Assessment of Human Intraoral Thermal Sensitivity with Simple Devices in the Clinic: Implications for Orofacial Pain Conditions

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Aims: To use simple thermal devices with different diameters and temperatures to investigate reliability and magnitude of human intraoral thermal sensitivity. **Methods:** Sixteen healthy volunteers participated. Six thermal devices with tapered circular ends (stimulus diameter 3, 5, and 10 mm) were used. Three different temperatures (room temperature, heat, and cold) were applied with each of the three diameters, ie, nine combinations. Participants were stimulated in randomized order at nine different sites: tongue, lip, maxillary attached gingiva adjacent to the left and right central incisors (without touching the lip) and to the left and right premolars (with or without touching the lip), and the left and right cheeks extraorally. Participants rated the perceived stimulus intensity on 0-50-100 numeric rating scales (NRS). The number of paradoxical thermal sensations was also recorded. Ten volunteers were examined twice on the same day and recalled for a second session for assessment with the 5-mm-diameter device of within- and between-session reliability (interclass correlation coefficients [ICC]). The results were analyzed using a three-way analysis of variance. **Results:** Reliability of NRS scores ranged from poor (ICC = 0.09, with cold stimulation at the premolar region) to excellent (ICC > 0.92, with cold stimulation at the cheek or tongue). NRS values varied with stimulus diameter ($P < .050$), temperature ($P < .001$), and sites ($P < .001$), with significant size × site and temperature × site interactions ($P < .001$). The tongue was the most sensitive site ($P < .001$) and the gingiva was the least sensitive site ($P < .050$). The 10-mm-diameter device produced higher NRS scores than the 3-mm-diameter device. **Conclusion:** The reliability of intraoral thermal sensitivity recorded with the 5-mm-diameter device varied greatly between different sites. Nonetheless, with this caveat in mind, the study did document that semiquantitative assessment of intraoral thermal sensitivity is feasible and applicable for clinical studies in different intraoral pain conditions. *J Oral Facial Pain Headache 2015;29:83–90. doi: 10.11607/ofph.1221*

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Quantitative sensory testing (QST) can be used for evaluation of somatosensory disturbances and can provide insights into mechanisms underlying different pain conditions in humans.[1–7] The reliability of QST has been found to be acceptable,[1,3–6] and QST may therefore assist the diagnosis of nociceptive and neuropathic pain conditions.[1,4,6,8] Also in the intraoral region, somatosensory sensitivity can be investigated with QST and may aid in the diagnosis and examination of underlying mechanisms in orofacial pain conditions.[2,4–6] Pigg et al concluded that the inter- and intraexaminer reliabilities of most QST measures were acceptable for evaluation of somatosensory function in the orofacial region including the intraoral area in humans.[2]

Although QST is useful, some of the standard instruments and devices are too large to be applied to different parts of the oral cavity.[5] For some stimulus modalities, Svensson et al suggested that specific probes for intraoral use should be developed.[5] Thus, a previous study in humans developed novel devices for assessment of intraoral mechanical sensitivity that consisted of modified palpometers and measured the

test-retest reliability within and between sessions.[9] The devices were small in size, lightweight, and provided easy access to the posterior region of the oral cavity. Importantly, the reliability scores in that study were all excellent.[9]

Heat and/or cold hyperalgesia (an increased response to a painful stimulus) or thermal allodynia (a painful response to a normally innocuous stimulus) are important symptoms in some neuropathic pain patients.[10] Quantitative measurements of thermal pain thresholds are therefore an essential part of QST in the clinical setting and in research studies of pain mechanisms.[11] To fully understand intraoral thermal sensitivity, investigation of spatial summation is also useful. Spatial summation of pain is the ability of the nervous system to integrate nociceptive information from the stimulated region in such a way that stimulation of larger areas leads to more pain.[12] Some studies have shown spatial summation is well characterized at different body sites.[12–15] Spatial summation has also been investigated in the extraoral region,[16–19] but there are only few studies on spatial summation in intraoral regions.[16–18]

The phenomenon of paradoxical thermal sensations, such as perceiving a cold stimulus as being hot, may be present in various neurologic disorders[20] and are more frequently seen during intraoral than during extraoral QST also in healthy human subjects.[2] Thus, investigation of paradoxical thermal sensations may prove helpful in the diagnosis of intraoral neuropathic disorders.

