Pressure from the tongue on the teeth in young adults

By Katrin Fröhlich, DDS, Dr med Dent; Urs Thüer, DDS, Dr med Dent; and Bengt Ingervall, DDS, Odont Dr

Pressure from the tongue on the teeth has been measured by Winders,[1,2] Gould and Picton,[3] Kydd et al.,[4] Proffit et al.,[5-7] Proffit,[8] Wallen,[9] Hensel[10-11] and Archer and Vig[12] among other investigators. These authors used pressure transducers based on strain gauges. The transducers were fastened to the lingual surfaces of the teeth[1,4,5,10,11] or mounted on an acrylic plate worn in the palate or in the lower jaw.[6-9,12]

A pressure transducer is comparatively bulky, especially when mounted on an acrylic plate. In some studies, the subjects to be tested wore a dummy appliance for several days in order to adapt to the measuring appliance before the actual test.[6-8] This is an important practical drawback and raises doubts as to whether the recorded values represent the unaffected pressure from the tongue on the teeth in a natural, undisturbed situation.

Another important drawback of the pressure transducer is that it cannot record negative pressure. Negative intraoral pressures in the rest position of the mandible and in the oral soft tissues have been reported for measurements in the palate[13] and in the vestibular fold.[14-18]

Pressure transducers are delicate and can be distorted when used intraorally during chewing. Pressure from the tongue on the teeth during chewing has not been measured, although one study has reported force values during chewing.[19]

A pressure-measuring system, based on an extraoral pressure transducer incorporated in a water-filled system has been previously described.[14] This system uses a small intraoral mouthpiece which is not distorted during chewing. This system registers both positive and

Abstract

Pressure from the tongue on the teeth was measured at the upper and lower central incisors and left first molars in 25 young adults with clinically normal occlusion. Repeated recordings with and without a period for accommodation to the intraoral measuring device, which was connected to an extraoral pressure transducer, were made in the rest position and during chewing and swallowing.

Only minimal effects of accommodation were found. The system can thus be used without a period of adaptation before the actual test. The intraindividual pressure variations were of the same magnitude as for measurements of the pressure from the oro-facial soft tissues on the teeth recorded in earlier studies.

The majority of the subjects had negative pressures at the upper and lower incisors and at the upper molar in the rest position. The pressures on the teeth during swallowing were comparatively great, while pressures during chewing were one-fourth to one-half of the swallowing pressures.

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Key Words

Tongue pressure • Oral function • Soft tissue

Figure 1
Mouthpieces for the measurement of the pressures in the upper jaw.

Figure 2
Mouthpieces for the measurement of the pressures in the lower jaw.

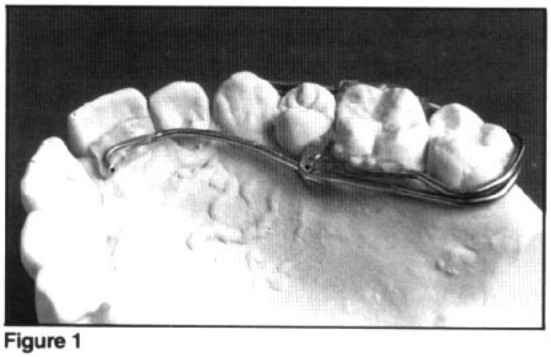

Figure 1

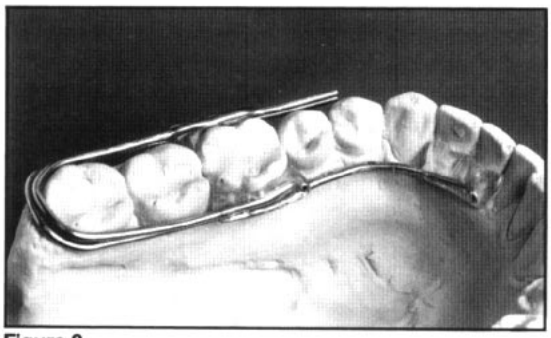

Figure 2

negative pressure and has been used to measure pressure from the lips and cheeks on the labial surfaces of the teeth and the alveolar process.

