Resting Tongue Pressures

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An equilibrium concept for the maintenance of tooth position has evolved from the observation that very light forces are able to move teeth while the dental arch form is relatively stable under normal circumstances. Weinstein[1] reported that forces as low as 1.68 g above the resting level, acting over sufficient time, are capable of moving teeth. Consequently, natural forces exerted on the teeth must be in balance or movement of teeth would occur.

The position of dentoalveolar structures can be altered by procedures that potentially would disturb a state of equilibrium of teeth. Harvold[2] found that altered neuromuscular functions of the tongue could be linked to deviant orofacial morphogenesis. He placed a piece of acrylic in the palatal vault of the rhesus monkey to change normal physiological relationships and, one year later, the animal manifested an anterior open bite and increased spacing of teeth. In another group of animals a two centimeter-long wedge was removed from the midsection of the tongue. After four to six months deepening of the bite and crowding of mandibular incisors became evident.

Investigators have had little success in clarifying the equilibrium concept by determining the specific factors that influence tooth position.[3-7] Both the resting and functional forces present in the oral environment have been implicated. Also, the forces of occlusion and dental eruption, morphology of teeth and inclination of teeth must be considered in a study of dental equilibrium. The question remains: what factors or combination of factors control physiologic movement of teeth?

Indirect evidence comes from clinical studies on the importance of the tongue in maintaining arch form. Briggs[10] observed a boy with congenitally complete aglossia. The maxillary and mandibular teeth and the alveolar bases were severely constricted. Gardner[11] reported similar findings after examining a boy with congenital partial aglossia. Walker[12] discussed a case of lymphangioma of the tongue with marked separation of the anterior teeth. In the latter example, after partial resection of the tongue and minor orthodontic therapy, the corrected malocclusion remained stable. Proffit, Gamble, and Christiansen[13] reported a case of generalized muscular weaknesses associated with severe anterior open bite in which the tongue was normal in posture and behavior. They concluded that the "syndrome of generalized muscular weakness undoubtedly contributed to the skeletal and dental deformities."

On the other hand Subtelny and Sakuda[14] observed a forward movement of lower incisors in only 44 percent of patients treated with lip bumpers. They implied that the influence of the tongue had possibly been overemphasized in the literature because, in the majority of instances, no forward movement of the incisors occurred with the bumper in place. Conflicting observations have also been reported on the role of the facial muscles. Briggs[10] observed a girl with a congenital cerebrofacial palsy. The patient displayed no lip or cheek activity, yet the incisors were well-aligned.

Efforts to quantify muscular activity have also failed to substantiate the

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equilibrium theory. Functional tongue pressures, as measured by electronic recording devices, usually exceed lip and cheek pressures. Using a modified strain gauge, Winders[4,15] found that in all malocclusions the lingual musculature is far more active than the perioral musculature during speech, swallowing, and maximum effort.

The role of functional forces has been deemphasized in recent years. Lear and Moorrees[5] commented upon the lack of a clear-cut relationship between intermittent functional activity of muscles and arch form and called for careful studies of other force variables. Proffit et al.[6] measured force levels of the tongue against the maxillary incisors and palate during normal swallowing and concluded that the resting position of the tongue was more significant than the swallowing position in determining arch form.

In the present study a specially designed strain gauge transducer was used to measure the magnitude of forces exerted by the relaxed tongue in the region of the mandibular canines. Because the literature presents varying opinions on using pressure or force as the preferred unit of measurement, the resting forces were measured with three sizes of transducer platforms.

The investigation was designed to study two problems, namely:

1. The lateral pressures of the resting tongue in the region of the mandibular canines and premolars at a point equal to, and also less than, the intercanine distance width in subjects having either normal occlusion or openbite malocclusion.

