

The Relationship Between Jaw Posture and Muscular Strength in Sports Dentistry: A Reappraisal

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ABSTRACT: From the late 1970s until the early 1990s, there have been several reports of improved appendage muscle strength and athletic performance. Much of the criticism of using a mouthguard alone or in conjunction with a splint, such as a mandibular orthopedic repositioning appliance (MORA), to enhance athletic performance has been aimed at study designs, controls, periods of time, double blindness, and the placebo effect. Although it would appear that designing a study which pleases both clinician and researcher would be a difficult task, studies have been performed that do meet the "gold standard." The results favor the premise that jaw repositioning can enhance appendage muscular strength and athletic performance. Studies performed during the mid-1980s, and to which the scientific community refers to continually, on closer examination are flawed.

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Several dentists who had been treating patients with temporomandibular disorders and orofacial pain for years, reported increased strength and performance in their patients as a result of changing their maxillo-mandibular relationships.¹⁻³

In the 1970s, the work of John Stenger,⁴ the dentist for the Notre Dame football team, attracted attention. He published several articles related to mouth protection in which he correlated some of his statistical findings on improved strength in both football and track and field. Dr. Stenger and several of his colleagues, namely, Drs. Lawton, Ricketts and Wright, had published a paper earlier, in 1964, in the Journal of the American Dental Association,⁵ dealing with the use of mouthguards and documenting their relationship with cervical stress release and postural influences. Similar results were reported by William Osmanski, a former professional football player, who fitted mouthguards to a specified thickness for a group of athletes.³

The primary goal of proponents of mouthguards was to provide universal protection of the teeth and jaws from trauma. Although much has been said and published on this subject over the past 40 years, the idea that mouthguards, mouth "protectors," or bite appliances could also provide some increment of increased muscle balance, strength, and/or coordination when it surfaced 18 years ago seemed to be an intriguing idea deserving of further research.

An article¹ which appeared 18 years ago dealt with oral orthopedic examination and the findings related to muscle testing of players on the Philadelphia Eagles football team. On clinical examination, the author found a significant number of TMD-related symptoms and made specific correlations in this and subsequent articles. At

that time, a low percentage of players surveyed (22%) had worn nightguards. Three years later more than 85% of the players wore mouthguards. Since that time, much has been published relative to the necessity of wearing mouthguards.

Athletic Performance and Jaw Posture

One of the first articles to appear on this subject was by Stephen Smith,¹ who performed a sample study on professional football team players with an emphasis on the temporomandibular joint and associated musculature.

Smith ascertained that there was a correlation between the corrected jaw posture and the ability to give a stronger contraction. This was measured first with both the teeth together in habitual occlusion, and then with a wax bite position, which was fabricated by bringing the player's lower jaw from physiologic rest position toward the closest speaking space with midlines evenly aligned. The measurements were made using a Cybex II Dynamometer in conjunction with the kinesiological deltoid press method.^{6,7} The Cybex data was not as significant as first believed.

Smith was the first person to investigate Stenger's proposed relationship. In Smith's experiment, isometric strength in three mandibular positions was tested subjectively: 1. acquired centric occlusion; 2. the wax bite position; and 3. the position produced by an unadjusted football mouthguard. This study was criticized later⁸ for not including a statistical analysis of the data.

However, Forgione, et al.,⁸ 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 while biting in acquired centric occlusion. Strength biting on the wax bite set at the functional criterion was significantly greater than biting on the unadjusted mouthguard.

In a later study, Smith⁹ recorded strength in response to the Isometric Deltoid Press (IDP) objectively with an electronic strain gauge. Again, Forgione, et al.,⁸ 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.

In 1980, Kaufman fabricated and positioned several splints for the United States Olympic luge and bobsled teams. He discovered that headaches previously reported by luge athletes during their runs, were alleviated to varying degrees in some of the athletes by use of these appliances. Some of these athletes also indicated an

increase in strength when pushing off at the start.

These original findings were then followed up by a double-blind study¹⁰ conducted to observe the effects of the mandibular orthopedic repositioning appliance (MORA) on football players on the 1982 C.W. Post College football team. Forty players were randomly divided into two groups, one wearing the MORA¹¹ and the other wearing conventional mouthpieces (CM).¹² The players were tested primarily to discover the effects of the MORA on performance, number, type and severity of injuries, as well as on three measures of physical fitness: strength, jumping ability, and balance and agility.

