Affecting Upper Extremity Strength by Changing Maxillo-Mandibular Vertical Dimension in Deep Bite Subjects

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ABSTRACT: The effect of vertical dimension of occlusion (VDO) on maximizing isometric deltoid strength (IDS) was measured in subjects with deep overbite. Sixteen female dental students with deep dental overbite and no history of temporomandibular joint disorder (TMD) were used as their own control and tested for isometric strength of the deltoid muscles, using a hand held strain gauge. Measurements were taken under four mandibular conditions: 1. habitual occlusion; 2. mandibular rest position; 3. biting on a bite elevating appliance set to the functional criterion of peak IDS; and 4. biting on a placebo appliance. Results showed that in deep bite subjects, isometric deltoid strength in habitual occlusion was significantly less than in the mandibular rest position. Isometric deltoid strength with the bite elevating appliance was significantly greater than isometric deltoid strength in habitual occlusion, as well as in the mandibular rest position. Isometric deltoid strength achieved in habitual occlusion and placebo did not differ. Results of this study support previous findings indicating that a change in the VDO will affect isometric strength of the upper extremities.

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It was observed by Stenger[1] that lack of posterior support and malocclusion were factors that limited athletic performance. He proposed that the posture of the mandible affects head posture and consequently influences muscular function in other parts of the body.

According to Rocabado,[2] proper position and stability of the mandible affects head posture and brings about proper alignment of the cervical vertebrae. Cervical and shoulder musculature may be restored to a normal physiological state of rest with the correction of temporomandibular joint (TMJ) and cervical realignment, which may also improve overall muscle performance. Gelb[3] proposed the *Oral Orthopedics Theory*, which states that "malrelationship of the mandible to the maxilla has an effect on the entire neuromuscular system involving the functioning of the head, neck, and shoulders."[4]

Smith[5] performed a study to examine the effect of an increased vertical dimension of occlusion (VDO) on isometric deltoid strength (IDS) in 25 members of a professional football team. It was determined that the postures of the mandible and arm isometric muscle strength were related. No statistical analysis was presented to support the results. However, Forgione, et al.[6] performed statistical analysis on Smith's published data and showed that

isometric deltoid muscle strength was significantly different between the three conditions tested, where biting on an unadjusted mouth guard produced greater strength than biting in acquired centric, but less than biting on a wax bite. Forgione, et al.[6] also analyzed Smith's subsequent published data[7] and found isometric strength biting at the mandibular position determined by the functional criterion to be significantly greater than biting in acquired centric or on an unadjusted mouth guard.

In 40 female subjects, Fuchs[8] measured isometric strength of six body parts in four mandibular positions using an electronic strain gauge and found significantly greater strength when the wax bite was used. 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.

Garabee[9] tested runners for isometric strength of the tensor fascia lata muscle with a pressure cuff in three positions: 1. when teeth were separated; 2. acquired centric occlusion; and 3. biting on a diagnostic wax jaw support. Forgione, et al.[6] applied statistics using the published results and found a significant increase in muscle strength when a diagnostic wax bite set to a functional criterion was used as compared to biting in habitual occlusion.

Forgione, et al.[10] assessed deltoid isometric strength in weight lifters with mixed occlusions using a Nautilus lateral raise exercising device. They found that the average strength obtained with the elevated bite set to the functional criterion was significantly greater than in all other bite conditions.

Jabbar, et al.[11] reported finding a relationship between mandibular position and isometric strength of the upper and lower extremities. Habitual bite and placebo did not differ in strength, and both were significantly less than strength with a bite elevating appliance (BEA). Their results strongly suggest that parts of the body other than the stomatognathic system can be affected by bite position.

The effect of VDO and mandibular position on isometric strength of the sternocleidomastoid (SCM) muscles was studied by Al-Abbasi, et al.[12] They found that biting at an elevated vertical dimension increased SCM isometric strength in deep overbite subjects irrespective of position, but elevated habitual and edge-to-edge positions increased the most.

The effect of a BEA on the strength of the back muscles was tested by Kang and Lee.[13] Results indicated an increase in the back muscle strength when using a BEA.

Tsukimura[14] tested back strength in eight subjects at different VDOs and found that back strength tended to reach peak strength at the range of 2-10 mm .

Yokobori and Horii[15] examined the strength of 40 college athletes using isometric and isokinetic tasks. Isometric strength increased when using a BEA while isokinetic strength did not.

