Muscle Contraction Patterns in Swallowing

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The main thrust of an investigation initiated in 1952 concerned electromyographic patterns of the superficial elevators among a large group of orthodontic patients, both clinic and private. As the experimental groups grew and the recording equipment became more sophisticated, other muscle areas were incorporated. That facet of the project began in earnest in 1962 as a cross-sectional pilot analysis of muscle activity while swallowing.[1] At that juncture the subjects were: 1. open-bite patients without orthodontic treatment, 2. control subjects with normal occlusion who had not received orthodontic treatment, and 3. edentulous adults.

The principal and most noteworthy observation of the pilot investigation was the existence of wide variation in muscle activity despite classification of groups studied. With the addition of other subjects during the years since 1963, serial records of the original and the continuing groups furnished the information for the present progress report of electromyographic and cephalometric records.

MATERIALS AND METHODS

The criteria for selection of subject categories were: 1. naturally occurring normal occlusion, 2. anterior open bite, natural dentition, and 3. nonopen-bite malocclusion. Table I summarizes the principal features of the three groups and, in the instance of the treated patients, the general mechanical treatment.

All subjects had lateral cephalometric roentgenograms, study casts, and intraoral and facial photographs.

The initial electromyographic recordings were made with an Offner Type R Dynagraph equipped with pen writers. This was an eight-channel data recording instrument modified for electromyography. The initial recordings utilized both the direct pen writing and integrated tracings. When recording the integrated potentials, the high frequency compensating circuit was eliminated to prevent excessive pen "wiggle." These recordings were taken with skin resistance less than 10,000 ohms and with an amplification level of one cm pen deflection equivalent to 0.5 millivolts input. The one-second timer recorded the duration of activity.

The electromyographic recordings of water swallowing were made at paper speeds of 25 mm and 100 mm per second. Nickel-silver surface electrodes, utilized throughout most of the study, were small saucer-shaped discs, 8.5 mm in diameter, modified by drilling a small hole in the center of each to permit injection of electrode jelly between the convex electrode face and the subject's skin. Skin preparation, electrode attachment, resistance reduction, and Faraday cage protection have been described elsewhere.[2, 3] A ground electrode was attached to the ventral aspect of the subject's forearm.

Bipolar surface electrodes were attached as described by Lipke.[4] They were fixed bilaterally to the posterior temporals, superficial masseters, and suprahyoid groups and over the midline superior orbicularis oris and the midline inferior orbicularis oris (mentalis region). Thus the simultaneous recording activity of eight muscle groups was possible.

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TABLE I

SUMMARY OF FEATURES OF THREE GROUPS
STUDIED FOR MUSCLE ACTIVITY IN SWALLOWING

Group	Ident.	Sex	Age (1st Rec.)	Angle Class	Treatment Synopses
A Control Subjects (Normal occlusion)	C.S. No. 1	M	40 yrs.	Class I	
	C.S. No. 2	F	21 yrs.	Class I	
	C.S. No. 3	M	16 yrs.	Class I	
	C.S. No. 4	F	22 yrs.	Class I	
B Control Subjects (Malocclusion)	C.S. No. 5	M	12 yrs.	Class I	Nonextraction; Full maxillary Edgewise Appliance; Fixed Lingual Mandibular with Recurved Finger Springs T. Mandibular Incisors.
	C.S. No. 6	F	13 yrs.	Class I	Same as Group B
C Open Bite Subjects	O.B. No. 1	M	11 yrs.	Class II Div. 1	$\frac{4\,\vert\,4}{4\,\vert\,4}$ Extraction; Full Edgewise Appliance; High-pull Extraoral Appliance; Vertical Elastics; ClassII Elastics
	O.B. No. 2	M	13 yrs.	Class II Div. 1	$\frac{74\,\vert\,47}{2\,\vert\,}$ Extraction; Full Edgewise Appliance; Cervical and High-pull Extraoral Appliance Class II and Vertical Elastics and Occlusal Adjustments
	O.B. No. 3	M	13 yrs.	Class II Div. 1	Nonextraction, Full Maxillary and Mandibular Edgewise Appliance. Kloehn Cervical Traction; Class II Elastics. Rubber Finishing Appliance.
	O.B. No. 4	F	11 yrs.	Class I	$\frac{4\,\vert\,4}{4\,\vert\,4}$ Extraction; Full Edgewise Appliance Occipital Extraoral Appliance Class II and Vertical Elastics.
	O.B. No. 5	M	10 yrs.	Class I	$\frac{4\,\vert\,4}{\,\vert\,}$ Full Edgewise Appliance, Extraoral Occipital Appliance Class II and Vertical Elastics.
	O.B. No. 6	M	10 yrs.	Class I	No Treatment; Swallow Training

Electrode Placement

The electrodes were placed as follows:

Masseter muscles: On each side of a point about midway between the origin and insertion of the muscle parallel to the fiber direction.

Temporalis muscles: Over the posterior fibers about 1 cm posterior to a vertical line passing through the middle of the external auditory meatus parallel to fiber direction. Palpation of this area aided final location.

Superior orbicularis oris: At each side of the midline parallel to fiber direction.

Mentalis: On each side of the midline midway between the chin tip and the vermilion border of the lower lip.

The suprahyoids: About 1 cm to the right and left of the midline, about 1.5 cm inferior to the lower border of the mandible, the electrodes placed when possible parallel to the fibers of the anterior digastric belly.

