The Measurement of Variations in Intraoral Air Pressure

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Introduction

The position and occlusion of the teeth are governed by many variable factors. Important among these factors are the size of the dentition, the size, shape and position of the jaws, and muscular activity in the region of the mouth. Such muscular activity may give rise to variations in intraoral air pressures which may, in turn, affect the position and occlusion of the teeth.

Although direct muscle pressures on the teeth have been widely studied, (Winders,[1] Gould,[2] Werner,[3] Abrams,[4] Lear,[5] Luffingham[6]) the air pressure within the mouth has received little attention.

It is apparent that, if the mouth is open to the outside, the pressure of air within the mouth is likely to equal that outside the mouth. If, however, the mouth is closed and sealed both anteriorly and posteriorly, the air pressure in that part of the oral cavity not occupied by the tongue and dentoalveolar structures will vary according to variations in position of the mandible, tongue and soft palate.

It seems likely that variations in intraoral pressure may exist both between individuals and in the same individual at different times. The effect of such pressure variation on the dentoalveolar structures will depend in part on the precise location of the air space between the tongue and the palate. For example, if the limits of this air space are confined to the area of the hard and soft palate, then little effect on the occlusion would be expected but if, with a lower tongue position, the boundaries of the enclosed space include the lingual surfaces of some of the premolar or molar teeth then the variations in air pressure will extend to the buccal sides of those teeth and will cause variations in the pressure of the cheeks against the teeth. It seems logical to suppose, therefore, that such variations between individuals may account in part for some of the differences in the position and occlusion of the teeth.

The measurement of variations in intraoral air pressure presents two main problems:

1. The intraoral part of any appliance must be unobtrusive in the mouth. If the apparatus is obtrusive it may cause abnormal muscle activity or jaw posture which itself may cause pressure variations.
2. As the pressure variations encountered are likely to be small, a sufficiently sensitive measuring and recording apparatus must be used.

A method has been developed which overcomes these problems and which enables even very small variations in intraoral air pressure to be recorded and measured.

Method of Measurement

Briefly, the method involves placing a narrow-bore, open-end tube in the required part of the mouth. The other end of the tube is connected to a pressure transducer, the output from which is suitably amplified and exhibited on an ultraviolet light recorder. A diagrammatic representation of the apparatus is shown in Fig. 1.

There are three main component

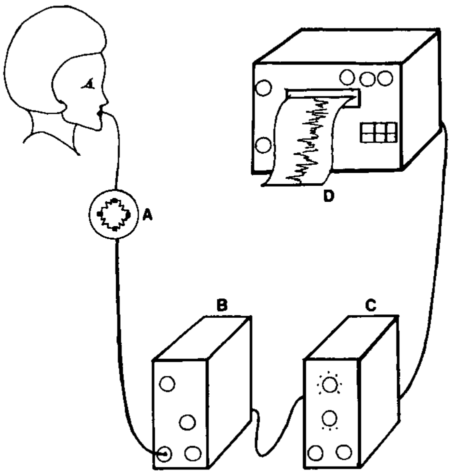

Fig. 1 Diagrammatic representation of apparatus used; A. Pressure transducer, B. Carrier preamplifier, C. Transducer conditioner, and D. Ultraviolet light recorder.

parts to the apparatus, viz.: the intraoral appliance, the pressure transducer and the amplification and recording equipment.

The intraoral part of the apparatus consists of a stainless steel orthodontic band placed on a suitable tooth, usually a premolar. Attached to the band are two stainless steel tubes of 0.5 mm internal diameter, one of which is contoured to fit against the palate, and the other to lie on the buccal side of the teeth. Both tubes are open at each end and extend forward on the buccal surface of the teeth. To the anterior end of either of these extensions is fitted a flexible polythene tube, 0.55 mm in diameter which connects with the pressure transducer outside the mouth (Fig. 2).