This paper reports the use of this system to measure tongue pressure on teeth. This study aims specifically at evaluating the reproducibility of the tongue pressure measurements as well as any effect of adaptation to the intraoral part of the measuring system. A further aim of this study is to report the pressure from the tongue on the upper and lower anterior and posterior teeth in a sample of young adults during natural functions.

Materials and methods

Twenty-five dental students (23 men and 2 women) participated in the study. Their ages ranged from 22 to 33 years (median age 23 years). All of the subjects had a complete dentition (third molars excluded) with the exception of up to four missing premolars in three individuals and one missing lower incisor in one individual. These teeth had been extracted for orthodontic reasons or were congenitally missing. Each subject had a neutral occlusion with normal overjet and overbite. One subject had a unilateral crossbite of the posterior teeth.

Measurement of the pressure from the tongue on the teeth

Pressure from the tongue on the lingual surface of the teeth was measured in four locations:

1) the interdental space between the upper central incisors (upper incisor),
2) the interdental space between the lower central incisors (lower incisor),
3) the interdental space between the upper left second premolar and first molar (upper molar) and
4) the interdental space between the lower left second premolar and first molar (lower molar).

Due to technical difficulties, upper molar pressure was measured on the right side in two cases and lower molar pressure was measured on the right side in four cases.

An open cannula (internal diameter 0.7 mm) was attached in each of the four test locations. Each cannula was embedded in a small custom-made acrylic shield (mouthpiece) which was bonded to the teeth (Figures 1 and 2). The mouthpiece projected 2 to 3 mm from the tooth surface. The open end of the cannula was flush with the acrylic surface; the other end extended along the lingual surface of the teeth, passing the most distal tooth of the dental arch along the buccal surface of the posterior teeth. From this position, the cannula was connected via a 1.3 mm-diameter tube that pased between the lips at the corner of the mouth to an extraoral pressure measuring system.

The extraoral system consisted of a bottle containing water and compressed air, a pressure transducer (Statham P 23 ID) and a flow-limiting valve. The pressure caused a small, constant stream of water (2 ml/min) to escape through the open end of the cannula. When this was covered by the tongue, a resistance was offered to the escape of the water. The pressure built up in the water system was recorded by the pressure transducer. This pressure reflects the pressure from the tongue on the mouthpiece with its open cannula.

Water escaping through the cannula was swallowed by the person being tested.

This pressure-measuring method has been used in several previous studies of pressure from the lips and the cheek on the labial surface of the teeth.[14-18] Details of the system, including the calibration procedure, are described in the article of Thüer et al.[14]

Electromyographic recordings

Electromyographic recordings of right masseter muscle activity, as well as activity of the muscles in the floor of the mouth, were made along with the tongue pressure registrations. Bipolar surface electrodes were placed over the right and left anterior digastric muscles and over the masseter muscles. Recordings were made and analyzed as described earlier.[14,20]

The masseter muscle activity recordings were used to evaluate the chewing cycle and to identify the act of swallowing. Recordings of muscle

Table 1
Accidental errors of the method (si) in g/cm² for duplicate determinations of tongue pressure in 25 subjects. The table also gives the si-value of % of the pooled standard deviation of the first and second series of recordings for pressure and simultaneous electromyographic recordings.

			Electromyographic recordings si in %	
	si	si in%	Masseter m.	Anterior digastric m.
Pressure in rest position				
Upper incisor	2.70	68	62	141
Lower incisor	2.20	53	54	81
Upper molar	4.30	108	72	88
Lower molar	3.02	70	50	77
Pressure during chewing				
Upper incisor	25.60	69	58	53
Lower incisor	47.37	73	93	50
Upper molar	36.74	77	46	59
Lower molar	70.82	95	54	53
Pressure during swallowing				
Upper incisor	84.74	76	57	49
Lower incisor	140.55	73	47	67
Upper molar	88.19	61	51	55
Lower molar	79.85	69	53	52

activity in the floor of the mouth were used to monitor the rest position of the tongue. Rest position was attained after a command swallow.

