Pain-Pressure Threshold in Human Gingivae

Anne S. McMillan BDS, PhD, FDS RCPS
Senior Lecturer
Department of Restorative Dentistry
University of Newcastle
England
United Kingdom

Correspondence to:
Dr Anne S. McMillan
Department of Restorative Dentistry
University of Newcastle
Framlington Place
Newcastle upon Tyne
England
United Kingdom
NE2 4BW

The pain-pressure threshold in human tissues such as muscles may be affected by the anatomic location of the recording site and the rate of applied pressure. However, it is uncertain how these variables affect the pain-pressure threshold in healthy oral tissues. In 10 subjects, a custom-made algometer was used to apply pressure at a constant rate to 12 sites on the attached gingivae apical to teeth 11 to 16 and 41 to 46. The pain-pressure threshold was measured at three different rates of applied pressure at weekly intervals for 4 weeks. The pain-pressure threshold was consistently higher at maxillary recording sites. There were, however, no differences in the pain-pressure threshold at different recording sites along the tooth row in the maxilla or mandible. The pain-pressure threshold measurements were consistent between recording sessions. The pain-pressure threshold was affected by the rate of pressure application and appeared to increase linearly with increasing rate. This suggests that the pain-pressure threshold may be measured consistently in attached human gingivae. When measurement of deep sensation in the oral mucosa is planned, the location of the recording site and the rate of applied pressure should be verified.
J OROFACIAL PAIN 1995;9:44–50.

Altered sensation is a potential complication following surgical procedures involving oral tissues, for instance, as a consequence of preprosthetic surgery or the extraction of a mandibular third molar tooth. Nerve damage results in a change in orofacial sensation that is often transient, but in some cases, may be persistent. When sensory disturbance is persistent, sensory testing should be performed to assess recovery. However, although the incidence of altered sensation following surgery to the dentoalveolar tissues has been documented extensively, changes in sensation have been poorly quantified.[1–4] Robinson et al[4] have described a series of simple clinical tests for assessing touch and pain sensation in facial tissues. However, these techniques are not sufficiently reliable for quantifying sensory recovery over time.[5]

Pressure algometry is often used in the assessment of pain perception in the jaws and limbs.[6–8] Estimation of the pain-pressure threshold (PPT) is used as a means of quantifying deep sensation and has been shown to be sensitive and reliable.[9–12] Measurements of deep sensation are common for jaw muscles, but there is a shortage of data on the PPT in oral tissues.[7,11,13,14] A study by Davenport[15] suggested that the PPT is relatively uniform on the gingival mucosa of the anterior maxilla, but the PPT was not measured at other locations on the gingival mucosa.

The aims of this study were *(1)* to map the PPT in different regions of the gingival mucosa of the maxilla and mandible, *(2)* to assess the long-term stability of the PPT, and *(3)* to measure the

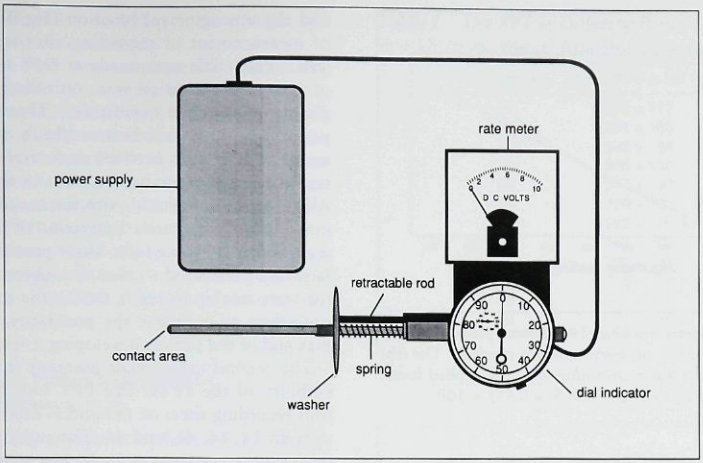

Fig 1 Component parts of the pressure algometer and rate meter.

effect of changes in pressure rate on the PPT in normal subjects. The author tested the hypotheses that the PPT of gingival mucosa varies according to the recording site along the tooth row, the measurement is consistent over time, and changes in the pressure rate alter the PPT in a predictable way. Knowledge of the PPT in normal gingival mucosa was considered to be a useful precursor to future studies of mucosal dysesthesia.