Unfortunately, thermal testing based on the standardized QST protocol suggested by the German Research Network on Neuropathic Pain[7] cannot easily be applied to the most posterior intraoral regions. Moreover, the thermotesters normally used for QST are very expensive and are typically found only in hospital or university settings.[2,3,5] Therefore, to investigate thermal sensitivity or spatial summation intraorally in humans, a simple thermal device is needed for screening purposes. Some studies have also suggested that a number of different thermal contact stimulators should be developed to allow more precise control of the thermal stimulus.[21–25] The contact area of thermodes is usually in the range of 0.25 to 9 cm^2. When applying thermal QST in the orofacial region, the size of the contact area must be within 4 cm^2 to be able to investigate the trigeminal nerve distributions separately, and it should be even smaller for intraoral testing.[5] There is a need for development of easy-to-use and simple tools, which are applicable also in a primary care dental office. Therefore, the aim of this study was to use simple thermal devices with different diameters and temperatures to investigate their reliability and magnitude of human intraoral thermal sensitivity.

Materials and Methods

Participants

Sixteen healthy volunteers (eight men and eight women; mean age ± SD, 30.1 ± 4.7 years) participated in this study. None of the participants reported any neurologic disorders or abnormalities in stomatognathic function or orofacial pain complaints, based on a medical and dental history including an oral examination. 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.

Heat and Cold Stimulation

Six custom-made thermal devices were used in this experiment.[8] The thermal devices were aluminum cylinders (15 mm diameter, 90 mm height) with tapered circular ends of stimulus diameters and approximate areas of 3 mm and 0.07 cm^2, 5 mm and 2.0 cm^2, and 10 mm and 0.79 cm^2, respectively. Each of the two ends could be applied to the tissues (a total of 12 applicable ends, 4 of each diameter) (Fig 1). The surface was flat, with diameters similar to or smaller than those of the intraoral thermodes of the Medoc Pathway Machine (thermotester, ATS, Medoc), which is often used in studies of orofacial thermal sensitivity.[2,4,5] The present 10-mm device was chosen based on the thermode for intraoral QST. However, a device of 10-mm diameter may in some cases or regions be too big or cumbersome, so two smaller devices were also tested. The 5-mm device was chosen based on a previous study.[8]

The devices were placed in either a water bath or a refrigerator, or kept at room temperature, to obtain a specific temperature of 51°C for heat stimulation, 5°C for cold stimulation, and 25°C for stimulation at room temperature. The temperature for the cold stimulation was based on a study in which the same aluminum cylindrical device was used,[8] and the temperature for the heat stimulation was based on previous QST studies which demonstrated that the heat-pain threshold of the skin and gingiva normally is below 51°C.[2–5] The perceived cold intensity of the room-temperature stimulus was also assessed, because the mucosa and skin temperature are higher than room temperature.

For heat stimulation, the devices were kept for at least 30 minutes in a temperature-regulated water bath (Salvis WB4ST water bath) set at 51°C. Each heated device was taken from the water bath, dried before its application to the orofacial tissues, and returned to the water bath immediately after stimulation. The devices for cold stimulation were cooled to 5°C in a refrigerator and kept in a thermal insulation box. The devices used for stimulation at room temperature

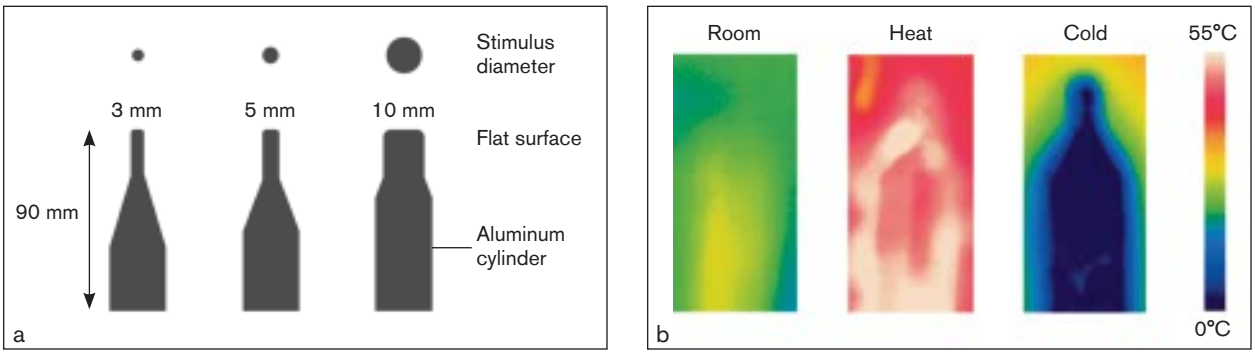

Fig 1 **(a)** Graphic representation of the three thermal test devices. The top row represents a cross section of the tip of the device and the lower row depicts the device cut along the length axis. **(b)** Images of the thermal test devices obtained with a surface thermal imaging camera (FLIR E60bx) before the examinations.

were adapted to room temperature for at least 30 minutes before stimulation.

