Application of a New Palpometer for Intraoral Mechanical Pain Sensitivity Assessment

Takuya Naganawa, DDS
Researcher/Visiting Scientist
Section of Clinical Oral Physiology
Department of Dentistry
Health, Aarhus University
Aarhus, Denmark
and Department of Oral and Maxillofacial Surgery
Tokyo Women's Medical University
School of Medicine
Tokyo, Japan

Takashi Iida, DDS, PhD
Assistant Professor
Department of Oral Function and Rehabilitation
Nihon University School of Dentistry at Matsudo
Chiba, Japan
Visiting Researcher
Section of Clinical Oral Physiology
Department of Dentistry
Health, Aarhus University
Aarhus, Denmark

Lene Baad-Hansen, DDS, PhD
Associate Professor
Section of Clinical Oral Physiology
Department of Dentistry
Health, Aarhus University
Aarhus, Denmark

Tomohiro Ando, DDS, PhD
Professor, Department of Oral and Maxillofacial Surgery
Tokyo Women's Medical University
School of Medicine
Tokyo, Japan

Peter Svensson, DDS, PhD, Dr Odont
Professor, Section of Clinical Oral Physiology
Department of Dentistry
Health, Aarhus University
and Center for Functionally Integrative Neuroscience
Mind Lab
Aarhus University Hospital
Aarhus, Denmark

Correspondence to:
Dr Takuya Naganawa
Section of Clinical Oral Physiology
Department of Dentistry
Health, Aarhus University
Vennelyst Boulevard 9
DK-8000, Aarhus C, Denmark
Fax: +45 8619 5665
Email: tanaganawa@gmail.com

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Aims: *To investigate the reliability and magnitude of intraoral mechanical pain sensitivity by using a palpometer with add-on devices with different physical properties.* ***Methods:*** *Sixteen healthy volunteers participated. Three palpometers (0.5, 1.0, and 2.0 kg) were used. Add-on devices were put on the circular metal stamp of the palpometer. Four diameters (3, 4, 5, and 10 mm) and two shapes of the rubber-top (flat and round) of the add-on devices were tested at each force level, ie, a total of 24 combinations. Participants were stimulated at the gingival mucosa around the maxillary central incisors and first molars on both sides by using the palpometers in randomized order. Participants rated perceived stimulus intensity on a 0-50-100 numerical rating scale (NRS). Ten volunteers were examined twice on the same day and recalled for a second session for assessment of within- and between-session reliability. Intraclass correlation coefficients were calculated for reliability measures, and NRS scores were analyzed with analysis of variance.* ***Results:*** *Reliability of NRS scores was excellent (interclass correlation coefficients 0.76 to 0.99). Analysis of NRS values corrected for pressure level revealed that there were main effects of site (*$P = .006$*), force (*$P < .001$*), size (*$P < .001$*), and shape (*$P < .001$*) but not side (*$P = .051$*).* ***Conclusion:*** *Reliability of intraoral novel palpometer measures of pressure sensitivity was excellent, and sensitivity to pressure stimulation was dependent on the applied force and physical properties of the add-on device. The study indicated that semi-quantitative assessment of intraoral mechanical sensitivity is feasible and could be applied in further studies on different intraoral pain conditions.*
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Key words: intraoral, pressure, quantitative sensory testing, somatosensory sensitivity

Clinical signs and symptoms have been reported to overlap between nociceptive and neuropathic pain conditions, leading to difficulties in differential diagnosis.[1] An accurate diagnosis is important, since treatment strategies for such conditions differ considerably.[2]

The German Research Network on Neuropathic Pain (DFNS) have developed a comprehensive quantitative sensory testing (QST) protocol, and they found good reliability on the face and upper and lower limbs.[3] Several studies have suggested that since somatosensory sensitivity is not well characterized in most orofacial pain conditions, mainly due to lack of tradition and techniques, intraoral QST may indeed provide a better description of the somatosensory sensitivity and underlying mechanisms in orofacial pain conditions.[4–6] Pigg et al also concluded that inter- and intra-examiner reliabilities of most QST measures are acceptable for assessment of somatosensory function in the orofacial region including the intraoral area.[2]