Materials and Methods

Subjects

Eight men and two women aged 23 to 30 years took part in the study. The subjects were undergraduate dental students who were healthy, were not taking any medication, had complete natural dentitions, and reported no history of jaw dysfunction or dysesthesia in the oral cavity. None of the subjects had received dental treatment during 6 months prior to the study.

Pain-Pressure Threshold Recording Procedure

Recording Device. The custom-made algometer comprised a mechanical dial indicator connected to a metal rod (length, 8.3 mm) with a spherical tip (diameter, 4.8 mm) (Fig 1). A metal spring attached over the rod was located between the tissue contact area and the dial to provide a variable linear resistance over a working range of 10 to 1000 g. A metal washer at the center of the rod secured the spring in place and also contacted a second retractable metal rod that was parallel to the first one. The second rod was coupled to an electronically driven meter that sensed the rate of pressure application of the transducer. The dial face had a main indicator and a revolution counter that were designed to measure distance increments of 10^{-3} inches (AGD type 25, LS Starrett, Athol, MA).[16] The rate meter, which was attached above the dial, indicated pressure rates of 0 to 100 g/s in increments of 1 g (Fig 1).

An Instron testing machine (Instron, Canton, MA) was used to calibrate the algometer.[16] The algometer was compressed at the recording tip through the range 0 to 1000 g. A calibration curve was then constructed to convert the dial reading to grams. The dial reading had a linear relationship with the applied force over the operational range (Fig 2).

Measurement of PPT. The subject was seated in a supine position in a dental chair. The subject's head was stabilized, and his/her neck was supported by a concave-shaped headrest attached to the chair. Only the operator and subject were present to minimize distraction from extraneous sources. The subject fixed his/her attention on the test stimulus (algometer) because a change in

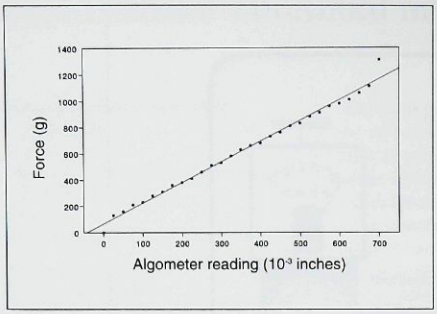

Fig 2 Algometer reading (10^{-3} inches) plotted against force (g) applied by an Instron testing machine. The dial reading had a linear relationship with the applied force: force (g) = [(dial reading × 0.015) + 0.85] × 100.

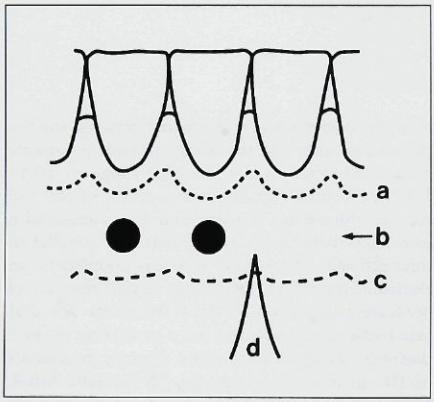

Fig 3 Location of recording sites at teeth 41 and 42 on the attached gingivae (b) are indicated by filled circles. a = free gingival groove, c = mucogingival junction, d = midline frenum.

attention has been shown to affect cutaneous sensitivity and neural responses to peripheral afferent inputs.[17,18] By raising their right hands, the subjects indicated when the pressure applied to the recording site had just changed from a sensation of pressure to pain, ie, the PPT as described by Fischer.[19] The algometer was then removed from the site.

In the first experiment, the PPT was measured at 12 recording sites on the attached gingivae apical to the midline of the crowns of teeth 11 to 16 and 41 to 46, midway between the free gingival groove and the mucogingival junction (Fig 3). The order of measurement of recording sites was randomized.[11] Five trials were made at each site. The rate of pressure application was controlled at 20 to 40 g/s throughout the experiment. There was a rest period of 60 seconds between each measurement and 4 to 5 minutes between each trial to minimize sensitization and/or habituation to the stimulus. All sites were measured with the mandible open 6 mm at the incisor teeth. Retraction of labial tissues was performed using light finger pressure. The dial face was positioned so that the subject and operator were unable to see it during the measurement procedure to minimize the possibility of operator bias and of the subject developing a response set.