Laboratory assessment has shown that the thermal test devices keep the experimental temperature within 1°C for about 50 seconds.[8] Nevertheless, to make sure that the stimulation was always performed with the same temperature, another device was chosen from the water bath or thermal insulation box for the next stimulation (see Fig 1a). Each temperature was confirmed by a surface thermal imaging camera (E60bx, FLIR) before the examinations (see Fig 1a). The participants were stimulated for 2 seconds during each measurement, and the stimulation of each test site was performed in randomized order. For each measurement, the examiner applied the device perpendicularly to the test site and was careful not to provoke mechanical pain or unpleasantness with the edge of the device. The devices were disinfected using alcohol swabs between participants.

After each stimulation, the participants were given 5 seconds to rate the perceived intensity of the stimulus on a 0-50-100 numeric rating scale (NRS). Prior to testing, the participants were carefully instructed in the use of the NRS, where 0 was defined as "no sensation of temperature at all except a sensation of touch," 50 was defined as "just barely painful," and 100 was defined as "most pain imaginable."[4]

To test the phenomenon of paradoxical thermal sensation and of lack of discrimination of temperature in the test-retest sessions (see below), the participants were asked whether the stimulations were perceived as "hot," "cold," or "neither." The number of paradoxical thermal sensations and lack of discrimination of temperature were recorded[2,7,26] and divided by a total of 30 stimulations per site with the different temperatures (10 subjects × 3 sessions) to determine their frequency. For room-temperature stimulation, paradoxical sensation and lack of discrimination of temperature were not recorded.

Experimental Protocol

There were three different measurement blocks: *(1)* heat stimulation, *(2)* cold stimulation, and *(3)* room-temperature stimulation, in randomized order, separated by more than 60 minutes. Participants were stimulated at nine test sites, which included the tip of the tongue, the maxillary attached gingiva adjacent to the right and left central incisors (without touching the lip), the maxillary attached gingiva adjacent to the right and left premolars (with and without touching the lip), and the right and left cheek extraorally. The thermal devices of different diameters were applied in randomized order within each measurement block. Each test region received a total of nine stimuli (3 diameters × 3 measurement blocks), ie, three different temperatures.

Only the gingiva in the maxilla was tested with two conditions, ie, with the probe touching or not touching the lip. A lip retractor (Dental Adult Size Double-headed T-Shape Intraoral Cheek Lip Retractor Opener, Zenith-Dental), designed for taking intraoral photographs, was used to keep the thermal device from touching the lip.

To evaluate test-retest reliability, 10 participants were re-tested twice by the same examiner. There were therefore three experimental sessions for these 10 participants: the initial assessment, a second assessment 15 minutes later on the same day, and a third assessment 5 days later. For the test-retest sessions only, the 5-mm device was used with the three different temperatures applied in randomized order at four different sites (right cheek, tongue, right maxillary incisor gingiva, and right maxillary premolar gingiva) and without touching the lip.

Statistical Analyses

All data are presented as means ± SD. The level of significance was set at $P < .05$. For the reliability analysis, intraclass correlation coefficients (ICC)

Table 1 Between-Session and Within-Session Reliability of the 5-mm-Diameter Device

	Between exams 1 and 2		Between exams 1 and 3	
	ICC	(95% CI)	ICC	(95% CI)
Room temperature				
Cheek	0.79	(0.21–0.95)	0.76	(-2.49–0.77)
Tongue	0.69	(-0.27–0.93)	0.12	(-2.34–0.78)
Gingiva (incisor)	0.69	(-0.16–0.92)	0.87	(0.51–0.97)
Gingiva (premolar)	0.37	(-1.37–0.84)	0.21	(-3.72–0.89)
Cold				
Cheek	0.96	(0.85–0.99)	0.85	(0.44–0.96)
Tongue	0.92	(0.71–0.98)	0.76	(0.38–0.94)
Gingiva (incisor)	-0.14	(-4.17–0.77	0.51	(-1.05–0.87)
Gingiva (premolar)	0.09	(-2.43–0.77)	-0.04	(-2.91–0.74)
Heat				
Cheek	0.93	(0.72–0.98)	0.87	(0.51–0.97)
Tongue	0.86	(0.48–0.97)	0.73	(-0.04–0.93)
Gingiva (incisor)	0.57	(-0.94–0.91)	0.51	(-0.88–0.87)
Gingiva (premolar)	0.57	(-1.22–0.92)	0.05	(-3.31–0.81)

< 0.4 = poor reliability; 0.4 to 0.74 = fair to good reliability; > 0.75 = excellent reliability. ICC = intraclass correlation coefficient; (95% CI) = 95% confidence interval, lower–upper. Exams 1 and 2 (same day) and exam 3 (5 days after exams 1 and 2). Number of subjects = 10.