The overall results were positive and in favor of the MORA. Among players using the MORA there were less severe injuries, decreased numbers of knee injuries, and greater strength and satisfaction. No significant findings favored the CM. These findings highlight the importance of the MORA to football players.

Two other studies conducted at well-known teaching institutions showed a positive correlation between changes in jaw relationship and increases in strength and muscle efficiency. One study¹³ showed a highly significant increase in muscle strength and efficiency (power) of a group of athletes as recorded by vertical jump (five percent increase) and a 17.3% increase in the grip test. However, there was no significant increase in strength recorded for the maximum hip sled or bench press test.

The other study tested 23 athletes, and compared mandibular position with appendage muscle strength. Three different mandibular positions were tested, along with all four appendages. The results indicated that mandibular position affects appendage muscle strength and may be important to total well-being. However, considerable variability of optimum muscle strength by muscle groups and mandibular positions was noted.¹⁴

Another double-blind study, performed at the University of Illinois, involved 20 randomly selected volunteer undergraduate students.¹⁵ The subjects were given oral examinations, and two appliances were then constructed for them: a MORA, which repositioned the mandible three dimensionally, as described by Gelb,¹⁶ and a placebo appliance that did not alter the occlusion.

The following bite conditions were then tested for each individual: centric occlusion, centric occlusion with the placebo splint inserted, and the position with the MORA inserted. Data was collected using a Cybex II Dynamometer with the subjects seated in a stabilized chair. The information obtained was for three bite conditions: a normal bite, a normal bite with the placebo splint inserted and a normal bite with the MORA splint inserted. Statistically significant differences were recorded between the MORA and normal bite conditions for shoulder

extension, peak torque; shoulder extension, average torque; and external rotation, average torque. No statistical differences were observed between the placebo and the normal bite condition.

Charges/Countercharges

Critics of the group favoring increased strength have contended that their work lacked:

1. Adequate controls in the research design (such as double-blind experimental designs).
2. Proper statistical analysis.
3. Knowledge of strength testing.

On the other hand, research indicating that the maxillary and mandibular orthopedic repositioning appliance (MORA) is ineffective for strength increases has been criticized because:

1. It did not allow adequate time for the MORA to work.
2. The MORA will only work on subjects with TM disorders or occlusal problems.
3. It is not known whether or not the appliance has placed the mandible in its optimal physiologic relationship.^{11, 17}

One other early study should be mentioned, because of inferences made that need to be corrected.¹¹ In this study 14 basketball players, none of whom had any clinical or historic evidence of TMD, myofascial pain dysfunction syndrome (MPDS) or posterior bite collapse, were tested in a randomly assigned order with an experimental opening appliance, a placebo appliance that did not alter the mandibular position or vertical dimension, and no appliance. Results clearly demonstrated there was no change in strength among the three groups.

Interestingly, of the 14 athletes, nine were Class I; three were Class II, subdivision 1; and two were Class II, subdivision 2. The results of the study reportedly indicated that "opening the bite" of the normal subject will not increase upper body strength.

If one assumes the study was done as stipulated, these authors would also agree that "opening the bite," or just increasing the vertical dimension of a normal subject, will not increase upper body strength, but this bears no relevance to the three-dimensional maxillomandibular relationship for each individual subject. This study, like others previously mentioned, showed a total lack of understanding of the model analysis as described by Lieb,¹⁸ or as addressed by Verban.¹⁹

Scientific Flaws

Although many of the earlier studies were definitely

flawed from a scientific viewpoint, from a strictly clinical standpoint, positive changes were noted. These changes of increased strength and performance deserved further investigation.

Two articles which appeared in March 1984 in the *Journal of the American Dental Association* warrant mention.^{20, 21} They describe two obviously flawed studies carried out at two universities in the same state. These studies were later refuted by credible scientific research. Yet, the later scientific studies were rarely mentioned at major meetings or in succeeding studies. Only the two obviously flawed studies were mentioned when the subject matter on which these articles were based was discussed. Is there a "double (gold) standard," because it serves a special group's purpose? This double "gold" standard denies the use of information of the utmost value to all practitioners regardless of their specialties.

