The Analysis Of Perioral Muscular Accommodation In Young Subjects With Malocclusion*

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The pattern and the effect of the forces and constraints exerted by intraoral and perioral soft tissues upon skeletal bone, alveolar processes, and the teeth are not clearly understood. It has been suggested that the form and configuration of hard tissue structures are determined by the primary morphogenetic factors upon which are superimposed secondary modifying factors produced by stresses and strains of muscle forces.[1] No correlation has been found thus far, however, between the intensity of labial and lingual forces and the occurrence of malocclusion.[2-4]

The method of quantitation of pressure graphs employed in the above "myometric" studies rested primarily upon the measurement of oscillation wave amplitudes only and, therefore, did not reflect the duration of these pressures. It is possible that this fact alone could be responsible for the apparent lack of equilibrium observed between the perioral and lingual musculature and the reported absence of significant differences between pressures recorded in subjects with excellent occlusion and malocclusion. It may be assumed that the magnitude of recorded forces is not reflected by pressure *peaks* alone, but the slopes of pressure growth and decay as well. These forces are, therefore, more accurately represented by the *areas* delineated by the deflection of styli from the baseline (Figure 1). This method of quantitation has been employed recently by Jacobs and Brodie[5] in a multiparametric study of perioral "modiolar" soft tissue structures in subjects with normal occlusion. The magnitude of the maxillary vestibular

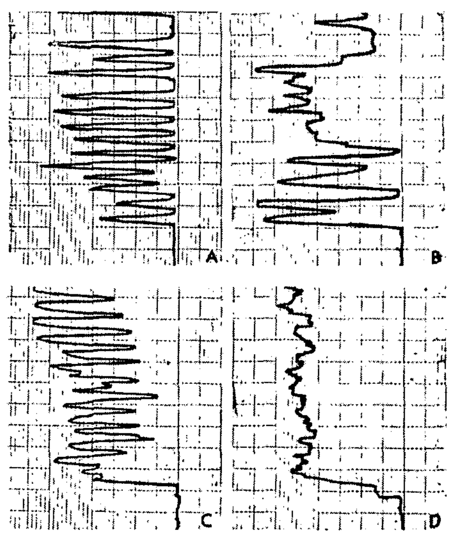

Fig. 1 Discordance of force-estimations determined by means of two different methods of measurement: 1. The magnitude of forces recorded in graphs A to D are found to be quite unequal when determined by means of the *curve-areas per unit of time: e.g.*, the force traced in graph D is twice as great as that in graph A. 2. These forces are viewed as similar in magnitude when they are expressed in terms of the *average curve-amplitudes.*

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forces, both contractile and tonic, was found to be greater than that in the mandibular vestibule, and the intensity of contractile forces per unit of time greater than that of tonic forces in both maxillary and mandibular vestibules. It has been suggested that the nature of the interrelation of the four adopted biophysical parameters, *i.e.,* contractile, tonic, maxillary and mandibular forces, could be further elucidated by an integrated quotient of these variables which has been labeled as an *Index of Muscular Accommodation* or I.M.A. The value of I.M.A. in a normal sample was found to be 1.43.

The objective of the present study was to explore the possible interdependence of tonic and contractile forces and to determine the values of I.M.A. in subjects representing various classes of malocclusion.

Material and Methods

Experimental sample. The experimental sample was selected from white subjects who had applied for treatment in the orthodontic clinic of the University of Illinois. Plaster study models and clinical examination records of the entire group of applicants were studied and forty-eight subjects were enrolled in this project. All selected cases appeared to reveal distinctive occlusal characteristics on the basis of which they could be expressly earmarked as representing one of the classical types of malocclusion.[6]

The entire sample was thus divided into five experimental groups, as follows:

Group I Twelve subjects with Class I malocclusion manifesting a normal anteroposterior relationship and crowding of both jaws.

Group II Twelve subjects exhibiting typical Class II, Division 1 malocclusion.

Group III Nine subjects presenting Class II, Division 2 malocclusion.

Group IV Nine subjects displaying Class III malocclusion.

Group V Six subjects disclosing Class I molar relationship and a prominent anterior open bite.

The average age of the sample was thirteen years.