Table 2 Frequency and Number (n) of Paradoxical Sensations and Lack of Temperature Discriminations

	Paradoxical sensation		Lack of discrimination temperature	
	n	%	n	%
Heat stimulation (51°C)				
Cheek	0	0	0	0
Tongue	0	0	0	0
Gingiva (incisor)	1	3.30	14	46.70
Gingiva (premolar)	2	6.70	17	56.70
Cold stimulation (5°C)				
Cheek	0	0	0	0
Tongue	0	0	0	0
Gingiva (incisor)	1	3.30	5	16.70
Gingiva (premolar)	0	0	14	46.70

Number of subjects = 10. Number of stimulations = 30 at each site with different temperature.

were calculated for each measurement site for sessions 1 and 2 (same day) and for sessions 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.[27]

The NRS scores were analyzed with three-way repeated-measures analysis of variance (ANOVA) with stimulus diameter (3, 5, 10 mm), temperature (5°, 25°, 51°C), and site (tongue, attached gingiva adjacent to right and left central incisors without touching the lip, attached gingiva adjacent to the right and left premolars with or without touching the lip, right and left cheek extraorally) as factors. Tukey Honestly Significant Difference (HSD) test with correction for multiple comparisons was used for post-hoc analysis when appropriate.

Results

Analyses of the between-session and within-session reliability in the case of the 5-mm-diameter device showed excellent ICC levels (ICC > 0.75) for the three different temperatures applied to the extraoral cheek sites. The between-session and within-session ICC levels for the tongue site were good to excellent for heat and cold stimulation. However, the between-session reliability was poor for room-temperature stimulation. Moreover, the ICC levels ranged from poor to good for heat and cold stimulation at the gingival sites (Table 1).

No paradoxical thermal sensations or lack of discrimination of temperature were observed for the cheek or tongue stimulation (Table 2). However, the patients reported a paradoxical thermal sensation in a total of 4 out of 120 thermal stimulations (3.3%) of the gingival sites for cold or heat stimuli, eg, in 3 out of 10 subjects: in 2 (1 cold stimulus and 1 heat stimulus) out of 60 stimulations (3.3%) at the incisor gingival sites (2 out of 10 subjects) and in 2 heat stimuli out of 60 stimulations (3.3%) at the premolar gingival sites (1 out of 10 subjects).

Lack of discrimination of both temperatures was recorded only for the gingival stimulation, eg, in a total of 50 out of 120 stimulations: in 19 (14 heat stimuli and 5 cold stimuli) out of 60 stimulations (31.7%) at the incisal gingiva (7 out of 10 subjects) and in 31 (17 heat stimuli and 14 cold stimuli) out of 60 stimulations (51.7%) at the premolar gingiva (9 out of 10 subjects); (Table 2).

There were significant main effects on NRS scores for stimulus diameter (size) ($P < .050$), temperature ($P < .001$), and sites ($P < .001$), with significant interactions between stimulus diameter (size) and site ($P < .001$) and temperature and site ($P < .001$); (Table 3). Post-hoc analyses showed that the stimulations with the 10-mm-diameter device produced significantly higher NRS scores than the 3-mm-diameter device ($P < .050$). However, there were no significant differences between the stimulations with the 3-mm- and 5-mm-diameter devices or between the stimulations with the 5-mm- and 10-mm-diameter devices ($P > .102$). The stimulations at room temperature induced significantly lower NRS scores than stimulations with the 5°C device ($P < .001$) and 51°C

Table 3 Results of the 3-way Analysis of Variance on Mean Numeric Rating Scale Scores

Factor	*P* value	Post hoc test
Size (3-, 5-, 10-mm diameter)	< .05	10 mm > 3 mm (*P* < .05)
Temperature (Room, Heat, Cold)	< .001	Heat > Cold (*P* < .05) Heat > Room (*P* < .001) Cold > Room (*P* < .001)
Site (Cheek R/L, Tongue, Gingiva RI/RP/LI/LP)	< .001	Tongue > Cheek (*P* < .001) Cheek, Tongue > Gingiva (*P* < .001) Gingiva RI > Gingiva RP (*P* < .05) Gingiva LI > Gingiva LP (*P* < .001)
Size × Site	< .001	
Temperature × Site	< .001	

R = right; L = left; RI = right incisor; RP = right premolar; LI = left incisor; LP = left premolar. Number of subjects = 16. Only statistically significant results of post hoc tests are given.

device (*P* < .001). Heat stimulations induced significantly higher NRS scores than cold stimulations (*P* < .050).