The second experiment assessed the long-term stability of the PPTs. The PPT was measured at four recording sites: on the buccal mucoperiosteum of teeth 11, 14, 41, and 44. The experimental conditions were the same as in the first study. The protocol was repeated at weekly intervals for 4 weeks.

The third experiment assessed effects of pressure rate on the PPT. The PPT was measured at the same four sites as in the second study. The experimental conditions were the same as those of experiments one and two, with the exception that three different rates of pressure application were used at each recording site. These were 0 to 20 g/s, 20 to 40 g/s, and 40 to 60 g/s. The rate of pressure application was randomized.

Data Analysis

The mean PPT from the five trials at each recording site was used for data analysis. An analysis of variance (ANOVA) model was used to analyze the PPT data at different recording sites, rates of applied pressure, and recording sessions. A 5% level of significance was used for these tests. Confidence intervals were then constructed to assess pairwise differences between mean PPTs at different recording sites (confidence limits, 95%). Intraclass correlations were used to assess the reliability of the PPT data among the five trials at each recording site.

Results

Pain-Pressure Threshold at Different Recording Sites

The mean PPTs (grams) measured at the 12 recording sites on the maxillary and mandibular mucoperiosteum are shown in Table 1. The mean

PPT ranged from 298 to 391 g in the maxilla and 218 to 284 g in the mandible.

The mean PPT was consistently higher for recording sites in the maxilla than for recording sites in the mandible ($P < .0001$). When mean PPTs in the maxilla were compared with each other and when mean PPTs in the mandible were compared with each other, confidence intervals revealed no statistically significant pairwise differences in the PPT along the tooth row (Fig 4).

The intraclass correlation for the PPT measurements over multiple trials (n = 5) was estimated to be .8, and thus the PPT data appeared to be reliable and homogeneous.

Pain-Pressure Threshold at Different Recording Sessions

The mean PPTs measured at four recording sites (teeth 11, 14, 41, and 44) at weekly intervals for 4 weeks are shown in Table 2. There was no statistically significant difference in the PPT at any site between recording sessions ($P > .28$), thus the PPT did not appear to vary over time.

Pain-Pressure Threshold at Different Pressure Rates

The distribution of the mean PPT at the recording sites (teeth 11, 14, 41, and 44) for the three different rates of pressure application (0 to 20 g/s, 20 to 40 g/s, and 40 to 60 g/s) are shown in Fig 5. In all cases, there was a significant increase in the PPT as the pressure rate increased ($P < .0001$). The relationship between the PPT and rate of applied pressure appeared to be linear.

Table 1 The PPT at Different Recording Sites (n = 12) in the Buccal Attached Gingivae

Site (tooth)	Mean PPT ± SD (g)
11	298 ± 117
12	391 ± 160
13	342 ± 84
14	366 ± 135
15	357 ± 97
16	339 ± 103
41	282 ± 90
42	284 ± 105
43	262 ± 88
44	218 ± 58
45	264 ± 79
46	271 ± 86

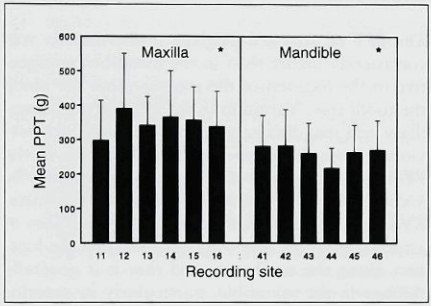

Fig 4 Recording site number plotted against the mean PPT (g) for recording sites at teeth 11 to 16 and 41 to 46. The error bars represent one standard deviation. The PPT was consistently higher in the maxilla (*$P < .0001$).