Instrumentation. The BLH, SR-4 weldable prebonded resistance gauges were used as strain-measuring devices. They were employed as one leg of a four-arm external Wheatstone bridge circuit. The output current of this bridge induced by changes in resistance of the strain gauge was measured on an Offner Type R multichannel recording assembly. Two strain gauge transducers were placed in the upper and lower peripheries of the maxillary and mandibular portions of the oral vestibule respectively, opposite the lateral aspects of the "modiolus", for simultaneous recording of pressures (Figs. 2 and 3). In a few subjects, occlusal acrylic onlays had to be affixed to the first molars to prevent dislodgment of the mandibular assembly by the forces of occlusion; Eastman 910 fast setting adhesive was employed as a bonding medium. The above outlined technique has been fully described elsewhere.[5]

Procedures. The following operations were adopted to translate the physiological manifestations of "passive tonicity" and "active contractility" into clinically observable events and were accepted as indicators of the above concepts.

(1) *Tonus* It has been assumed that manual reflection of perioral tissues resting upon the transducer, and the resulting deflection of the polygraph-stylus from the baseline represent a valid measure of static tension and tonus of these tissues. It has also been assumed that this experimental procedure elicits only minimal muscle

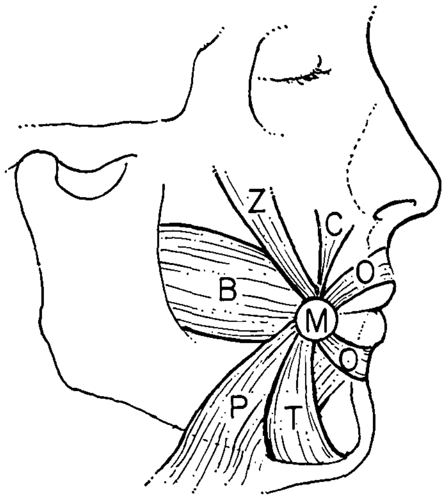

Fig. 2 Muscular modiolar configuration. B, buccinator; Z, zygomaticus major; C, caninus (levator anguli oris); O, orbicularis oris; T, triangularis (depressor anguli oris); P, platysma - risorius complex; and M, modiolus.

activity and, therefore, our measurements reflect primarily the passive elastic properties of the tissue.[5] It must be recognized, however, that the tonic forces which are normally determined by the size, form and relation of the mandibular and maxillary skeletal bases and dentures will be amplified by the standardized encroachment of transducers into the vestibular space.

(2) *Contractility.* In order to incorporate a possibly wide range of contractile forces and permit an integrated expression of the physiologically determined pattern of strains characteristic for various muscular activities, the following standardized volitional movement exercises have been adopted as a measure of muscular contractility:

Counting from one to twelve, completed in twelve seconds, has been adopted as a simple sound exercise. Gwynne-Evans[7] suggested that articulated speech was based upon formation of specialized habitual movements of orofacial musculature superimposed up-

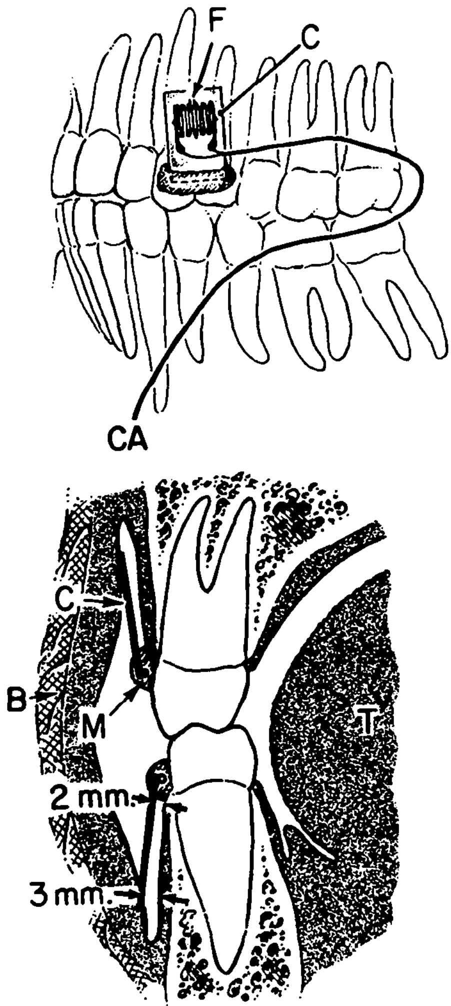

Fig. 3 Placement of transducers. Lateral view (above): F, foil element; C, carrier; and CA, cable. Transverse view (below): C, carrier; M, mounting base and retention tube; B; buccinator muscle; and T, tongue.