There were no significant differences in NRS scores between the right and the left cheek (*P* = .999) and between the right and left side for any of the gingival stimulation sites (*P* > .998). The NRS values reported for tongue stimulation were significantly higher than those for cheek stimulation (*P* < .001). The NRS scores reported for incisor gingival stimulation were significantly higher than those reported for premolar gingival stimulation (*P* < .050) (Table 3). The use of the lip retractor did not influence the gingival thermal sensations (*P* > .351). However, most participants spontaneously reported that it was more difficult for them to detect the temperature applied to the gingiva when the device also touched the lip than when it did not.

The use of the post-hoc test of the interaction between device diameter and stimulation site showed that the NRS scores recorded for stimulation of both cheeks were significantly higher with the 10-mm-diameter device than with the 3-mm- and 5-mm-diameter devices (*P* < .010) but not different between the 3-mm- and 5-mm-diameter devices (*P* > .991). Moreover, the NRS scores recorded for stimulation of the tongue were significantly higher with the 10-mm-diameter device than the 3-mm-diameter device (*P* < .001) but not significantly different between the 3-mm- and 5-mm-diameter devices or between the 5-mm- and 10-mm-diameter devices (*P* > .234).

The interaction between temperature and sites showed that the cold and heat stimulations evoked more intense pain sensations than that at room temperature, both for the cheek and tongue sites (*P* < .001). Also, cold (*P* < .001) but not heat stimulation (*P* > .418) elicited more intense sensations from the tongue than the cheek (Fig 2).

