Strength and Bite, Part I: An Analytical Review

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Abstract

The original clinical observations and research in the area of bite and strength enhancement studied individuals with obvious malocclusion and a subject population with mixed occlusions. An increase in isometric strength was obtained when biting on a K-MORA, an intraoral device that supports a mandibular position determined by a functional criterion. The criterion is a locking response to the Isometric Deltoid Press, a muscle challenge used by kinesiologists. Rather than replication with improved design, subsequent research (1) employed different mandibular positions based on therapeutic, electrical impulse or structural criteria; (2) tested mainly isokinetic strength; (3) referred to "strength" without qualification, implying more generalization than the findings actually allowed; (4) criticized and rejected positive findings by attributing strength increase to the placebo effect even though in no instance has the placebo effect been demonstrated in this field. Considering published and unpublished research on isometric strength and the irrelevance of many studies that found no difference in isokinetic strength, it is concluded that it is most probable that isometric strength is increased by the K-MORA in mixed populations.

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A 1977 clinical report by Stenger\(^1\) indicated that lack of posterior bite support and malocclusion were factors that limited athletic performance. It was proposed that the posture of the mandible affects head posture and consequently influences muscular function in other parts of the body. This report stimulated investigation that has produced apparently conflicting results and unopposed criticisms of findings supporting Stenger's proposal. The current literature on variation in strength of extraoral muscles as a function of bite relationship comprises 20 experimental and clinical studies\(^2-21\) and two reviews or commentaries.\(^22,23\) The review that follows will attempt to organize what has been found, identify the inappropriate use of terms, point out questionable statistical practices, question the conclusions of faulty experimental designs and scrutinize the unfounded generalizations that have resulted. Should Stenger's proposal prove to be correct, it will have implications not only for athletic performance, but also for the more central role of occlusion in health and behavior.

In Part II, an experiment will be reported that was designed to correct some of the faults of former attempts to measure variations in isometric strength associated with mandibular position.

I. The Investigation of Strength Variation in Subjects with Apparent Malocclusion

In the first published investigation of Stenger's proposed relationship, Smith\(^2\) studied 25 professional football players with a variety of temporomandibular joint dysfunction and stomatognathic muscle and bite abnormalities. The behavioral test employed to assess strength was the Isometric Deltoid Press (IDP), a muscle challenge commonly used by applied kinesiologists and chiropractors. A wax bite positioner was fashioned for each player, guided by variations in strength of the deltoid muscle to the IDP. (A mandibular orthopedic repositioning appliance, or MORA, set in this manner will be referred to hereafter as a K-MORA). Since the deltoid muscle is somewhat distant from and not considered a component of the stomatognathic musculature, a variation in its strength associated with differences in bite position would substantiate a relationship between bite and extraoral body muscle function.

Each subject was tested in three mandibular positions: acquired centric, K-MORA and an unadjusted mouth guard. Smith's findings have been criticized because statistical analysis was not performed.\(^7,9,10-13\)

But nonparametric tests\(^*\) performed on his published data show that when measured isometrically, deltoid strength was significantly different among the three conditions (Friedman Test: Chi-square = 25.98; df, 2; \(p < 0.0001\)). Biting on the unadjusted mouth guard produced significantly greater judged strength than biting in acquired centric (Wilcoxon Signed Rank Test: Bite < Unadjusted Tray: two-tailed significance <0.05). Strength biting on the K-MORA was judged significantly greater than with the unadjusted tray (two-tailed significance <0.05). An attempt to demonstrate a relationship between isometric strength tested with the IDP and isokinetic strength was unsuccessful. A Wilcoxon Signed Rank Test showed no difference between the acquired centric and the K-MORA.

Smith's report was followed by 19 studies\(^3-21\) that produced apparently conflicting results. A commentator,\(^22\) one reviewer,\(^23\) and authors of three of these studies\(^11,14,19\) have made emphatic general statements critical of the original results and later studies that supported Stenger's proposed relationship, in spite of the following:

1. Most of these experiments used subjects with no apparent malocclusions or lack of posterior support\(^7,13,16,18-21\) and others, mixed occlusions.\(^2,3,11,12,17\)

2. Most researchers\(^7,9,21\) set bite appliances by techniques other than kinesiological guidance, a functional technique, assuming or implying that all MORAs are equivalent.

3. Researchers used data showing no increase in isokinetic tests of strength to criticize studies of isometric strength\(^7,9,11-15,18\) while commenting on "strength" unqualifiedly.

