Pressure-Pain Threshold in the Human Tongue

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Aims: *A new pressure algometer was used to quantify the pressure-pain threshold (PPT) in the human tongue.* **Methods:** *A custom-made device controlled by software and a personal computer was used to measure the PPT in the anterior part of the tongues of 14 young, healthy subjects. The PPT was measured at 3 different rates of pressure application on 3 occasions, 1 week apart. Data were evaluated with analysis of covariance and intraclass correlations.* **Results:** *The prototype device had linear output characteristics within the operational range. The mean PPT ranged from 18 to 44 g. The PPT appeared to increase approximately linearly with increasing rate of pressure application ($P < 0.001$). There were no significant differences in the PPT on different experimental occasions. In individual subjects, the PPT was reliable and uniform. There were significant inter-subject differences in the PPT ($P < 0.001$).* **Conclusion:** *The PPT can be measured consistently in the anterior part of the tongue, provided the pressure rate is controlled. The new pressure algometer appears to have potential clinical utility for quantifying sensation in the human tongue.*
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Key words: sensory thresholds, tongue, pain measurement

Psychophysical testing is commonly used to assess sensory recovery following oral surgical procedures, such as mandibular third molar extraction and implant placement, that have resulted in nerve damage.[1–4] In addition, sensory testing is an important adjunct in the postoperative assessment of oral tissues that have been reconstructed by sensate flap procedures, for example, reconstruction of the hemi-tongue by a procedure using an innervated radial forearm flap.[5] Clinical tests have mainly involved measurement of 2-point discrimination, light-touch sensation, pinprick, and hot and cold perception by techniques varying from the simple use of a dental probe or needle to more complex assessment using soft tissue lasers.[4–7]

Pressure algometry is used in the quantitative assessment of pain perception in the jaws and limbs.[8–11] Estimation of the pressure-pain threshold (PPT) is used as a means of quantifying deep sensation. However, cutaneous afferents in overlying tissues have been shown to contribute to the PPT measured in deep tissues in the orofacial region.[12,13] Pressure-pain threshold measurements are common in the jaw muscles, but there is very limited information on the PPT in oral tissues, particularly the tongue.[14,15]

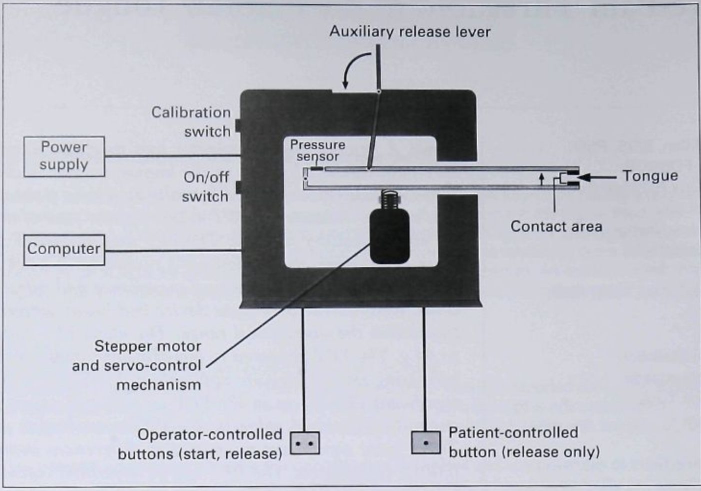

Fig 1 Component parts of the prototype algometer. The torque motor, the origin of the parallel bars, and the pressure sensor were housed within a metal container (20 × 20 × 30 cm). The parallel bars extended approximately 10 cm from an opening on one side of the container.

In this study we used a prototype pressure algometer *(1)* to quantify the PPT in the tongues of normal subjects, *(2)* to determine the effect of a change in the pressure rate on the PPT, *(3)* to assess the long-term stability of the PPT, and *(4)* to determine the consistency of PPT measurements in individual subjects. We considered that it was necessary to collect data on the PPT in the normal tongue prior to investigations of tongue dysesthesia.