Electromyographic recordings, made with an Offner Type 504A Series 108, were taken after the initial series were

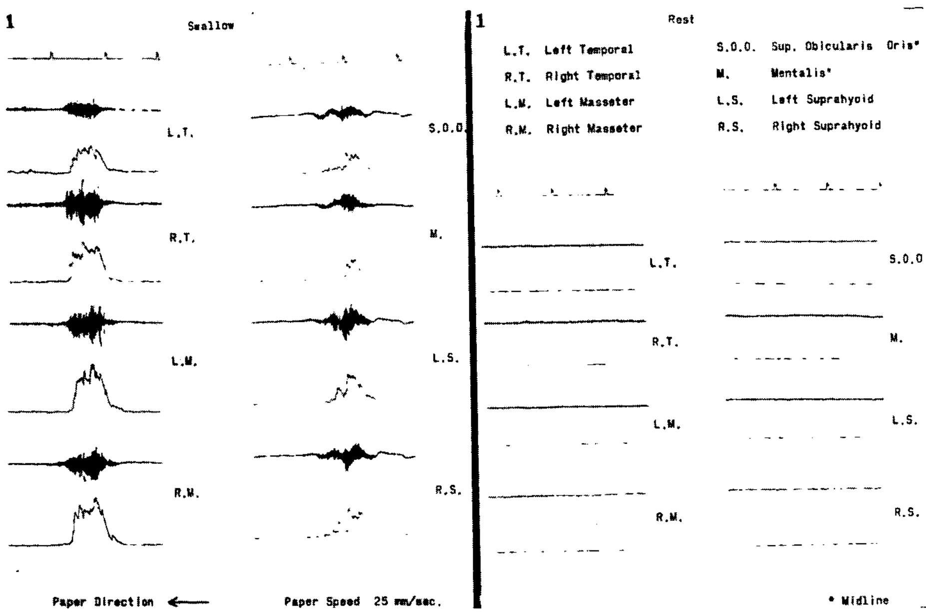

Fig. 1 Left: Sample water swallow with direct and indirect EMG trace. Right: Minimal activity of "rest" as recorded between each swallow.

all integrated. The procedures, amplifications, and exercises were the same as those with the Offner Type R Dynagraph.

Procedure Exercises

The electromyographic test originally instituted included many mandibular movements such as those made in speech, mastication, deglutition, stress reaction, and isometric and isotonic contraction. As this report deals with only one element of the several tests and is limited to only a few of the muscles active in the process of swallowing a specific quantity of water, the swallowing of saliva and various food boli is not considered here.

The subjects were comfortably seated in the Faraday cage. Having previously completed other procedures, they were acclimated to the experimental environment.

1. Each subject was provided with three paper cups containing 15 cc each of room temperature water.

2. Subjects were told to take the water in a paper cup but to hold it in the mouth until commanded to swallow. This procedure was repeated for each cup (Fig. 1).

The integrated trace was surveyed with a compensating polar planimeter according to the method of Allgood.[3] The area in square centimeters beneath the trace was a measure of the electrical activity associated with muscle group contraction. The integrated traces, as measured with the planimeter, were charted for the three separate swallows of water. The three swallows were then averaged and charted for each individual muscle group active in the process of swallowing. In the instance of the treated subjects the before treatment, at retention, and after treatment averages were charted. The nontreated control subjects cited (with the exception of C.S. No. 1) have only a single session averaged.

The interval times of one second at

paper speeds of 100 cm per second permitted averaging the duration of muscle activity to the nearest .10 millisecond. The paper used with the dynagraph had vertically ruled lines at 20 mm intervals. The average of the three durations was recorded for each muscle group and chartered as for charting the amplitudes.

Observations

It early became apparent that variation in pattern activity between persons in a cross-sectional analysis was the rule rather than the exception. This was evident in the intergroup and intragroup performances. Glass[5] confirmed this in his work; however, Glass observed a pattern of strong mentalis activity as opposed to the activity of the superior orbicularis oris for all his open-bite group but not for his adolescent control group.

Because of the variables in the early cross-sectional analysis, some of the original subjects were followed through orthodontic treatment and retention in order to ascertain which functional patterns are altered, or not altered, with the change in structural relations and maturation.

Control Subjects

Two male and two female control subjects were selected for the comparative study. Three were adult; one was a male adolescent. The control subjects had almost ideal occlusions and good cephalometric facial patterns. Orthodontic treatment for dental, facial, or functional improvement would not have been necessary.

In general the four controls showed evidence of mandibular elevator contraction when swallowing water, with some perioral and suprahyoid action (Fig. 2). The presence or absence of tooth contact is unknown; but the observations by Brill[6] and his colleagues in 1959 suggest the absence of contact.

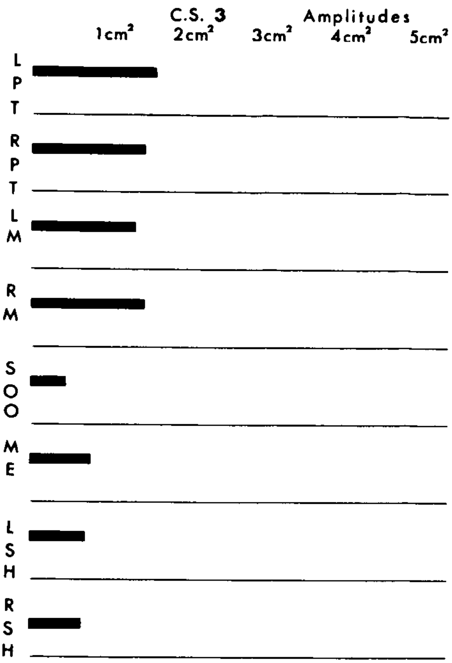

Fig. 2 Average integrated EMG amplitudes of water swallow control subject No. 3.

Comparatively, the saliva swallows in this group had a stronger amplitude pattern of elevator action than did the water swallows. The elevator muscles also had a greater duration of action in the control subjects. One control subject (C.S. No. 1) had participated frequently in comparative studies; a review of the muscle group activity when swallowing indicated a similar pattern of action but not an exact replication of duration and magnitude (Fig. 3). That observation parallels the observations by Doty and Bosma[7] regarding reflex deglutition studies of animals.

Open-Bite Subjects

The open-bite subjects were selected from a large group of persons who had been serially and cross-sectionally studied. Selection was based on diverse possible contributing factors to malocclusion.