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Although QST is very useful extraorally, some devices are too large to access the different parts of the oral cavity. For example, an electronic pressure algometer for measurement of pressure pain threshold is too large to apply in some of the most posterior parts of the oral cavity.[5] For other stimulus modalities, Svensson et al suggested that specific probes for intraoral use should be developed.[5] A novel palpometer has been found suitable for standardization of the palpation pressure during a clinical examination for temporomandibular disorders (TMD) and other musculoskeletal pain conditions, such as tension-type headaches and fibromyalgia.[7] In addition, it has been established that use of the palpometer has low test-retest variability and provides a more accurate and reproducible pressure stimulus than manual palpation.[8] However, this palpometer is not applicable to most intraoral regions because of the shape and length.

The aim of this study was to investigate the reliability and magnitude of mechanical pain sensitivity in the intraoral region by using the novel palpometer with add-on devices with different physical properties.

Materials and Methods

This study was approved by the local ethics committee (M-20100240) and performed in accordance with the Helsinki Declaration II. Written informed consent was obtained from all participants.

Participants

Sixteen healthy participants (nine men and seven women, mean ± SD age of 29.9 ± 5.5 years) participated in this study. None of the participants reported any neurological disorders or abnormalities in stomatognathic function or orofacial pain complaints based on a medical and dental history, their responses to standard questionnaires, and an oral examination.

Palpometer

Three palpometers were used in the experiment, each with a different force level (0.5, 1.0, or 2.0 kg).[7] The palpometer consisted of a plastic cylindrical shell, spring, circular metal stamp, and an add-on device. The diameter of the plastic cylindrical shell was 20 mm. The circular metal stamp was made of aluminum and had a diameter of 10 mm.[7] The spring was composed of stainless steel and controlled the pressure force in this study. The three palpometers had springs prepared for application of the three different force levels.[7] Add-on devices were positioned on the circular metal stamp of the palpometer. These add-on devices consisted of a rubber hose, dental silicone material, aluminum probe (30 mm long), and a rubber top (Fig 1a). The rubber top was made of dental silicone material and was placed on the aluminum probe in order to avoid noxious stimulation from the metal. The height of the rubber top was 1 mm. Four different diameters of the aluminum probe with rubber tops (3, 4, 5, and 10 mm) were applied in this study. Two different shapes of the rubber top were applied (flat and round shape) (Fig 1b). The rubber top was bonded onto the aluminum probe by using instant glue.

The other end of the palpometer plastic cylindrical shell had a hole through which the stamp-tapering end could be pushed out.[7] When the examiner felt the tapering end on the finger, it corresponded to a pressure force of 0.5, 1.0, or 2.0 kg, respectively. The palpometer was held perpendicularly to the surface with the thumb and middle finger. The examiner detected the tapering end with the index finger when the correct pressure was applied.

Study Design

Twenty-four different combinations of the palpometer parameters were used in randomized order to stimulate the participants at the buccal gingival mucosa of the maxillary central incisors and first molars on both sides. The 24 different combinations were composed of three force levels (0.5, 1.0, and 2.0 kg), four different diameters of the aluminum tip with rubber top (3, 4, 5, and 10 mm), and two different shapes of the rubber top (flat and round shape) (Fig 1b). The sterilization method involved covering the top of the add-on device with clean cellophane film, which was replaced between participants. In addition, the top was wiped with 70% alcohol between participants.

