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MUSCLE PRESSURES AND TOOTH POSITION: A REVIEW OF CURRENT RESEARCH*

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Over the years, orthodontic ideas about environmental influences on the dentition have fluctuated widely. Implicit in Edward Angle's ideal of 32 natural teeth in perfect occlusion was a belief that this was possible for every individual — and that environmental influences had led to the malocclusion, preventing the original potential from being realized. Orthodontists in the 1920's and 1930's were quite concerned about the effects of various habits and muscular pressures on the teeth. This "environmentalist" point of view found its greatest exponent in Alfred P. Rogers, who used various exercises and muscle therapy exercises in his orthodontic practice, largely instead of orthodontic appliances (1).

The reaction in the late '30's and '40's to obvious relapses after non-extraction treatment led to an accompanying re-evaluation of the enenvironment-heredity roles in producing malocclusion in the first place. For Tweed, the basic reason for extraction was a hereditary discrepancy between tooth mass and jaw size (2). For Begg, extraction was necessitated by modern man's diet which prevented attritional reduction of tooth mass (3). With both treatment approaches, there was little concern about the environmental factors which concerned the orthodontic leaders of the earlier generation and philosophy. The dominance of this point of view was reflected in the strong technical rather than biological emphasis of the period.

In the 1950's in the U.S., Walter Straub struck a responsive chord when he pointed out difficulties with open bite problems, whether or not extraction treatment was used (4). The muscular environment was blamed for these problems. This renewed interest in muscular influences led to orthodontically-oriented research in which new electronic techniques were used to study the magnitude, duration and wave form of oral muscular pressures. Such studies had not been possible in the earlier era. Research of the last 15 years has produced answers too slowly to satisfy many clinicians, so muscular forces are currently somewhat out of vogue, but the pendulum swings of opinion are being dampened out as greater knowledge leads to better overall perspective.

Development of Methods for Studying Tongue and Lip Pressure

Stetson in the 1930's used small balloons as pressure sensors within the mouth and pneumatic-mechanical linkage to record pressure waves on smoked kymograph drums (5). Similar technology was employed by some of the first dental workers of the 1950's, but real advances required electronic pressure sensing devices based on use of strain gauges, and on the development of high quality electronic amplification systems which could handle the small signals from miniature intra-oral pressure transducers. A number of investigators played a role in the slow development of the necessary instrumentation (6). Only in the last few years (perhaps since 1963) has the instrumentation itself reached a satisfactory stage of reliability and accuracy.

One design of a modern intra-oral pressure transducer, designed and built in the orthodontic department at the University of Kentucky, is shown in figure 1. Extremely small foil strain gauges, carefully matched to the temperature coefficient of the beam on which they are mounted, have replaced the bulkier wire strain gauges of earlier days. The pressure transducer is designed to be mounted in a thin plastic carrier, as shown in figures 1 and 2. When it is mounted, only the pellet at the end of the cantilever beam is exposed to the pressure of the tongue or lips. It is also

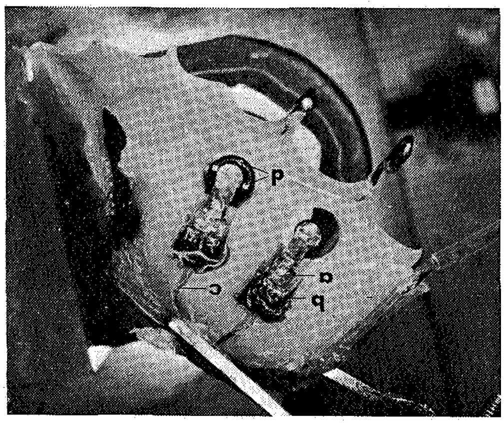

Fig. 1 — Strain gauge pressure transducers mounted in a palatal appliance, internal view. A — foil strain gauge at end of cantilever beam, B — mounting platform, partially covered with wax, C — lead wires from transducer, D — calibration guide.