Materials and Methods

Algometer

The authors developed a custom-made device that had strain gauges attached to lightweight parallel bars resembling modified tissue forceps (Fig 1). The bars had 2 opposing cylindric flat surfaces (stainless steel, 3 mm in diameter) at their tips. The bars were attached to a torque motor that applied a known force at a steady rate; this was controlled by custom-written software and a personal computer. Subjects pressed an electronic switch to register the PPT. The motion of the bars stopped immediately, then opened to permit easy release of the tongue. Safety features included an operator-controlled switch to stop and reverse the movement of the bars and a manually controlled lever that immediately disarticulated the bars. The device was calibrated with known weights, in increments of 10 g, attached via a pulley system to the tips of the bars. A calibration curve was then calculated to convert digital counts to grams. The output data had a linear relationship with the applied load over the operational range (0 to 500 g).

Subjects and Protocol

Fourteen subjects (7 male, 7 female) aged 21 to 25 years took part in the study. Subjects were healthy, with complete natural dentitions and with no history of oral dysesthesia. Experimental sessions were scheduled to avoid cyclical hormonal fluctuations in female participants.

Subjects sat upright in a chair. Only the operator and the subject were present to minimize distraction from extraneous sources.[16] The subject fixed his attention on the test stimulus. With the tongue protruded, the algometer applied pressure in a pinch-like manner at a constant rate to the anterior tongue in the midline, 10 mm from the tip. No other part of the tongue was in contact with the device. The tongue was moist, and it was protruded only for brief periods when recordings were made; otherwise, it was kept in a retruded resting position. No instruction was given regarding the level of voluntary contraction of the tongue.

The PPT was defined as the point at which the pressure stimulus applied to the tongue changed from a sensation of pressure to pain, ie, the first report of pain.[17] When this point was achieved, subjects triggered a handheld switch that recorded the PPT on the computer and released the tongue from the device. Each measurement consisted of 5 trials. The PPT was measured at 3 different rates of applied pressure (20, 40, and 60 g/s) delivered randomly. The pressure rate was controlled by software and easily adjusted by a keystroke. There was a rest period of at least 2 minutes between each trial to reduce the possibility of habituation or sensitization to the stimulus. The experiment took place on 3 different occasions, 1 week apart.

Data Analysis

The mean PPT over the 5 trials (replicates) was used as the outcome variable. It was calculated at each recording rate. An analysis of covariance (ANCOVA) model, with subject and occasion as factors and pressure rate as the covariant, was used to analyze the data. Intraclass correlations were used to assess the reliability of the PPT data among the 5 replicates. A 5% level of significance was used for the tests.

Results

The mean PPT averaged across subjects, pressure rate, and experimental occasion was 29 g (standard deviation 17 g; interquartile range 15 to 41 g). There were statistically significant inter-subject differences in the PPT ($P < 0.001$). The intraclass correlations for the PPT over multiple trials ($n = 5$) were 0.86 for 20 g/s, 0.84 for 40 g/s, and 0.70 for 60 g/s. The PPT in individual subjects appeared to be reliable and uniform.

PPT at Different Pressure Rates

The distribution of the PPT (mean and 95% confidence interval) for the 3 different rates of pressure application, collapsed across all subjects and measured at weekly intervals for 3 weeks, is shown in Fig 2. The PPT was affected by the rate of pressure application and appeared to increase approximately linearly with an increasing rate ($P < 0.001$).

PPT at Different Recording Sessions

The temporal effect of experimental occasion appeared to be significant ($P = 0.003$), this effect being the result of an increase in the PPT from week 1 to week 2 at all rates of pressure application, particularly at 60 g/s (Fig 2). However, for each experimental occasion, the measurements at each rate were not independent. When the effect of rate was allowed to vary from week to week by incorporating an appropriate interaction in the ANCOVA model, the occasion effect was found to be non-significant ($P = 0.9$).

Discussion

The PPT in the tip of the tongue of young, healthy subjects was measured with a new algometer. The method appeared to be sensitive and reliable, since the PPT was reproducible between trials and over time. This finding is in agreement with previous investigations of PPT stability in the jaw muscles and gingivae.[15,18–20] It is also likely that afferent fibers in the tongue mucosa contributed to the PPT measurement.[13] Thus the pinch-like approach of the measurement device appeared to be effective, despite the compressible nature of tongue tissue and the variability in tongue thickness between subjects at the test site. Given the nature of the testing device, a potentially more accurate term for the measurement would be "pain threshold to pinch." However, for ease of comparison with other relevant studies, the term PPT was retained.