The electromyographic signal of the muscles of the floor of the mouth was connected to an electrostathic writer (GOULD ES 1000) and an oscilloscope (Tectronix 5111 A) for permanent registration. The oscilloscope was placed in front of the subject being studied. The subject could thus follow the degree of activity of the muscles of the floor of the mouth (including the activity of the tongue muscles) on the oscilloscope screen. Pressure recordings in the rest position were then made when a steady state of minimal activity from the floor of the mouth was visible on the oscilloscope screen. This biofeedback procedure helped the subject keep the tongue at rest for the pressure recording.

Position of the head

The recordings were made with the subject's head in natural balance (natural head position). The natural head position was established with the relaxed subject standing upright looking out a window at the Alps. A horizontal light beam projected on the cheek was then marked with a horizontal line. During the actual recordings, the subject was seated in a dental chair with a head support, and the position of the head was controlled by projecting the horizontal light beam on the line previously marked on the cheek.

Order of the recordings

At each recording session, recordings were made, one at a time, from the four mouthpieces in the following order: 1) upper incisor, 2) upper molar, 3) lower incisor, 4) lower molar. It was decided by chance at which point of this sequence the recordings were to start. For example, a recording session could start with the lower molar mouthpiece followed by the upper incisor and so on.

The sequence of the recordings was as follows:
1) in the rest position,
2) during two acts of chewing 2 cm² of crisp bread,

Table 2
Median and range of variation in g/cm² for the pressure recorded at the various positions in 25 subjects.

	Median	Range
Rest		
1. Upper incisor	-1.7	-14.7 — 4.1
2. Lower incisor	-0.1	-12.8 — 10.1
3. Upper molar	-0.3	-3.9 — 3.7
4. Lower molar	4.9	-6.8 — 12.3
Significant differences 1-2, 1-3, 1-4, 2-4, 3-4		
Chewing		
1. Upper incisor	51.8	15.1 — 157.6
2. Lower incisor	96.0	15.4 — 218.7
3. Upper molar	95.2	48.9 — 237.3
4. Lower molar	146.1	52.7 — 331.4
Significant differences 1-2, 1-3, 1-4, 2-4, 3-4		
Swallowing		
1. Upper incisor	200.4	71.2 — 425.6
2. Lower incisor	332.9	94.7 — 627.7
3. Upper molar	310.8	127.5 — 648.7
4. Lower molar	281.9	114.5 — 505.5
Significant differences 1-3, 1-4		

Table 3
Coefficients of correlation between the pressures recorded during swallowing at the various locations.

	1. Upper incisor	2. Lower incisor	3. Upper molar	4. Lower molar
1. Upper incisor	—			
2. Lower incisor	0.45^{x}	—		
3. Upper molar	0.63^{xx}	0.54^{xx}	—	
4. Lower molar	0.44^{x}	0.29	0.53^{xx}	—

$x = 0.001 < P < 0.05$, $xx = 0.001 < P < 0.01$

3) during two acts of swallowing water (on command)
4) in the rest position.

Repetition of the recordings

In all subjects, recordings were made during three separate sessions. The recordings at the second session were a repetition of those at the first session and were made 1 to 40 days (median interval 6 days) after the first session. The third session took place 4 days after the second and included recordings from either the upper (10 subjects) or the lower (15 subjects) mouthpieces. These mouthpieces were kept *in situ* during the 4-day interval between the second and third sessions. The recordings at the third session were made in order to evaluate any effect of adaptation to the mouthpieces with time.