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possible to place the transducer in a thin metallic housing and cement it directly to the teeth, attach to arch wires, etc. Since the mounting of a transducer can affect its sensitivity, accuracy requires that each transducer be individually calibrated after being mounted (figure 3).

Any time instrumentation is introduced into the mouth, or other areas of the body, there is a possibility that the physiological activity being studied will be altered by the presence of the recording instrument. This phenomenon, called "physiologic reactance" by Code (7), is a very real hazard in the mouth, particularly when lingual pressures are to be recorded. The pattern of tongue activity is likely to be changed to avoid the pressure transducers. If the devices cause discomfort, avoidance is all but guaranteed. To combat this, in our studies a dummy lingual appliance is worn by subjects for approximately 48 hours prior to placing the actual recording appliance. This allows accommodation to the appliance to take place, which can be evaluated by the disappearance of speech distortion. There are no sharp projections on the recording appliance, and speech difficulties do not reappear when it is placed.

Analog pressure waves are produced by tongue or lip contacts with a transducer. Pressures, duration of contact, area under the pressure curves (time-pressure integral), and time relationships between pressure curves at multiple recording locations may all be measured by hand, but the volume of data requires computer assistance for more than small-scale studies. At Kentucky, an IBM 1800 computer is connected directly to the pressure-recording instrumentation, and data are fed immediately to the computer while being monitored in the lab. Calibration sensitivities of each transducer are taken into account while the calculations to produce pressure and time data are carried out. With the computer, data are reported in only a few minutes. Computed data are also retained on magnetic tape at the computer for later statistical calculations. Developments in electronics in the late 1960's leading to improved stability of both the transducers and the amplifying system were necessary before this computer application was possible.

The most recent technical step has been development of a portable system which can be used for pressure recording outside the laboratory. A special portable amplifier was constructed to build up signals from the pressure transducers to the level required for recording on analog data tape (figure 4). This equipment was used in central Australia in 1972 to obtain labial and lingual pressure measurements on members of the Walbiri group of aborigines whose dental development has previously been studied extensively by Barrett, Brown and others at Adelaide University, Faculty of Dentistry.* The data tapes were analyzed by the computer at Kentucky in the same way as data generated in the lab there.

Summary of Current Data and Its Clinical Implications

Two broad questions of interest to orthodontists may be asked with reference to studies of labial and lingual pressures: (1) what do they reveal with reference to the etiology of malocclusion, and (2) what are their implications for stability or relapse after orthodontic treatment?

Muscle pressures and etiology. This question, so pertinent to the changing views of orthodontists over the years, revolves around the validity of the "equilibrium theory" of tooth position, or, more correctly, around the contributions of the tongue and lips to the equilibrium. Since the teeth do remain in a stable position most of the time in most people, and since tooth movement is observed when additional forces are exerted (as by orthodontic appliances, by a poorly-designed

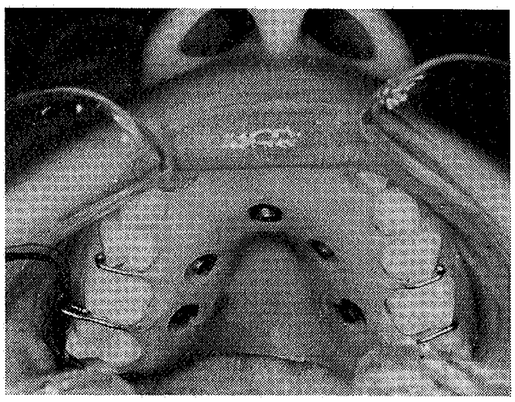

Fig. 2 — Palatal appliance containing five transducers, in a child's mouth.

