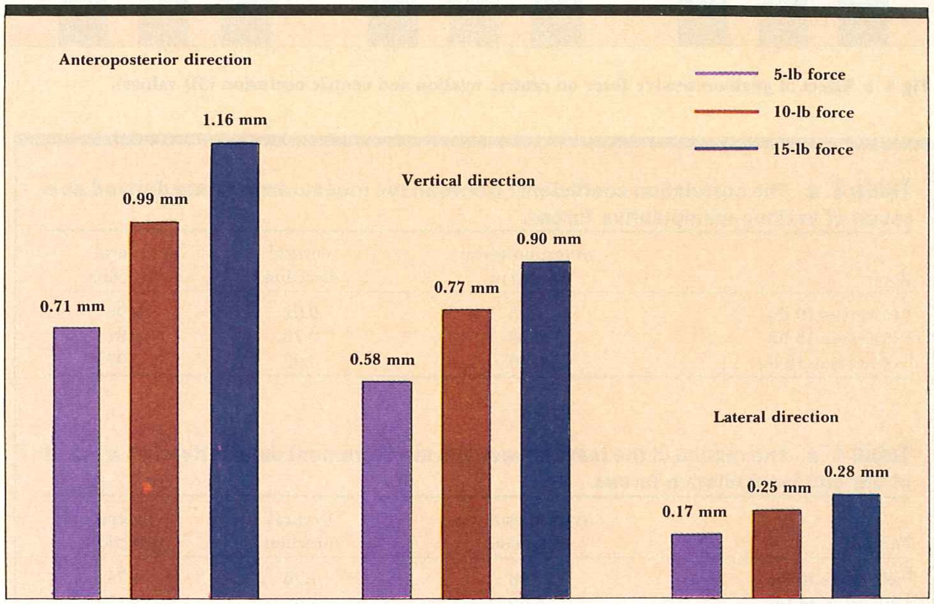

Fig 3 ■ Effect of gnathoretrusive force on centric occlusion and centric relation (mean values).

Statistical analysis of the data supports the notion that by ignoring discomfort and applying larger amounts of force, the researcher would reach the amount of force at which restraining ligaments would be taut and beyond which no more change in the position would be obtained. The experimental data from this study indicate that such force is in excess of 15 lb for male subjects.

The use of a manually directed retruded centric relation of the mandible to the skull is, on the basis of this study, unreliable, and in the light of uncontrolled variability probably not reproducible.

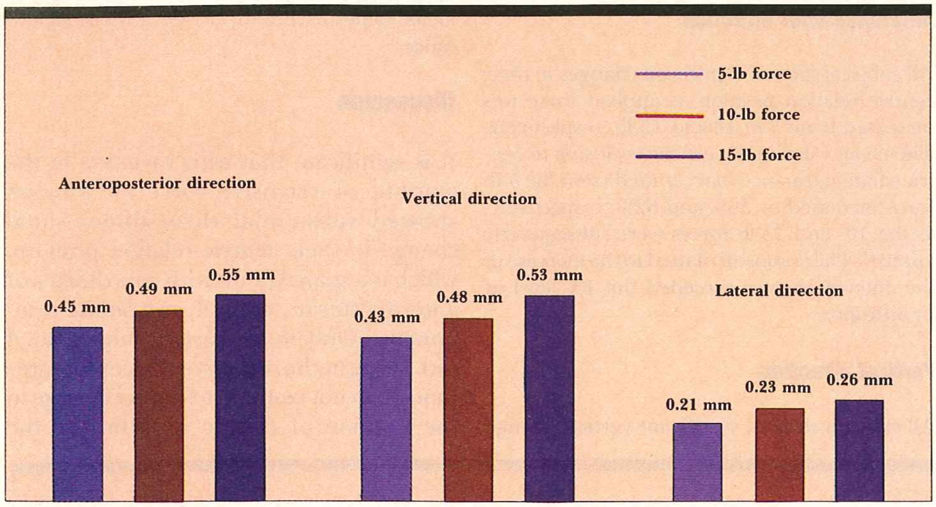

Fig 4 ■ Effect of gnathoretrusive force on centric relation and centric occlusion (SD values).

Table 3 ■ The correlation coefficient *r* between the measurement data derived as a result of various manipulative forces.

Force	Anteroposterior direction	Vertical direction	Lateral direction
r (5 versus 10 lb)	0.95	0.92	0.96
r (5 versus 15 lb)	0.88	0.78	0.91
r (10 versus 15 lb)	0.96	0.92	0.97

Table 4 ■ The results of the test between the measurement data derived as a result of various manipulative forces.

Force	Anteroposterior direction	Vertical direction	Lateral direction
t (5 versus 10 lb)	6.98	4.26	4.74
t (5 versus 15 lb)	6.69	3.58	3.15
t (10 versus 15 lb)	4.16	2.45	1.73

Summary

Measurement of the influence of the degree of applied manipulative force on the resulting retruded border position of the mandible (centric relation) established that the position varied significantly in all three dimensions according to variation in the amount of force. It is apparent that with respect to the factor of force alone, ignoring other obvious variables, such as existing muscle tension, the centric relation position could only be repetitive for each individual if the amount of force were precisely controlled with each application. There is a positive correlation between the amount of gnathoretrusive force and the resulting centric relation position. The positional changes in response to forced change also varied in quantitative degree between individuals.

The collective data establish that significant positional changes occurred in all three dimensions as the applied force was increased beyond 5 to 10 and then to 15 lb. In the anteroposterior direction, the mean value of the centric occlusion-centric relation discrepancy increased by 39% and 62%, respectively. In the vertical direction, the mean value of the centric occlusion-centric relation discrepancy increased by 34% and 56%, respectively. In the lateral dimension, the mean value discrepancy was 48% and 69%, respectively. On the basis of the analysis of the *t*-tests that contained a sampling error of 8%, it can be concluded that increasing the manipulative force on the mandible will in the general male population result in a significant increase in the distance between centric occlusion and centric relation.

The measurement data document the variability of the retruded centric relation position in all three dimensions according to the different amounts of applied retrusive force. The data question the choice of the retruded border position on the basis of its repetitiveness.

JADA

This study was done by Myo-Tronics Research, Inc.

Dr. Jankelson is director of research, and Mr. Adib is director of engineering, Myo-Tronics Research, Inc, 720 Olive Way, Suite 800, Seattle, WA 98101. Address requests for reprints to Dr. Jankelson.

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