Chakfa, et al.[16] examined the effect of a stepwise increase in VDO on the isometric strength of cervical flexors and deltoid muscles in nonsymptomatic females and found that the strength of these muscles increased significantly from habitual occlusion as the VDO increased. This strength then diminished as the VDO was increased further.

Despite the controversy in the dental literature as to the effect of mandibular posture on skeletal muscles,[1,5,7,10,17-25] the above studies support the contention that changes in VDO and mandibular position affect muscle function in other parts of the body.

The purpose of this study is to evaluate the effect of changing maxillo-mandibular vertical dimension on isometric strength of the deltoid muscles in normal subjects with deep overbites.

Materials and Methods

Sixteen female volunteers (mean age: 28; S.D. ±4 yrs) were included in the study. Volunteers were dental students of Tufts University School of Dental Medicine. They were selected on the basis of the following inclusionary criteria: 1. healthy individuals with no history of recent trauma; 2. present a dental occlusion with a deep overbite (covering 60% or more of the mandibular anterior teeth in a maximum intercuspation position); and 3. when tested subjectively, there was a noticeable difference in the IDP between the two mandibular positions, a. teeth disoccluded and b. habitual occlusion.

Exclusionary criteria included: 1. five or more permanent dental restorations; 2. loose or broken teeth; 3. fillings or crowns which could be further damaged during the course of the study; and 4. subjects with a history of allergy to any of the dental materials used.

The M-T computer (**Figure 1**) was used to measure the resisting strength of the group of muscles being tested (Forgione, et al.[10]). Each subject received two appliances. The first was a BEA (**Figure 2**), which was a mandibular removable, full coverage, intraoral acrylic appliance, fabricated to elevate the vertical dimension and to correct frenal midline discrepancy. The base of the appliance was fabricated by stretching a heated two mm thick acrylic disk over a mandibular stone cast in a Dentsply Vacupress (Right-Guard Corp. York, PA). Cold curing orthodontic acrylic resin was used to fill the interocclusal distance between the maxillary and mandibular premolars and molars . The second appliance the subjects received was a placebo appliance, which was a mandibu-

Figure 1
The MT Computer (Bio-My Products, Carlsbad, CA) used in this study.

lar, removable, intraoral acrylic appliance with no occlusal coverage (**Figure 3**).

Intraoral Appliance Insertion Procedure

The bite elevating appliance (BEA) "A" was inserted and balanced to the functional criterion of peak isometric deltoid press (IDP).[10] Each subject was seated erect in a dental chair with the head supported by the chair's head rest. With the teeth disoccluded (mandibular physiologic rest position), a vertical downward increasing strength was applied subjectively to the subject's arm, extended horizontally at a 180˚ angle to the chest (**Figure 4**). The examiner applied vertical pressure gradually and increasingly to the subject's wrist with one hand while the contralateral shoulder was stabilized using the other hand. Force was applied until the subject could no longer maintain the arm horizontal. At the point of yielding, the examiner released the pressure. Subjects were then requested to bite slowly and gently into a slightly softened, ten mm thick bite registration wax and to hold the position of the mandible at a one mm interval. IDP was performed at each interval until the IDP strength began to decrease. We measured the vertical dimension of occlusion at which the maximum IDP resistance for both arms was registered. This IDP resistance approximated that achieved with the teeth apart in most instances The BEA was set to that exact height by adding cold cure acrylic resin to the vacuum pressed acrylic base and having the subject bite slowly into it until it had set into a hard state. The appliance was then removed from the subject's mouth and polished. It was then reinserted and checked for any occlusal prematurities and/or interferences using a carbon marking paper. Subjects were retested with the IDP bilaterally. Once the IDP matched that performed with the wax bite, the BEA was considered to be set to the functional criterion. Final polishing was then performed and the appliance was considered ready for the M-T computer testing.

For the placebo condition, a mandibular, removable, intraoral acrylic appliance with no occlusal coverage was fabricated (**Figure 3**). This appliance was fabricated with the same material and using the same method as the BEA with the exception of occlusal coverage.