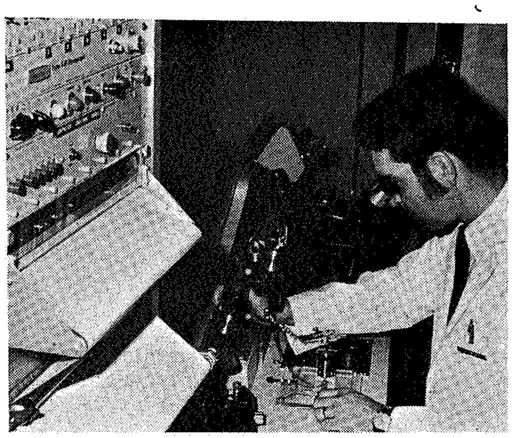

Fig. 3 — Calibration set-up, with microscope being used to orient transducer for calibration after it has been mounted.

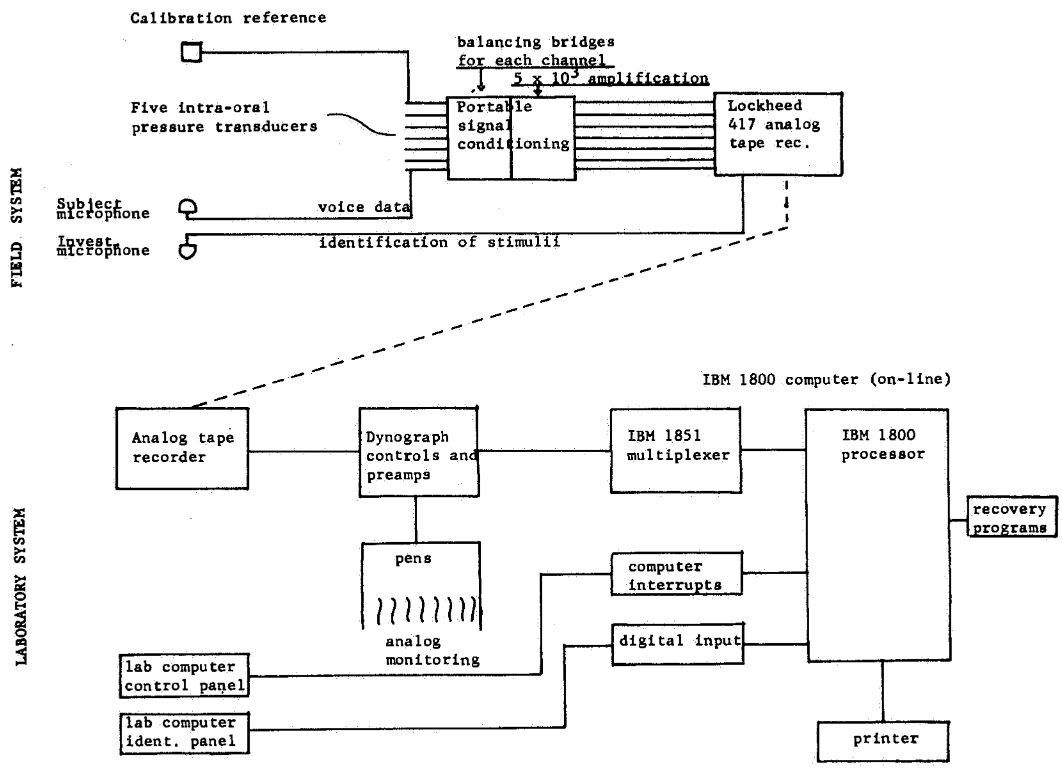

Fig. 4 — Block diagram, field recording system.

partial denture, or by contracting scar tissue after an injury), it is apparent that there is an equilibrium which can be upset.

Direction, duration and magnitude of muscular force or pressure are important variables which must be identified before data can be evaluated. Almost all workers have used pressure transducers which were sensitive in only one direction.

The transducers were mounted to record horizontally-directed pressures. Vertically-directed forces, as discussed below, may be significant in establishing the vertical position of teeth, but these have been little studied.