The two flawed studies reported in *JADA* showed little comprehension of the procedures for fabricating appliances for TMD and athletically involved patients that have been advocated for years. Each of these studies used treatment splints that were fabricated using the design recommended by Gelb, but not the three-dimensional model analysis as prescribed by Lieb,¹⁸ which calls for subsequent mounting on a Galetti Articulator to achieve the corrected maxillomandibular relationship for each subject.

In one study,²¹ the vertical dimension between the incisors was increased by a constant 2 to 3 mm for all subjects. None of the subjects gained or lost muscle strength through the use of the mandibular orthopedic repositioning appliance.

In the other study,²⁰ the occlusal portion of the splint occupied the subject's freeway space and was adjusted to provide even contact in centric occlusion. Forty-two percent of the subjects (20) had clicking in the TMJ, but none of the subjects had palpation tenderness of the masticatory muscles or the TMJ. All subjects underwent a chiropractic-applied kinesiologic evaluation to test isometric muscle strength. This examination showed nine subjects would benefit from wearing a MORA. Five subjects received treatment splints, and four wore placebo splints.

This procedure is certainly questionable, since the bite positionings were not adjusted by kinesiologic guidance or by the chiropractor's suggestion.

Verban¹⁹ summed up much of what was wrong with these two studies in a letter to the editor published in the July 1984 *JADA*. He said, "It is not the MORA, but rather the position obtained with the MORA that is important. This position is not universal and must be determined for each individual. Under this hypothesis, a study in which

each MORA is constructed exactly the same could not prove a benefit of statistical significance."

Yates in the June 1984 *JADA*, responding to another letter to the editor, shows his lack of understanding by saying, "I should like to remind him that our testing procedures come from the claims of MORA supporters,²² who show pictures in their publications indicating that strength is increased simply by inserting the MORA."

This could not be further from scientific reality and indicates a lack of understanding of the actual procedures performed.

Gaining New Perspectives

Forgione, Mehta, Westcott and McQuade^{8, 23} surveyed 20 experimental and clinical studies and two review commentaries. Their study attempted to organize what has been reported to date; 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. They state that if Stenger's original concept is proved to be correct, it will have implications, not only for athletic performance, but for the more central role of occlusion in health and behavior.

In their review they found that a commentator,²⁴ a reviewer,²⁵ and the authors of three of the studies^{11, 20, 21} made emphatic general statements critical of the original results and several studies that followed supported Stenger's original proposed relationship in spite of several factors, which they enumerated as follows:

1. Most of these experiments used subjects with no apparent malocclusion or lack of posterior support, and other subjects who had mixed occlusions.
2. Most researchers set bite appliances by techniques other than kinesiologic 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 while commenting upon "strength" unqualifiedly.
4. Some researchers employed either questionable statistics, experimental design or both.
5. Some authors and a commentator have invoked placebo as a criticism of evidence that supported Stenger's proposal even though the placebo effect has not been demonstrated in any of the studies that employed a placebo control condition. The belief that the placebo effect is omnipresent has even fostered an explanation for its lack of appearance.

In addition, they mention the possible role of body test

position, and its consequent influence on the bite as it affects results.

Their manuscript dealt not only with a review of the current literature on variation in strength of extraoral muscles as a function of bite relationship, but also includes a reversal design study using a K-MORA (kinesiologically determined using the isometric strength of the deltoid muscle), a deflection appliance, and a placebo appliance.^{8, 23}

In this study of the effect on isometric strength of biting on three different intraoral devices and habitual occlusion, it was concluded that a relationship does exist between bite and isometric strength. They also found that the previous speculation concerning the role of the placebo effect was not substantiated by the data gathered in their experiment.