Table 2 The PPT at Different Recording Sites During Four Different Recording Sessions, One Week Apart

	Mean PPT ± SD (g)			
Site	Week 1	Week 2	Week 3	Week 4
11	322 ± 125	361 ± 146	365 ± 128	365 ± 140
14	402 ± 129	383 ± 127	415 ± 123	417 ± 145
41	286 ± 86	279 ± 95	316 ± 120	290 ± 102
44	234 ± 81	228 ± 92	239 ± 80	236 ± 102

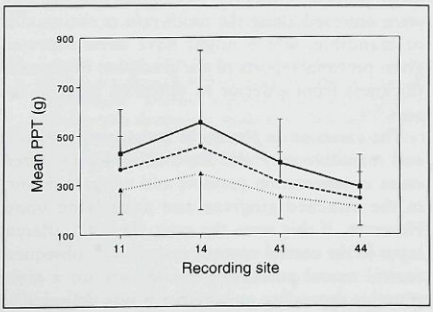

Fig 5 Recording sites (teeth 11, 14, 41, and 44) plotted against the mean PPT (g) for three pressure rates, ▲ = 0 to 20 g/s, ● = 20 to 40 g/s, and ■ = 40 to 60 g/s.

Pain-Pressure Threshold in Different Subjects

The mean PPT for trials 1 to 5 collapsed across the 12 recording sites for each subject, ranged from 172 to 444 g. When these PPT data were analyzed, there were statistically significant differences between PPTs reported by different subjects ($P < .001$). The subject effect varied according to the measurement site ($P < .001$), although no consistent pattern was disclosed. Intersubject variability in the PPT was also observed when the long-term stability of the measurement was assessed, and when different pressure rates were used ($P < .001$), however, the differences were not consistent among subjects.

Discussion

The PPT of attached gingivae in the maxilla was consistently higher than in the mandible, irrespective of the location of the measurement site along the tooth row. Variation in the PPT between maxillary and mandibular gingival tissues has not previously been demonstrated. The difference in the PPT at maxillary and mandibular locations may be a consequence of variation in mucosal thickness. Kydd et al[20,21] have shown that the thickness of attached gingivae may vary according to the location along the tooth row and that it is generally thinner in the mandible, particularly in anterior tooth locations. Masticatory mucosa is generally firm and offers significant resistance to deformation under load, thus the lower thresholds observed in the mandible could be attributed to reduced tissue resistance associated with thinner mucosa.[21] Davenport's[15] observations also support the role of mucosal thickness in the PPT measurement process. However, no changes in the PPT were observed along the tooth row in the maxilla or mandible, which might have been expected given previous reports of the gradation of mucosal thickness from anterior to posterior gingival tissues.[20,21]

The variation in threshold between the maxilla and mandible may also have been due to differences in innervation patterns and receptor density in the attached gingivae and underlying bone. However, if this were the case, the total afferent input to the central nervous system and subsequent central neural processing would vary for a given stimulus depending on whether it was delivered to a maxillary or mandibular site. This seems unlikely because a decrease in oral sensibility generally occurs when the stimulation site is moved laterally and posteriorly from the midline rather than from maxilla to mandible (reviewed in Sessle[22]).

The variation in threshold may also have been caused by the lower resistance to the applied pressure offered by the mandible compared with the maxilla during the testing procedure. However, if movement of the mandible occurred, presumably away from the transducer, one would have expected the PPT to be greater than that recorded in the maxilla.

The PPT was, in general, higher than previously recorded in the attached gingivae. However, in the previous study, the spherical tip of the algometer was a different diameter, and the rate of applied pressure was not rigorously controlled.[15] These features alone could account for the difference because the PPT has been shown to vary with the size of the recording surface of the measuring device and the pressure rate.[10,11]

The PPT increased linearly with increasing rates of pressure application, a feature that has been demonstrated at other anatomic locations.[11,12] However, it is possible that the observed monotonic increase in the PPT with increasing rate is an artifact of subject reaction time to the test stimulus.[23] In normal subjects, the reaction time to the stimulus is likely to be consonant irrespective of the rate of pressure application. This may account, at least in part, for the apparently higher PPT with increased rate of pressure. Nonetheless, control of pressure rate during the measurement process is essential if reliable data are to be obtained on different occasions.[12]

In the present study, the PPT in the attached gingivae was reproducible between trials, which has not been described previously in the oral mucosa. The stability of the PPT at different recording sessions is in agreement with previous studies of the oral mucosa and at other muscle and joint sites in the body.[10,11,15]

Throughout the present study, a pressure range was used rather than a specific pressure rate because, in practical clinical terms, it was difficult to apply such small forces consistently at a fixed rate during each trial. The pressure range 20 to 40 g/s was most consistently attainable during PPT measurement in the gingivae.