The pressure transducer used is an S.E.4.81 Mk 2 which is designed primarily for continuous blood manometry but is also suitable for gas or fluid pressure measurements of physiological proportions. It consists of a single crystal silicon diaphragm 4.5 mm in diameter onto which is diffused a fully active four arm bridge using integrated circuit techniques. Each arm of the bridge consists of two strain guages positioned at 90° to each other to compensate for any temperature changes. It is activated by a five volt alternating current.

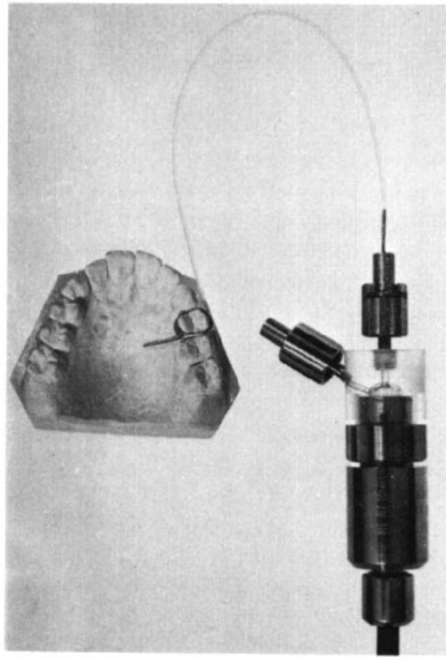

Fig. 2 Intraoral appliance connected by polythene tube to pressure transducer outside the mouth. Showing buccal and palatal tubes.

The output from the pressure transducer is fed into a carrier preamplifier S.E. 4912 where it is demodulated and amplified. The output from the preamplifier is fed into a D.C. transducer conditioner S.E. 4910 where the amplification can be adjusted either by an attenuator with fixed tappings to give whole multiples or by a variable control.

An ultraviolet light recorder is used to record the electrical output from the transducer conditioner, the attenuator control being set to give a nearly full scale deflection on the recorder for the highest pressures that are likely to be recorded, and the variable gain control being adjusted so that each division of the grid graticule on the recorder represents a suitable whole number of units of pressure.

Calibration was achieved by connecting the pressure transducer to a manometer containing colored water. The deflection of the recorder was checked for air pressure ranging from $+100 \times 10^2$ NM^{-2} to -100×10^2 NM^{-2} as these were considered to be the outside limits of physiological pressure within the mouth. The response was also checked for each unit of pressure between $\pm 20 \times 10^2$ NM^{-2}. In both cases the response proved to be linear.*

Generally, suitable calibrations were either 10^2 NM^{-2} or 2×10^2 NM^{-2} per centimeter deflection for most of the intraoral pressure recordings, but where thumbsucking or swallowing pressures were being investigated it was necessary to calibrate to 20×10^2 NM^{-2} per centimeter deflection of the recorder.

By connecting the polythene tube from the pressure transducer to one of the tubes on the intraoral appliance, air pressure either in the palate or in the buccal vestibule of the mouth could be recorded on light sensitive paper in the U.V. recorder. The sensitivity of the apparatus to even very small changes in intraoral air pressure can be well seen in the tracings obtained from the following preliminary studies.

Using the apparatus described, a preliminary study was carried out on three subjects: subject A whose occlusion and oral muscle function came near to the accepted ideals and two others (subjects B and C) who exhibited rhythmic sucking activity.

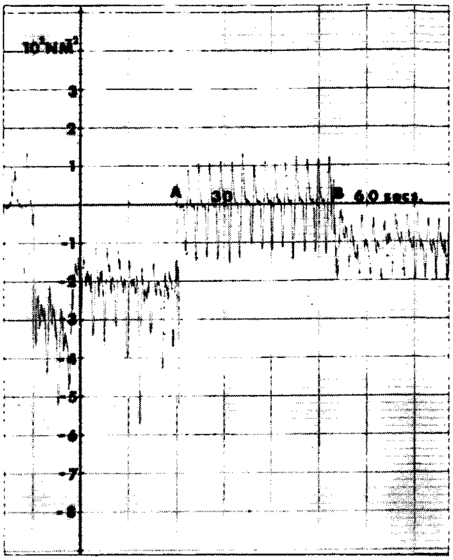

Fig. 3 Trace of air pressure in palatal vault from subject with normal occlusion: A. Point where posterior oral seal of tongue with soft palate is broken. B. Point where posterior oral seal is re-established.

