Effect of Increased Maxillo-mandibular Relationship on Isometric Strength in TMD Patients with Loss of Vertical Dimension of Occlusion

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ABSTRACT: The effect on isometric strength of the shoulders and limbs while biting in habitual occlusion, on a bite-elevating appliance and on a placebo appliance was analyzed. Twenty female volunteer patients, presenting with temporomandibular pain dysfunction syndrome and obvious loss of vertical dimension, served as subjects. All were weaker to the manual application of the Isometric Deltoid Press (IDP) when biting, as opposed to maintaining the mandible in an unsupported rest position. Two intraoral appliances were fabricated for each subject: a bite-elevating appliance (BEA) set by a functional criterion of peak strength to the IDP and a placebo appliance which did not interfere with occlusion but was "set" with a mock IDP procedure. Testing was carried out by the Neuromuscular Research Testing Laboratory of the Neurology Department of Tufts New England Medical Center. Testing was independent of the dentist who fabricated and set the appliances. A standard neuromuscular test with the Maximal Voluntary Isometric Contraction apparatus was used to assess strength of right and left shoulder, elbow and knee flexion and extension as is routinely performed with all neuromuscular disease patients. Twelve strength tests were carried out for each of three conditions: 1. Baseline–biting in habitual occlusion; 2. Elevated–biting on the BEA; and 3. Placebo–biting with the placebo appliance inserted. The order of conditions 2 and 3 was counterbalanced without knowledge of the subjects. Twelve repeated measures ANOVAs (each subject as their own control) were conducted for each of the 12 strength measures. All F-tests indicated a significant main effect for treatment differences ($p<0.0001$). Mean strength biting on the BEA was consistantly greater ($p< 0.001$) than Baseline or Placebo strength. Baseline and Placebo condition were equivalent. These findings confirmed previous observations at this TMD Center: individuals with loss of vertical dimension of occlusion respond to a bite raising appliance by increased isometric-strength.

Dr. Tariq Abduljabbar *received his D.D.S. at King Saud University, College of Dentistry in Riyadh, Saudi Arabia in 1984. He spent the next four years as a prosthetics resident. In 1989 he joined the TMJ program at the Gelb Craniomandibular Orofacial Pain Center at Tufts University School of Dental Medicine. He combined a prosthetics program with his TMJ studies and was awarded his Masters in Dental Research in 1995. He is currently working on a Ph.D. in Oral Biology at Harvard School of Dental Medicine.*

Following the publication of a clinical report by Stenger[1] in 1977 a number of studies attempted to determine whether or not increasing the vertical dimension of occlusion also increased muscle strength. Based on his clinical observations, Stenger proposed that lack of posterior bite support and malocclusion may be factors limiting athletic muscle performance. He theorized that the posture of the mandible may affect head posture and, consequently, influence muscular function systemically. The implication of Stenger's proposal is far-reaching for dentistry. If validated, the influence of maxillo-mandibular relationship could expand beyond the stomatognathic system to include total body muscle function and health.

In 1991, Forgione, et al.[2] reviewed the 20 experimental and clinical studies and two major commentaries which intended to examine Stenger's claim. These authors

found that: l. Most of the experiments used subjects with no apparent malocclusion or lack of posterior support; 2. Elevated vertical dimension of occlusion was set by diverse methods, assuming all bite elevating appliances to be equivalent; 3. Data gathered from isokinetic strength tests were used to criticize findings of isometric strength tests ("strength" was ill-defined); and 4. Placebo effect was used to explain findings of increased isometric strength by some authors even though these authors did not find this phenomenon in their own studies, nor has the placebo effect ever been found to be significant in any of the published studies. Forgione, et al.[2] had also argued that studies cannot be compared directly unless the same independent variable (design of the appliance to correct the particular condition set to an equivalent criterion) and the same dependent variable (measure of isometric strength) are used. Clearly, isokinetic strength findings are inconsistent and may not necessarily agree with those for isometric strength. They concluded that sufficient information exists to suggest that bite position may influence isometric strength as well as some forms of isokinetic strength.

Recently (1993) Yokobori and Horii[3] have reported that when the same subjects were tested for isometric and isokinetic strength, isometric strength increased significantly with a bite-elevating appliance while isokinetic strength did not.

Thus, the question of principal issue is whether isometric strength increases with a bite-elevating appliance in individuals with loss of vertical dimension of occlusion. A brief summary of research designed to answer this question follows.