Placebo appliance *B* was inserted and checked using the carbon marking paper for any occlusal contact. Since the subjects had deep overbites, slight contact was unavoidable in relation to the buccal cusps of the maxillary teeth. However, this did not interfere with maximum intercuspation (centric occlusion), since the acrylic was flexible enough to be depressed when the subjects occluded their teeth. Mock equilibration and IDP were performed as with the BEA. Less vertical pressure was exerted on the subject's wrist to give the impression that there was no difference in the deltoid muscle strength as compared to that performed when the BEA was inserted.

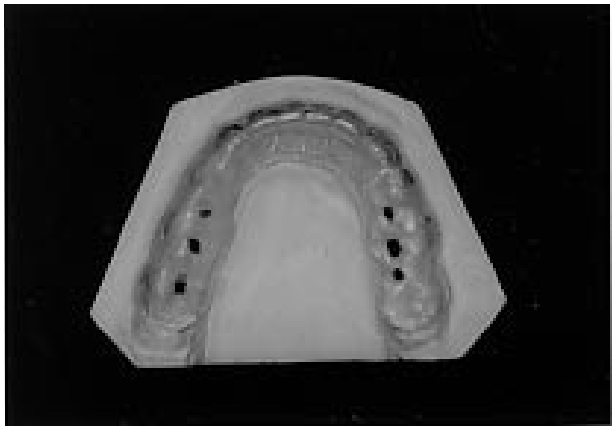


Figure 2
The bite elevating appliance (BEA).

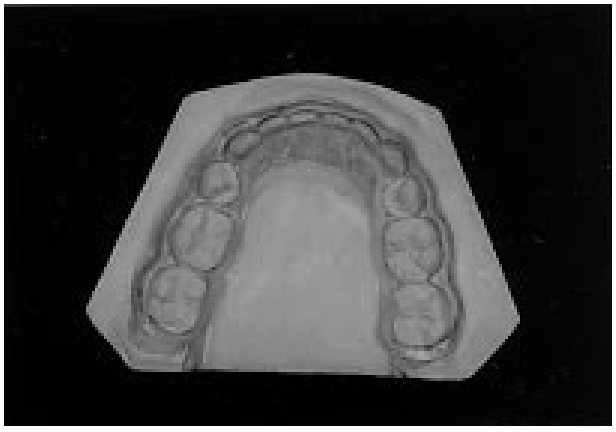


Figure 3
The placebo appliance with no occlusal coverage.

Figure 4
Isometric deltoid press applied to the subject's horizontally extended arm.

Throughout the study, treatment and placebo appliances were referred to as appliances *A* and *B* consecutively for blinding purposes.

Subjects were assigned to one of two groups, which only differed in the testing sequence (**Table 1**): group I (habitual occlusion, teeth apart, appliance *A)*, then appliance *B*; and group II (teeth apart, habitual occlusion, appliance *B* and then appliance *A)*.

Table 1
Testing Sequence and Randomization

	Group one	Group two
Trial I	Habitual occlusion	Teeth apart
Trial II	Teeth apart	Habitual occlusion
Trial III	Treatment appliance	Placebo appliance
Trial IV	Placebo appliance	Treatment appliance

Examiner Reliability

It was important to determine the degree of interexaminer and intraexaminer reliability for IDP M-T Computer measurements. To establish interexaminer reliability, three examiners tested five subjects, independently and randomly, for the four mandibular position (**Table 2**).

Throughout the experiment, two consecutive measurements were recorded for each of the 16 subjects in all four mandibular positions. The mean for the two measurements was used. This procedure was done to evaluate intraexaminer reliability (**Table 3**).

Testing Sequence

One examiner assigned the subject to either group I or group II while the examiner performing the M-T Computer testing remained outside the examination room. The subject was requested to maintain a certain mandibular position or to wear either of the two appliances, depending on the group to which she was assigned and the trial being tested. The second examiner was then called in to perform the testing. At no time was the subject informed as to the relevance of jaw position or the effect of either appliance on isometric strength of the deltoid muscles.

The dominant arm for all subjects was the right arm. Once the appliances were considered to be equilibrated and set to the functional criterion of IDP and the patient was assigned to either group I or II, muscle testing for the right deltoid was performed as follows: the subject was seated upright in the dental chair, instructed to extend the right arm to her side and parallel to the floor (**Figure 4**) and to *maintain the jaw position* throughout the testing. The load cell was held by the investigator's left hand with the sensor resting on the dorsal aspect of the subject's right wrist while the investigator's right hand supported the subject's left shoulder. Pressure to the wrist was then applied by the investigator slowly and increasingly while the subject was motivated verbally *to resist as much as* she could. Once the arm lost its resistance and began to fall downward, the strip chart's pen stopped the measurement at that point (peak resistence) and went back to baseline. If at any time the subject was fatigued, a resting period was provided. In most cases, two minutes of rest were sufficient. Muscle testing was duplicated for all four positions (teeth apart, habitual occlusion, with appliance *A* and with appliance *B*) in the two groups.