(1) R. J., a private-practice patient

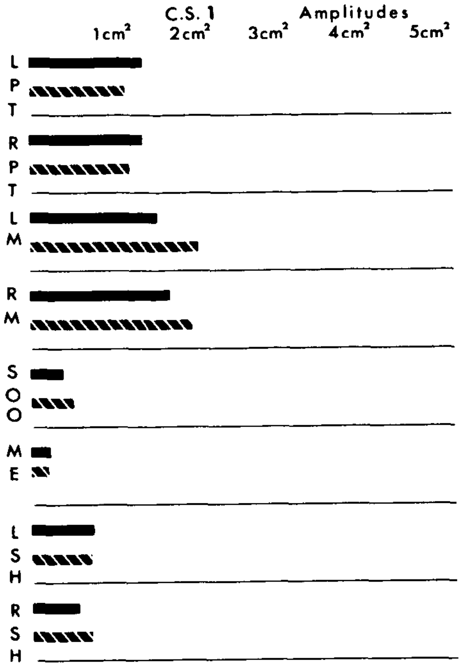

Fig. 3 Average integrated EMG amplitudes of water swallow control subject No. 1.

who was initially examined at age eleven, had a Class II, Division 1 open-bite malocclusion. He had a history of long-term and continuing thumbsucking. A six-month period of habit appliance with cervical traction was initiated. After that, the patient and mother reported that the habit had been overcome. The recommendation was for extraction of four first premolars, placement of a full edgewise appliance, and institution of therapy. Six months after full treatment had been initiated, the patient and mother admitted that thumbsucking was still a problem. After twenty-eight months of active therapy, occipital traction, vertical elastics, cross-palatal thumbsucking prongs, Class II elastics, and cajoling, retention appliances were at last placed.

(2) D. H., a private-practice patient had been initially examined at age nine, but treatment was deferred until age thirteen. The occlusion was classified as Class II, Division 1. The parents reported that the boy had received a laceration on his chin at age six in a minor automobile accident when he was thrown from the front seat of a car against a metal dashboard. Trauma to the dentition or to the tongue was not recorded as a consequence.

Serial cephalometric roentgenograms from age nine to age thirteen disclosed an inferior and a posterior vector of mandibular growth. Treatment was initiated with extraction of the maxillary first premolars, full edgewise appliance, a cervical traction appliance, and a palatal holding arch with palatal button. Mandibular treatment was intentionally deferred. Sixteen months after initial extraction, the maxillary second molars and mandibular right lateral incisor were extracted. A complete edgewise mandibular appliance was placed. Cooperation was poor. Retention was accomplished after thirty-two months of therapy, including the extraction of five teeth, four of which were maxillary, placing a full edgewise appliance, application of cervical and occipital traction, applying vertical elastics, and making occlusal adjustment.

(3) D.T., a private-practice patient was first examined at age thirteen. The patient had a Class II, Division 1 malocclusion and a pronounced open bite. The pattern of mouth breathing was apparent; minimal air passed through the nares when the lips were sealed while exhaling. The parents' religion prohibited adequate examination of a deviation of the septum, suggested nasal obstruction and the probable need for their correction.

A full maxillary appliance was placed in combination with a cervical appliance. Cooperation was satisfactory. The mandibular arch was fully banded and Class II elastics were utilized. After twenty-nine months of active therapy, a rubber finishing appliance was placed. The patient returned for a two-month recall when he admitted not having worn the rubber retainer because he could not breathe with it in his mouth. Instead, a maxillary Hawley appliance incorporating a tongue guard crib was placed.

(4) C. P., a private-practice patient, was first examined at age eleven. The patient had a Class I open-bite malocclusion with blocked maxillary canines. The history did not suggest habit patterns or trauma; however, the left temporomandibular joint clicked when wide open. A nonextraction procedure was initiated with full maxillary appliance. The space for the canine eruption could not be achieved; four first premolars were removed one year after initiation of treatment. Full maxillary and mandibular appliances were placed in conjunction with occipital extraoral anchorage. The appliances were removed twenty-one months after extraction; a maxillary Hawley retainer was placed with a mandibular canine-to-canine retainer.

(5) T. T., a young man, originally was a clinic patient but later was transferred to private practice because of the need for extensive plastic surgical procedures. The patient was ten years of age when first examined. He had been referred for an electromyographic record and possible orthodontic treatment. The boy had had anterior bulbar poliomyelitis at eight years of age when a tracheotomy had been necessary. The only muscles permanently impaired were the left gastrocnemius, the right and left temporalis and masseter muscles, and certain right seventh nerve muscles. The original occlusion was a Class I. Initially orthodontic treatment was considered unnecessary. Subsequent retrognathic growth prompted clinic treatment with maxillary premolar extractions. Full maxillary and mandibular edgewise appliances were placed.

After bilateral vertical osteotomy of the ramus, rib graft to the chin, facial muscle graft to the right orbicularis oris region, and left mentalis muscle denervation, the patient, seventeen years later, is still wearing a maxillary Hawley retainer.

(6) J. K., was a private-practice patient referred by a speech therapist. The boy was first seen at ten years of age when he had a Class I open-bite occlusion. The parents and patient denied any digital sucking habits. A decided tongue thrust on swallowing was assessed as recommended by Straub,[8] Gwynne-Evans,[9] and Tulley.[10]

Barich[11] proposed the method utilized in this case. The patient was instructed to place a small shirt button on the tip of his tongue and press it firmly against the palate, posterior to the lingual incisive papilla, and swallow forcibly. The summer vacation enabled the patient to repeat this exercise 100 times each day for two months and then return. Parental interest and control were achieved by a casual comment that orthodontic treatment could possibly be prevented. Unfortunately, the child swallowed several buttons during the first weeks, thus requiring a different approach. A small M & M chocolate candy replaced the button in the same location. The patient was to suck the candy with the tongue elevated until the center chocolate was reached. He was advised to do this as much as possible until the two-month recall. Orthodontic appliances were never required.

To provide some comparative recordings, two other cases were selected from the serial file. They were chosen as examples of deep overbite, nonextraction orthodontic cases. Their descriptions here are minimal because their pertinence is only in reference to the muscle patterns observed.

Findings

Control subject no. 5 R. S., a boy with a deep overbite, crowded Class I malocclusion, was first examined at eight years of age. Treatment was initiated at twelve years of age. A full maxillary edgewise appliance was placed with advancement and depression to the maxillary incisors. A fixed lingual appliance with recurved finger springs against the mandibular incisors initiated the mandibular arch therapy. Retention was accomplished in 21 months with a maxillary Hawley retainer and a mandibular canine-to-canine retainer (Figs. 4, 5).

Control subject no. 6: M. B., a girl, had a moderate overbite, Class I occlusion and blocked maxillary and mandibular canines. She was first examined when thirteen years of age at which time treatment was proposed. A full maxillary appliance and a fixed lingual mandibular arch and recurve finger spring were placed. Treatment was without extraction. A fixed lingual canine-to-canine retainer and maxillary Hawley appliance retained occlusion. Total treatment time was nineteen months (Figs. 6, 7).