Smith[4] was first to investigate Stenger's proposed relationship. Twenty-five professional football players with a variety of temporomandibular joint dysfunction (TMD) and bite abnormalities were assessed with the Isometric Deltoid Press (IDP), a muscle challenge first described by Kendall and Kendall,[5] commonly used by chiropractors and similar to tests performed by neurologists. A wax bite was fashioned for each player with the height of the elevated habitual occlusion guided by variations in the strength of the deltoid muscles to the IDP. With the arm extended horizontally, the subject bit slowly into the wax as a vertical downward pressure was applied to the wrist by the tester. When peak strength was judged subjectively to have been achieved in both the extended arms, the mandibular position was considered as "set" to the functional criterion. In Smith's experiment, isometric strength in three mandibular positions was tested subjectively: l. acquired centric occlusion; 2. the wax bite position; and 3. the position produced by an unadjusted football mouthguard. This study was criticized in later publications for not including statistical analysis of the data. However, Forgione, et al.[2] calculated nonparametric statistics on Smith's published data and found significant differences in isometric strength of the deltoid muscles between the three conditions: strength while biting on the unadjusted mouthguard was significantly greater than biting in acquired centric occlusion and strength biting on the wax bite set at the functional criterion was significantly greater than biting on the unadjusted mouthguard. In a later study, Smith[6] recorded strength in response to the IDP objectively with an electronic strain gauge. Again, Forgione, et al.[2] calculated statistics of the published data and found isometric strength biting at the mandibular position determined by the functional criterion to be significantly greater than biting in acquired centric occlusion or on an unadjusted mouthguard.

A methodologically improved experiment designed to measure multiple body sites in 40 women was carried out by Fuchs.[7] Isometric strength of six body parts was measured: right and left arm (extension), foot and knee (extension), upper body and lower body. Combined data for all body parts for the group of 40 subjects showed no significant difference in strength between disoccluded, acquired centric and placebo bite conditions. However, with the wax bite set to a functional criterion, greater strength was recorded than in these three other conditions. When individual tests of body parts were performed, the lower body was significantly stronger with the wax bite than with the teeth disoccluded, and the upper body was stronger with the wax bite than with placebo. Significant results of strength tests on the appendages were mixed: wax bite strength was significantly l. greater than placebo in the left foot and 2. stronger than biting in acquired centric occlusion in only the right arm and the left foot. The 40 females were divided equally into five groups: l. TMD patients, 2. athletic TMD symptomatic subjects, 3. sedentary, TMD symptomatic subjects, 4. normal athletic subjects and 5. normal sedentary subjects. Analysis of the data from this perspective was unproductive. In summary, the author commented that in all cases, the strength means were greater and the standard deviations smaller in the wax bite condition than in any other bite condition.

A clinical study by Garabee[8] tested runners for isometric strength of the tensor fascia lata with a pressure cuff. Occlusal condition was not described. Forgione, et al.[2] performed statistics on the published results and found a significant increase in strength from habitual occlusion with a bite set to the IDP functional criterion.

In a study which used subjects as their own control and repeated strength tests, Forgione, et al.[9] assessed deltoid isometric strength in weight lifters with mixed occlusions

by means of a Nautilus Lateral Rise (Nautilus International, Independence, VA) exercise device. Testing with this device is almost identical to the subjectively applied IDP (the arms are extended horizontally to the side and weights are applied vertically to the upper arms). On the first day of this study, 35 subjects, biting on the appliance set to the functional criterion, sustained their maximum sustainable weight for an average of 25.4 sec, significantly greater than the 18.62 sec biting in habitual occlusion. This finding confirmed the IDP objectively. Then, strength while biting was measured twice in counterbalanced order in each of three bite conditions: 1. An acrylic appliance with the vertical dimension of occlusion set bilaterally to the functional criterion of the subjectively applied IDP; 2. An acrylic appliance set to the vertical dimension of the previous condition but fabricated so as to contact initially on the right canine and shift the mandible to the right; and 3. An acrylic placebo appliance which did not disturb habitual occlusion. The deflection and the placebo group means, 13.46 sec and 13.31 sec respectively, were statistically equivalent, while the mean (21.13 sec) biting on the appliance set to the functional criterion was greater than both. Repeated testing showed consistent responding. On the second day of testing, each subject bit in habitual occlusion for six trials to provide a trial-by-trial matched sequence baseline for the previous day's testing. Again, the average strength obtained with the elevated bite set to the functional criterion was greater than in all other bite conditions. Nineteen of the 23 subjects returning for the second day of testing showed a greater sustaining time than their sequentially matched habitual bite control trial. Fourteen of these subjects showed at least a 50% increase over their habitual bite control strength.

Isometric strength of the sternocleidomastoid muscles (SCM) was assessed in 15 subjects demonstrating deep bite and loss of vertical dimension by Al-Abbasi et al.[10] In the preliminary part of the experiment all subjects were tested sitting, with the head unsupported and the teeth l. disoccluded and 2. biting in habitual occlusion. SCM strength with the teeth disoccluded was 51.4% greater than when biting in habitual occlusion. Four types of acrylic lower appliances were then fabricated: l. Habitual bite, elevated to the functional criterion of the IDP. This vertical dimension was transferred to an articulator and three other appliances were fabricated at the same vertical dimension; 2. Edge-to-edge; 3. Retruded; and 4. Lateral shift of l mm to the left. Each subject was tested twice by an operator blind to mandibular position and subjects biting with and without appliance in habitual occlusion, edge-to-edge, retruded and lateral shift positions. The mean SCM strength of 27.17 lbs obtained when biting in all the elevated vertical positions was greater than 21.73 lbs biting without a bite-elevating appliance. More detailed analysis showed: l. without an appliance, SCM strength, biting in habitual occlusion, was lower than in the edge-to-edge position, and 2. with appliances, SCM strength of the same subjects was greater in habitual and edge-to-edge positions than in retruded but not lateral shift positions. The findings indicated that, while biting at an elevated position determined by the IDP, SCM isometric strength can increase regardless of position. However, an elevated edge-to-edge position and an elevated habitual position maximized SCM isometric strength.