During each measurement, participants were stimulated for approximately 2 seconds (investigator counting "1001 1002" inside his head). Each stimulation was repeated three times at each measurement site (buccal gingival mucosa of maxillary left and right central incisors and maxillary left and right first molars). After each stimulation, there was a 5-second interval during which participants were asked to rate the perceived intensity of the stimulus on a 0-50-100 numerical rating scale (NRS). The participants were carefully instructed in the use of the NRS, where 0 was defined as "no sensation at all," 50 was defined as "just barely painful," and 100 defined as "most pain imaginable."[4]

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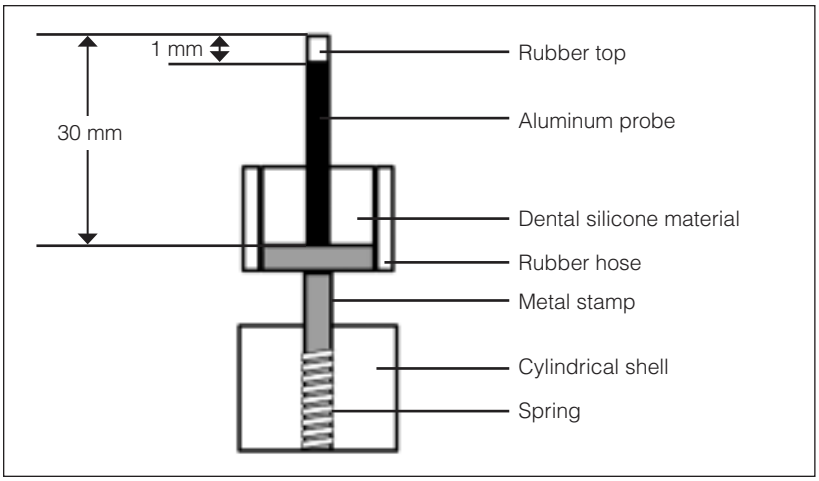

Fig 1a An add-on device consisted of rubber hose, dental silicone material, aluminum probe, and rubber top.

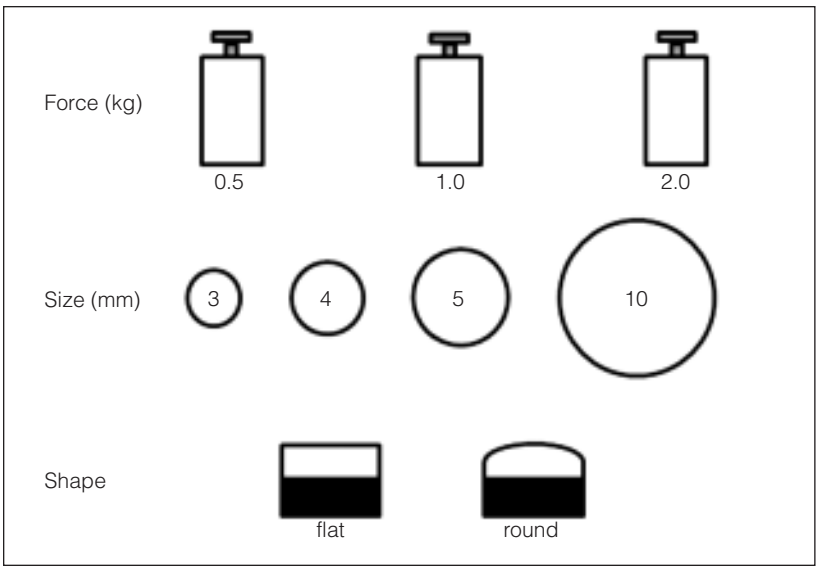

Fig 1b Three different palpometers with different force levels (0.5, 1.0, and 2.0 kg) were used. Add-on devices were mounted on the circular metal stamp of the palpometer. Four different diameters (3, 4, 5, and 10 mm) and two different shapes of the rubber top (flat and round) were applied, ie, a total of 24 different combinations (3 force levels × 4 diameters × 2 shapes).

To evaluate test-retest reliability, 10 participants were re-examined twice by the same examiner. Thus, in total, there were three measurement sessions for those 10 participants: *(1)* initial examination, *(2)* re-examination (15 minutes later the same day), and *(3)* re-examination 5 days later. The same four gingival sites as above were tested by the same examiner. For the re-examinations, only two different palpometers were used: (0.5 kg and 2 kg) with the 4-mm round-shaped add-on device. The four test sites were randomized during all tests. All tests were always performed using the right hand of the examiner.