Findings

Subject A

A trace of the air pressure in the palatal vault recorded from subject A exhibits three phases but all show the same rhythmic fluctuations in pressure as a result of quiet breathing through the nose (Fig. 3). During the first twenty seconds it can be seen that there is always a negative pressure and this pressure is further reduced during inhalation and increased during exhalation with a brief pause where the pressure is steady before the next inhalation. After twenty seconds, at point A, the pressure can be seen to increase to equal atmospheric pressure (zero on the trace). This sudden change was caused by the subject breaking the posterior oral seal of the tongue with soft palate, whilst maintaining the anterior oral seal and thus establishing continuity between the oral cavity and the nasopharynx. For the next thirty-five seconds the pattern of the trace becomes

* N (newton) is the unit of force in the S.I. system and is that force which gives an acceleration of 1 m/s^2 to a body of 1 Kg. mass. This means that a mass of 1 Kg. under the influence of gravity exerts a force of approximately 9.8 N. 10^2 NM^{-2} is approximately equivalent to gm/cm^2. These units are fully described in "The International System (S.I.) Units," British Standard 3763:1964

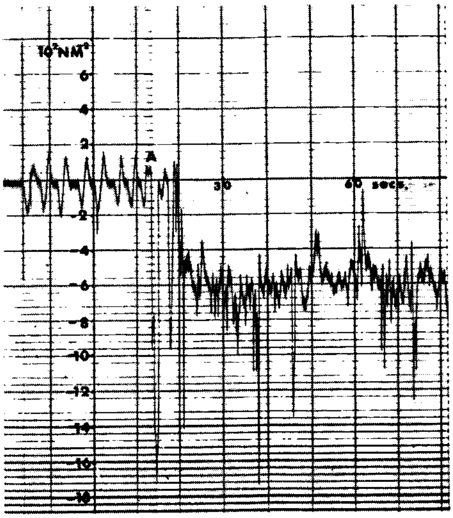

Fig. 4 Trace of air pressure in palatal vault from subject aged twenty with crowding of upper and lower dental arches and a unilateral molar crossbite. At point A the subject makes momentary contact with dorsum of tongue against soft palate.

more regular and distinct and fluctuates about zero. Because there is no posterior oral seal the small movements of the tongue, which are always taking place, do not affect the intraoral pressure as was the case during the first twenty seconds of the trace. After about fifty-five seconds, at point B, the posterior seal is again complete and the trace returns to a negative value in all phases of breathing, but this negative pressure is not as great as during the first twenty-seconds phase when the tongue was more active. Thus the trace from subject A illustrates the recording of two breathing patterns, the first with the oral cavity sealed at the front by the lips and at the back by the soft palate and the tongue, and the second with the oral cavity sealed only at the front.

Subject B

Subject B, aged 20 years, had a unilateral crossbite and the upper dental arch narrower than the lower. Crowding had been relieved by extraction of the right first molars and the left second premolars; there was no history of any digital sucking or other observed sucking activity. She had not had any orthodontic treatment.

Figure 4 shows the trace recorded in the palatal vault from subject B. It should be noted that in this trace the time scale is the same as in the trace from subject A but the pressure scale is twice as great, this being necessary owing to the much wider fluctuations in pressure.