Researchers in Korea and Japan have recently taken an interest in this relationship between vertical dimension of occlusion and muscle strength. The effect of a bite-elevating appliance on back muscle strength of 22 male football players and 22 female archers was tested by Kang and Lee.[11] Both groups of athletes and a control group were tested using a digital back muscle dynamometer before and after 30 days of appliance wear. Back muscle strength increased with the bite-elevating appliance (15.2% in males and 12.4% in females) but the control group's mean strength did not change. Tsukimura[12] tested back strength of eight subjects at different vertical dimensions. In the disoccluded mandibular position, back strength was the weakest, but tended to increase as a 2, 5, and 10 mm splint was worn and tended to decrease when a 15 mm appliance was worn. Maximum strengths were obtained in the 2 to 10 mm range of splinting.

Yokobori and Horii[3] performed the critical experiment supporting the contention of Forgione, et al.[2] that isokinetic and isometric strength may not be related. Forty college athletes were fitted with bite-elevating appliances and tested on both isometric and isokinetic tasks with and without the appliance. With the appliance, significant increases in isometric strength were obtained in back extension, leg extension, and plantar extension but not in arm flexion and grip strength. Isokinetic strength of knee extension and flexion showed no difference when tested on a Cybex II Dynamometer (Lumex, Inc., Ronkonkoma, NY) at angular velocities of 60, 120 and 240 deg/s. Interestingly, these authors also found that equilibrium was improved in these subjects while wearing the appliances.

The present double-blind study was designed to test the bilateral isometric strength of the extremities and shoulder girdle of female TMD patients. The prevalence of female TMD patients, high frequency of deep bites in this group and homoginization of associated strength variables dictated a single gender subject sample. These patients all demonstrated obvious loss of vertical

dimension of occlusion by a deep overbite, occlusion missing posterior supporting teeth, or obvious tooth wear due to bruxism or repeated occlusal adjustments. All these patients exhibited a discriminable weakness to the subjective application of the IDP when biting in habitual occlusion as opposed to response to the IDP with the mandible in the disoccluded rest position. The strength testing was carried out at the Neuromuscular Disease Research Laboratory of the Department of Neurology at the Tufts New England Medical Center under supervision of Dr. T. L. Munsat. An improvement over Fuchs' design, testing was applied by the staff of this independent medical facility, using the apparatus and procedures[13, 14] routinely used to assess the isometric strength of patients with neurosmuscular diseases.

Materials and Methods

Subjects

Over 68 clinic days, every female presenting for treatment to the Gelb Craniomandibular Orofacial Pain Center at Tufts University School of Dental Medicine Center, meeting the following criteria, was asked to participate in the study:

1. Having no history of recent physical trauma.
2. Having no history of chronic illness or untreated chronic illness.
3. Having had a complete physical examination within the last year.
4. Being between 30 and 50 years of age.
5. Having an obvious loss of vertical support through total or partial loss of teeth, or wear of the teeth.
6. Demonstrating a subjectively detectable decrease (greater than zero) in muscle strength of the deltoid muscles from teeth disoccluded to biting in habitual occlusion on the isometric deltoid press.

Of 28 eligible female candidates, 20 volunteered for the study.

Intraoral Appliances

Each subject received two appliances for strength testing:

1. Experimental appliance: the base of the appliance was constructed by stretching a heated 2 mm thick acrylic disk over a mandibular impression in a Dentsply Vacupress (Dentsply International, York, PA). The appliance was cut to form a full coverage appliance, extending to the gingival margins labially and 4 mm beyond the gingival margin lingually. For missing teeth, the acrylic sheet was pressed over the gingival surface and cold cure acrylic was used to fill the space to the opposing maxillary teeth intraorally. A layer of acrylic was then applied to the contact surface of the appliance, and when partially set, the mandible was positioned as follows:

With the teeth disoccluded (rest position) and the subject seated erect, the strength of the deltoid muscle was tested for each arm using the IDP as in Forgione, et al.[9]

Briefly, the IDP is performed as follows:

> With the subject's arm extended hotizontally to the side, the subject bites gently into the acrylic or onto his occlusion. A vertical, downward pressure is applied to the wrist of the subject's extended arm by the tester. Simultaneously an equal downward pressure is applied to the shoulder of the opposite arm. When peak resistance or "locking" of the deltoid is judged to have been achieved in both the extended arms by the tester, the mandibular position is considered as "set" to the functional criterion.