Open-bite subject no. 5: The patient, a young man, has been under observation for the longest period of any of the patients in the series. The contributing disorder was specific: anterior bulbar poliomyelitis. The first recordings are not included here because suprahyoid or perioral records were not made; they indicated some fibrillatory activity in the temporals. At the time of the studies of swallowing reported here, the fibrillatory activity had disappeared, and elevator muscle activity was entirely absent. The principal evidence of contraction was in the hyoids, and then in the perioral muscles. The magnitude and duration of these patterns have increased from 1956 to the present (1971) on each succeeding study session. The

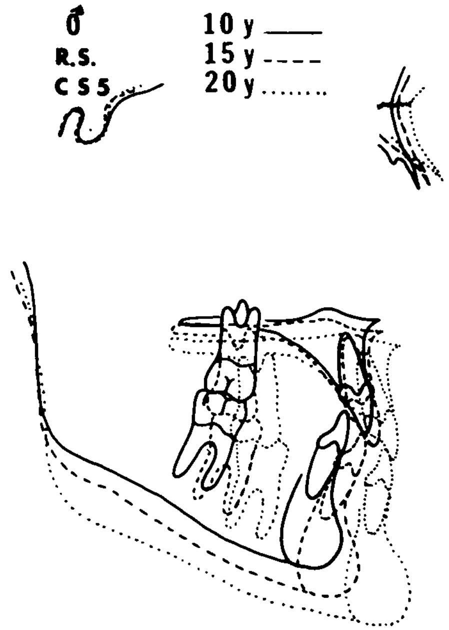

Fig. 4 Cephalometric composite tracing control subject No. 5.

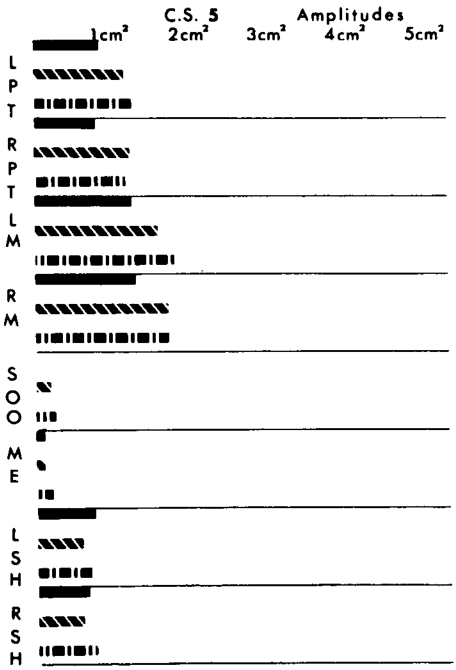

Fig. 5 Average integrated EMG amplitudes of water swallow control subject No. 5 (before treatment, at retention, postretention).

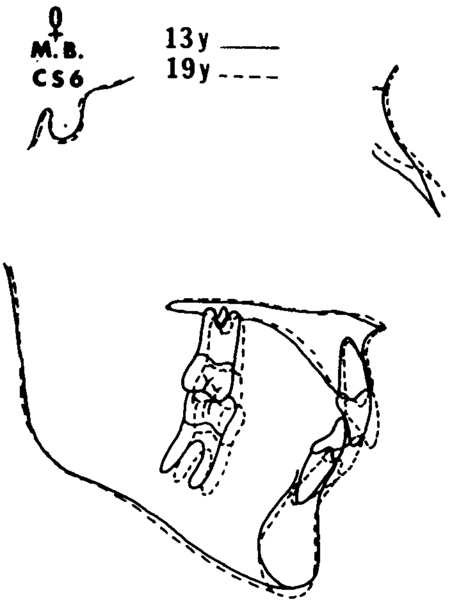

Fig. 6 Cephalometric composite tracing control subject No. 6.

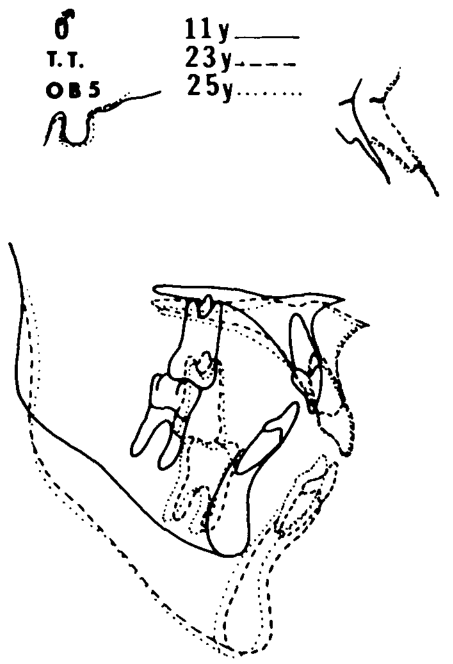

Fig. 8 Cephalometric composite tracing of open-bite subject No. 5.

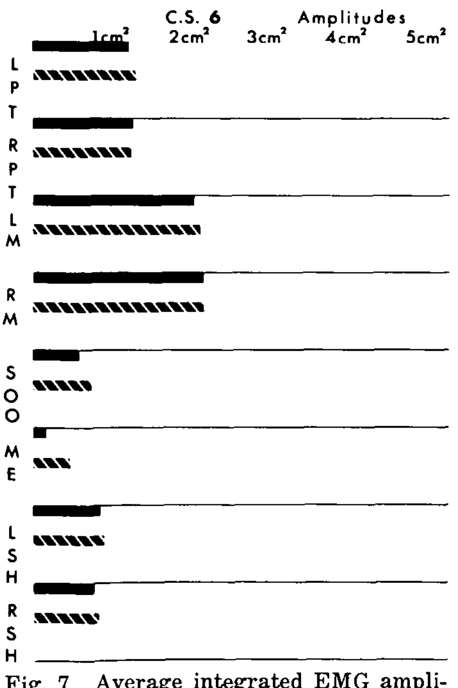

Fig. 7 Average integrated EMG amplitudes of water swallow control subject No. 6 (before treatment, at retention).