on "stereotyped inborn reactions common to all." Variations in orofacial morphology have been found to be closely associated with variations in articulation[8] which are thought to have great influence on alveolar structure.[9]

Drinking water through a straw has been adopted as a suck-swallow exercise. Suction is created by lowering of the anterior portion of the tongue from the hard palate which produces an intraoral negative pressure and draws fluid up the straw into the resulting space. The act of sucking is not a continuous process as is suckling,[10] but requires frequent "swallowing interruptions" in order to dispose of the fluid accumulated in the oral cavity. Accordingly, the data derived from suck-swallow exercise must be considered as complex end-results of an interaction between two physiological mechanisms, *i.e.*, sucking and swallowing.

The thumb-sucking exercise was adopted as an experimental procedure in order to observe soft tissue activity during continuous sucking which does not require intermittent swallowing of accumulated fluid as in suck-swallow exercise.

Puckering or "kissing" movements were adopted as an experimental procedure in order to observe soft tissue behavior during an exercise which does not require continuous labial seal.

It should be recognized that the stipulated characteristics of muscular tissue cannot be fully described by the operational definitions of the above two variables alone. Our study is lacking a third dimension which would be represented by the *muscle length* which, unfortunately, cannot be defined accurately in a "clinical" investigation. This third variable, however, must be shown to exist and will be referred to frequently, if only in speculative terms, in the interpretation of our data.

The nature of our standardized exercises was explained to the subject being tested and then rehearsed until sufficiently perceived. Thereafter, the transducer assemblies were inspected for stability and the subject was engaged in relaxed conversation.

Two complete and consecutive series of the experimental procedures were recorded with few minutes of rest between them, while the subject was seated in a relaxed, upright position. All "contractile" exercises were performed for thirty seconds each, while tissue reflection was registered three times for ten seconds only because of the occurrence of tapering thermal drift.

After completion of recording the transducers were again calibrated and sterilized.

Findings

The magnitude of forces recorded during each replication of subject/exercises was determined by measuring the areas delineated by the deflection of styli from the baseline with a polar planimeter, as described before.[5] It has been noticed that the variation among subjects was generally large compared with the variation among observations in a particular subject. Therefore, our measuring procedures may be assumed to be adequate. Variation among experimental groups was frequently greater than intersubject variability.

Group means of recorded vestibular forces are shown in Table I and Figure 4. Standard errors of group means were computed as a qualitative guide to avoid proliferation of conjectures regarding the homogeneity of the experimental groups. No rigorous, multiple statistical comparison procedures in respect to group means seemed to be indicated because of the inequality of group size, heterogeneity of variance and doubtful normality of the data.

An occurrence of compressive, *i.e.*, negative strains was recorded in a few subjects representing all experimental groups, except Class I Anterior Open Bite, primarily during the suck-swallow exercise. This was, however, a sporadic event only in contrast to the conspicuous display of compressive strains revealed in all but one replication-tracings of mandibular vestibular forces of

		TONIC FORCES	CONTRACTILE FORCES			
			Count	Suck-Swallow	Suck-Thumb	Pucker
Cl. I	Mx	146.1±16.93	76.4±11.27	299.6±42.08	402.6±75.12	246.5±25.56
	Md	81.3±8.72	103.8±11.70	399.2±72.04	573.5±69.80	352.6±43.99
Cl. II Div. I	Mx	167.7±14.61	46.5±10.54	294.7±61.75	282.2±37.93	142.8±34.78
	Md.	36.5±6.97	96.3±5.64	452.4±78.43	354.4±43.74	206.7±34.03
Cl. II Div. II	Mx	95.5±9.63	75.5±11.54	221.6±60.09	309.6±67.23	195.1±36.44
	Md	63.9±11.28	114.5±19.51	247.3±51.21	359.4±52.29	234.9±42.50
Cl. III	Mx	90.5±9.46	44.8±11.29	241.5±70.55	234.9±55.91	233.2±67.50
	Md	104.6±15.94	73.0±12.70	145.3±42.16	336.2±46.31	280.5±104.33
Open Bite	Mx	145.3±28.55	84.7±13.61	386.0±95.04	269.8±62.25	176.0±20.83
	Md	242.4±53.78	88.0±7.97	360.2±58.35	365.2±53.95	174.3±22.49

Table 1. Group means and standard errors of the means of recorded vestibular pressures in $g/cm^2/sec$.