With the incisal frena aligned, the subject was asked to bite gently into the acrylic and hold that position as the IDP was applied bilaterally. This procedure was repeated until response to the IDP was at its greatest. If IDP strength began to decrease, the appliance was removed, the acrylic remolded slightly to elevate the acrylic and the appliance reinserted. The subject was then asked to close gently into the grooves and the IDP applied again. Once peak strength ("locking") was achieved bilaterally, the appliance was removed and polished. All acrylic higher than the occlusal contacts was ground away and the subject was retested with the IDP bilaterally, with fine adjustments performed with carbon paper marking to ensure balanced contacts on the right and left sides. The vertical dimension was then considered set to a functional criterion by the bite-elevating appliance (BEA) shown in **Figure 1**.

2. Placebo appliance: This appliance was constructed as above but without occlusal coverage. The device rested on the lingual and labial aspects of the gingiva

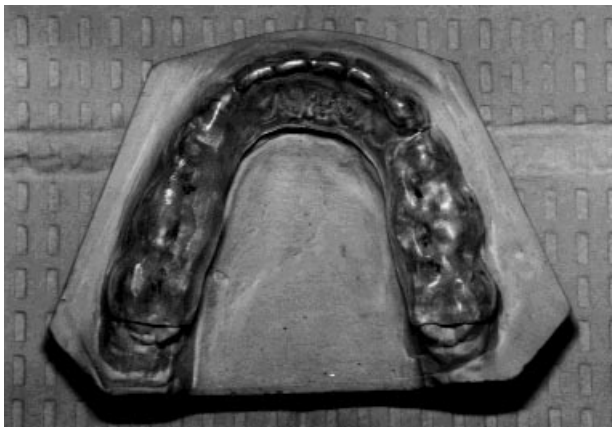

Figure 1
Bite-elevating appliance.

and did not interfere with the usual bite of the subject (**Figure 2**). When the device was fitted intraorally, mock equilibration and testing with the IDP were performed as with the BEA. During the IDP, Dr. Tariq Abduljabbar tested strength, using minimal downward pressure giving the impression that peak strength was achieved.

Each appliance was checked by Dr. Noshir Mehta with the IDP. In cases where the two evaluators did not agree that the strongest response to the IDP had been achieved, adjustments were made on the appliance until both evaluators could agree.

Testing Equipment

All actual strength testing was performed by the Neuromuscular Disease Research Laboratory of the Department of Neurology at Tufts New England Medical Center. Standard maximal voluntary isometric contraction testing,[13, 14] uses a system of pulleys and electronic strain gauges to measure objectively skeletal muscle strength in the shoulders and upper and lower extremities. Twelve strength measures were obtained from each subject by taking the greater value of two trials of each of the following: l. Flexion and extension of the right and left elbow (four measures), flexion and extension of the right and left shoulder (four measures) and 2. Flexion and extension of the right and left knee (four measures). These 12 measures were taken under three bite conditions: habitual occlusion, placebo and BEA. In all, 72 strength measures were obtained from each subject, 36 of which were used in the study. The sequence of the testing was the same for each subject with a three minute rest between each of the 72 trials. The greater of the two values for each test was used for analysis, because it was thought to more closely reflect the peak strength for a given subject on each test rather than the average of the two.

Figure 2
Placebo appliance.

Testing Sequence

Each subject served as their own control. The testing sequence was randomly counterbalanced with ten subjects tested with the BEA first, the placebo second, and conversely with the second ten. Only the dentist who originally assigned appliances to envelopes "A" and "B" was aware of their contents. After each patient presented to the testing laboratory with their two appliances:

a. The first test sequence always measured baseline strength with the subject biting in her dental, habitual occlusion (without appliance). At least three minutes rest was allowed between each test and following sequences.
b. Following a ten minute rest, the second test sequence was carried out biting on "Appliance A". For half the subjects this was the bite-elevating appliance.
c. Following a ten minute rest, the third test sequence was carried out biting on "Appliance B." For half the subjects this was the bite-elevating appliance.

Blinding Control

Dr. Abduljabbar was responsible only for evaluating the patient and fabricating the appliances as described previously. Both he and Dr. Mehta, who checked the BEA, were not in communication with any member of the neuromuscular testing team or the patients during the testing. Subjects appeared at the medical center for testing with two envelopes containing appliances marked "A" and "B" (appliance order having been counterbalanced and coded). The study, therefore, was double-blinded with respect to appliance and strength measurement, with neither the subjects nor the testing technician aware of the order of the appliances or the expected effect of each appliance. None of the researchers at the dental school, including the statistician were aware of the code or results until testing and statistical analysis had been completed.

Results

Pearson Product Moment correlations between initial level of strength and changes due to increased vertical dimension were performed for each of the 12 strength tests and the three test sequences. In no case were initial strength levels significantly correlated with changes in strength (all $Ps > 0.10$). Data for each of the 12 tests were subjected to a two-way ANOVA for repeated measures.

Table 1 lists results of Bartlett's tests for homogeneity of variance. The results showed homogeneity of error variance for all 12 ANOVAs, validating the use of the ANOVAs for tests of means in strength among the three conditions of bite.