Early workers observed that maximum lingual pressure outweighed labial pressure at all intraoral locations. There was a great deal of variability between subjects, but neither group nor individual values showed any evidence of an equilibrium on this basis. Lip pressures are of longer duration than tongue pressures, and there may be resting lip pressures of some magnitude. Taking these duration figures into account, however, still does not produce a balance of functional pressures. Typical peak pressures during swallowing are, in the maxillary incisor region, 75 ± 50 gm/cm^2 lingual, 55 ± 20 gm/cm^2 labial; in the maxillary molar region, 140 ± 50 gm/cm^2 lingual, 30 ± 15 gm/cm^2 buccal. The amount of variation is for a group. Individuals reproduce themselves much more closely (6, 8, 9, 10). Time-pressure integrals come closer but still do not balance. Taking duration factors into account as fully as possible, Lear carried out an experiment using a summation of four-hour recordings, with extrapolation to 24 hours from a knowledge of the subject's activities. Over this longer period, there was still no balance of muscular forces (11).

Other evidence also indicates that horizontal tooth position is not sensitive to pressures during swallowing and speech. There is no relationship between the increment in maxillary intermolar width and lateral tongue pressure during swallowing in children (10). Bilaterally symmetric dental arches are common, but symmetric lateral tongue pressures are rare. Most individuals have definite "sidedness" in tongue pressures, with stronger pressure during swallowing and speech on one side. The majority are left-tongued (10). Oral

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cavity volume, as measured from head films and dental casts, has a correlation coefficient with tongue pressure during swallowing of only 0.50 (12). Perhaps one should speak, not entirely facetiously, of a "semi-functional matrix".

These data do not indicate that there is no equilibrium, only that the conditions defining it are not yet understood. It is probable that duration of pressure will have to be considered differently in the future. To obtain orthodontic tooth movement, light pressures suffice if they are maintained continuously or nearly so. Heavy pressures of short duration, on the other hand, have little effect. Resting pressures seem remarkably like the effective orthodontic forces, while pressures from occlusion, speech, mastication, swallowing and other activities would all be too short-acting to be effective orthodontically. In order to achieve an understanding of the equilibrium components, it may be necessary to eliminate pressures which are not maintained for a threshold time, or to weigh the longer-lasting pressures considerably more heavily than short-acting pressures. At present it does seem evident that teeth are not pushed into malocclusion by tongue or lip activity. It is increasingly unlikely, for instance, that the degree of bimaxillary protrusion can be related to tongue pressures during swallowing.

Another factor which may need consideration is the geometry of the dental arches. Allan Brader hypothesizes that the radius of curvature of the arch influences the stresses on it, just as is true for other closed containers (13). Recent experimental evidence indicates that the relationship is not as simple as Brader hoped, for resting pressure multiplied by radius of curvature is not a constant (14). Nevertheless, arch curvatures may indeed influence the equilibrium situation. By analogy to engineering principles, it would be surprising if they did not.

All the above relates to *horizontal* position of teeth in the arches. *Vertical* position, on the other hand, may be influenced by functional activity. The mechanism of tooth eruption remains poorly understood, but the forces accompanying it are only a few grams. Vertically directed intermittent forces accompanying swallowing and other activities might well be able to influence the rate or amount of eruption and thus create an open bite. Clinical observations support this hypothesis. Unfortunately, there are as yet no pressure data to support the concept.

Muscle pressures and relapse. To the extent that the etiologic factors which caused malocclusion remain active after orthodontic treatment is completed, relapse toward the original malocclusion can be expected. Putting the teeth into a stable position has often been equated with putting them into a position which the musculature will accept. This view again, of course, reflects an underlying concept of environ-