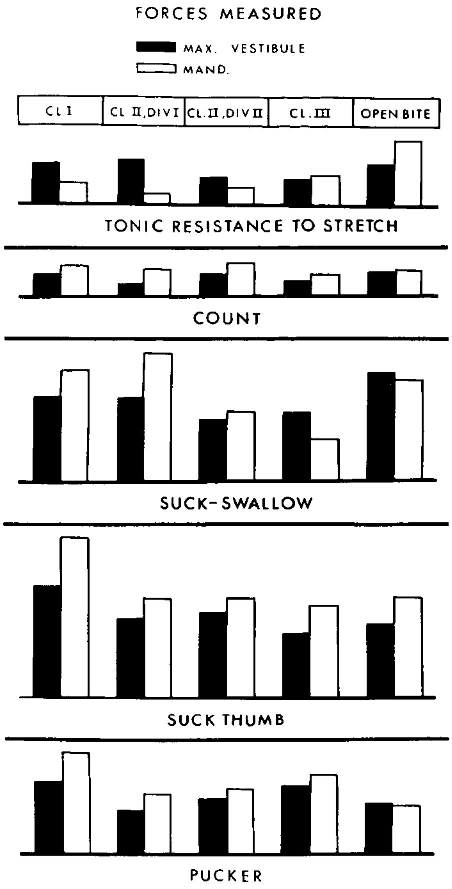

Fig. 4

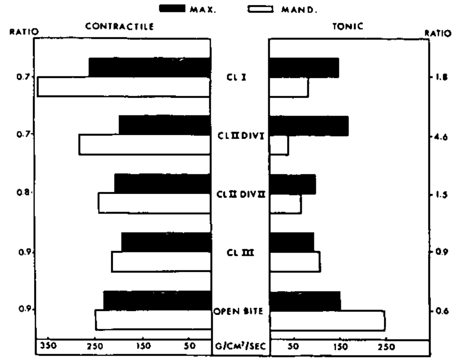

Fig. 5 Ratio of maxillary to mandibular forces.

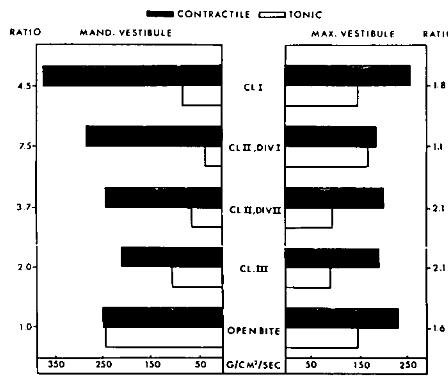

Fig. 6 Ratio of contractile to tonic forces.

the "normal" group.[5] One subject in the Class II, Division 2 group exhibited compressive maxillary forces in both replications of recording of thumb-sucking. It is interesting that the same subject also manifested compressive pressures during suck-swallow exercise. It is possible that these findings might be related to positive intraoral pressures observed in some finger-sucking patients.[11]

The ratios of maxillary to mandibular forces and contractile to tonic forces are presented in Figures 5 and 6, respectively. The contractile forces have been expressed by the values of the means of group means of the four volitional exercises of each experimental group to allow an integrated exposition of the whole spectrum of the recorded contractile strains.

The derived values of the *Index of Muscular Accommodation** in all experimental groups are shown in Table 2.

Table 2
Index of Muscular Accommodation.

	Mand. $\frac{CF}{TF}$	Max. $\frac{CF}{TF}$	I. M. A.
Cl I	4.51	1.76	2.51
Cl II Div. 1	7.51	1.14	6.59
Cl II Div. 2	3.69	2.08	1.78
Cl III	2.00	2.06	0.97
Cl I A.O.B.	1.02	1.56	0.65

Discussion

The dynamic state of equilibrium of intraoral and perioral forces involves a constant reciprocal accommodation of function and structure of soft and hard tissues. This process follows a chain of intermediary interactions and feedbacks to manifest itself as a clinically observable entity which can be defined by Angle's classification. The complex interplay of these integrant forces produces dynamic alterations of the state of equilibrium and fixation of the "modiolus" which can be viewed as a pivotal point for the converging muscular configuration (Figure 2). Any change in modiolar fixation produces a deviation of vectors of static tensions exerted by these muscles at rest, and may also induce a reciprocal conversion of isometric and isotonic contractions.