Table 1
Summary of Three Group by 20 Subject ANOVAs (Repeated Measures) for Each of 12 Strength Tests

Strength Test	Mean Baseline (Kg)	Mean Placebo (Kg)	Mean Elevated (Kg)	F-Ratios df=2 P Levels	Bartlett's Test Equality of Variances	Baseline vs. Elevated	Baseline vs. Placebo	Elevated vs. Placebo
Elbow Flexion Right	16.52	16.5	17.91	24.28 p=0.00001	>0.10	t=5.98 df38 p<0.001	t=0.11 df38 p>0.10	t=6.09 df38 p<0.001
Elbow Flexion Left	15.87	15.63	17.22	36.3 p=0.00001	>0.10	t=6.72 df38 p<0.001	t=1.18 df38 p>0.10	t=7.90 df38 p<0.001
Elbow Extens. Right	11.3	11.16	12.53	38.34 p=0.00001	>0.10	t=7.16 df38 p<0.001	t=0.78 df38 p>0.10	t=7.94 df38 p<0.001
Elbow Extens. Left	11.58	11.4	13.03	40.92 p=0.00001	>0.10	t=7.34 df38 p<0.001	t=0.91 df38 p>0.10	t=8.25 df38 p<0.001
Shoulder Flex. Right	13.69	13.63	15.22	23.89 p=0.00001	>0.10	t=5.87 df38 p<0.001	t=0.22 df38 p>0.10	t=6.09 df38 p<0.001
Shoulder Flex. Left	13.14	13.18	14.55	25.21 p=0.00001	>0.10	t=6.25 df38 p<0.001	t=0.21 df38 p>0.10	t=6.04 df38 p<0.001
Shoulder Ext. Right	14.65	14.68	16.46	41.16 p=0.00001	>0.10	t=7.92 df38 p<0.001	t=0.13 df38 p>0.10	t=7.79 df38 p<0.001
Shoulder Ext. Left	14.3	13.82	15.84	16.66 p=0.00001	>0.10	t=4.21 df38 p<0.001	t=1.31 df38 p>0.10	t=5.52 df38 p<0.001
Knee Flexion Right	14.2	14.27	15.76	27.67 p=0.00001	>0.10	t=6.58 df38 p<0.001	t=0.29 df38 p>0.10	t=6.29 df38 p<0.001
Knee Flexion Left	14.13	13.96	15.33	15.06 p=0.00001	>0.10	t=3.98 df38 p<0.001	t=1.28 df38 p>0.10	t=5.26 df38 p<0.001
Knee Extens. Right	25.39	25.5	28.25	29.66 p=0.00001	>0.10	t=6.79 df38 p<0.001	t=0.25 df38 p>0.10	t=6.54 df38 p<0.001
Knee Extens. Left	25.51	25.33	27.7	12.67 p=0.00001	>0.10	t=4.18 df38 p<0.001	t=0.34 df38 p>0.10	t=4.52 df38 p<0.001

F-ratios for main effects of the 12 strength measures were all significant at $p < 0.00001$. Comparing mean strength biting in habitual occlusion with the mean strength obtained with the bite-elevating appliance, 12 t-tests at df = 38 showed the mean elevated bite strength was significantly greater at $p < 0.001$ in each case. Similarly, **Table 1** shows that in every case with respect to elevated bite strength versus placebo bite strength, the mean elevated bite strength was significantly greater ($p < 0.001$). On the contrary, mean habitual bite strength was equivalent to mean placebo strength in each of the 12 strength tests.

Considering strength, measured during habitual bite as a baseline, **Figure 3** shows the mean differences between baseline and both bite-elevated and placebo strength means for 20 subjects in each of 12 tests. It can

Table 2
Analysis of Distribution of Total Number of 240 Strength Responses in Each of Three Bite Conditions and Their Relationship with Other Bite Conditions

	Habitual	Placebo	Bite-elevated
Number Responses Greater than Placebo	148		231
Number Responses Greater than Habitual		92	223
Number Responses Greater than Elevated	17	9	