Results

Sixteen subjects who met the criteria of selection for the study were selected from 25 volunteer dental students at Tufts University School of Dental Medicine. The mean age was 28 years (SD=3.97). The mean overbite for these

subjects was 82.5% (SD=11.25). Resistance of the deltoid muscle to IDP in pounds pressure (lbs) was registered by the M-T Computer in four conditions (**Graph 1**); biting in habitual occlusion, with the teeth apart, biting on a BEA and biting on a placebo appliance.

The degree of interexaminer reliability was performed for the first five subjects and results were analyzed using the Pearson product moment correlation (r) (**Table 2**). Resistance (lbs) of the deltoid muscles to IDP measured by the first investigator in habitual occlusion was compared to that obtained by the second and third examiners for the same subjects. This comparison was performed at the four mandibular positions. Results (*p* values) indicated a high degree of interexaminer reliability.

The primary investigator performed two consecutive IDP measurements on the 16 subjects for each of the four mandibular positions tested (**Table 3**). Results indicated a high degree of intraexaminer reliability.

A two-way (AS) analysis of variance for three or more related samples was used to determine significant differences in isometric strength of the deltoid muscle as registered by the M-T Computer in all four conditions (Table 1). In habitual occlusion, the mean resistance of the deltoid muscle was significantly ($p<0.001$) less than with the teeth apart (in a mandibular physiologic rest position).

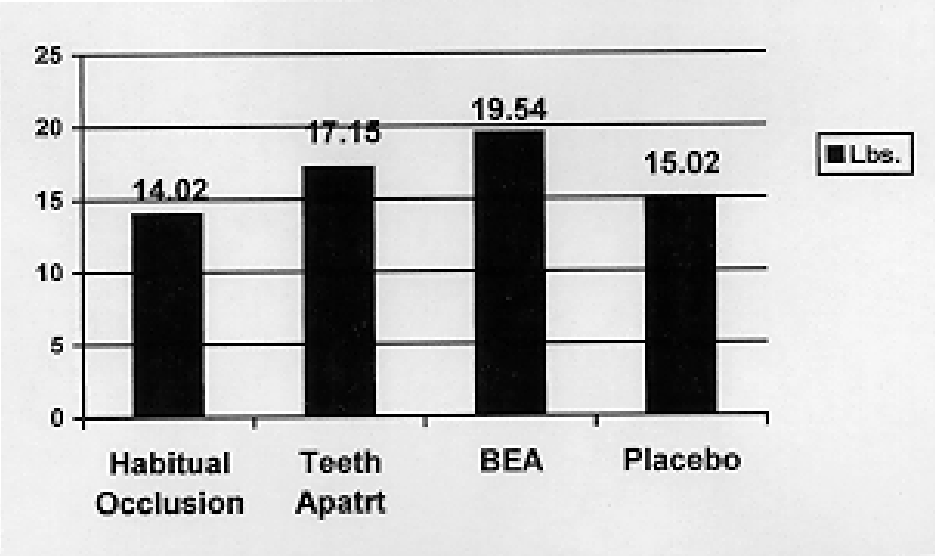
An increase in the VOD by the BEA significantly increased ($p<0.001$) the isometric resistance of the deltoid muscle when compared to IDP in habitual occlusion. When IDP in habitual occlusion was compared to it with the subjects using the placebo appliance, there was a tendency towards a placebo effect (IDP resistance with the placebo appliance being greater for eleven subjects than habitual occlusion). The difference was not statistically significant ($p>0.05$). Resistance of the deltoid muscle with the BEA was significantly ($p<0.001$) higher than with the teeth apart (**Table 5**). IDP resistance was significantly ($p<0.001$) greater with the teeth apart as compared to the placebo appliance.

Discussion

The isometric deltoid press (IDP) is a muscle challenge used extensively by chiropractors. It is an isometric test of strength, much like the postural function of muscles, maintaining a sustained tension against an applied force, gravity. 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. In this study, the peak strength of the deltoid muscle was tested.