Statistical Analyses

All data are presented as means ± SD. The significance level was set at $P < .05$. For the reliability analysis, intraclass correlation coefficients (ICC) were calculated for each gingival site for examinations 1 and 2 (same day) and for examinations 1 and 3 (separate days). The ICC values were classified as follows: < 0.4 = poor reliability; 0.4 to 0.75 = fair to good reliability; and > 0.75 = excellent reliability.[9]

The mean of three NRS scores was calculated for all test sites for each of the 24 types of palpometer with the add-on device. The mean NRS scores were analyzed with 5-way analyses of variance (ANOVA) with side (left, right), site (incisal, molar), force (0.5, 1.0, 2.0 kg), size (3, 4, 5, 10 mm), and shape (round, flat) as factors.

The NRS scores per pressure unit were also analyzed with a 5-way ANOVA with side (left, right), site (incisor, molar), force (0.5, 1.0, 2.0 kg), size (3, 4, 5, 10 mm), and shape (round, flat) as factors. Pressure was calculated as force (N) divided by the area of the surface on contact (mm^2). Tukey honestly significant difference (HSD) tests were used for post-hoc analysis when appropriate.

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Results

Analyses of the between-session and within-session reliability showed excellent ICC levels (ICC > 0.75) for all measurement sites and palpometer combinations (Table 1).

There were significant main effects on NRS scores of side ($P = .005$), site ($P < .001$), force ($P < .001$), size ($P < .001$), and shape ($P < .001$), with a significant interaction between site and size ($P = .005$), force and size ($P < .001$), and size and shape ($P = .004$) (Table 2). Post-hoc analyses revealed that the left side was significantly more sensitive than the right side ($P = .005$). The incisal region was significantly more sensitive than the molar region ($P < .001$). The NRS scores to 2 kg stimulation were significantly higher than to 1 kg ($P < .001$) and the NRS scores to 1 kg stimulation were significantly higher than to 0.5 kg ($P < .001$). The NRS scores increased with decreasing diameters of the add-on device ($P < .005$). The round shape induced significantly higher NRS scores than the flat shape ($P < .001$). The post-hoc test of the interaction between site and size showed that the incisal region was more sensitive than the molar region to stimulation with the 3-mm-diameter ($P < .001$) and 4-mm-diameter ($P = .002$) add-on device, but there was no significant difference between incisal and molar regions to stimulation with the 5- or 10-mm-diameter add-on device ($P > .079$) (Fig 2). The post-hoc test of the interaction between force and size ($P < .001$) indicated that for each diameter of the add-on device, all NRS scores to 1 kg stimulation were significantly higher than 0.5 kg ($P < .001$) and NRS scores to 2 kg stimulation were also significantly higher than 1 kg ($P < .001$). The post-hoc test of the interaction between size and shape demonstrated that the round shape induced significantly higher NRS scores than the flat shape for diameters of 3 and 5 mm ($P < .001$) (Table 2).

The 5-way ANOVA analysis of the NRS values corrected for pressure level revealed that there were main effects of site ($P = .006$), force ($P < .001$), size ($P < .001$), and shape ($P < .001$), but not side ($P = .051$), with significant interactions between site and force ($P = .049$), force and size ($P = .001$), and force and shape ($P = .003$) (Table 2). A post-hoc test showed that the incisal region was significantly more sensitive than the molar region ($P = .006$) and that stimulation with 0.5 kg induced significantly higher NRS scores per pressure unit than 1 kg ($P = .019$) and 2 kg ($P < .001$). There was no significant difference between the stimulation of 1 kg and 2 kg ($P = .207$). Another post-hoc test showed that the stimulation with the 10-mm-diameter add-on device induced significantly higher NRS scores per pressure unit than all the other diameters (3, 4, and 5 mm [$P < .001$]). The round shape induced significantly higher NRS scores per pressure unit than the flat shape ($P < .001$). The post-hoc test of the interaction between site and force demonstrated that the incisor region was more sensitive than the molar region to stimulation with 0.5 kg ($P = .006$). The post-hoc test of the interaction between force and size showed that stimulation with 0.5 and 1 kg induced significantly higher NRS scores per pressure unit than 2 kg with the 10-mm-diameter add-on device ($P < .033$). The post-hoc test of the interaction between force and shape indicated that stimulation with the round shape induced significantly higher NRS scores per pressure unit than the flat shape for 0.5 and 1 kg ($P < .017$). The post-hoc test of the interaction between size and shape demonstrated that stimulation with a round shape induced significantly higher NRS scores per pressure unit than flat shape for the 10-mm-diameter add-on device ($P < .001$) (Table 2).