The point of fixation of the "modiolar pivot" and consequent redistribution of forces will be greatly affected by a disharmony between the size, shape and/or relation of mandibular and maxillary skeletal bases and/or dentures. Similar observations in regard to hyoid bone-mandibular pivot have been recorded by Nove:[12]

> "[Normal] behaviour pattern takes place because there is an integration of all the structural units connected with mastication, deglutition, and respiration so that when at physiological rest they remain in a state of equilibrium, with the mandible and hyoid bone as a combined pivot or fulcrum. . . . When the jaws are incorrectly apposed medially, anterio-posteriorly, or vertically, this indispensable pivot or fulcrum for normality is out of true, and all the structural units concerned with mastication, deglutition and respiration are compelled to function by means of adaptation."

$$^{*}\frac{\text{Mand.}\ \dfrac{\text{Contractile Forces}}{\text{Tonic Forces}}}{\text{Max.}\ \dfrac{\text{Contractile Forces}}{\text{Tonic Forces}}}$$

Let us now explore the probable course of biomechanical events within the pivotal configuration of modiolar structures (Figure 2) in our experimental groups.

As can be readily seen in Figure 5, the ratio of maxillary tonus to mandibular tonus rises to its highest value of 4.6: 1 in the Class II, Division 1 group, and shows a striking decline to 0.6: 1 in the Class I Anterior Open Bite group. We wish to propose the following interpretation for the observed range of variation of this ratio:

As a result of anteroposterior disharmony of mandibulomaxillary skeletal base relation in Class II, Division 1, the mandibular attachments of the modiolar muscles are displaced posteriorly. This does not alter significantly the length of the triangularis muscle because of its vertical and slightly oblique course. The buccinator muscle, however, runs anteroposteriorly and therefore a retrognathic position of the mandible represents a most effective line for elongation and stretch of its inferior peripheral filaments. Under normal conditions these fibers, when at rest, are longer than the distance between their fixed points, *i.e.,* origin from external oblique line and modiolar insertion and, therefore, they control the modiolar fixation to a minor extent only.[13] The increased static tension of these filaments produces a disturbance of muscular equilibrium and brings about a posteroinferior shift of the modiolar pivot which may have the following effects: (1) stretch and increased tension of the caninus muscle and maxillary portion of the orbicularis oris with the resulting increase of the maxillary vestibular tonus (167.7g/cm^2/sec); (2) shortening of the triangularis and platysma muscles and consequent decrease of the tonus of these muscles with a resulting decline of mandibular static tensions (36.5g/cm^2/sec); (3) possible eversion of lower lip.

It should be recognized that the recorded ratio of mandibular to maxillary tonus of 4.6 : 1 illustrates only one element of the total ontogenetic syndrome of soft tissue accommodation which is associated with Class II, Division 1. It is well known that this syndrome usually involves perversion of tongue movements and hyperactivity of the mentalis muscle which represent expression of an adaptive effort to sustain oral seal during deglutition.

The posteroinferior displacement of the modiolus with the resulting increase of static tensions in the maxillary vestibule is probably responsible for the narrowing of the maxillary arch and may possibly explain the change of arch shape from triangular to semicircular, as noted[14] in forty-eight subjects with Class II, Division 1 malocclusion treated with maxillary headcap only. It may be suggested that the observed reshaping of dentures was brought about by the force of exaggerated vestibular static tensions, whereby the potential space between first molars and second bicuspids was being utilized and continuously obliterated.

The distribution of tonic forces is altered significantly in cases with Class II skeletal relation in which lower lip has not lost control over the upper incisal area.[15] The differential factor is provided by the absence of protrusion of the maxillary denture which may have the following effects:

(1) Lowering of the tonus in the maxillary portion of orbicularis oris muscle and decrease of maxillary vestibular forces (95.5g/cm^2/sec).

(2) Intensified tonic forces exerted by the posteriorly displaced, inferior fibers of the buccinator are not offset by a stressed orbicularis oris muscle, as in Class II, Division 1. Consequently, the posteroinferior shift of the modiolar pivot is more severe in Class II, Division 2 than in Class II, Division 1. This may only be a factor which augments the inferior vector of force exerted upon the anterior segment of the maxillary denture, producing a deep overbite and inverse curve of spee.

The Class III group displays a decreased tonic ratio (0.9 : 1), primarily due to an increment of forces in the mandibular vestibule. This is believed to be due to an anterior displacement of the mandibular attachment of the triangularis muscle.