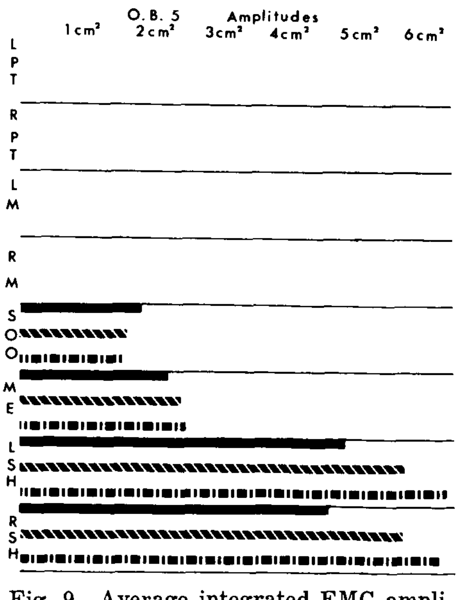

Fig. 9 Average integrated EMG amplitudes of water swallow open-bite subject No. 5 (before treatment, postretention and late postretention).

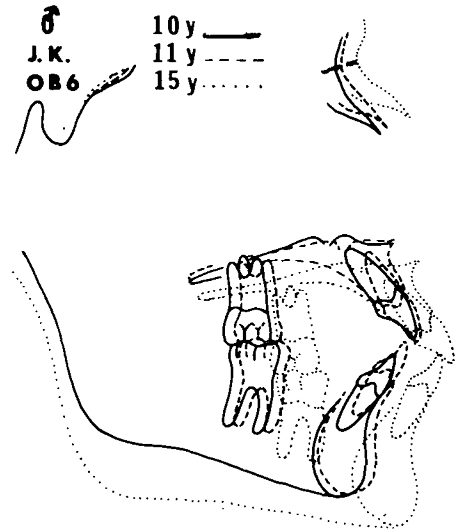

Fig. 10 Cephalometric composite tracing of open-bite subject No. 6.

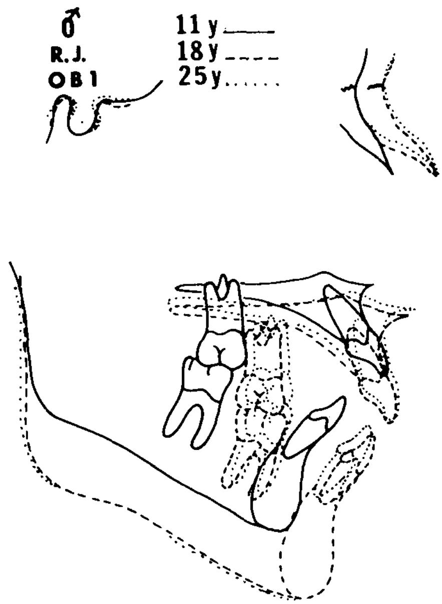

Fig. 12 Cephalometric composite tracing of open-bite subject No. 1.

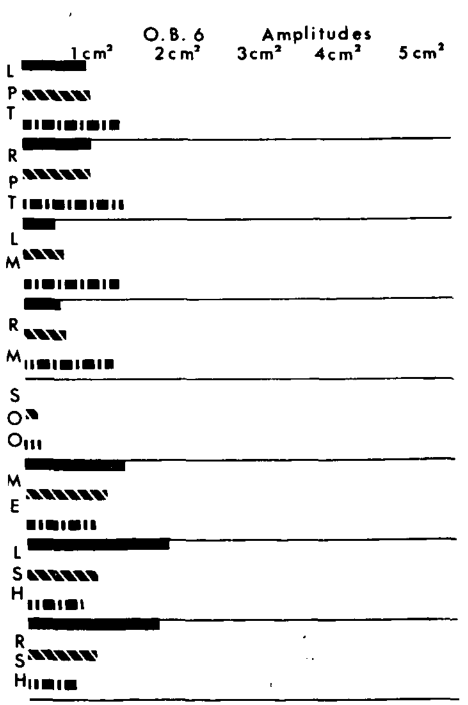

Fig. 11 Average integrated EMG amplitude of water swallow open-bite subject No. 6 (before therapy, posttherapy and late posttherapy.

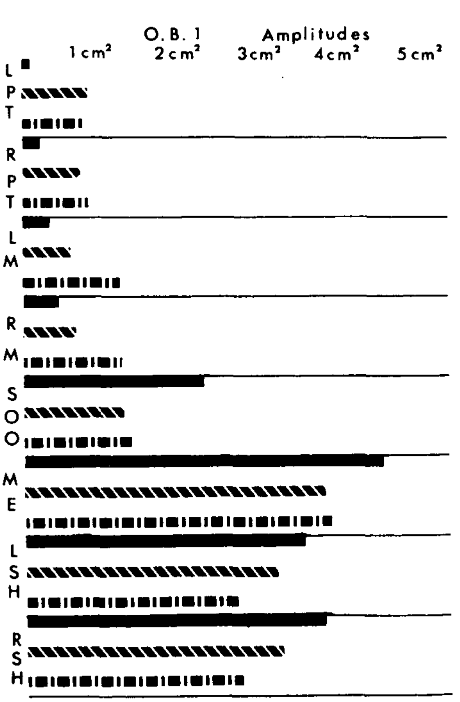

Fig. 13 Average integrated EMG amplitudes of water swallow open-bite subject No. 1 (before treatment, postretention and late postretention).

cephalometric record indicates a significant change with treatment and time in the ratio of anterior to posterior facial height. The case represented by open-bite subject No. 5 is extreme (Figs. 8, 9).

Open-bite subject no. 6: If the preceding subject No. 5 was at one end of the malocclusion spectrum, subject No. 6 belongs at the opposite end. The patient, a young man, did not require mechanical therapy. Through diligence, he was able to change the magnitudes and duration of the suprahyoid and perioral muscles. With this change in the muscle activity and improved elevator contraction patterns, dental occlusion was better. There was no evidence of tonsillar or adenoid tissue at the initiation of treatment nor was there a digital sucking habit. Apparently a tongue-thrust pattern when swallowing had been contributory. Therapy was as described utilizing a modification of Barich's recommendation (Figs. 10, 11).

Open-bite subject no. 1: The patient, a young man, had been a long-term thumbsucker; efforts to stop the habit before initiation of orthodontic treatment were mistakenly believed successful. Full orthodontic therapy with removal of four premolars was eventful in that the efforts failed. The patient later reported that he had sucked his thumb at night throughout three years in the Navy and had stopped only when he was married.