Table 1 Reliability of Intraoral Measurements with Palpometer and Add-on Device

		95% CI	
	ICC	Lower	Upper
Between exams 1 and 2—0.5 kg			
Right molar	0.88	0.55	0.97
Right incisor	0.98	0.91	0.99
Left molar	0.99	0.99	0.99
Left incisor	0.97	0.88	0.99
Between exams 1 and 3—0.5 kg			
Right molar	0.95	0.80	0.99
Right incisor	0.76	0.10	0.94
Left molar	0.86	0.46	0.96
Left incisor	0.93	0.76	0.98
Between exams 1 and 2—2.0 kg			
Right molar	0.97	0.91	0.99
Right incisor	0.95	0.80	0.98
Left molar	0.94	0.79	0.99
Left incisor	0.96	0.86	0.99
Between exams 1 and 3—2.0 kg			
Right molar	0.94	0.79	0.99
Right incisor	0.95	0.79	0.99
Left molar	0.95	0.82	0.99
Left incisor	0.95	0.83	0.99

< 0.4 = poor reliability; 0.4 to 0.75 = fair to good reliability; > 0.75 = excellent reliability.
The between-session and within-session reliability of the use of palpometer modified for intraoral use was excellent (ICC > 0.75).
ICC = intraclass correlation coefficient. CI = confidence interval.
Examinations 1 and 2 (same day) and examination 3 (5 days after examinations 1 and 2).

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Table 2 Result of 5-way Analysis of Variance (ANOVA) with Side, Region, Force, and Shape as Factors

	Absolute NRS scores		NRS scores corrected for pressure	
	P	Post-hoc test	*P*	Post-hoc test
Side (right-left)	.005	L > R (*P* = .005)	.051	
Site (molar-incisor)	< .001	I > M (*P* < .001)	.006	I > M (*P* = .006)
Force (0.5, 1, 2 kg)	< .001	2 > 1 (*P* < .001) 1 > 0.5 (*P* < .001)	< .001	0.5 > 2 (*P* < .001) 0.5 > 1 (*P* = .019)
Size (3, 4, 5, 10 mm)	< .001	3 > 4 (*P* < .001) 4 > 5 (*P* = .005) 5 > 10 (*P* < .001)	<.001	10 > 3 (*P* < .001) 10 > 4 (*P* < .001) 10 > 5 (*P* < .001)
Shape (round-flat)	< .001	r > f (*P* < .001)	< .001	r > f (*P* < .001)
Site × Size	.005			
Force × Size	<.001		.001	
Size × Shape	.004		.018	
Site × Force			.049	
Force × Shape			.003	

L = left, R = right, I = incisor, M = molar, r = round, f = flat.

Discussion

The first main finding in this study was that the between-session and within-session reliability of the palpometer modified for intraoral use was excellent (ICC > 0.75). The device may thus be useful for examination of mechanical pain sensitivity of the intraoral region. In comparison, Bernhardt et al concluded from using the Somedic algometer that the ICC for the intra-examiner comparison of pressure pain thresholds of masticatory muscle and the temporomandibular joint ranged from 0.73 to 0.96.[10–14]Also, Pigg et al showed that intraoral use of a digital algometer was associated with excellent intra-examiner reliability (0.82, right gingiva; 0.80, left gingiva).[2] Moreover, they concluded that excellent reliability for pressure pain threshold was found for all sites, which is in accordance with several other studies on the face and oral cavity.[15–19] The stability of pressure sensitivity at different recording sessions is also in agreement with previous studies of the oral mucosa and at other muscle and joint sites in the body.[1,17,20] The advantage of the present palpometer approach for assessment of intraoral mechanical sensitivity is that it is cheaper than an electronic algometer and more easily accessible to different intraoral regions.