This trace shows similar features to those recorded from subject A but considerable differences in degree. During the first fifteen seconds of the trace the familiar breathing pattern can be observed. At point A the tongue makes momentary contact with the soft palate only to separate again for about five seconds before completing the posterior oral seal again and producing a continuous negative pressure for the remainder of the trace. In this subject the tongue is much more active than in subject A and the negative pressure produced is much greater and fluctuates more. It is difficult therefore to observe the fluctuations of pressure caused by breathing. One further difference in subject B was that the sustained negative pressure measured in the palatal vault could also be shown to be present in the buccal vestibule.

Subject C

Subject C, a boy of ten years of age, still sucked his thumb. He had a Class II malocclusion with large dental arches and sucked his thumb with his tongue protruded over the crowns of the lower incisors, canines and premolar teeth.

The trace of subject C which is shown in Fig. 5 was made in the buccal vestibule and has a different time and pressure scale from those of subjects A and B. Owing to the intensity of the sucking activity it was necessary to adjust the attenuation control to give a deflection of one unit on the grid

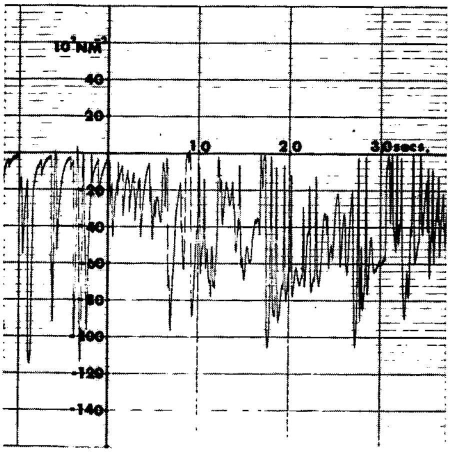

Fig. 5 Trace of air pressure in buccal vestibule from subject whilst thumb sucking. Note the very high negative pressure which causes the cheeks to be forced against the buccal surfaces of the molar teeth.

graticule for every twenty units of pressure and it will be seen that negative pressures in excess of 100 $\times$ 10^2 NM^{-2} were recorded.

It will be noted that whilst the subject was sucking the thumb the pressure never rose above atmospheric pressure and that the rhythmic sucking activity produced a corresponding fluctuation of the trace at an average rate of twelve to fourteen pulses per ten seconds.

In some other subjects who were digital suckers is was noted that the rhythmic sucking activity did not always cease when the digit was removed from the mouth but continued intermittently with much the same intensity. In one observed case this rhythmic sucking activity has persisted for three months after the cessation of thumb sucking.

Discussion

This paper is intended only to demonstrate a method of measuring accurately the intraoral pressure variations. The air pressure tracings shown are from only three subjects out of a great many who have been examined and it is not possible from these three alone to draw any firm conclusions.

Frankel[7] has suggested that negative air pressure variations could affect the shape of the developing arches. Little is known about such effects or about the effect of negative air pressure on features such as buccal crossbites.

The use of this apparatus also throws some light on the position and activity of the tongue. Thus, if there is a constant negative pressure in the palatal vault the oral cavity is sealed by the tongue both anteriorly and posteriorly. If this same negative pressure is recorded in the buccal vestibule also, this indicates a low tongue position and the two features of low tongue position and negative air pressure in the buccal vestibule may predispose to molar crossbite. Further research along these lines is obviously necessary. No mention has yet been made of that primary area of suction, the lips and incisor region. The angulation of the incisor teeth may be affected as much by sucking activity with the lips closed as by the pressure exerted by the lips themselves.

The simultaneous use of two or more pressure transducers on either side of the teeth will help to solve a number of these problems.

The apparatus can also be adapted to measure the actual pressure of the tongue, lip or cheek on the teeth by replacing the open end of the tube with a small balloon and filling the whole system with water. However, if it is desired to make measurements of the pressure exerted by the soft tissues on the teeth, it will first be necessary to find out to what extent any negative air pressure in the mouth is causing lips or cheeks to be pressed on to the teeth by the pressure of the atmosphere. The apparatus described here was designed primarily with this objective in mind.

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