The ratio of maxillary to mandibular tonic forces is further decreased in the Class I Anterior Open Bite group (0.6 : 1). The concurrent amplification of both mandibular and maxillary tonus seems to be related to a vertical increase in the distance between the point of attachment of the triangularis muscle and the origin of the caninus and zygomatic muscles.

Question might be raised as to how the tonus, *i.e.*, the tension-length relation of the muscle at rest, can be affected by the anteroposterior or vertical displacement of its attachments, in spite of the known occurrence of muscle creep and stress relaxation when a sustained physical force is applied. Some elucidation of this point might have been offered by the recent work of Alexander and Johnson.[16] They challenged the independence of the "active" and "passive" components of the muscle machine and demonstrated the participation of the contractile machine in the viscoelastic adjustment of frog muscle. According to their schema, an active contraction and release of contractile energy tend to erase the set length of the muscle, established in a state of a passive equilibrium, of tension, and serves to rapidly reset the resting length of the "tonic system".

This could possibly induce a restoration of the original length of the muscle following such transient phenomena as creep and a delayed compliance.

If we now direct our attention to the left side of Figure 5, we notice that in this experimental group in which the maxillomandibular ratio of tonic forces is the highest (Class II, Division 1), the ratio of contractile forces is the lowest. Similar relationship manifests itself at the other extreme of the recorded range where the maxillary to mandibular contractile forces in the Class I Anterior Open Bite group show a relatively high ratio.

Further comparative arrangement of contractile and tonic forces is presented in Figure 6. It will be noticed that in the mandibular vestibule the highest ratio, by far, reveals itself in Class II, Division 1 (7.5: 1), while the lowest has been recorded in Class I Anterior Open Bite (1 : 1). In the maxillary vestibule the range of variation is considerably narrower with the highest ratio displayed by the Class III and Class I Anterior Open Bite groups (2.1 : 1) and the lowest by Class II, Division 1 (1.1: 1).

Our findings seem to corroborate the general consensus that in Class II, Division 1 the upper lip is relatively functionless,[17] but they do not support the supposition that it is also hypotonic. On the contrary, the tonicity of the upper lip in Class II, Division 1 subjects, as determined by the recorded static tensions in the maxillary vestibule (Figure 6) and the suggested elongation pattern of the modiolar structures, seems to be rather high.

The analysis of the ratios presented in Figures 5 and 6 indicates an apparently negative correlation of contractile to tonic forces. This observation seems to be in agreement with the hypotheses that: (1) The stretching of an unstimulated muscle produces an altered intensity of contractility upon the subsequent stimulation[16,18] and; (2) The distribution of tension over a cross section of a stimulated muscle, from its periphery to the center, is the reverse of that of an unstimulated muscle.[19]

The nature of the interrelation of the four variable components of oral-vestibular forces, *i.e.*, mandibular, maxillary, contractile, and tonic is further elucidated by a quotient which integrates these four parameters, *i.e.*, the Index of Muscular Accommodation (Table 2).

It may be suggested that this index reflects not only the vestibular pressures, but also, by an inference of adaptive feedback, those exerted by the tongue. This scope of the I.M.A. could be readily tested.

Undoubtedly, the observed variation of I.M.A. is partially produced by statistical fluctuation of our data and inherent experimental errors. It is to be noted, however, that the general disposition of the values follows the pattern suggested by the concepts incorporated in the model of biomechanical behavior of skeletal muscle and our schema of pivotal modiolar configuration. We wish to propose that:

(1) The tendencies toward small I.M.A. values found in Class III (0.97) and Class I Anterior Open Bite (0.65) coincide with a disharmony of the vertical tier of modiolar configuration, while (2) the large values observed in Class II, Division 1 (6.59) concur with a horizontal disarray of muscle tensions.

It is interesting that in a study of skeletal form and behavior pattern of orofacial muscles, Walther[20] has observed the smallest incidence of "abnormal muscle postures and habits capable of producing abnormal pressures for abnormal lengths of time" in those cases of malocclusion in which both skeletal and dental pattern were characteristic for that class of malocclusion.

We may speculate, therefore, that a correlation of serial cephalometric records with serial I.M.A. data might reveal many thought-provoking facts regarding the mechanics of orthodontic relapses, and might possibly suggest a method of predicting and preventing such failures.

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