The second main finding in this study was that the physical properties of the add-on device influenced the mechanical sensitivity. In general, stimulation with smaller diameters and higher force levels induced higher NRS scores. This is in accordance with Greenspan and McGillis, who concluded that the pressure pain threshold on the finger varies with the probe sizes.[21,22] Moreover, it is possible that the difference between the round- and the flat-shaped contact area is caused by the slightly smaller contact area of the round-shaped add-on device compared with the flat-shaped device and that the pressure exerted by the round-shaped device could be concentrated more at the center of the add-on device. This is also in agreement with Greenspan and McGillis, who found that pressure pain threshold in the finger increases as probe angle becomes obtuse.[22]

The present results showed that there were significant differences in NRS values corrected for pressure level between the incisor and molar regions. McMillan concluded that the variation in somatosensory sensitivity between different intraoral regions may be due to differences in innervation patterns and receptor density in the attached gingiva and underlying bone.[18] Although regional features of the innervation pattern have not been identified, nerve endings vary considerably in morphology and distribution among different sites of the oral mucosa.[23] Dixon also concluded that receptors are more commonly situated in the anterior part of the mouth than in the posterior.[24]

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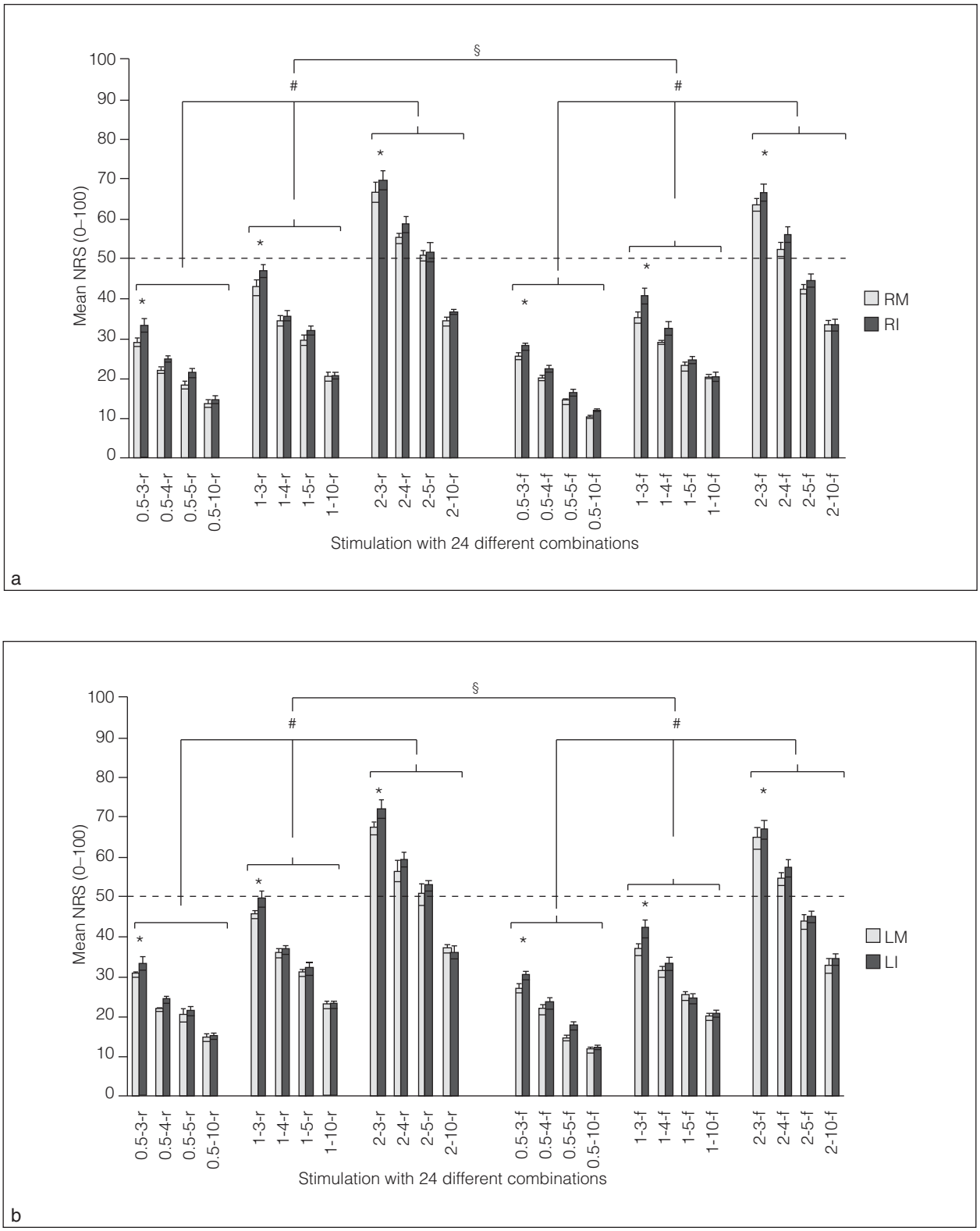