4. Some researchers employed either questionable statistics, experimental design or both.\(^7,11-13\)

5. Some authors\(^11,12,14,22\) and a commentator\(^22\) have invoked placebo as a criticism of evidence that supports Stenger's proposal even though the placebo effect has not been demonstrated in any of the studies that have employed a placebo control condition. The belief that the placebo effect is omnipresent has even fostered an explanation for its lack of appearance.\(^10\)

Early observations of increased strength were based on subjects who exhibited malocclusions\(^1\) and were

\(^*\) Smith's data (p. 283) were reconstructed by assigning a value of "1" for stronger, "0" for no difference and "-1" for weaker. The designations "significantly stronger" and "slightly stronger" were disregarded because the subjective discrimination between these two levels was difficult to define and the use of the term "significant" was unwarranted without statistical tests.
apparently weaker biting in a maloccluded state to the IDP. Any valid test of these findings would require the use of subjects who display these characteristics and a research design that used either subjects as their own control or matched samples with respect to baseline performance.

**Replications with the K-MORA Using Apparently Maloccluded Subjects**

Smith used subjects as their own control in a later experiment and IDP data were recorded objectively by means of an electronic strain gauge rather than subjectively with the IDP alone. Statistical analysis of the data was not included in his report but the data were presented in a form that permits analysis readily. Each reading in kilogram/second was converted to a force-time score by multiplying the force (kilogram) by the time (second) sustained. Only data for the eight initial adjustments were included in the analysis. Analysis of variance for repeated measures showed a significant main effect ($F_{4,14} = 5.05$, $p = 0.02$). Newman-Keules q-99(r,14) showed the strength measure obtained with the K-MORA was greater than with either the acquired centric bite or the unadjusted mouth guard. Later critics disregarded Smith's findings because no statistics were performed and no placebo condition was included. But the critics elected not to perform the statistics or reproduce the experiment with a placebo condition. Smith's comparison of strength, measured objectively under three conditions, diminishes the critical need for a placebo condition. Added to this, the significantly greater response obtained with the K-MORA argues against a facile rejection of the findings.

A methodologically refined replication of Smith's experiment was performed in this laboratory in 1981. An unpublished dissertation by Fuchs compared isometric strength of 40 females divided equally into five groups: TMJ patients, athletic TMJ-symptomatic subjects, sedentary TMJ-symptomatic subjects, normal athletic subjects, and normal sedentary subjects. Identical with Smith's experiments, a wax bite was fashioned for each subject guided by the IDP. But unlike Smith's research design, both a disoccluded and a placebo condition were included. Strength of six body parts (left and right arm, left and right foot, upper and lower body) were measured under four bite conditions: (1) mouth open 3 mm, (2) bite in acquired centric, (3) K-MORA, and (4) bite with a placebo wax buccal device. An electronic strain gauge identical with that employed by Smith recorded responses in kilogram/second with the analog output simultaneously recorded on the stripchart of a Beckman Dynograph. Mean strength scores for the whole sample were found to be significantly different. Tukey's multiple comparison technique revealed no significant differences among mouth open, acquired centric, and placebo conditions. Greater strength was obtained with the K-MORA than in all other conditions. For the lower body, a significant difference in strength was obtained between the K-MORA and mouth open. Similarly, K-MORA strength was greater than the placebo in the upper body and left foot even though the K-MORA performance was stronger than habitual occlusion in only the right arm and left foot. Fuchs concluded that with no exception, the strength means were greater and the standard deviations lower in the K-MORA position than in any other position. Fuch's replication of Smith's research answers the unchallenged placebo criticisms in the literature that tend to obviate Stenger's and Smith's seminal findings prematurely.

As it is routinely practiced, the IDP is used as a diagnostic screening device. It is applied to both arms, first with the mouth open, then while the subject bites in acquired centric. A relative weakness to the IDP in acquired centric is interpreted by applied kinesiologists as indicative of some type of malocclusion. A weaker response to the IDP while biting provides an indication of whether the particular subject has the potential for increased strength should the bite be changed. Of the 21 studies reviewed, two studies and two clinical reports tested strength in the disoccluded state and biting in acquired centric. In accord with the kinesiologic criterion, a clinical study by Garabeo is included in this section although evidence of apparent dental malocclusion was not reported. Garabeo did not include data with the mouth open and did not perform statistics. Isometric strength of the tensor fascia lata was measured with a pressure cuff. A $t$ test performed on his data did show a significant increase in isometric strength with the K-MORA from the level biting in acquired centric ($t_{46} = -5.698$, $p$ two-tail = 0.0013). Kaufman and Kaufman found that bench press scores of a group wearing K-MORA were significantly greater than a group wearing a stock mouth guard while vertical jump and rope jump scores did not differ. However, this study cannot make a strong statement concerning increase in strength in subjects because independent groups were not matched prior to the experiment.
Studies Examining Strength in Maloccluded Subjects Using MORAs Set by Techniques Other Than the IDP

These experiments introduce two different variables. First, it is unknown whether a bite position (the independent variable) determined by the IDP is equivalent to one set with a myomonitor (hereafter referred to as a myo-MORA) or whether these MORAs are equivalent to the MORAs in all other studies reviewed below. Second, the dependent variable, the test of strength, in these experiments is different. It will be substantiated below that a test of isokinetic strength is not identical or equivalent to a test of isometric strength.