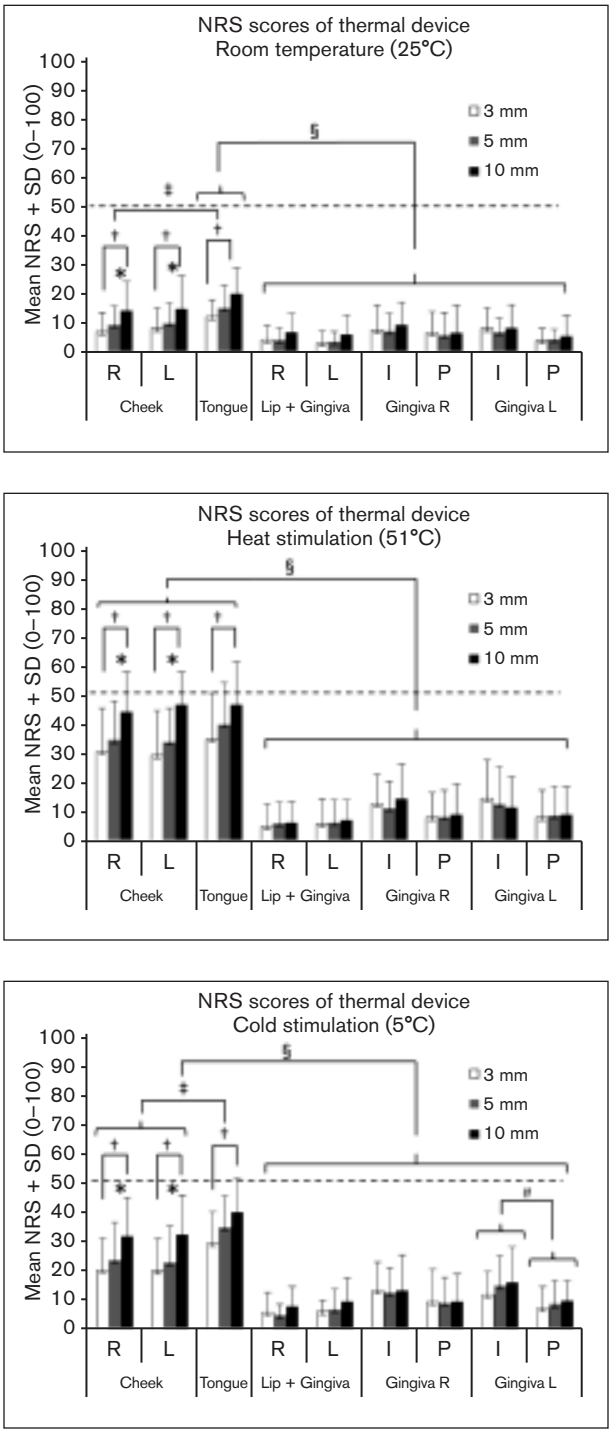

Fig 2 0-50-100 Absolute numeric rating scale (NRS) scores and SD from four test sites (R = right; L = left; I = incisor; P = premolar; Gingiva R = right gingiva; Gingiva L = left gingiva). 3 mm, 5 mm, and 10 mm = diameters of the device tips. *Significant difference between the NRS scores recorded with devices with 5- and 10-mm diameters (*P* < .010). †Significant difference between the NRS scores recorded with devices with 3- and 10-mm diameters (*P* < .001). ‡Significant difference between the NRS scores after cheek and tongue stimulation. §Significant difference between the NRS scores after cheek or tongue and gingival stimulation. #Significant difference between the NRS scores after left side incisor and premolar gingival stimulation. Number of subjects = 16. The dotted line indicates the pain threshold.

Discussion

This study has demonstrated significant differences between the orofacial test sites in reliability and thermal sensitivity obtained with easy-to-use and simple thermal devices. Overall, these results are in agreement with previous findings using more sophisticated psychophysical techniques and devices.[2]

Reliability

A main finding of this study was that the between- and within-session reliability of the 5-mm-diameter thermal device depended strongly on the test site. The sensitivity to heat and cold stimulation showed good to excellent reliability when the stimulus was applied to the cheek and tongue regions. This is in accordance with other studies reporting good reliability for cold pain threshold (CPT) and heat pain threshold (HPT) at skin or tongue sites.[2,3,28–31] On the contrary, the heat and cold stimulation of the different gingival sites showed only poor to good reliability. The reason for these site differences in reliability may be associated with greater difficulties in recognizing a thermal stimulus applied to the gingiva than to the cheeks or tongue. It is necessary to point out that the NRS scores recorded for gingival stimulation were generally low and only few subjects reported pain (> 50 on NRS).

The reliability results agree with those of Pigg et al, who also reported a poor reliability for warmth detection thresholds (WDTs) at the gingival sites and a large mean intraindividual variability.[2] These findings led the authors to conclude that WDT assessment is associated with a greater uncertainty so that clinically relevant changes in warmth perception may be more difficult to detect.[2] In addition, the study reported that the reliability for cold detection threshold (CDT) varied greatly, from poor to excellent, between different sites.[2] The authors hypothesized that this large variability could reflect variations in cold-sensitive afferent fiber density or biophysical properties.[2] The results of the present study support the conclusions based on the use of more advanced QST devices for intraoral use.

Despite the fact that the determination of thermal pain thresholds is widely used as a clinical and research tool in order to investigate the pathophysiology of pain conditions,[32–35] and knowledge about the reliability of a method is essential[11] in order to be used diagnostically, the reliability of intraoral thermal tests has been rarely investigated.[11] The custom-made devices used in the present study can be manufactured with minimal costs compared with state-of-the-art thermotesters like the ones used in the QST protocol from the German Research Network on Neuropathic Pain.[7] Thus, these devices may be useful in clinics without access to a thermotester for the examination of thermal sensitivity at intra- and extraoral regions.

It should be noted that for practical reasons, eg, due to time limitations, the reliability was only tested in the present study for the 5-mm-diameter device. Although it might be expected that the reliability would be similar for the other devices, further studies will be needed to test this hypothesis.

Spatial Summation

The second main finding of this study was that the diameter of the tapered end of the testing devices influenced the thermal sensitivity at the cheek and tongue regions. In general, stimulation with larger-diameter devices induced higher NRS scores. This is in accordance with the findings of Susser et al[20] and may be explained by spatial summation.[16,25,36,37] In the intraoral region, Pigg et al concluded that while the test sites affect orofacial thermal thresholds substantially, time variability and spatial summation on the tongue appear to be modest.[16] The present findings are in contrast to that conclusion, since stimulation with larger-diameter devices induced higher NRS scores at the tongue. Svensson et al have also shown spatial summation in the intraoral region by way of an argon laser with different stimulus diameters.[18] In the present study, participants could not detect the changes in stimulus diameters at the gingival sites, which is in agreement with previous studies.[16,18] However, the surface of the gingiva is usually not flat because of bony prominences or differences in the thickness of the gingiva. Therefore, when spatial summation is investigated at the gingival sites, thermal devices with a more flexible surface may be needed to secure complete contact between the test device and the gingival surface.