Fig 2 Absolute numerical rating scale (NRS) scores 0-50-100 and SD from four test sites: *(a)* right molar (RM), right incisor (RI); and *(b)* left molar (LM), left incisor (LI). The 24 different types of palpometer stimulation were composed of three force levels (0.5, 1.0, and 2.0 kg), four different diameters of the aluminum probe with rubber top (3, 4, 5, and 10 mm), and two different shapes of the rubber top (flat and round). On the x-axis, the marks are composed of the force level (0.5, 1.0, or 2.0 kg), the diameter (3, 4, 5, or 10 mm) and the shape of the rubber top (r = round, f = flat). * indicates significant difference between molar and incisor region for stimulation with 3- and 4-mm-diameter ($P < .01$); # indicates significant difference of force levels; § indicates significant difference between round shape and flat shape.

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The present study demonstrated that the mean absolute NRS scores from the left side were significantly higher than from the right side. However, the NRS scores corrected for pressure level showed no significant difference between sides. Another study using the palpometer extraorally found no differences between sides.[8] Ogimoto et al used a custom-made pressure algometer and showed that there was a significant correlation in pressure pain thresholds between the right and left buccal sites.[15] Pigg et al concluded that individual side-to-side variance appears to occur intraorally.[2] The minor, but significant, side-to-side differences may possibly result from the use only of the examiner's right hand in the test, resulting in a difference in the examiner's position in relation to the test site between sides. However, it was more difficult to use the opposite hand to apply the palpometer to the test site. This novel palpometer may need to be modified to allow use of the nondominant hand. Alternatively, the examiner may need to change body position when shifting from one test side to the other in order to reduce the risk of systematic side-to-side differences. However, sides (right and left) were randomized during all experiments in the current study, thus there was no sequence effect.

In conclusion, the reliability of the novel intraoral palpometer measures of mechanical sensitivity was excellent, and the sensitivity to the pressure stimuli was dependent on the applied force and physical properties of the add-on device. Due to the advantages resulting from the modifications for intraoral use (small, lightweight, easy access to posterior regions of the oral cavity, purely mechanical), the novel palpometer may serve as a useful alternative to pressure algometers for evaluation of intraoral pressure pain sensitivity. Future studies in different intraoral pain conditions are needed to determine the applicability of the novel palpometer modified for intraoral use in clinical practice.