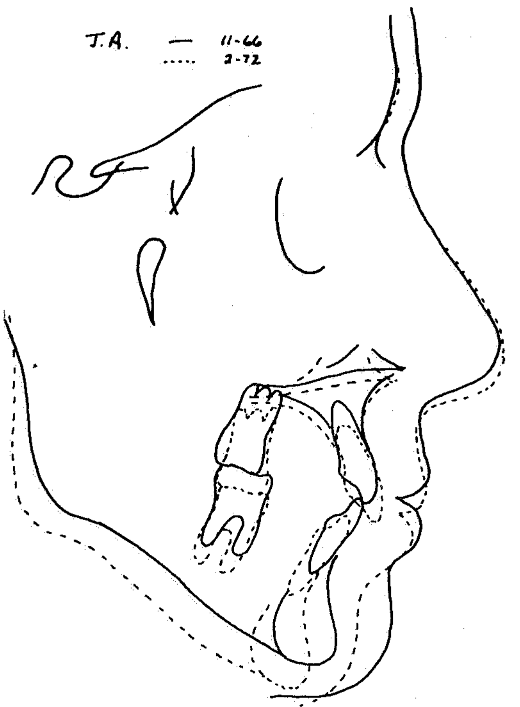

Fig. 5 — Relapse into mild open bite and overjet following orthodontic treatment. Vertical changes, with mandibular rotation, account for the altered dental relationships (courtesy M. Sims, Adelaide).

mental factors as important in determining tooth position. Orthodontists frequently observe that in the presence of a "tongue thrust" swallow there is a tendency for both anterior open bite and maxillary overjet to recur after correction. Two inferences are often drawn: (1) the tongue is responsible for the changes in the occlusion, and (2) the relapse occurred as the tongue pushed the anterior teeth into new positions. The discussion of equilibrium factors above suggests that while the first inference may be more or less correct, the second is almost surely incorrect.

It has been shown that horizontal changes in tooth position due to functional pressures are unlikely. An increase in overjet, as well as return of anterior open bite, can accompany changes in vertical position of teeth. All that is required is rotation of the mandible, with greater eruption of posterior than anterior teeth. Typical cephalometric findings in such relapse are shown in Figure 5. In this instance, as in most post-orthodontic patients, vertical growth occurred after treatment. Even when there is no growth, however, open bite and increased overjet develop, not through direct movement of the anterior teeth to new positions, but through differential eruption and rotation of the mandible. The rest position as well as the occlusal position of the mandible may alter as this occurs.

Retention difficulties due to tongue and lip activity are frequently expected in the aftermath of orthodontic-surgical correction of severe malocclusions. Radical changes in the volume of the oral cavity are made quickly with surgery. In some European centres in the past, it was common practice to reduce the size of the tongue at the time of jaw surgery, in the hope of obtaining greater stability of the dental correction. Surgical procedures on the tongue have been shown not to be necessary in most instances, however, because of the marked physiologic adaptation which occurs post-operatively. The tongue is carried lower in the mouth, as demonstrated by a change in hyoid position (15). Studies of tongue and lip pressures show these are little changed after operation in most patients, and that stable results without tongue reduction occur in these individuals. Occasionally, a marked change in pressure patterns is seen post-operatively, and then the failure of physiologic adaptation may require further treatment. It is not known whether the tooth movement which occurs in these cases (for when relapse not related to growth occurs after surgery, jaw segments remain stable while teeth alter their horizontal position on supporting bone) is related to functional or resting pressures (16). These cases may represent the tolerance limits of imbalance in functional pressures.

Future Research Areas

It seems apparent that clarifying relationships between muscular pressures and tooth position will require work in two major areas:

(1) the effect of pressure duration on its effectiveness in influencing tooth position. Resting pressures are probably more important than pressures during swallowing or speech, but how to build time factors into an equilibrium equation has not been solved. It is important clinically to know how large is the area of muscular tolerance of tooth position, the "trough of muscular equilibrium", and to use this information in determining arch form after orthodontic treatment. A better understanding of equilibrium factors will be required in order to accomplish this. Hopefully, the studies of pressure patterns in Australian aborigines, which are being undertaken now, will allow further elucidation of the equilibrium components.

(2) the effect of muscular pressures on vertical rather than horizontal tooth positions. The vertical component of tongue and lip forces has received little attention, but these forces, studied jointly with the forces of eruption, may explain many aspects of malocclusion which are related to vertical dimension. Research in this area is only beginning.

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