A notable feature of the algometer design was that the rate of pressure application was software-controlled; therefore there was no overt interaction between the examiner and subject during the measurement process. Operator expectancy bias was thus minimized.[21] This contrasts with PPTs measured in other orofacial structures (eg, jaw muscles and gingivae) with hand-held algometers, where the pressure rate is monitored by the operator and there is an inherent potential for operator expectancy bias. However, response bias from subjects was still a concern, since the conventional ascending method of limits approach was used. The ascending method of limits approach is used exclusively in contemporary PPT studies.[21] However, it may be possible to reduce subject response bias if alternative psychophysical

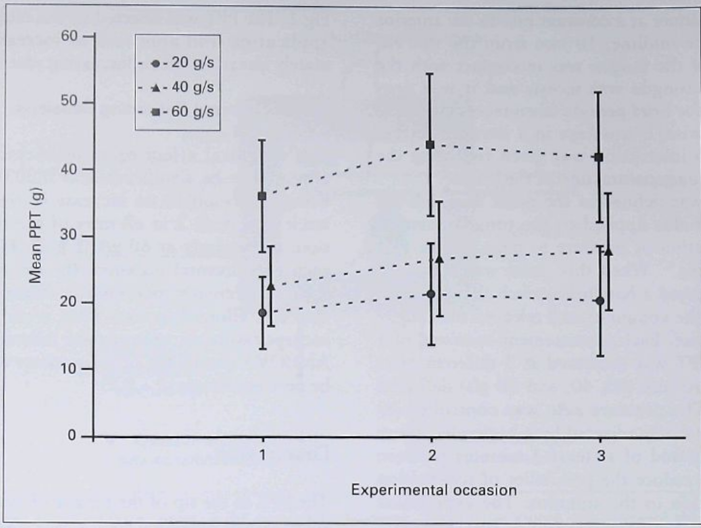

Fig 2 The mean pressure-pain threshold (95% confidence interval) at 3 pressure rates (20, 40, and 60 g/s) as measured on 3 different experimental occasions (n = 14).

approaches, such as the multiple random staircase method, are employed.[22,23]

There was a relatively linear increase in the PPT as the pressure rate increased. This characteristic has been shown at other locations in the head, neck, and limbs.[18,20] However, it is possible that this phenomenon is an artifact of subject reaction time to the pressure stimulus.[15,24] Nevertheless, it is necessary to constrain the pressure rate during the measurement sequence to ensure reliability of the data. In the present study, controlled rates of 20 to 40 g/s appeared to yield the most consistent PPT.

Although the ANCOVA statistical model of pain thresholds on different experimental occasions revealed no difference between the first and second recording sessions, it is probable that there was inherent learning bias. Yarnitsky et al[25] demonstrated such a practice effect when experimental heat pain was measured in multiple sessions. They suggested that data from a single experimental session, particularly the initial reading, should be treated with caution. Recordings made at the second and succeeding sessions appeared to be more representative of baseline data.[25]

In this study, the PPT was measured at only 1 site on the tongue. However, it is likely that mapping of the PPT in different regions would yield variations in threshold due to differences in connective tissue density, tissue compliance, and distribution of nociceptors. Design features of the algometer, particularly the spacing of the parallel bars, and the subject's ability to protrude the tongue would be potential limiting factors in any future mapping experiment.

The observed inter-subject variability of the PPT has been observed previously in various anatomic regions and highlights the subjective, multidimensional nature of pain perception.[19,20,26,27] Therefore, it is important to use individual data rather than pooled PPTs when assessing changes in sensation over time in a clinical setting. Nonetheless, the range of normal values described is essential for establishing an upper limit of pressure application. This value can be incorporated into custom-written software. There would then be no possibility of tissue injury during the measurement process in tongues with reduced sensation.

Mechanical stimulation of the tip of the tongue with a custom-made algometer appears to have potential utility, provided that the rate of pressure application and maximum pressure limits are constrained. The algometer may be used as an adjunct in future clinical studies of altered deep sensation in the human tongue.

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