2. The relationship between the area of the sensor and the measured levels of force and pressure.

Material and Methods

The apparatus consisted of five basic components (Fig. 1): 1) the base, 2) two rigid beams, 3) two adjustable screws to control distance and angle between the sensors, 4) four strain gauges, and 5) three pairs of interchangeable sensing platforms with diameters of 2.6, 4.9, and 5.9 mm.[16] The framework of the apparatus fabricated from stainless steel was 135 mm in length. Two strain gauges were mounted on each beam near the fixed end of the instrument and were bonded to the beams with a thin layer of M-bond 610 adhesive and protected against the oral fluid with M-Coat A polyurethane coating. Wheatstone bridge circuits in a three lead configuration were used to complete the transducer, and the output was fed into a recorder. Calibration and reproducibility of measurements were carefully monitored.

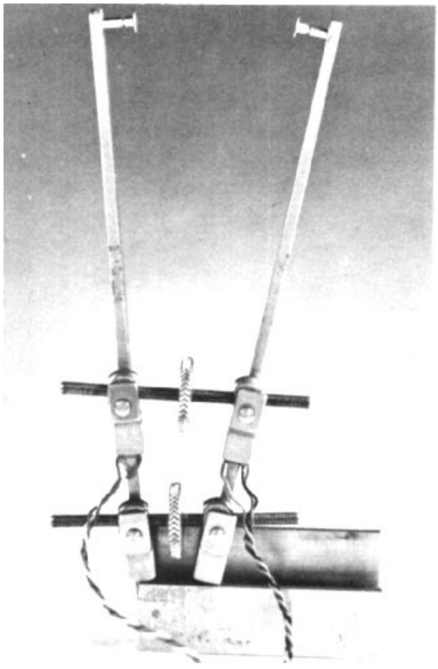

Fig. 1 The strain-gauge transducer used to measure resting-tongue forces. The sensor platforms are changeable.

To determine the relationship be-

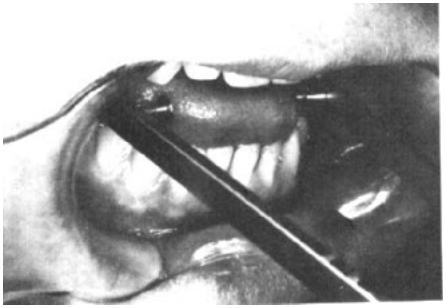

Fig. 2 The sensors in position against the tongue in the region of contact with the mandibular canines.

tween recorded force and area of the sensor tip, measurements were made initially on seven healthy male individuals ranging in age from 28 to 33 years with complete natural dentitions exclusive of third molars. With the subject's mouth open slightly, dots were placed with a fine-point indelible pencil on the dorsum of the tongue directly above the cusp tips of the mandibular left and right canines. Subsequently, dots were placed directly inferior to the initial dots at the point where the tongue was resting against the mandibular arch. Each subject was instructed to place his relaxed tongue at the position of the lowermost dots between the sensing platforms that were adjusted to his intercanine distance (Fig. 2). The subject was permitted to use a mirror positioned directly in front, and to tip his head forward and downward slightly to maintain the tongue in a position accessible to the instrument. The intercanine distance was determined with a divider on plaster casts made from each subject.

First, the effect of varying the area of tissue contact on the recorded force was established at the canine tips by using the three different pairs of interchangeable sensing heads. A series of trial recordings was made until the investigator judged that an accurate record of relaxed tongue pressure was achieved. Subsequently, the 4.9 mm platforms were used and the intercanine distance was constricted a total of 6 mm in 2 mm increments. Decreasing the intercanine distance farther to 8 mm constriction stimulated rapid motor fibrillatory activity in three subjects. Finally, the 4.9 mm diameter platforms were used to measure resting-tongue force in additional subjects: ten individuals having normal occlusion (4 males, 6 females, age range 19-30), and six having an anterior open bite with molars in neutroclusion (2 males, 4 females, age range 15-28).