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References

1. Melis M, Lobo SL, Ceneviz C, et al. Atypical odontalgia: A review of the literature. Headache 2003;43:1060–1074.
2. Pigg M, Baad-Hansen L, Svensson P, Drangsholt M, List T. Reliability of intraoral quantitative sensory testing (QST). Pain 2010;148:220–226.
3. Geber C, Klein T, Rolke R, et al. Test/retest- and interobserver-reliability in quantitative sensory testing according to the protocol on the German network on neuropathic pain (DFNS). Eur J Pain 2007;11:587.
4. Baad-Hansen L, Staehelin Jensen T, Svensson P. A human model of intraoral pain and heat hyperalgesia. J Orofac Pain 2003;17:333–340.
5. Svensson P, Baad-Hansen L, Pigg M, et al. Guidelines and recommendations for assessment of somatosensory function in oro-facial pain conditions: A taskforce report. J Oral Rehabil 2011;38:366–394.
6. Baad-Hansen L, List T, Jensen TS, Svensson P. Increased pain sensitivity to intraoral capsaicin in patients with atypical odontalgia. J Orofac Pain 2006;20:107–114.
7. Futarmal S, Kothari M, Ayesh E, Baad-Hansen L, Svensson P. New palpometer with implications for assessment of deep pain sensitivity. J Dent Res 2011;90:918–922.
8. Kothari SF, Kothari M, Baad-Hansen L, Svensson P. Comparison of techniques for evaluation of deep pain sensitivity in the craniofacial region. J Orofac Pain 2012;26:225–232.
9. Shrout PE, Fleiss JL. Intraclass correlations: Uses in assessing rater reliability. Psychol Bull 1979;86:420–428.
10. 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.
11. List T, Helkimo M, Falk G. Reliability and validity of a pressure threshold meter in recording tenderness in the masseter muscle and the anterior temporalis muscle. Cranio 1989;7:223–229.
12. Ohrbach R, Gale EN. Pressure pain thresholds in normal muscle: Reliability, measurement effects, and topographic differences. Pain 1989;37:257–263.
13. Chung SC, Kim JH, Kim HS. Reliability and validity of the pressure pain thresholds (PPT) in the TMJ capsules by electronic algometer. Cranio 1993;11:171–176.
14. Bernhardt O, Schiffman EL, Look JO. Reliability and validity of a new fingertip-shaped pressure algometer for assessing pressure pain thresholds in the temporomandibular joint and masticatory muscles. J Orofac Pain 2007;21:29–38.
15. Ogimoto T, Ogawa T, Sumiyoshi K, Matsuka Y, Koyano K. Pressure-pain threshold determination in the oral mucosa: Validity and reliability. J Oral Rehabil 2002;29:620–626.
16. Antonaci F, Sand T, Lucas GA. Pressure algometry in healthy subjects: Inter-examiner variability. Scand J Rehabil Med 1998;30:3–8.
17. List T, Helkimo M, Falk G. Reliability and validity of a pressure threshold meter in recording tenderness in the masseter muscle and the anterior temporalis muscle. Cranio 1989;7:223–229.
18. McMillan AS. Pain-pressure threshold in human gingivae. J Orofac Pain 1995;9:44–50.
19. McMillan AS, Walshaw D. Pressure - pain threshold in the human tongue. J Orofac Pain 2000;14:93–97.
20. Davenport JC. Pressure-pain threshold in the oral cavity in man. Arch Oral Biol 1969;14:1267–1274.
21. Greenspan JD, McGillis SL. Thresholds for the perception of pressure, sharpness, and mechanically evoked cutaneous pain: Effects of laterality and repeated testing. Somatosens Mot Res 1994;11:311–317.
22. Greenspan JD, McGillis SL. Stimulus features relevant to the perception of sharpness and mechanically evoked cutaneous pain. Somatosens Mot Res 1991;8:137–147.
23. Rapp R, Kirstine WD, Avery JK. A study of the multiplicity of nerve endings in the human gingiva and periodontal membrane. J Can Dent Assoc 1957;23:637–643.
24. Dixon AD. The position, incidence and origin of sensory nerve termination in oral mucous membrane. Arch Oral Biol 1962;7:39–48.

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