There was a statistically significant difference in the PPT between subjects. This was not unexpected given the variation in responsiveness to painful stimuli seen clinically. The problems inherent in measurement of pain in the subjective dimension is well known.[5] Even when a subject's response to pressure stimulation is automated, eg, by depressing a switch to stop the test, the vari-

ability of the PPT measurement is not diminished.[23] This should be taken into account when the PPT is used as a measure of sensory recovery because pooled data from groups of subjects may obscure individual responses. It must be noted, however, that the sample size was small and the gender ratio skewed; therefore, the "normal" values presented in this study should be interpreted with caution.

Stimulation using a pressure algometer is one of the most common forms of clinical sensory testing because it involves minimal risk of tissue damage.[3] However, such "natural" stimuli are often considered to be less easily controllable than electrical stimuli, which are commonly used in laboratory-based experiments. The results of these experiments do, however, indicate that the measurement of the PPT in the attached gingivae of healthy subjects using an algometer is both reliable and reproducible over time when stimulus response variables are controlled. Thus, the pressure algometer appears to be an effective tool for the clinical measurement of deep sensation in gingival mucosa.

Acknowledgments

The author wishes to thank Mr Ping Ma of the Statistical Consulting Service at the University of British Columbia. This study was supported by the Medical Research Council of Canada.

References

1. Bailey PH, Bays R. Evaluation of long-term sensory changes following mandibular augmentation procedures. J Oral Maxillofac Surg 1984;42:722–727.
2. Merrill RG. Prevention, treatment, and prognosis for nerve injury related to the difficult impaction. Dent Clin North Am 1979;23:471–488.
3. Osborn TP, Frederickson J, Small IA, Torgerson TS. A prospective study of complications related to mandibular third molar surgery. J Oral Maxillofac Surg 1985;43:767–769.
4. Robinson PP, Smith KG, Johnson FP, Coppins DA. Equipment and methods for simple sensory testing. Br J Oral Maxillofac Surg 1992;30:387–389.
5. Handwerker HO, Kobal G. Psychophysiology of experimentally induced pain. Physiol Rev 1993;3:639–671.
6. Jaeger B, Reeves JL. Quantification of changes in myofascial trigger point sensitivity with the pressure algometer following passive stretch. Pain 1986;27:203–210.
7. Ohrbach R, Gale EN. Pressure pain thresholds, clinical assessment, and differential diagnosis: Reliability and validity in patients with myogenic pain. Pain 1989a;39: 157–169.
8. Reeves JL, Jaeger B, Graff-Radford SB. Reliability of the pressure algometer as a measure of myofascial trigger point sensitivity. Pain 1986;24:313–321.
9. Graff-Radford SB, Reeves JL, Baker RL, Chiu D. Effects of transcutaneous electrical stimulation on myofascial pain and trigger point sensitivity. Pain 1989;37:1–5.
10. Jensen K, Andersen HO, Oleson J, Lindblom U. Pressure-pain threshold in human temporal region. Evaluation of a new pressure algometer. Pain 1986;25:313–323.
11. Ohrbach R, Gale EN. Pressure pain thresholds in normal muscles: Reliability, measurement effects, and topographic differences. Pain 1989b;37:257–263.
12. List T, Helkimo M, Karlsson R. Influence of pressure rates on the reliability of a pressure threshold meter. J Craniomandib Disord Facial Oral Pain 1991;5:173–178.
13. McMillan AS, Blasberg B. Pain-pressure threshold in painful jaw muscles following trigger point injection. J Orofacial Pain 1994;8:384–390.
14. McMillan AS, Lawson ET. Effect of tooth clenching and jaw opening on pain-pressure thresholds in the human jaw muscles. J Orofacial Pain 1994;8:250–257.
15. Davenport JC. Pressure-pain threshold in the oral cavity in man. Arch Oral Biol 1969;14:1267–1274.
16. Gallagher RW, Dal Santo FB, Rugh JD. Design and construction of a pressure algometer. J Craniomandib Disord Facial Oral Pain 1989;3:159–162.
17. Bushnell MC, Duncan GH, Dubner R, Jones RL, Maixner W. Attentional influences on noxious and innocuous cutaneous heat detection in humans and monkeys. J Neurosci 1985;5:1103–1110.
18. Pertovaara A, Kemppainen P, Leppanan H. Lowered cutaneous sensitivity to nonpainful electrical stimulation during isometric exercise in humans. Exp Brain Res 1992;9: 447–452.
19. Fischer AA. Pressure algometry over normal muscles. Standard values, validity, and reproducibility of pressure threshold. Pain 1987;30:115–126.
20. Kydd WL, Daly CH, Wheeler JB. The thickness measurement of masticatory mucosa in vivo. Int Dent J 1971; 21:430–441.
21. Kydd WL, Daly CH, Waltz M. Biomechanics of oral mucosa. Front Oral Physiol 1976;2:108–129.
22. Sessle BJ. Temperature, touch, taste, and olfaction. In: Roth GI, Calmes R (eds). Oral Biology. St Louis: Mosby, 1981:51–89.
23. Lavigne G, Thu Thon M, Rompré P, Duncan GH, Goulet JP. Sensory descriptors from touch to pressure-pain and experimental variables: A psychophysiological study on pressure-pain threshold in humans. In: Gebhardt GF (ed). [Proceedings of 7th World Congress on Pain, July 1993, Paris, France]. New York: Elsevier Press, 1994.