Allen et al. selected eight subjects with malocclusions. No difference was found between a myo-MORA, placebo device or baseline on peak torque measurements (quadriceps, hamstrings, biceps, and triceps) obtained with an isokinetic strength testing device (Cybex dynometer). In a well-designed experiment using subjects as their own control, McArdle et al. studied 11 selected temporomandibular joint (TMJ) subjects on a test battery that included reaction time, limb strength (peak maximum), and physiological variables. No difference was found between habitual occlusion, myo-MORA, accentuated-malocclusion-MORA, and placebo. Neither the myo-MORA nor placebo appears to have any effect on these dependent variables: increases in strength when measured with an isokinetic test, grip, limb strength (isometric peak value), cardiovascular/aerobic response, perceived exertion, anaerobic power, and short-term maximal exercise capacity.

The assumptions that electrical impulses can set the mandible in an "optimal position" with respect to some therapeutic or structural theory may not have relevance to a functional effect on strength or muscle-related functions. Any suggestion that a myo-MORA is equivalent to a K-MORA or any other MORA should be examined with caution until the necessary comparative research has been performed. One indication that the findings with the myo-MORA may not generalize is provided by Bates and Atkinson who found a significant increase in grip strength of normals between habitual bite and a MORA of different design.

II. Investigation of Strength Variation in Subjects with Apparently Normal Occlusion

Since the original purpose of the bite positioner (MORA) was to restore an obvious fault in occlusion, investigating the effect of a bite positioner in subjects with apparently normal occlusion is not directly relevant to changes in the body associated with repositioning a maloccluded bite. The acronym "MORA" has come into general use in the literature of bite and strength enhancement. MORA refers to a mandibular orthopedic repositioning appliance that is appropriate in the case of a malocclusion (e.g., lack of support, vertical dimension collapse, lateralizing contacts, crossbites). The Random House Dictionary (1967) defines orthopedics as "the correction or cure of deformities (and diseases) of the (spine) bones, joints, muscles or other parts of the skeletal system." Since, by definition, a normal bite requires no correction, it is technically inappropriate to use the term "MORA" to refer to a repositioner that is inserted in a subject with an apparently normal bite. A more descriptive acronym for such a device is MAMA (mandibular malpositioning appliance). A much simpler alternative is to disregard the implication that the use of a bite positioner with normals has any relevance to the MORA's effect on malpositioned mandibles.

Regardless of the level of sophistication of experimental design, before results of experiments can be considered to have any direct bearing on each other, it must be ascertained that the independent variable, the MORAs or MAMAs used in each experiment, is equivalent. Unless bite appliances are equivalent both by construction and effect on the subject according to some criterion, differences in results will tend to be attributed to other variables such as placebo or experimental design.

Assumed equivalence of the independent variable, aside from creating confusion, tends to negate positive results obtained with appliances fixing the mandible in other positions. For example, a K-MORA is set to a functional criterion, response to the IDP. Other MORAs are set to a therapeutic and/or structural criteria. The criticism of results obtained with a K-MORA (or any other MORA) based on results obtained with yet another type of MORA does not follow logically.

Confusion multiplies when this practice is combined with the assumption or implication that isokinetic data are equivalent (or similar) to isometric data.

From the comments of certain authors, it is obvious that bite appliances were assumed to be equivalent even though the methods of fixing the bite were quite diverse, e.g., IDP guidance, inomonitor, isokinetic performance, bilateral first molar contact, flat no contact posterior to middle of first molars, standard height, forward, incisors open 2 to 3 mm, not stated and (listed in order of similarity to the Gelb appliance) even contact in centric
occlusion,\textsuperscript{11} 1.5 mm anterior to centric open approximately 3 mm,\textsuperscript{20} supported rest position, and closest speaking space,\textsuperscript{17} as described by Gelb\textsuperscript{14,16}.

Studies That Disrupt Apparently Normal Occlusion and Examine Variations in Isokinetic Strength

In the majority of studies in this group, the dependent variable is an isokinetic test of strength. None of the experiments used the IDP to set the bite in the MAMAs. Five experiments in this group are directly comparable on the basis of identical or very similar dependent variables.