Analysis of the recordings

The recordings were analyzed on the paper strips of the electrostathic writer. The analysis included measurement of the level of the characteristic pressure at rest. This measurement was made when the recording showed a straight pressure level with a simultaneous minimal activity of the muscles of the floor of the mouth for at least five seconds. The measurements of the level of pressure during the two recordings at rest were averaged.

Maximum pressure during four randomly selected chewing cycles during each of the two acts of chewing was measured and averaged.

Maximum pressure during two acts of swallowing was also measured and averaged.

Statistical methods

Systematic differences between the variables recorded were tested with a paired *t*-test. The accidental errors, si, (standard deviation of the single observations) were calculated from the repeated recordings with the formula

$$si = \sqrt{\frac{\Sigma d^2}{2n}}$$

where d is the difference between two determinations.

Differences between distributions were tested at the 5% level with Wilcoxon's matched-pairs signed-ranks test adjusted according to Bonferroni-Holm.[21] Correlations between variables were tested with Spearman's rank-correlation.

Results

Reproducibility of the pressure recordings

The reproducibility of the measurements of pressure was evaluated by the calculation of systematic and accidental errors between the repeated recordings.

There was only one significant difference

between the recordings on occasions 1 and 2. The pressure measured at the lower molar during chewing averaged 22.6g/cm² greater on the first than on the second occasion ($0.01<P<0.05$, $n = 25$).

In order to assess any effect of adaptation to the mouthpieces with time, the recordings on occasion 3 were compared with the average of the values recorded on occasions 1 and 2. Only one significant difference was found. The pressure recorded at the upper molar during chewing was on average 45.2 g/cm² greater on the third than on the two previous occasions ($0.01<P<0.05$, $n = 10$).

The accidental errors of the method, calculated from the first and second recordings are given in Table 1. The table also gives the accidental error (si) in percent of the pooled standard deviation of the first and the second series of recordings both for the pressure variables and, for comparison, for those of the electromyographic recordings.

As Table 1 shows, the intraindividual variation was great both for the pressure and for the electromyographic recordings and was of similar magnitude during all functions studied.

Average pressure values

The median values and the range of variation for the pressures recorded are given in Table 2. The table is based on the means of the values recorded on the first and second occasions. The median values are also shown in Figures 3 and 4.

As is evident from Table 2, the median pressures in the rest position were negative at the upper and lower incisors and at the upper molar. A negative pressure at rest at the upper incisor was found in 20 of the 25 subjects, at the lower incisor and upper molar in 14 subjects and at the lower molar in one subject. The maximum pressure recorded during chewing and swallowing was positive in all subjects.

Pressure in the rest position and during chewing was significantly lower at the upper incisor than at the other three locations. Pressure at the lower molar at rest and during chewing was significantly higher than at the other three locations. During swallowing, a significantly lower pressure was recorded at the upper incisor than at the molars.

Correlation between the pressures recorded

The coefficients of correlation between the pressures recorded at the various locations in the rest position were low and not significant.

Only one significant correlation was found between the pressures recorded at the different locations during chewing. There was thus a positive correlation between the pressures recorded at the lower incisor and upper molar (rho = 0.53, $0.001<P<0.01$).