Resumen

Umbral de dolor-presión en las encías de seres humanos

El umbral de dolor-presión en los tejidos humanos como por ejemplo los músculos, puede ser afectado por la localización anatómica del sitio donde se determina y al ritmo con que se aplica la presión. Sin embargo, no se sabe cómo es que estas variables afectan el umbral de dolor-presión en los tejidos orales saludables. Se utilizó un algómetro hecho a la medida para 10 personas, a quienes se aplicó presión con un ritmo constante en 12 sitios sobre la encía adherida localizada apicalmente a los dientes 11–16, y 41–46. El umbral de dolor-presión fue medido de acuerdo a tres ritmos diferentes de presión aplicada en intervalos semanales por 4 semanas. El umbral fue consistentemente mayor en los sitios registrados en el maxilar superior. Sin embargo, no se detectaron diferencias en cuanto al umbral registrado en diferentes sitios a lo largo de la hilera de dientes en el maxilar superior o inferior. Las medidas del umbral de dolor-presión fueron consistentes entre las sesiones de registro. El umbral fue afectado por el ritmo de aplicación de la presión y parece que aumentó linealmente a medida que el ritmo aumentó. Esto indica que el umbral puede ser medido consistentemente en la encía adherida de humanos. Cuando se planee medir la sensación profunda en la mucosa oral, la localización del sitio de registro y el ritmo de la presión aplicada deben ser verificados.

Zusammenfassung

Druckschmerzschwelle bei menschlicher Gingiva

Die Druckschmerzschwelle bei menschlichen Geweben wie Muskeln kann durch die anatomische Lokalisation der Messstelle und die Druckanstiegsgeschwindigkeit beeinflusst werden. Es ist jedoch unsicher, wie diese Variablen die Druckschmerzschwelle bei gesunden oralen Geweben beeinflussen. Bei 10 Personen wurde die Druckschmerzschwelle mit einem selbstentwickelten Algometer mit einer konstanten Druckanstiegsgeschwindigkeit an 12 Stellen der angewachsenen Gingiva apikal der Zähne 11 bis 16 und 41 bis 46 gemessen. Die Aufzeichnungen wurden mit drei verschiedenen Druckanstiegsgeschwindigkeiten einmal wöchentlich während vier Wochen wiederholt. Die Druckschmerzschwelle lag bei den Oberkiefermessstellen immer höher. Es wurden keine Unterschiede in der Druckschmerzschwelle entlang einer Zahnreihe im Oberkiefer beziehungsweise im Unterkiefer festgestellt. Die jeweiligen Druckschmerzschwellen blieben bei allen Sitzungen gleich. Die Druckschmerzschwelle wurde durch die Druckanstiegsgeschwindigkeit beeinflusst und schien linear mit ansteigender Druckanstiegsgeschwindigkeit zu steigen. Dies legt nahe, dass die Druckschmerzschwelle reproduzierbar in der angewachsenen menschlichen Ginigiva gemessen werden kann. Wenn eine Messung der Druckschmerzschwelle der oralen Mukosa geplant ist, soll die Lokalisation der Messstelle und die Grösse des angewandten Druckes geprüft werden.