With respect to shoulder abduction or adduction, three experiments that employed 48 apparently normal subjects in total found no significant difference between placebo, normal bite, and raising the bite with either a Gelb/Leib appliance,\textsuperscript{14} an unspecified appliance\textsuperscript{15} or a Gelb, 3-D supported rest position.\textsuperscript{16} In contrast, Williams et al.\textsuperscript{17} studied three bite positions in a population of apparently mixed occlusions. Twenty-three athletes showed significantly greater average strength (isokinetic) in both arm abductors and adductors with a supported rest position than acquired centric and only significantly greater adductive response when compared with performance with a bite appliance designed to extend mandibular position 5 mm. This study found no difference in leg extensors or flexors. It is important to note that body position differed somewhat among these experiments: reclined, seated position,\textsuperscript{14} seated upright,\textsuperscript{16,17} and not stated.\textsuperscript{15} A standing position was used in a study of arm (shoulder) adduction with 10 nonathletes.\textsuperscript{18} Mean peak torque differences from normal bite baseline showed no significant difference from those of placebo, a resilient device of arbitrary height or a rigid bite positioner determined by peak arm adductor isokinetic performance. The standing position does not isolate upper body or reduce potential stabilization from the legs. This study also found no difference in quadriceps performance. Verban et al.\textsuperscript{16} investigated shoulder strength more extensively than the aforementioned studies. Investigating six isokinetic tasks and a Gelb appliance that supported rest position, 20 athletes with normal bites performed with significantly greater strength than normal bite or placebo on shoulder extension (both peak and average measures) and external rotation.

Three studies investigated whole body movements rather than specific muscle groups. Yates et al.\textsuperscript{19} tested 14 football players on two isometric tasks (dead lift and two-arm pull) and an isokinetic task (upright rowing). No difference was found between peak strength performance without an appliance, a placebo, or an appliance that shifted the bite "forward" an unspecified amount and opened the incisors "approximately 2 to 3 mm." It is not specified whether subjects were instructed to bite during each test. Two experiments that did not include a placebo condition\textsuperscript{20,21} found significant differences. Bates and Atkinson\textsuperscript{20} used a maxillary bite positioner set at 1.5 mm anterior to centric occlusion (acquired centric) with 12 weight lifters and football players. No differences were obtained with hip sled and bench press tasks, but performance in the vertical jump (isotonic) and handgrip (isometric) showed significant increases when wearing the bite positioner. It is unknown whether subjects were instructed to bite during the tests. Novich and Schwartz\textsuperscript{21} tested a group of track and field athletes with isotonic tests of shoulder and elbow flexors and extensors, push-ups and pull-ups. The reader is reminded that this type of test is markedly different from all the tests reviewed in this section. In each test, weight was equal and number of repetitions was the dependent variable. In reconstructive statistics by the current authors, \(t\) tests performed on the data in the original article by Novich and Schwartz\textsuperscript{21} showed the mean number of pull-ups increased significantly from 3.4 to 5.7 (\(t_{df,6} = 3.36, p \text{ two-tail} = 0.015\)) as did the mean number of push-ups from 18 to 27 (\(t_{df,6} = 5.46, p \text{ two-tail} = 0.002\)). The bite positioner used in this experiment was a flat plane device with upper and lower components and no contact posterior to the middle of the first molars.

Independent Groups Design Experiments That Assume Equivalent Baseline Strength and Employ Questionable Statistical Tests

Four experiments\textsuperscript{2,11−13} used an independent groups design to study subjects. The authors assumed equivalent base-level strength in these groups because no attempt was made to match groups with respect to baseline strength and no descriptive baseline statistics were offered. This deficiency limits the comparisons that can be made between groups and the questionable assumption of equal strength baselines with such a small number of subjects in each group limits both the validity and the generalizability of the findings.

Hart et al.\textsuperscript{7} tested elbow flexor isokinetic strength in 27 apparently normal subjects while varying bite opening in bilaterally equal steps. No apparent differences were found between rest position, acquired centric, and bites at 1, 3, 5 and 7 mm open. At first glance, these results appear to contradict the inverted...
"U" phenomenon proposed by applied kinesiologists with isometric strength. According to this phenomenon, a rapid drop in isometric strength occurs when the bite is opened excessively. However, a closer examination of Hart's experiment reveals (1) the group that bit in acquired centric was independent of the gradual increased bite group and subjects were not matched, and (2) statistics were not reported even though performed and some form of reconstructive statistics was not possible.

Schubert et al. allowed chiropractors to determine kinesiologically which might benefit from MORAs, but bite positioners were not adjusted by kinesiologic guidance or by the chiropractors' suggestions. Unjustifiably, the results of no difference from an independent group of subjects wearing placebos were used to argue against results obtained in experiments studying K-MORAs with subjects as their own controls. These authors, assuming equivalent baseline strength in the independent groups, did not match subjects and provided no baseline information. They then went on to infer from their data that there was no increase (improvement) in strength with the MORA rather than stating simply what the design of the experiment permitted, i.e., that one group wearing a placebo was no stronger than another group wearing a MORA of a particular design.

Two experiments by Burkett and Bernstein also employed an independent groups design in order to reduce the influence of the placebo effect. Even though they converted each score on a series of tests to percentage of change from baseline, they did not match subjects according to baseline score or any other variable. No descriptive statistics of baseline performance of any of the groups were reported.