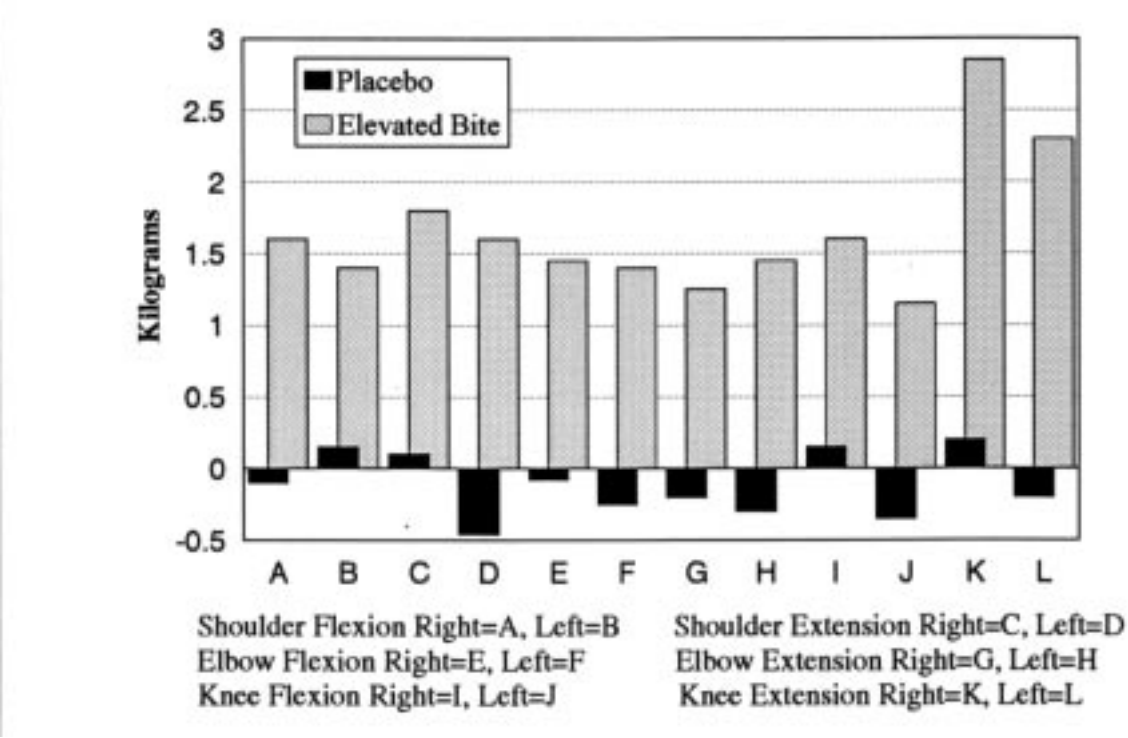

Figure 3
Mean difference (Kg) from baseline strength for 12 tests, 20 subjects biting on elevating appliance and placebo.

be seen that the mean difference for the elevated bite condition are all one kilogram (2.2 lbs) or greater, while mean placebo difference scores range between +0.2 and -0.5 kg.

An analysis of the frequency and relative magnitude of strength responses is summarized in **Table 2**. Of a total of 240 strength measures in each bite condition, the bite-elevated condition had the greatest number of responses: 231 greater than placebo and 223 greater than habitual bite. Assuming the distribution of strength responses in habitual and placebo conditions to be equal, 120 responses would be expected to be found on each side of the mean. **Table 2** shows that 148 habitual responses were greater than placebo (instead of 120) and 92 placebo responses were greater than habitual (instead of the 120 expected by chance). The mean difference for the 240 comparisons (habitual/placebo) was 0.12 kg. The mean difference of 240 comparisons between bite-elevating appliance and habitual bite (BEA/habitual) was 1.61 kg and between BEA and placebo, 1.59 kg.

An analysis of subjects benefiting the most from bite elevation was performed by splitting subjects into the upper and lower halves for each test and calculating the percent difference from baseline (habitual bite strength) of both elevated and placebo strength values. **Table 3** shows means of the top responders wearing the elevated appliance range from 12.5 to 21.5 percent with a grand mean of 17.2%, while the means of the lower responders vary from -0.3 to 6.1 percent with. a grand mean of 4.1%.

Figures 4, **5** and **6** compare bite-elevated and placebo means and complete ranges of strength scores as percent difference from baseline for each of the 12 tests for the top ten responders. With two exceptions (placebo shoulder flexion left and placebo knee extension left) the complete ranges of the percent difference from baseline scores of the top ten responders wearing the bite-elevating appliances were only overlapped by the ranges of the placebo scores below the mean in six tests and were not overlapped at all in four tests.

Discussion

No evidence of a placebo effect was found in the results of this experiment. The grand mean strength (240 individual measures) of biting in habitual occlusion (15.88 kg) was almost identical to the mean strength biting on the placebo appliance (15.75 kg). The grand mean strength of biting on the bite-elevating appliance was 17.48 kg. **Table 2** shows that in only 9 of 240 comparisons did placebo strength values exceed those

Table 3
Comparison of Elevated and Placebo Appliance Strength Expressed as Percent Mean Difference from Habitual Strength as Baseline. Twenty Subjects Divided into Ten Highest Responders vs. Ten Lowest Responders

Body Part Tested	Elevated High Responders	Placebo High Responders	Elevated Low Responders	Placebo Low Responders
Elbow Extension R	17.0	0.4	4.9	-3.3
Elbow Extension L	18.9	0.1	6.1	-2.3
Elbow Flexion R	13.4	1.9	3.2	-2.1
Elbow Flexion L	12.5	-0.5	4.5	-2.5
Shoulder Extension R	17.3	0.9	7.0	-0.3
Shoulder Extension L	17.4	-1.8	3.1	-4.4
Shoulder Flexion R	18.7	0.7	3.8	-1.6
Shoulder Flexion L	16.1	3.2	5.6	-3.1
Knee Extension R	19.8	2.0	4.8	-0.8
Knee Extension L	21.5	3.1	-0.3	-2.4
Knee Flexion R	18.0	4.2	4.9	-1.9
Knee Flexion L	15.9	0.1	1.3	-3.5
Mean of all Means	17.2	1.2	4.1	-2.3

obtained with the bite-elevating appliance, and in only 92 instances did placebo measurements exceed habitual bite measurements (slightly less than the expected 120 had the placebo and habitual bite distributions been determined by chance with 120 distributed equally on each side of the mean). That 62% of the habitual bite values were greater than placebo strength values with a mean difference (habitual/placebo) of 0.12 kg reinforces the absence of a placebo effect and supports the contention that the differences between the two conditions were small and tended to be equally distributed around zero.