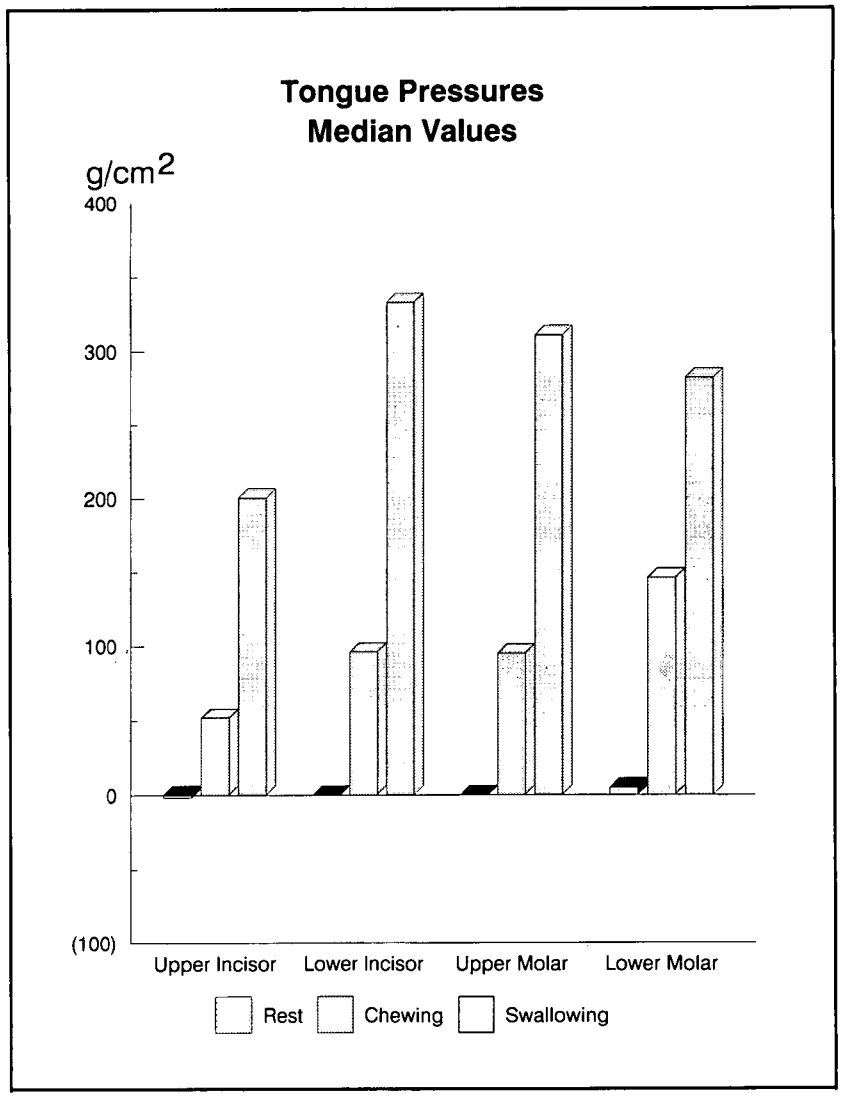

Figure 3

Figure 3
Tongue pressures at the various locations during the functions studied.

The coefficients of correlation for the pressures recorded during swallowing are given in Table 3.

Only positive correlations were found. The correlations were significant between the pressure measured at the upper incisor and the other three locations, and between the lower incisor and upper molar, as well as between the upper and lower molars.

Only two significant correlations were found between the pressures recorded at the same location during the different functions. The pressure recorded at the lower incisor at rest was thus correlated with the pressure at the same location during chewing (rho = 0.47, $0.01<P<0.05$), and the pressure at the upper molar during chewing was correlated with the upper molar swallowing pressure (rho = 0.61, $0.001<P<0.01$).