The authors of the last three experiments cited employed statistical techniques that are questionable. In each case, a series of independent statistical tests was performed on data produced by the same subjects on each of these tests. Rather than obtaining an indication of relative performance of each group over the series of tests, each test was treated as an independent experiment. In addition, the data of the earlier Burkett and Bernstein study suggest the inappropriate use of parametric statistics. Large discrepancies in the variances and the small differences in the means indicate that Bartlett's Test for Homogeneity of Variance would have shown that the repeated F test was inappropriate for these data. A Kruskal-Wallis ANOVA by rank would have been appropriate. In order to determine whether the high frequency of larger means in the myomonitor condition occurred by chance, data were analyzed by the current authors as follows: each of the 12 tests was regarded as a case and the response of each group was rank ordered (1, 2, or 3). A Friedman test for correlated samples comparing rank of each condition (control, placebo, and myomonitor-set bite positioner) over all 12 tests yielded a Chi-square = 11.17, df 2, p = 0.0038. Paired Wilcoxon Signed Rank Tests indicated that the control and placebo conditions were not different (two-tail significance using normal approximation = 0.239), the experimental was slightly greater than placebo (p = 0.0499) and definitely greater than control (p = 0.0054). It is doubtful whether these differences, should they exist, or the equality of the responses as reported in the two experiments have strong relevance to strength enhancement because groups were not matched on baseline strength. For the sake of logic and semantics, it must be emphasized that unless matched subjects are used in an independent groups design, no strong statement or inference can be made concerning an increase in strength in the individuals manifesting the increase.

Burkett and Bernstein compared the performance of one group of 12 wearing a placebo with that of a second group of 15 wearing a myo-MORA. TMR symptoms were reported only for the experimental group. It is unknown whether they were distributed similarly in the placebo group. A test battery of 14 tests included 12 tests of static and dynamic strength. Rather than considering analysis of variance (or a nonparametric test because of questionable homogeneity of variances), 14 independent t tests were performed. The use of multiple, independent t tests when measures are obtained from the same subjects is a highly insensitive practice. The authors rendered their statistical analysis even more insensitive in an attempt to avoid type I error. They imposed Games' method in which each independent t test had to reach 0.01 level to be significant at the 0.05 level. This highly conservative technique discourages the analysis of trends in the data. Even though each t test did not attain significance, a number of means close to significant levels may attain significance in an all-inclusive analysis. In order to ascertain the possibility of such a trend, a nonparametric Sign Test was performed by the current authors. The means of the 12 tests of strength (myo-MORA minus placebo) presented by Burkett and Bernstein showed a tendency for the myo-MORA means to exceed the means of the placebo group: 11 cases with positive difference and one case with a negative difference (two-tailed significance, exact = 0.0063). The average of the placebo means for the strength tests was found to be 4.14 while that of the myo-MORA group was 9.21.
In light of these tendencies in the data and without offering substantiation, the authors concluded that “The evidence from this study ... strongly indicated the placebo effect of the MORA on strength.” The questionable use of statistics, the failure to match subjects when a small number was used in each condition and the use of electrical stimulation to set the MORA must temper the general statement of the authors “that for the normal population the MORA does not: (1) increase muscular strength, (2) increase muscular endurance.

III. The Question of Placebo Effect

Speculation about placebo effects is sprinkled liberally throughout the literature of bite and strength enhancement. In one case it is reported as a fact22: “Every scientific study so far says [the appliance] is nothing more than a placebo . . . .” To clarify this statement, it must be pointed out that the authors of these scientific studies only speculated about placebo effects in the discussion sections of their reports. The studies themselves did not produce evidence of the placebo effect.

The strongest argument leveled against the findings of increased isometric strength in some subjects and in isokinetic performance when it has been reported is that no placebo control condition was included in the research18 and that when increased strength was obtained, it was due to a “placebo effect.”11,14,19 Chiodo and Rosenstein23 concluded in 1986:

“To date, the body of scientific, well-designed studies of the MORA and athletic performance indicate that any improvement in strength or performance is the result of psychological not physiological factors.”

In the context of the mix of differing experimental approaches reviewed, strong statements concerning placebo effects would appear to be premature. Dealing with a contradiction to one’s finding by attribution to placebo eliminates the inconsistency in short order, but neglects the fact that a placebo effect has never been demonstrated objectively in this field of study, i.e., found significantly different from control. Nine of the 20 studies reviewed included a placebo condition. Although isokinetic strength findings appear to be contradictory at times, one finding is very clear and consistent. In no case was a placebo effect obtained.

Unfounded speculation about placebo effect, if left unchallenged, tends to obviate seminal findings that have the potential for opening avenues of research that may lead to greater knowledge of the role of the oral cavity. Logic forces critics to deal with the obvious question: why do placebo responses occur (as alleged) in the experiments being criticized while they do not occur in their own experiments that include a placebo control condition? It must be made clear that a placebo condition in an experiment controls nothing; it only allows the assessment of a placebo effect should it occur. It is incumbent on those who wish to attribute findings to the placebo effect to provide objective support for their speculation.