Stimulation With or Without Contact Between Lip and Device

The third main finding was that gingival testing with and without the use of the lip retractor produced similar NRS scores. It can be argued that both approaches involved an extra (unwanted) mechanical sensory input during the test due to the pulling of lips and cheeks with the use of the lip retractor and due to the contact between the device and the lip in the condition without the lip retractor. Indeed, the lip has to be either retracted or touched to be able to target the gingival sites. Interestingly, most participants spontaneously reported that it was more difficult for them to detect the temperature applied to the gingiva when the device also touched the lip than when it did not. Therefore, based on these comments, it is recommended to use a lip retractor in future studies.

Paradoxical Thermal Sensations

The final main finding of the study was that none of the healthy participants reported paradoxical thermal

sensations after stimulation of the face or tongue, which agrees with the findings by Rolke et al for paradoxical heat sensations at the skin.[7] All participants could detect the right temperature during heat or cold stimulation of these sites. In contrast, paradoxical thermal sensations were reported by a few participants when the gingiva was stimulated. Moreover, the participants often had more difficulty in discriminating between different temperatures during gingival than during cheek and tongue stimulation. A previous QST study showed that 15 of 21 subjects perceived one or more cold stimuli applied to the maxillary gingiva as warm, at least once during the thermal limen procedure.[2] Pigg et al therefore suggested that temperature discrimination is more difficult intraorally (eg, at the gingiva) than extraorally, since paradoxical heat sensation from cold stimulation was such a frequent outcome when stimulating the gingiva in healthy subjects.[2] This is an important finding that should be kept in mind when thermal stimulation is used to assess pathologic intraoral conditions.

Susser et al reported that paradoxical heat sensation occurs more frequently with the use of smaller probes or with preheating the test area and that paradoxical heat sensation may be a peripheral phenomenon in healthy subjects.[20] The association of paradoxical heat sensation with the probe size and the rate of temperature change may be explained by the relatively small number of A-delta fibers innervating the test region[20]; a smaller probe and a shorter stimulus duration all tend to reduce the amount of A-delta–evoked activity to less than the minimum required for a sensation.[20] The number of paradoxical heat sensations found in the present study was smaller than that reported in other studies,[2,14,38,39] though smaller devices were used. Differences in stimulus methodology may explain this discrepancy (eg, use of fixed intensity stimuli vs threshold measurements). On the other hand, a lack of temperature discrimination was reported more frequently than a paradoxical thermal sensation in this study.

In conclusion, the reliability of the thermal sensitivity recorded with the 5-mm-diameter device varied greatly from poor (for example, at the premolar gingival region with cold stimulation) to excellent (for example, at the cheek or tongue with cold stimulation). Moreover, the perceived intensity of the evoked sensations was dependent on the diameter of the probe and on the recording site. Thus, these simple, low-cost and easy-to-use thermal devices can be applied in settings without access to conventional thermal QST devices to test the somatosensory function of the trigeminal nerve.

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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, Jensen TS, 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. Rolke R, Baron R, Maier C, et al. Quantitative sensory testing in the German Research Network on Neuropathic Pain (DFNS): Standardized protocol and reference values. Pain 2006;123:231–243.
8. Thygesen TH, Nørholt SE, Jensen J, Svensson P. Spatial and temporal assessment of orofacial somatosensory sensitivity: A methodological study. J Orofac Pain 2007;21:19–28.
9. Naganawa T, Iida T, Baad-Hansen L, Ando T, Svensson P. Application of a new palpometer for intraoral mechanical pain sensitivity assessment. J Orofac Pain 2013;27:336–342.
10. Jensen TS, Baron R. Translation of symptoms and sighs into mechanisms in neuropathic pain. Pain 2003;102:1–8.
11. Wasner GL, Brock JA. Determinants of thermal pain thresholds in normal subjects. Clin Neurophysiol 2008;119:2389–2395.
12. Defrin R, Sheraizin A Malichi L, Shachen O. Spatial summation and spatial discrimination of cold pain: Effect of spatial configuration and skin type. Pain 2011;152:2739–2745.
13. Green BG, Zaharchuk R. Spatial variation in sensitivity as a factor in measurements of spatial summation of warmth and cold. Somatosens Mot Res 2001;18:181–190.
14. Defrin R, Givon R, Raz N, Urca G. Spatial summation and spatial discrimination of pain sensation. Pain 2006;126:123–131.
15. Price DD, McHaffie JG, Larson MA. Spatial summation of heat-induced pain: Influence of stimulus area and spatial separation of stimuli on perceived pain sensation intensity and unpleasantness. J Neurophysiol 1989;62:1270–1279.
16. Pigg M, Svensson P, List T. Orofacial thermal thresholds: Time-dependent variability and influence of spatial summation and test site. J Orofac Pain 2011;25:39–48.
17. Svensson P, Bjerring P, Arendt-Nielsen L, Nielsen JC, Kaaber S. Comparison of four laser types for experimental pain stimulation on oral mucosa and hairy skin. Lasers Surg Med 1991;11:313–324.
18. Svensson P, Bjerring P, Arendt-Nielsen L, Kaaber S. Quantitative determinations of sensory and pain thresholds on human oral mucosa by argon laser stimulation. Pain 1992;49:233–239.