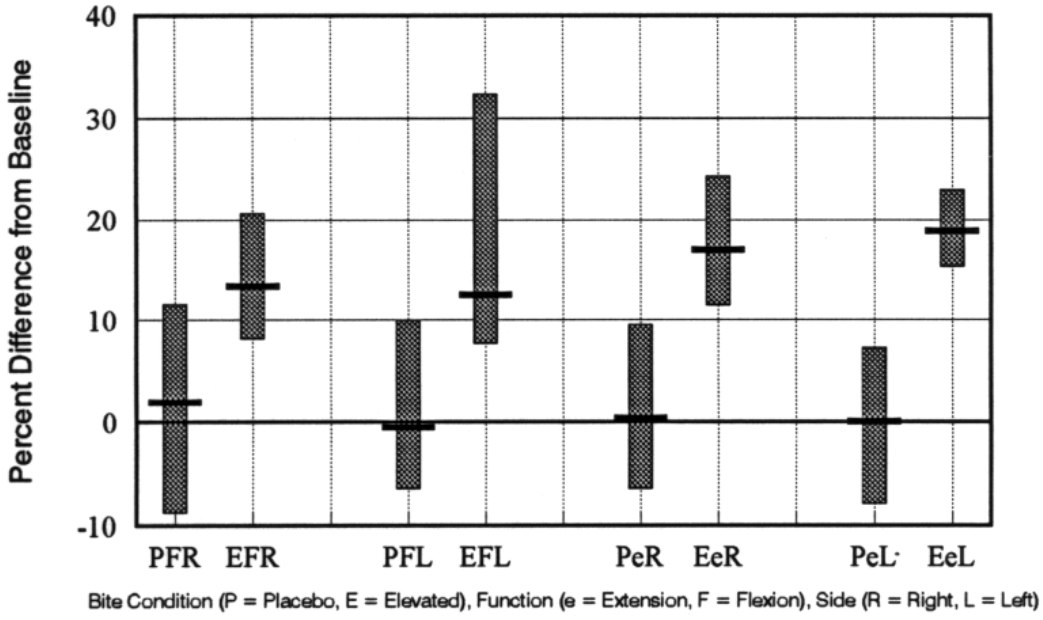

Figure 4
Mean (**bar**) and range of % increase from baseline of top ten Ss for elbow strength extension and flexion, right and left, comparing placebo (**P**) with elevated (**E**) bite response.

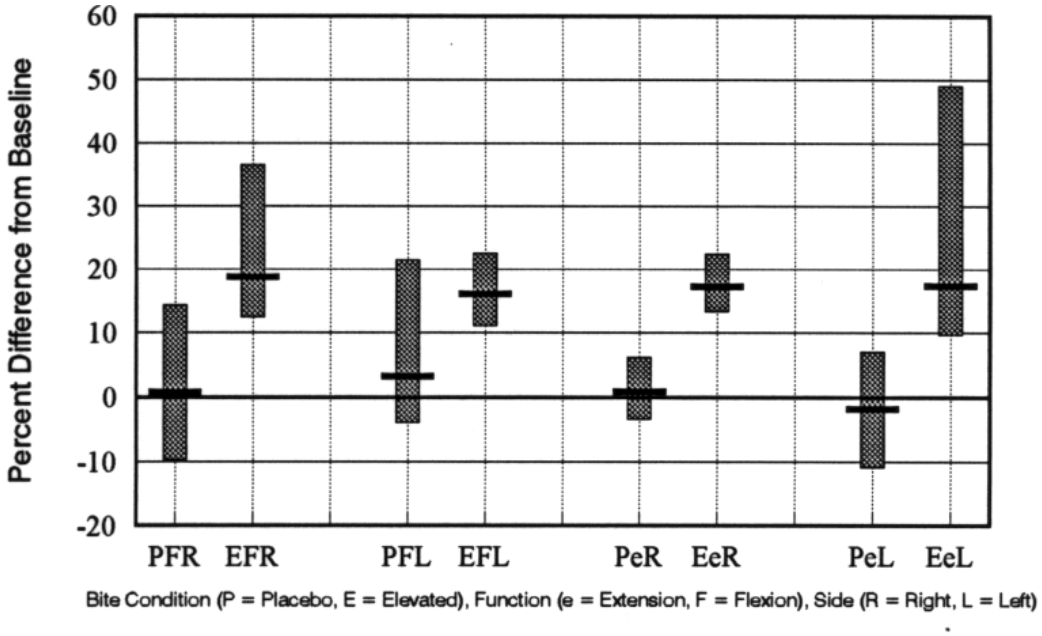

Figure 5
Mean (**bar**) and range of % increase from baseline of tope ten Ss for shoulder strength extension and flexion, right and left, comparing placebo (**P**) with elevated (**E**) bite responses.