IV. The Kinesiological Phenomenon

According to Parker et al.18 the IDP is a “subjective procedure in which the operator and the patient are vulnerable to suggestion.” When a strain gauge is employed3,4 the subjective aspect is minimized. It remains to be demonstrated in this area of research whether it matters whether the operator or the subject makes a personal judgement about strength or weakness. Until that time, criticism without substantiation should not be considered seriously. The IDP is a muscle challenge used extensively in the area of chiropractic. It is important to remember that it is an isometric test of strength, much like the postural function of muscles, maintaining a sustained tension against an applied force, gravity. In this respect, strength which is defined by some instantaneous peak value (as in isokinetic testing with the Cybex) is not representative of sustained force over an extended period of time. A Force-Time measure is representative of postural behavior in everyday life such as sitting before a computer and many critical athletic behaviors such as static blocking of an oncoming player. The IDP tests either the peak strength at which the ability to sustain an increasing force is lost or the time an applied force can be sustained.

It is a general, clinical finding that with individuals who test as strong while biting as with the mouth open to the IDP, the introduction of a MORA, which either raises the bite5 or deflects the bite laterally,3 weakens the deltoid strength. With the exception of these individuals, the relationship between vertical dimension and strength of the deltoid muscle, based on clinical observations, follows the form of an inverted “U.”5 With individuals who test weaker when biting, as opposed to posturing the mandible in the rest position, isometric strength increases rather sharply to an increase in vertical dimension. At a height specific to that subject, strength will be maintained through a
narrow range then rapidly decrease should the height be increased even further. These clinical observations await experimental validation. This phenomenon, readily observed in the clinical setting with patients exhibiting loss of vertical dimension was not observed in one formal experiment studying subjects with apparently normal bites. Hart et al.7 studied the effect on isokinetic strength of subjects by raising the vertical dimension in small, equally bilateral steps. Although a preliminary test was performed to determine whether the subjects were weaker while biting in habitual than in rest position, no statistical analysis was reported, even though performed. Because of how results were reported, it is difficult to be certain how the analysis was performed. However, it appears that an independent control group was used along with raw data (rather than the percentage of difference from baseline) and experimental subjects were not matched to controls.

Of the 20 studies and reports reviewed, only six2-7 tested strength with the mouth open and closed.1

V. Strength is Operationally Defined by the Method of Measurement

An isokinetic task such as in the Cybex Dynamometer is useful in comparing muscle force outputs at different movement speeds, but it has limitations with respect to strength measurement.

First, motivation is a large factor in this type of test. Because the resistible force is determined by the applied muscle force, the subject is under control of how much force is applied. The subject must be highly motivated to maintain maximum muscle force throughout the entire movement range. As a reduction in muscle force is matched by an equal reduction in resistible force, but no change in movement speed, this is often a difficult task.

Second, the effects of momentum are not entirely eliminated by isokinetic equipment. Although movement speed does not change, numerous variations in applied muscle forces and resistible forces occur. When muscle force is first applied to the resistance lever, there is a slight delay before resistible force is encountered. The brief build up of momentum produces a matching resistible force that is greater than the muscle's actual force output. This interplay of muscle and resistible forces continues throughout the movement, making the actual torque recordings rather rough. Only by incorporating a damping device are the torque readings smoothed out enough to provide a mean level of force for study.

Third, the speed of movement affects the measured muscle force. Westcott24 has pointed out that an increase of movement speed causes a decrease in maximum force output. He showed that as the movement speed increases from 60 degrees/second to 120 degrees/second to 180 degrees/second, the peak quadriiceps force decreases from 168 foot pounds to 120 foot pounds to 94 foot pounds, respectively. According to Jones et al.,25 during concentric contractions, part of the force developed in the muscle is used to overcome internal friction between contractile components. Faster movement speeds produce more internal friction resulting in reduced force outputs. Since these differences may produce greater variability than an isometric test, an approximation of strength measured with an isokinetic device would require a much larger group of subjects than has been commonly used and tested over multiple trials to reduce distortion of the variability.

Because muscle movement affects measurable force output, isometric (static) contractions provide a more accurate and reliable assessment of muscle strength. Static contractions also eliminate changes in biomechanics (leverage factors) and contributions from recruited muscle groups that complicate isokinetic evaluations of muscle strength. With the less complex dependent variable, time, a smaller variation in measures would be expected. The isometric task presented by a device such as the Nautilus lateral raise machine, requiring the sustaining of a fixed position to an applied weight, discourages recruitment of other muscle groups and reproduces the kinesiological test objectively. Less expensive devices such as a kinesiometer (a simple strain gauge) or a simple pressure gauge also produce objective data.