Weak elevator pattern, and strong perioral and suprahyoid contraction are evident in all three of his listed record sessions. The dominance of muscle contraction patterns was similar to that in the case of poliomyelitis (open-bite case No. 5), although the reason differed. The cephalometric tracings indicate a near vertical facial development (Figs. 12, 13).

Open-bite subject no. 2: In retrospect, the patient seems to have undergone bilateral trauma to the condyles at an early age. Injury to the condyles possibly interfered with the development of the lateral pterygoid muscles necessitating the increased suprahyoid action when opening and while swallowing. The magnitude of the elevator muscle pattern was weak; its duration was short. The opposite was true for the perioral and depressor muscles. The cephalometric recordings mirror the increased ratio of the anterior to the posterior facial heights, again similar to the condition observed in the patient who had had poliomyelitis (Figs. 14, 15).

Open-bite subject no. 3: The patient, a young man, had a severe nasal obstruction. Parents and patient had declined to see an otolaryngologist but did want orthodontic treatment. Kloehn cervical traction and a full edgewise appliance were helpful. At the time of retention overjet was completely reduced, but the overbite was unsatisfactory. It was illogical to place a rubber finishing appliance based on the known breathing difficulty. Superb previous cooperation overcame reluctance; however, as the patient was unable to wear the appliance, the overjet recurred. A second period of treatment reduced the overjet; a Hawley retainer was placed. Relapse recurred. The electromyographic records of the subject indicated a more favorable elevator pattern than the other open-bite subjects had reported; however, the dominance of the depressors is still apparent and the perioral activity is strong. The cephalometric tracings indicate the architecture of failure (Figs. 16, 17).

Open-bite subject no. 4: Faulty mechanics may have introduced an iatrogenic complication. The subject had a Class I crowded malocclusion with anterior open bite. When the attempt to gain space with nonextraction mechanics failed, four first premolars were removed, and a cervical type extraoral

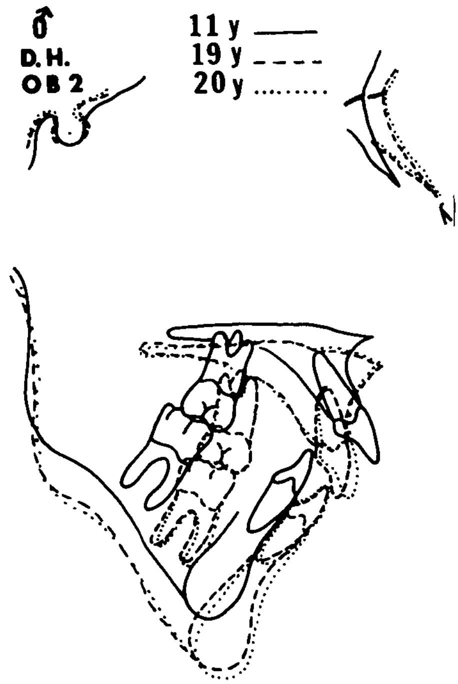

Fig. 14 Cephalometric composite tracing of open-bite subject No. 2.

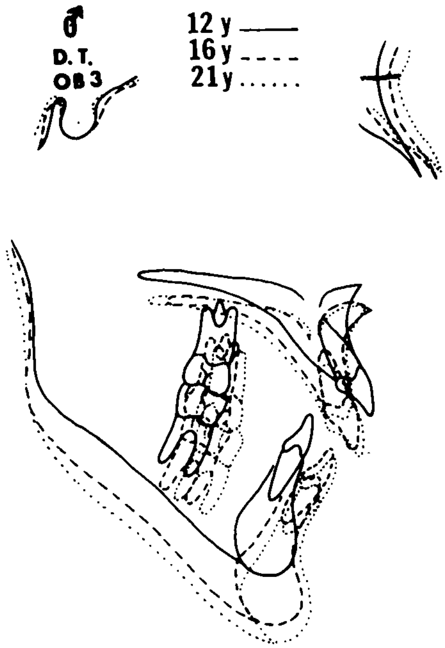

Fig. 16 Cephalometric composite tracing of open-bite subject No. 3.

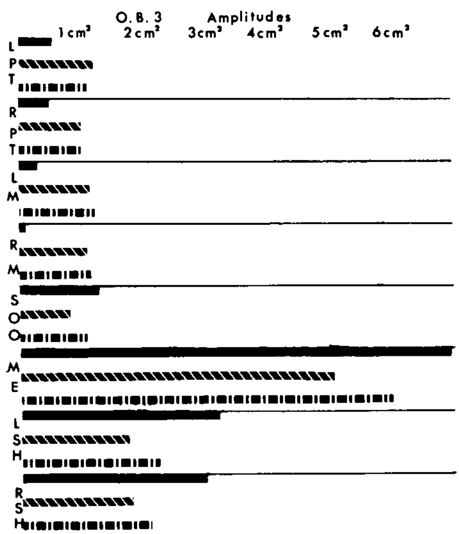

Fig. 17 Average integrated EMG amplitudes of water swallow open-bite subject No. 3 (before treatment, postretention and late postretention).

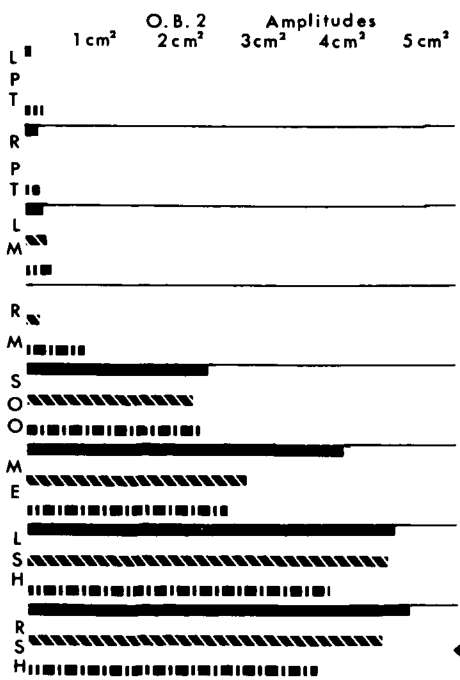

Fig. 15 Average integrated EMG amplitudes of water swallow open-bite subject No. 2 (before treatment, postretention and later postretention).