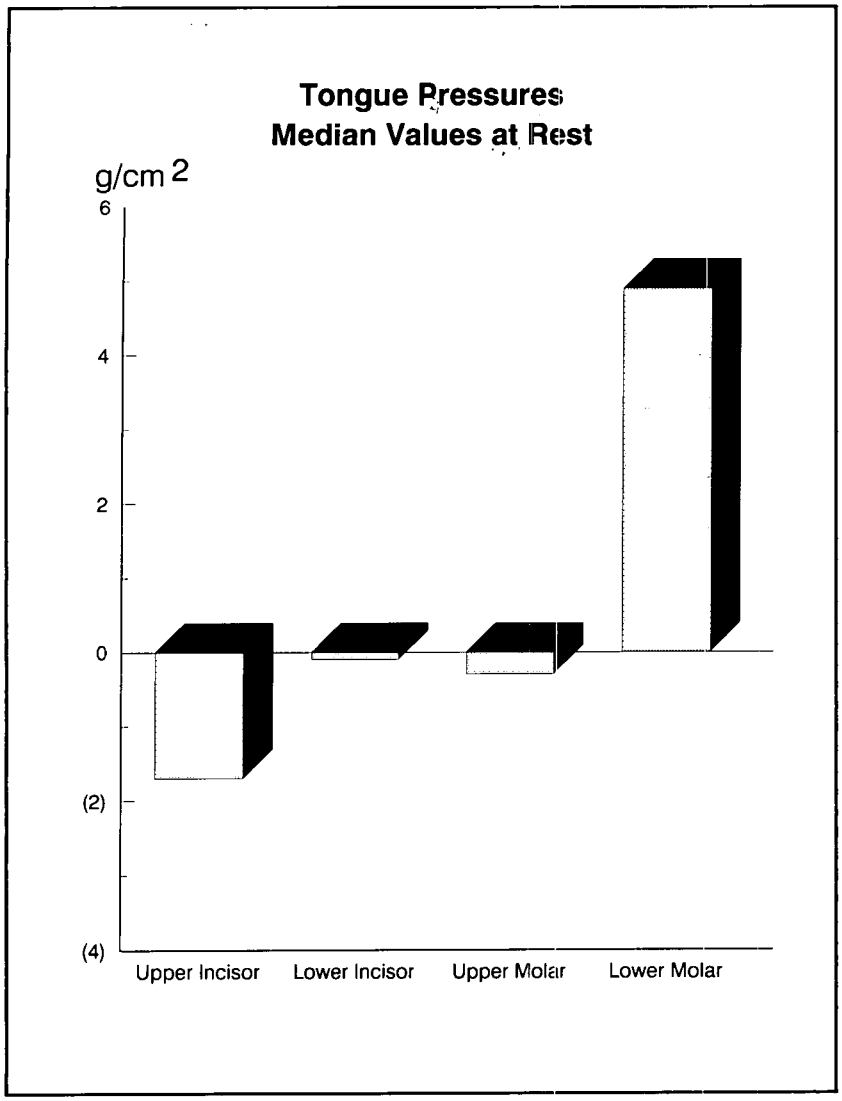

Figure 4

Figure 4
Tongue pressures at the various locations in the rest position.

Discussion

Systematic differences between repeated pressure recordings were found only for single variables during chewing; no such effects were discernible for the recordings at rest or during swallowing. The recordings made after the subjects wore the mouthpiece for a 96-hour accommodation period differed systematically for only one variable. In contrast to other methods, a period of accommodation seems to be unnecessary with this method. The recording device used with this method is less bulky than those used in other studies. Additionally, this study used electromyograpy to assess the level of muscle activity, an advantage when recording resting pressure.

Accidental errors of the method were comparatively great. Large intraindividual variation in the tongue pressure recordings is in accord with our previous results measuring lip and cheek pressure on the teeth. Errors in the tongue pressure recordings were no greater than errors in orofacial soft tissue recordings. These errors are mainly biological in nature and are, like variations in electromyographic recordings of similar size, unavoidable. Although intraindividual variation has to be taken into consideration, it is encouraging to know that tongue pressure recordings can be made with the same degree of reproducibility as orofacial soft tissue recordings. This has not been systematically evaluated previously.

Intraindividual variation is biological in nature; the mean of repeated recordings can be used to establish a 'pressure level' for an individual during a certain function. This was done for the pressures recorded at the four locations and the functions studied.