Conclusion

Stenger's original observations were made on subjects with obvious malocclusion. The first published experimental test of his proposal was carried out by Smith on subjects with mixed occlusions. Strength increase was assessed by the Isometric Deltoid Press

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(IDP). Subsequent research, critical of these findings, base arguments on isokinetic data derived in the main from subjects with normal occlusion.

Smith's research\textsuperscript{2,3} and reports of others finding isometric strength increase with the K-MORA were published without either a placebo control condition or statistical analysis. Surprisingly, focusing on experimental design rather than data, all critical reference to these early studies did not perform a statistical analysis of the data presented. When performed, it was revealed that a significant increase in isometric strength was obtained with the K-MORA in each case. Critics went on to disregard the findings because a placebo control condition was not included. Following a tortuous course of research, investigators elected not to replicate the original research with a refined design in order to maintain the original variables. Instead, bite positioners of a different design were chosen. These positioners were based on structural or therapeutic criteria instead of the original functional criterion. In addition, a different dependent variable was employed. Finally, six of the critical studies\textsuperscript{7,13-15,18,19} tested only subjects with apparently normal bites.

Although 10 of the 20 studies reviewed employed MORAs of different design and isokinetic tests of strength, their authors did not qualify general comments concerning "strength" and "the MORA." These comments either state or imply relevance to experiments employing isometric tasks with populations of mixed or maloccluded subjects.

To date, only one experiment that meets accepted design standards\textsuperscript{4} studied isometric strength with the K-MORA. This study found no difference between mouth open, habitual bite, and placebo. Significant increase in strength over placebo was obtained with a K-MORA and, opposed to isokinetic data, significant increases in the lower body were observed. Smith's experiment contained within it the most logical course of research to answer the important question of the relationship between bite and strength, i.e., does isometric strength increase when a maloccluded bite is repositioned according to a functional criterion (IDP) and does this position also increase isokinetic performance in the same subjects? This course of research has not been explored.

Table 1 shows that isokinetic data has been collected from subjects wearing a variety of bite positioners other than the K-MORA. These data indicate that opening the apparently normal bite 2 to 3 mm (and some indication up to 7 mm with elbow flexion) does not affect strength of shoulder adduction and abduction when compared with biting with no appliance. Moreover, the data present no evidence that lower body isokinetic strength is affected by variations in bite opening. When a supported rest position is employed and subjects with mixed occlusions are seated erect, significant isokinetic strength increase is obtained in arm abduction and adduction tasks\textsuperscript{11} as well as shoulder extension and rotation.\textsuperscript{16} The implication made by Parker et al.\textsuperscript{18} that the positive results obtained by Williams et al.\textsuperscript{17} are due to a placebo effect fails to recognize that the absence of a placebo condition is not critical if an ordered, functional relationship can be demonstrated using multiple conditions. Parker et al. are correct to point out that a number of differences exist in experimental protocols. This applies to experiments critical of positive findings as well. Although three key studies\textsuperscript{14,16,17} used similar mandibular positioners, the study that found no difference in isokinetic strength\textsuperscript{14} tested in a reclined position. It is not stated at which posture the bite positioner was adjusted. Mehta and Forgione\textsuperscript{26} presented evidence that occlusion changes dramatically as upper body tilt moves toward a recumbent position.

Regarding Table 1 uncritically with respect to the independent variable, it is apparent that the K-MORA has produced significant increase in isometric strength in mixed and exclusively maloccluded populations without exception. Similarly, criticisms aside, the myo-MORA has not produced an increase in isokinetic strength or exercise performance in normal and maloccluded subjects. A MORA fixed on the basis of isokinetic performance\textsuperscript{18} produced strength levels no different from control of placebo in normal subjects. Three experiments\textsuperscript{14,15,18} found that normal occlusion is associated with the same isokinetic strength as with bite positioners while with mixed occlusions, two experiments found significant differences\textsuperscript{16,17} while one did not.\textsuperscript{11} With isotonic tests, there is a strong indication that significant differences occur between a supported open position and acquired centric in normals\textsuperscript{20} and in a group of subjects with mixed occlusion.\textsuperscript{21}