Results showed that increasing the VDO in normal subjects with a deep overbite increases the isometric resistance of the deltoid muscle. There was no statistically significant difference between IDP strength in habitual occlusion compared to wearing the placebo appliance ($p>0.05$). IDP resistance with the BEA was significantly greater than habitual occlusion and placebo in all subjects. The mean resistance of the deltoid muscle when a BEA was used was 45% (SD=22.9%) greater than in habitual occlusion.

These results clearly support previous studies investigating the effect of mandibular position on isometric strength of the extremities,[5,7,10,11,15,16] which concluded that increasing the VDO in subjects with a relatively abnormal maxillo-mandibular relationship has a positive effect on isometric strength of the muscles tested. In a personal communication, Professor J. Kronman,



Graph 1
Mean IDP resistance (lbs) in all four conditions.

Table 2
Interexaminer Reliability

IDP in: habitual occlusion	Mean (lbs)	SD (lbs)	N samples
1st examiner	11.6	4.09	5
2nd examiner	11.93	3.97	5
3rd examiner	12.15	3.95	5

1st vs. 2nd: (r=0.9951, p<0.001)
1st vs. 3rd: (r=0.9997, p<0.001)
2nd vs. 3rd: (r=0.9963, p<0.001)

IDP in: teeth apart	Mean (lbs)	SD (lbs)	N samples
1st examiner	15.55	5.09	5
2nd examiner	16.10	5.11	5
3rd examiner	16.02	5.16	5

1st vs. 2nd: (r=0.9961, p<0.001)
1st vs. 3rd: (r=0.9973, p<0.001)
2nd vs. 3rd: (r=0.9905, p<0.001)

IDP in: BEA	Mean (lbs)	SD (lbs)	N samples
1st examiner	16.77	4.36	5
2nd examiner	16.62	4.27	5
3rd examiner	16.98	4.45	5

1st vs. 2nd: (r=0.9878, p<0.01)
1st vs. 3rd: (r=0.9987, p<0.001)
2nd vs. 3rd: (r=0.9920, p<0.001)

IDP in: placebo	Mean (lbs)	SD (lbs)	N samples
1st examiner	11.81	4.11	5
2nd examiner	12.29	4.18	5
3rd examiner	12.30	4.40	5

1st vs. 2nd: (r=0.9896, p<0.01)
1st vs. 3rd: (r=0.9956, p<0.001)
2nd vs. 3rd: (r=0.9957, p<0.001)

[p values based on the Pearson Product Moment Cofficient (r)]

Table 3
Intraexaminer Reliability

IDP in: habitual occlusion	Mean (lbs)	SD (lbs)	N samples
1st measure	13.83	5.47	16
2nd measure	14.21	5.45	16

1st vs. 2nd: (r=0.9821, t for r=19.49, df=14, p<0.001)

IDP in: teeth apart	Mean (lbs)	SD (lbs)	N samples
1st measure	17.12	5.60	16
2nd measure	17.19	5.42	16

1st vs. 2nd: (r=0.9516, t for r=11.58, df=14, p<0.001)

IDP in: BEA	Mean (lbs)	SD (lbs)	N samples
1st measure	19.93	6.02	16
2nd measure	19.13	5.90	16

1st vs. 2nd: (r=0.9614, t for r=13.07, df=14, p<0.001)

IDP in: placebo	Mean (lbs)	SD (lbs)	N samples
1st measure	15.34	6.19	16
2nd examiner	14.73	5.96	16

1st vs. 2nd: (r=0.9925, t for r=30.3239, df=14, p<0.001)

[p values based on the Pearson Product Moment Cofficient (r)]

Orthodontics and Anatomy at Tufts University, proposed a possible neurological explanation, and there is some basis for this in the literature,[30] that describes a possible connection between the motor neurons of the trigeminal and cervical systems.