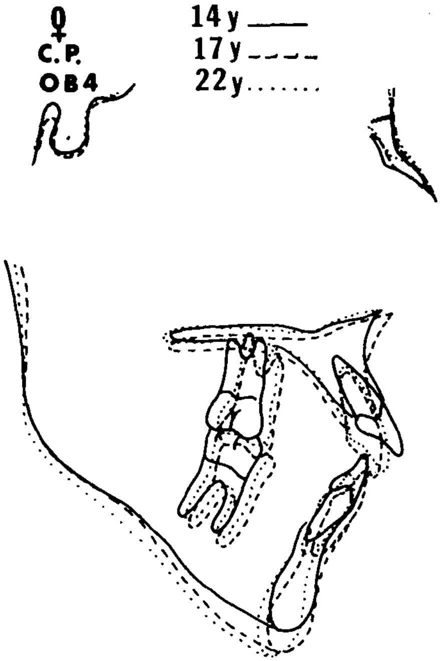

Fig. 18 Cephalometric composite tracing of open-bite subject No. 4.

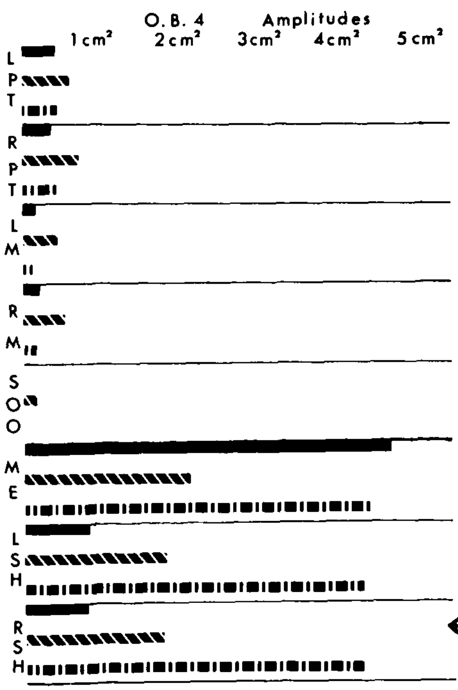

Fig. 19 Average integrated EMG amplitude of water swallow open-bite subject No. 4 (before treatment, postretention and late postretention).

anchorage appliance was used. As tipping of the occlusal plane resulted, the open-bite pattern increased, and subsequent tongue posturing anteriorly increased, as did mandibular depressor and perioral activity. The cervical traction was changed to occipital anchorage, but the harm had been done. The electromyographic converts indicate a pattern similar to that in the other open-bite failures, (Nos. 5, 1, 2, 3). Cephalometric tracings confirm failure after an interval of a year and a half during which a rubber finishing appliance had not been worn as ordered (Figs. 18, 19).

Discussion

In some of the case examples cited here for open-bite cases, stability and favorable esthetic or improved functional relations were not achieved. What do such examples of failure teach?

The concepts of alveolar and skeletal (gnathic) open-bite disorders have been mentioned by Tulley,[12] Rix,[13] Ballard,[14] Gwynne-Evans and Tulley,[15] and Schwarz[16] among others. Truesdell and Truesdell,[17] Moyers,[18] and Straub[8] have stressed the effect on tongue posture of obstructed nasal airways and of various digital sucking habits. Thompson and Brodie[19] described the unusual patterns of mandibular development after condylar injury and later, Thompson[20] classified malocclusions logically into functional and structural categories. Winders[21] and Kydd[22] have cited the variation in tongue and lip pressures in the possible production of specific malocclusion. Subtelny,[23] Milne and Cleall[24] and their coworkers, with serial cineroentgenographic recordings, have well demonstrated the variations in tongue posture while swallowing. Those reports support the results of the present study to date. In each of the studies cited, specific factors producing malocclusion had been reported. Some investigators have cited habits, others trauma or disease processes, still others mention interference with respiratory function. All factors seem to have a bearing on the accentuation of the malocclusion during the growth process. In the selection of cases to illustrate this facet of the study, the objective was to match a specific case with one of the causative factors advanced, although a single factor, however paramount, may not have been solely causative.

In most instances the untreated control subjects had a greater magnitude and duration of contraction activity in the mandibular elevators than in the mandibular depressors when swallowing 15 cc of water each of the three times in the test. Regrettably, a means of recording tooth contact had not been utilized; subjective appraisal is inexact and unreliable.

The treated control-subjects had similar action patterns, with the greater activity in the elevators present before treatment, at retention, and after treatment. The two treated control-subjects were selected because of the overbite and orthognathic skeletal pattern.

The open-bite subjects cannot be assessed as a unit, for each had a specific feature believed contributory to the result.

Today's concepts of diagnosis and treatment are being discounted on the one hand, and reinforced on the other by extensive research into the functional aspects of the human organism. The stomatognathic system is a functional component of the human being. That system is concerned with respiration, deglutition, mastication, emotion, and speech. The unknowns of the stomatognathic system's function are legion, but daily research, little-by-little, brings enlightenment. Dentistry has widened attention from the tooth to the teeth and on to the total stomatognathic system. Professional effort has garnered information from basic research. The application of electromyography to dental disorders began in the forties; its limitations were quickly recognized. The clarity of EKG records and EEG classification was not to accompany the EMG. EMG limitations were related to many clinical factors: among them were structural variations, reflex patterns, adaptation of the individual, experimental environment, and the possible psychic influence on reflex muscle activity. The foremost restriction of the EMG is the method of application of the instrument and the interpretation of the results.

The electromyograph was used in the studies reported here as a diagnostic adjunct, such as the cephalometer or study cast. The electromyograph, as the other adjuncts, represents a patient's functional record at an instant in time. The electromyograph records the initiation, magnitude, and cessation of action in proportion to the contraction. It does not differentiate single anatomic muscle entities. Serial readings do permit some functional interpolation, but teleologic reasoning and 20-20 hindsight seem more helpful.