Results

The resting-tongue force measured at the lingual surfaces of the mandibular canines was recorded with sensing-platform diameters of 2.6, 4.9 and 5.9 mm diameter in the initial group of seven male subjects (Table I). At 2.6 mm, the forces ranged from 0.2 g to 0.7 g. The mean force was 0.5 g ± 0.3 g. The mean load increased to 0.8 g ± 0.3 g at 4.9 mm diameter-sensing platform with a range of 0.4 to 1.1 g. With the 5.9 mm diameter sensor, the mean force was 1.1 g ± 0.4 g with a range of 0.4 to 1.5 g. To relate the forces to the area of the sensing platforms, pressures were calculated. The pressure readings with the 2.6 mm diameter platforms were consistently highest for all subjects. The pressures

TABLE I
Force Changes with Different Sensor Diameters

Subjects	*5.9 mm Grams*	*4.9 mm Grams*	*2.6 mm Grams*
1	0.9	0.8	0.5
2	0.4	0.4	0.2
3	1.0	0.8	0.5
4	1.5	0.8	0.7
5	1.5	1.1	0.7
6	0.7	0.6	0.2
7	1.4	0.9	0.6
Mean	1.1±0.4	0.8±0.3	0.5±0.3

ranged from 0.035 g/mm² to 0.135 g/mm.[2] The mean pressure was 0.089 g/mm². The mean resting pressure was 0.039 g/mm² with both 4.9 and 5.9 mm diameter platforms.

In the other group of ten subjects with normal occlusion the average force value with the 4.9 mm diameter sensors was 0.7 g ± 0.3 g with a range of 0.3 to 1.1 g. When the data from both normal groups were pooled to examine the relationship between force measurements and mandibular intercanine distance, a correlation of r = —0.4 was obtained, that is, a decreasing force reading with increasing intercanine distance.

The average force value obtained with 4.9 mm tips in the anterior open-bite sample was 0.6 g ± 0.3 g. The range was 0.3 to 1.0 g. Three of the open-bite subjects had difficulty placing the tongue properly between the sensors owing to poor coordination and they required much practice before measurements were made.

Changes in force levels resulting from tissue displacement in the group of seven males were measured by constricting the tongue between 4.9 mm platforms (Table II). At intercanine distance the forces ranged from 0.4 to 1.1 g with a mean of 0.8 g, as stated before. When the tongue was constricted by 2 mm increments (1 mm on each side), the mean force increased to 1.0 g at minus 2 mm, 1.3 g at minus 4 mm, and 1.8 g at minus 6 mm. At 6 mm of constriction, the forces exerted by the resting tongue ranged from 1.3 to 2.8 g.

Deflection Gradient

The rate of change of the force with respect to displacement of the lingual musculature is represented by the deflection gradient (G)

$$G = \frac{dF}{dS}$$

TABLE II

Force Changes During Lingual Constrictions

		Intercanine Width		
		—2 mm	*—4 mm*	*—6 mm*
Subjects	*Grs*	*Grs*	*Grs*	*Grs*
1	0.8	1.1	1.5	1.7
2	0.4	0.6	0.8	1.3
3	0.8	1.0	1.2	1.8
4	0.8	1.1	1.6	1.9
5	1.1	1.4	1.9	2.8
6	0.6	0.7	0.9	1.7
7	0.9	1.1	1.1	1.4
Mean	0.8	1.0	1.3	1.8

TABLE III

	A Deflection Gradient g/mm	*B* Stiffness g/mm
Subjects		
1	0.30	2.16
2	0.28	1.20
3	0.32	2.26
4	0.37	2.43
5	0.57	4.29
6	0.37	1.88
7	0.17	1.92
Mean	0.34	2.30

where dF is the force change at any incremental tongue displacement dS. The mean gradient for the seven subjects was 0.34 g/mm (Table III) with a range of 0.17 to 0.57 g/mm. No correlation between gradient and intercanine width was obvious.