A striking result of this study was the negative pressure recorded in the rest position at the upper and lower incisors and at the upper molar in the majority of the subjects. This pressure was undetected in previous studies because the methods used could not record negative pressure. Some authors have, however, reported zero resting pressure at the upper and lower incisors[1] and in the upper dental arch.[7]

The median resting pressure at the upper and lower incisors and at the upper molar in our study was negative. The negative median values in the upper dental arch fit with the absence of pressure reported by Proffit et al.[7] The previously reported lingual resting pressure against the lower incisors has varied between 6 and 14 g/cm^2.[1,7,12] The lower median value found in this study is probably an effect of the considerably less bulky recording appliance used.

We found a median resting pressure against the lower molar of about 5 g/cm^2 which compares very favorably with values reported by Hensel[10,11] but is smaller than the figures (12 — 33 g/cm^2) reported by Proffit et al.[7] and by Archer and Vig.[12] Again, the size of the recording device may have had an influence.

The pressures we recorded at the upper incisors during swallowing are in accordance with previous results;[4,7-9] recordings made at the lower incisors and molars are higher than those reported by other authors.[2,6-11] We also found, as did Proffit et al.,[7] higher swallowing pressure at the upper molars than at the upper incisors.

Several significant positive coefficients of correlation were found between the recordings made at the various locations during swallowing. There was a tendency for an individual to swallow with either a high or a low pressure against the teeth at several locations in the oral cavity.

Pressure from the tongue on the teeth during

chewing has not been reported previously. We found it to be one quarter to one half the swallowing pressure, and higher at the molars than at the incisors of the same dental arch.

This method has also been used to record pressure on the incisors from the upper and lower lips, and on the upper molars from the cheeks, in children and adults. In these studies, the median resting pressures found were higher than those from the tongue at the corresponding location in this study. The pressures from the tongue during swallowing were, however, considerably larger than those from the lips and the cheek recorded in previous investigations. The pressures from the tongue during chewing were smaller (at the lower incisors) or higher (at the upper incisors and molar) than previously recorded from the oro-facial soft tissues in adults.[17,18]

Many authors maintain there is no balance between the forces on the teeth from the tongue and from the orofacial tissues, the forces from the tongue being larger (for a review and discussion see Proffit[22,23]). Our results suggest that this may be true only for some functions. The resting forces on the teeth, because of their practically constant duration, are considered to have the most influence on the position of the teeth. The results of this study suggest that in the rest position there may very well be a balance between the outer and the inner forces on the teeth and that previous results may have been partly influenced by the testing methods used. This must, however, be further studied by recording the labial and lingual pressures on the teeth simultaneously with our method.

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Commentary: Pressure from the tongue

By William Proffit, DDS, MSD

There has recently been a revival of interest in tongue and lip pressures. This scientifically excellent work is a significant contribution to the recent data.

The system used by these investigators differs considerably from the electronic pressure transducers used by most previous workers. As the authors point out, their method has the advantage of reduced size. It also is well suited to the measurement of resting pressure, which is acknowledged to be the pressure of greatest potential clinical significance. And this system has provided the only good data on soft tissue pressure during chewing.

The method does have a potential disadvantage that may account for some of the differences between these and other data. As a consequence of its design, the water-filled system almost surely does not have as great a frequency response as the previous methods that placed a strain gauge transducer in the mouth. Because of this, the pressure curve during activities like swallowing might be somewhat different from what would be measured with a different system, and the peak pressure could differ. I would have thought that would produce lower values for pressure during swallowing because a sharp peak was rounded off, however, not the higher ones these authors have reported.

Author's response

When we began working with this system 8 years ago, we were also concerned with the frequency response. We quickly realized the importance of eliminating air inside the system. Gas, unlike fluid, can be compressed and cause a delay in the frequency response. Therefore, the valves are assembled in water, preventing air being trapped in them; the water incorporated in the system is boiled to eliminate dissolved air.

With these precautions taken, the frequency response is the same as with strain gauge transducers in the mouth. We have verified this by comparative tests.

We appreciate very much the recognition of the merits of our measuring system as mentioned by the commentator.