19. Stohler CS, Kowalski CJ. Spatial and temporal summation of sensory and affective dimensions of deep somatic pain. Pain 1999;79:165–173.
20. Susser E, Sprecher E, Yarnitsky D. Paradoxical heat sensation in healthy subject: Peripherally conducted by Aδ or C fibers? Brain 1999;122:239–246.
21. Fruhstorfer H, Detering I. A simple thermode for rapid temperature change. Pflugers Arch 1974;349:83–85.
22. Kenshalo DR, Bergen DC. A device to measure cutaneous temperature sensitivity in humans and subhuman species. J Appl Physiol 1975;39:1038–1040.
23. Morrow TJ, Casey KL. A contact thermal stimulator for neurobehavioral research on temperature sensation. Brain Res Bull 1981;6:281–284.
24. Taylor JD, McGillis SL, Greenspan JD. Body site variation of heat pain sensitivity. Somatosens Mot Res 1993;10:455–465.
25. Nielsen J, Arendt-Nielsen L. Spatial summation of heat induced pain within and between dermatomes. Somatosens Mot Res 1997;14:119–125.
26. Baad-Hansen L, Pigg M, Ivanovic SE, et al. Intraoral somatosensory abnormalities in patients with atypical odontalgia—A controlled multicenter quantitative sensory testing study. Pain 2013;154:1287–1294.
27. Shrout PE, Fleiss JL. Intraclass correlations: Uses in assessing rater reliability. Psychol Bull 1979;86:420–428.
28. Cathcart S, Pritchard D. Reliability of pain threshold measurement in young adults. J Headache Pain 2006;7:21–26.
29. Meh D, Denislic M. Quantitative assessment of thermal and pain sensitivity. J Neurol Sci 1994;127:164–169.
30. Wasner GL, Brock JA. Determinants of thermal pain thresholds in normal subjects. Clin Neurophysiol 2008;119:2389–2395.
31. Heldestad V, Linder J, Sellersjö L, Nordh E. Reproducibility and influence of test modality order on thermal perception and thermal pain thresholds in quantitative sensory testing. Clin Neurophysiol 2010;121:1878–1885.
32. Verdugo R, Ochoa JL. Quantitative sensory thermotest. A key method for functional evaluation of small calibre afferent channels. Brain 1992;115:893–913.
33. Yarnitsky D. Quantitative sensory testing. Muscle Nerve 1997;20:198–204.
34. Baron R, Wasner G. Quantitative thermotest—Investigations of thermal and nociceptive afferents in neuropathy. Is a multicentric approach useful to investigate rare painful neuropathies? Schmerz 1998;12:209–211.
35. Klein T, Magerl W, Rolke R, Treede RD. Human surrogate models of neuropathic pain. Pain 2005;115:227–233.
36. Douglass DK, Carstens E, Watkins LR. Spatial summation in human thermal pain perception: Comparison with and between dermatomes. Pain 1992;50:197–202.
37. Price DD, Mchaffle JG, Larson MA. Spatial summation of heat-induced pain: Influence of stimulus area and spatial separation of stimuli on perceived pain sensation intensity and unpleasantness. J Neurophysiol 1989;62:1270–1279.
38. Hämäläinen H, Vartiainen M, Karvanen L, Järvilehto T. Paradoxical heat sensations During moderate cooling of the skin. Brain Res 1982;251:77–81.
39. Hansen C, Hopf HC, Treede RD. Paradoxical heat sensation in patients with multiple sclerosis. Evidence for a supraspinal integration of temperature sensation. Brain 1996;119:1729–1736.