Kronman offered a possible mechanism for the relationship between bite and isometric strength. The head is innervated by the cranial nerves, whereas the trunk is innervated by the spinal nerves. There are similarities in the functional organization between these two groups of nerves as well as the organization of the components of the central nervous system with which they are directly

Table 4
Means and Standard Deviations for M-T Computer Measurements

	Mean	SD	N samples
Habitual occlusion	14.0194	5.4408	16
Teeth apart	17.1594	5.4528	16
BEA	19.5406	5.9059	16
Placebo	15.0256	6.0580	16

Table 5
The Two-Way Analysis of Variance (ANOVA for Repeated Measures)

Source	df	Mean square	f-ratio	p-level
A	3	287.8574	39.6838	0.00001
S	15	1854.9102		
Error/AS	45	108.8066		
Total	63	2251.5742		

connected. Sensory axons in cranial nerves synapse in sensory cranial nerves nuclei whereas sensory axons in spinal nerves synapse on neurons of the dorsal horn of the spinal cord and the dorsal column nuclei.[26] Like the motor nuclei of the ventral horn, motor cranial nerve nuclei contain the motor neurons whose axons project to the periphery. Extending this parallel between brain stem nuclei and spinal cord gray matter further, the autonomic cranial nerve nuclei are analogous to autonomic nuclei of the intermediate zone of the spinal cord, which contains autonomic preganglionic neurons.[27]

The trigeminal nerve is the largest of all cranial nerves and has three main divisions: 1. ophthalmic, 2. maxillary, and 3. mandibular. The trigeminal nerve contains both sensory and motor fibers. Tactile sensation and jaw proprioception is mediated by the largest diameter fibers (myelinated), while pain and temperature sensations are mediated by small diameter (myelinated and nonmyelinated) fibers. Proprioceptive impulses are conveyed from the teeth, periodontium, hard palate, and the temporomandibular joint (TMJ). Afferent fibers also convey impulses arising from stretch receptors in the masticatory muscles.[26] The spinal tract is divided into three parts: subnucleus oralis, subnucleus interpolaris, and the subnucleus caudalis.[28] Facial nociceptive afferents are thought to project to the subneucleus caudalis.[29] This subnucleus is thought to be homologous to the spinal dorsal horn's substancia gelatinosa. This would allow dorsal horn structure information to be applied to the subnucleus caudalis.[30]

Table 6
Resistance (lbs) of the Deltoid Muscle to IDP in All Four Conditions

	Teeth apart	BEA	Placebo
Habitual occlusion	p<0.001	p<0.001	p>0.05*
Teeth apart		p<0.001	p<0.001
BEA			p<0.001

*Not significant

Table 7
Raw Data for the Isometric Deltoid Press (lbs) Using the M-T Computer

Subject	Habitual occlusion	Teeth apart	BEA	Placebo	Overbite
1	10.00	14.10	14.50	12.50	90%
2	10.50	13.50	16.00	12.14	60%
3	18.50	25.50	28.25	22.70	80%
4	17.00	20.25	23.55	17.50	80%
5	25.65	24.70	28.50	28.20	70%
6	18.25	16.70	26.75	21.00	90%
7	12.10	17.20	18.40	15.80	80%
8	12.70	13.80	16.70	12.00	90%
9	15.00	20.45	21.65	13.75	100%
10	20.25	25.25	26.05	19.75	90%
11	11.20	13.30	15.90	11.50	80%
12	5.00	7.85	9.90	5.00	70%
13	15.00	19.00	18.00	13.00	100%
14	9.16	13.65	14.00	10.10	80%
15	6.25	8.75	12.00	6.57	70%
16	17.75	20.55	22.50	18.90	90%

It has been observed clinically that elevating the VDO in subjects with a clinically judged loss in the VDO will increase isometric strength of the extremities. This may be of relevance when reconstructing dental occlusion through prosthetic and/or orthodontic techniques.

Tests on inter- and intraexaminer reliability were performed to assess the subjectivity and variability between testers of the isometric deltoid press. Results of intraexaminer reliability for sixteen subjects and interexaminer reliability between three examiners for five subjects indicate a high degree of reliability (**Tables 2** and **3**).

Use of the subjective IDP to determine the VDO in this experiment resulted in an occlusal height of the BEA that provided peak isometric strength of the deltoid muscle. This strength was greater than that of both habitual occlusion and the placebo appliance in all subjects.

Conclusion

1. Increasing the VDO by using a BEA in normal subjects with a deep overbite increased isometric resis-

tance of the deltoid muscle.

2. The occlusal height of the BEA provided peak isometric strength of the deltoid muscle obtained with the M-T Computer and coincided with that produced by the subjective IDP.
3. The difference between IDP resistance in both habitual occlusion and the placebo appliance was not statistically significant.

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