Regarding Table 1 from currently acceptable experimental standards, only five of the experiments should be considered worthy of serious consideration. Based on this standard, there is evidence that the K-MORA increases isometric strength.\textsuperscript{4} There is evidence that two types of isokinetic strength increase significantly\textsuperscript{16} with mixed occlusions but not abduction and adduction of the shoulder in mixed\textsuperscript{14} and normal occlusions.\textsuperscript{15} Finally, strength tests that involve the entire body\textsuperscript{19} show no difference in normally occluded subjects between a bite positioner and normal bite.
<table>
<thead>
<tr>
<th>Study Number</th>
<th>Independent Variable</th>
<th>Dependent Variable</th>
<th>Bite Status</th>
<th>Results</th>
<th>Comments</th>
<th>Statistical Fault</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>K-MORA (IMF)</td>
<td>Isometric</td>
<td>Mixed</td>
<td>K-MORA</td>
<td>Subjective data</td>
<td>(No placebo?)</td>
</tr>
<tr>
<td>3</td>
<td>K-MORA (IMF)</td>
<td>Isometric</td>
<td>Mixed</td>
<td>K-MORA</td>
<td>Independent groups</td>
<td>Not matched</td>
</tr>
<tr>
<td>4</td>
<td>K-MORA (IMF)</td>
<td>Isotropic</td>
<td>All types</td>
<td>K-MORA</td>
<td>Myomonitor</td>
<td></td>
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<tr>
<td>8</td>
<td>K-MORA (IMF)</td>
<td>Multiple</td>
<td>Mixed</td>
<td>K-MORA</td>
<td>=</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Myo-MORA (NM)</td>
<td>Isokinetic</td>
<td>Maloccluded</td>
<td>=</td>
<td>Myomonitor</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Myo-MORA (NM)</td>
<td>Multiple</td>
<td>Maloccluded</td>
<td>=</td>
<td>Independent groups</td>
<td>Not matched</td>
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<tr>
<td>12</td>
<td>Myo-MORA (NM)</td>
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<td>Mixed</td>
<td>=</td>
<td>Independent groups</td>
<td>Not matched</td>
</tr>
<tr>
<td>13</td>
<td>Myo-MORA (NM)</td>
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<td>Mixed?</td>
<td>=</td>
<td>Independent groups</td>
<td>Not matched</td>
</tr>
<tr>
<td>11</td>
<td>Gelb type (T)</td>
<td>Isokinetic</td>
<td>Normal</td>
<td>=</td>
<td>Testing posture</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Gelb type (T)</td>
<td>Isokinetic</td>
<td>Mixed?</td>
<td>Gelb-MORA</td>
<td>=</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Gelb type (T)</td>
<td>Isokinetic</td>
<td>Angle Class I and II</td>
<td>Gelb-MORA</td>
<td>=</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Gelb type (T)</td>
<td>Isokinetic</td>
<td>Mixed</td>
<td>Gelb-MORA</td>
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<tr>
<td>20</td>
<td>Flat, 1.5 mm (S)</td>
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<td>Normal</td>
<td>2 Tests</td>
<td>Maxillary MORA</td>
<td>4 t tests</td>
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<td>19</td>
<td>Forward (S)</td>
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<td>=</td>
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<tr>
<td>18</td>
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<td>Flat upper (S) and lower open 3 mm</td>
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<td>=</td>
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<tr>
<td>18</td>
<td>Isokinetic</td>
<td>Isokinetic</td>
<td>Normal</td>
<td>=</td>
<td>=</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Unknown</td>
<td>Isokinetic</td>
<td>Normal</td>
<td>=</td>
<td>=</td>
<td></td>
</tr>
</tbody>
</table>

*Beginning with a functional criterion for positioning the mandible using the IMF (IMF), studies are clustered under neuromuscular criterion (NM), therapeutic criteria (T) and structural criteria (S) with therapeutic applications. The list ends with a MORA set to a functional criterion based on isokinetic performance (IKF). Studies 5 and 6 are not included in chart.

Indicates significance, = indicates no difference.

Only confusion can result if strength operationally defined by an isokinetic test is interpreted as equivalent to strength defined by an isometric test. Peak strength determined by an isokinetic test gives no information about power. Achieving some peak value for an instant gives no information on the ability to sustain a weight at that value for a longer period of time.

Logic demands that criticism of a study without a placebo condition be followed by replication of the study with the deficiency corrected. Little is to be gained by performing another experiment with different independent, dependent variables, and in some cases, different subject populations. The practice of not finding a placebo effect in one's own experiment then arguing that placebo effect is a factor in another experiment without the placebo condition is seen as unjustified. The most consistent finding in this area of research is that no placebo effect has been demonstrated. It is suggested that the question of placebo effect be answered with data rather than speculation before placebo criticisms be taken seriously. Seminal findings, regardless of the faults in experimental de-
sign, should be put to the test of experimentation rather than be rejected outright by argument and speculation.

The field of bite and strength research has been found to be marked by the failure to make clear distinctions between (1) jaw positions caused by MORAs of different design, (2) isokinetic and isometric tests of strength, (3) empirical statements and assumption of the influence of placebo effect, and (4) implications drawn from research based on apparently normal and apparently maloccluded subjects. It appears that sufficient information exists to conclude that bite position does affect isometric strength and possibly some types of isokinetic strength in maloccluded subjects. More research is required before the preliminary results of isometric strength increase are to be seen as reliable. It is hoped that future research will be performed to qualify these statements.

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