The Female Experience

A methodologically refined replication of Smith's experiment was performed by Fuchs²⁶ in 1981. This unpublished dissertation compared isometric strength of 40 females divided equally into five groups: TMJ patients, athletic TMJ-symptomatic subjects, sedentary TMJ-symptomatic patients, normal athletic subjects, and normal sedentary subjects. Identical with Smith's experiments, a wax bite was fabricated for each subject guided by the IDP. But unlike Smith's research design, a disoccluded and a placebo condition were both included. The 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, an intra-oral device that supports a mandibular position determined by a functional criterion, which is a locking response to the IDP, a muscle challenge used by kinesiologists; and 4. bite with a placebo wax buccal device. An electronic strain gauge identical with that employed by Smith⁹ 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 markedly different. Tukey's multiple comparison technique showed no significant differences among mouth open, acquired centric, and placebo conditions. Greater strength was obtained with the K-MORA than in all the other conditions. For the lower body, a significant difference in strength was obtained between the K-MORA and the mouth open. Similarly, the 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 then 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. Fuchs replication of Smith's research helps answer the unchallenged placebo criticisms in the literature that tend to obviate Stenger's and Smith's seminal findings prematurely.

A double-blind study (Abduhl Jabbar, et al., 1994)²⁷ was designed to test the bilateral isometric strength of the extremities and shoulder girdle of female TMD patients. The 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. The strength testing was carried out at the Neuromuscular Disease Research Laboratory of the Department of Neurology at the Tufts New England Medical Center, an independent medical facility, using the apparatus and procedures^{28, 29} routinely used to assess the isometric strength of patients with neuromuscular disease.

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 a K-MORA; 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 K-MORA was consistently greater ($p < 0.001$) than baseline or placebo strength. Baseline and placebo conditions were equivalent.

These findings confirm observations that individuals with loss of vertical dimension of occlusion respond to a bite-raising appliance by increased isometric strength.

Isometric strength of the sternocleidomastoid muscles (SCM) was assessed in 15 subjects demonstrating deep bite and loss of vertical dimension by al-Abasi, et al.³⁰ In the preliminary part of the experiment all subjects were tested sitting, with the head unsupported and the teeth 1. disoccluded and 2. biting in habitual occlusion. Strength with the teeth disoccluded was significantly greater than biting in habitual occlusion. Four types of acrylic lower appliances were then fabricated:

1. 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.
4. Lateral shift of 1 mm to the left.

Each subject was tested twice, biting with and without appliance in habitual occlusion, edge-to-edge, retruded and lateral shift positions. Analysis of variance showed a significant difference between groups. The mean sternocleidomastoid muscle (SCM) strength of 27.17 lbs. obtained when biting in all the elevated vertical positions was greater than 21.73 lbs. obtained biting without a bite elevating appliance.

More detailed analysis showed:

1. Without an appliance, SCM strength, biting in habitual occlusion, was lower than in the edge-to-edge position but not in the retruded and lateral shift positions; 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.

Far Eastern Contributions

Researchers in Korea and Japan have taken an interest recently 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.³¹ 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.

Tsukimura³² tested back strength of eight subjects at different vertical dimensions. In the disoccluded mandibular position, back strength was the weakest, but tended not to increase as a 2, 5 and 10 mm splint was worn and decreased when a 15 mm appliance was worn. Maximum strength was obtained in the 2-10 mm range of splinting.

Yokobori and Horii³³ performed the critical experiment supporting the contention of Forgione, et al.,⁸ 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 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.

A study presented last year³⁴ suggested that wearing appropriate complete dentures is essential to not only the restoration of masticatory function, but also the maintenance of the ability of physical exercise. A previous study done by the same investigators suggested that the occlusal support played an important role for the normal dentate subjects who exhibited teeth clenching during physical exercise. Since the occlusal support is obtained by wearing complete dentures in edentulous patients, physical exercise should be affected whether wearing dentures or not.

Summary

The clash that exists between the clinician and some scientists is becoming ever more visible as the differences between applied and basic biological research narrow, and the time lag between a fundamental discovery and clinical application shrinks. In a number of cases, the opposite can be true. It is no surprise that clinical application of value to the patient may outstrip scientific verification because of differences in training and individual interests. Scientists spend five to ten years of postgraduate training learning how to conduct proper research, whereas physicians devote the bulk of their training to patient care. This also holds true for dentists.³⁵

The time has finally come for dental clinicians and scientific researchers to develop greater mutual respect, thereby providing better and more cost-effective care to our patients sooner and with less suffering.

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