Stiffness

Weinstein et al.[7] described a formulation for the rate of change of force with displacement as the stiffness or elastic index of the tissue. He reported buccal stiffness of 1.27 g/mm to 3.0 g/mm in the bicuspid region. The mean and standard deviation were 1.94 g/mm and 0.308 g/mm, respectively. The results of this study (mean of 2.29 g/mm) compared closely with his reports on the buccal tissues. It is, therefore, noted that the rate of change (measured in stiffness) of buccal and lingual musculatures during displacement have similar patterns. The stiffness values ranged from 1.20 g/mm to 4.29 g/mm.

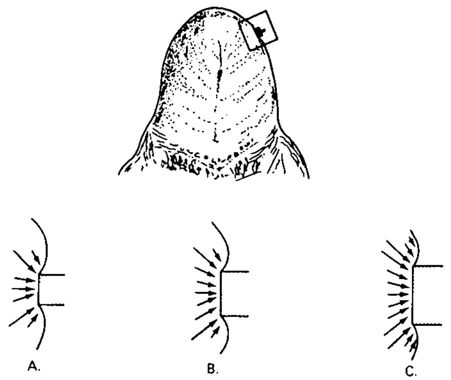

Fig. 3 Contact of lingual tissue with sensors of different diameters: *A*. 2.6 mm, *B*. 4.9 mm, *C*. 5.9 mm. The effect of the tissue surrounding the sensor becomes more important when the diameter of the sensor is small.

Discussion

Because greater force values were recorded when larger sensing platforms are used, it is important to report platform size as well as force levels. The observation that the smallest sensors recorded the highest pressures reflects the influence of the tissue adjacent to the sensors but not directly under it. Figure 3 illustrates the hypothetical influence of the adjacent tissue on the recording sensors. The ratio of circumference of the sensors to the area was greatest with the small platform and it diminished as the area of the sensor increased. Thus, the influence of adjacent tissue appears to be greater with the smallest tip and the pressure is erroneously elevated.

The observation that lingual pressures in subjects with open bite are essentially the same as in control subjects may seem unusual when considering the resting pressures of the tongue as a cause for the open-bite malocclusion. Pressures were actually less than the normative values when open bite prevailed. However, other factors such as differences in tongue position may be present without affecting force levels.

The lack of a striking relationship between tongue pressure, anterior open bite, or its absence suggests that the morphology and functional environment are in balance. The low negative correlation between intercanine distance and tongue pressure lends some support to the observation by Proffit[17] that individuals with wider dental arches have less lingual pressure, but this requires further study owing to the low correlation observed (r = —0.4).

The relative importance of strong, intermittent forces as compared with weaker, but constant, resting forces in maintaining dental equilibrium is of more than casual interest in clinical situations. The treatment of speech and swallowing abnormalities such as tongue thrusting and the prevention of relapse after orthodontic or orthognathic surgical treatment would have a more rational basis if the nature of the forces and other variables involved in dental equilibrium were understood.

Summary

A specially-designed force transducer was used to measure lateral resting-tongue pressure in 23 subjects. Seventeen subjects had normal occlusion and six had dental open-bite conditions. Three sensing tips with different contact areas were used to study the relationship between sensor area and measured force. The average force of the resting tongue was 0.8 g when measured with a 4.9 mm diameter sensor (pressure = 0.039 g/mm^2). When the size of the sensor tip was increased, the force of the tongue increased in a nonlinear manner. Controlled incremental lingual constrictions of 6 mm resulted in an average increase in lingual force of 230 percent. The mean rate of change, measured in deflection gradient, was 0.34 g/mm. The mean stiffness of the lingual musculature was 2.30 g/mm. A correlation of r = —0.4 was found between resting-tongue pressure and mandibular intercanine width.

CONCLUSIONS

1. The normal relaxed tongue produces a very low force against the lingual surfaces of the mandibular dentition.

2. The level of lingual force in patients with a dental open-bite malocclusion was found to be similar to that of normal subjects.

3. Resting lingual forces increase rapidly as tongue width is decreased by the force transducer.

4. Whenever force recordings are reported in myometric studies, the size of the sensor area should also be given to specify pressure levels.

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