In the specialty of orthodontics we often try to utilize the vectors, velocities and magnitudes of growth to alter structural relations to improve the function and esthetics of the dentofacial complex. Previous serial electromyographic studies[2] indicated that significant changes in mandibular elevator muscle function accompanied orthodontic correction of malocclusion. Similar information has been presented concerning patients who had undergone surgical correction of Class III malocclusions in which instances, however, certain muscle dominance was related to minor relapses.[25]

The study presented here seems to

bear out the importance of recognizing treatment limitations—not in what we can do but in how we do it. Most orthodontic patients respond favorably to procedures for tooth movement. Certain patterns of structure and function, however, require maximally informed diagnosis to achieve minimal functional disturbance or alteration. Failure of correct diagnosis results in failure of treatment. It is conceivable that in some cases of failure more favorable results might have been had if heavy or orthopedic force had been used. Muscle training, as in open-bite subject No. 6, is important; however, in other frank functional cases the value of muscle training is questionable. Mechanotherapy different from that applied may well have had a more favorable result. In one case cited here (open-bite No. 4), this happened; whether it might have in the others is an open question. Surgical-orthodontic procedures for subject open-bite No. 5 did not appreciably alter either the muscle function pattern or the developmental pattern. The surgical-orthodontic approach to such open-bite problems may ultimately prove the most efficient. Cases under study are so far encouraging.

Orthodontists must recognize the functional features of the stomatognathic system, not only regarding masticatory movements and concomitant equilibration, but also the entire range of function. The muscles are attached directly to the mandible and, in some instances, indirectly. Their contractile forces and patterns of activity can alter the structural relations of the mandible to the maxilla.

The modification of form by orthodontic efforts does not always alter functional patterns. When it does not, the orthodontist must accept relapse and the necessity for repeating surgical treatment or applying perpetual retention.

When orthodontists are able to modify function by training, they can modify form, but only in a minor way as in open-bite subject No. 6 who originally had an alveolar open bite.

Structural aberrations due to trauma, disease, habit, and genetics produce functional patterns that adapt to and may accentuate the structural disturbances. The orthodontic movement of teeth in the alveolar processes in such cases cannot assure attainment of better function or stability.

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References

1. Storer, R., Fhyrie, P., and Perry, H. T.: An electromyographic-cephalometric evaluation of saliva and water-swallows in the human. Read before the Northwestern University Orthodontic Alumni Reunion, 1963.
2. Perry, H. T.: Kinesiology of the temporal and masseter muscles in chewing a homogeneous bolus. Ph.D. Dissertation, *Northwestern University Dental School,* Chicago, 1961.
3. Allgood, P. J.: Variability of masticatory performance and swallow threshold in man. Ph.D. Dissertation, *Northwestern University Dental School,* Chicago, 1963.
4. Lipke, D. P.: An electromyographic and cephalometric roentgenographic study concerning the influence of various neural structures on the postural position of the mandible. M.S. Thesis, *Northwestern University Dental School,* Chicago, 1963.
5. Glass, P. J.: An electromyographic study of certain masticatory, facial, and hyoid muscles involved in voluntary swallowing in open-bite subjects. M.S. Thesis, *Northwestern University Dental School,* Chicago, 1964.
6. Brill, N., Lammie, G. A., Osborne, J., and Perry, H. T.: Mandibular positions and mandibular movements. *Brit. Dent. J.* 106: 391-400, 1959.
7. Doty, R. W., and Bosma, J. F.: An electromyographic analysis of reflex deglutition. *J. Neuro-physiol.* 19: 44-60, 1956.
8. Straub, W. J.: Malfunction of the tongue, part II: The abnormal swallowing habit: Its causes, effects, and results in relation to orthodontic treatment and speech therapy. *Am. J. Orthodont.* 47: 596-617, 1961.

9. Gwynne-Evans, E.: An analysis of the orofacial structures with special reference to muscle behavior and dental alignment. *Speech* 16: 36-44, 1952.
10. Tulley, W. J.: Methods of recording patterns of behavior of the orofacial muscles using the electromyograph. *Dent. Record* 73: 741-748, 1953.
11. Barich, F.: Graduate orthodontic lecture. Northwestern University Dental School, Chicago, 1953.
12. Tulley, W. J.: Long-term orthodontic results. *Dent. Pract.*, 12: 253-260, 1962.
13. Rix, R. E.: Some observations upon the environment of the incisors. *Dent. Record*, 73: 427-441, 1953.
14. Ballard, C. F.: Clinical significance of innate and adaptive postures and motor behavior. *Dent. Pract.* 12: 219-227, 1962.
15. Gwynne-Evans, E., and Tulley, W. J.: Clinical types. *Dent. Pract.* and *Dent. Record*, 6: 222-235, 1956.
16. Schwarz, A. M.: Roentgenostatics, practical evaluation of the x-ray head plate. *Am. J. Orthodont.*, 47: 561-585, 1961.
17. Truesdell, B., and Truesdell, F. B.: Deglutition: with special reference to normal function and the diagnosis, analysis and connection of abnormalities. *Angle Orthodont.*, 7: 90-99, 1937.
18. Moyers, R. E.: The role of musculature in orthodontic diagnosis and treatment planning. *Vistas in Orthodontics*, Chapter 7, Kraus, B. S. and Reidel, R. A. (Eds.), Philadelphia, Lea & Febiger, 1962, pp. 309-327.
19. Thompson, J. R., and Brodie, A. G.: Factors in the position of the mandible. *J.A.D.A.*, 29: 925-941, 1942.
20. Thompson, J. R.: Function—the neglected phase of orthodontics. *Angle Orthodont.*, 26: 129-143, 1956.
21. Winders, R. V.: Forces exerted on the dentition by the perioral and lingual musculature during swallowing. *Angle Orthodont.*, 38: 226-235, 1958.
22. Kydd, W. L., Akamine, J. S., Mendel, R. A., and Kraus, B. S.: Tongue and lip forces exerted during deglutition in subjects with and without anterior open bite. *J. Dent. Res.*, 42: 858-866, 1963.
23. Subtelny, J. D.: Malocclusions, orthodontic corrections and orofacial adaptation. *Angle Orthodont.*, 40: 170-201, 1970.
24. Milne, I. M., and Cleall, J. F.: Cinefluorographic study of functional adaptation of the oropharyngeal structures. *Angle Orthodont.*, 40: 267-283, 1970.
25. Malkin, Y. G.: Changes in mandibular position subsequent to surgical resection in cases of Class III malocclusion as shown by cephalometric analysis. M.S. Thesis, *Northwestern University Dental School*, Chicago, 1966.