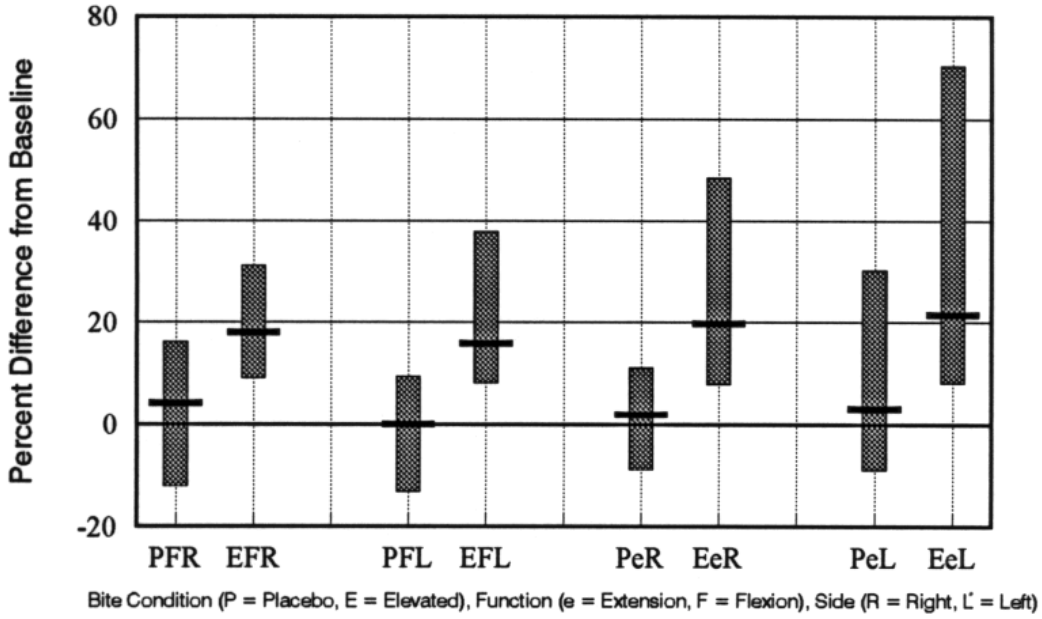

Figure 6
Mean (**bar**) and range of % increase from baseline of top ten Ss for knee strength extension and flexion, right and left, comparing placebo (**P**) with elevated (**E**) bite responses.

The increase in strength obtained with the bite-elevating appliance was not due to a few subjects with large increases. Considering that 223 of the bite-elevating appliance strength values out of 240 were greater than habitual values attests that almost every subject increased in strength over habitual bite levels in almost every test. Significant mean increases in the bite-elevating appliance condition, as shown through the analyses of variance, were the result of a consistent pattern of increased strength and not due to a small number of exceptional subjects. The latter would have obviated distribution assumptions tested in the ANOVAs and produced excessive error variance.

In anticipation of the criticism that the mean increase of approximately l.6 kg from baseline in the bite-elevated condition is not large enough to be "clinically significant" or "clinically relevant," the responses of the subjects were divided into upper and lower halves. The size of the increase in strength from baseline for biting on the elevated appliance was 17.2% for the top ten responders, while the bottom half of the group averaged 4.1%. Half the subjects then, demonstrated a sizable increase in strength. In a clinical situation, these findings indicate that approximately 50% of patients demonstrating loss of vertical dimension will benefit from a bite-elevating appliance with approximately a 17% increase in isometric strength in the shoulders and extremities. Isometric strength is known to be involved in sustaining long-term muscle contraction and the maintenance of body posture.

This study was performed specifically on temporomandibular disorder patients suffering from pain and associated disabilities. The findings of this study indicate that temporarily elevating the maxillo-mandibular relationship in at least half of these patients may assist physical therapy in helping to strengthen and stabilize muscles. Increasing posture strength in these patients may reduce the muscle stress and increased tension necessary to perform everyday motor tasks.

Should future studies continue to corroborate these findings, the first strong functional relationship between maxillo-mandibular position and function of muscles quite removed from the oral cavity will be established. Once established, this relationship may foster investigation of the neurologic pathways and the neuromuscular mechanisms of the phenomenon and possibly open the way for dentistry to define the role of the masticatory system in general health.

Conclusion

Twelve measures of isometric strength, obtained from 20 female TMD patients with loss of vertical dimension of occlusion, increased significantly from habitual bite and placebo levels when a bite-elevating appliance set to a functional criterion was worn. No evidence of a placebo effect was found in this double-blind experiment. The findings suggest a functional relationship between maxillo-mandibular changes and variations in isometric strength throughout the body.

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