Acute Oral Pain Intensity and Pain Threshold Assessed by Intensity Matching to Pain Induced by Electrical Stimuli

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Aims: *To investigate a recently developed pain-intensity matching device (Painmatcher) in terms of reproducibility, pain intensity, and unpleasantness experienced by healthy individuals upon pain threshold assessment, as well as differences in pain threshold between genders and between healthy individuals and patients with acute oral pain, and the relation between pain-intensity assessments by the Painmatcher and a visual analog scale (VAS) in the patients.* ***Methods:*** *Forty healthy individuals and 28 patients with acute oral pain participated. The Painmatcher produces an eventually noxious stimulus by increasing electrical impulses between 2 fingers. Pain thresholds were assessed twice in the healthy individuals and the provoked pain intensity and unpleasantness were recorded on a VAS. In the patients, pain threshold and ongoing pain were assessed with the Painmatcher and the ongoing pain was recorded on a VAS.* ***Results:*** *Painmatcher scores for the 2 pain threshold assessments were equally correlated in the healthy individuals and patients. VAS scores for ongoing pain and pain caused by the Painmatcher when the ongoing pain intensity was assessed were positively correlated. In the healthy individuals, the degree of unpleasantness was higher than the pain intensity at the pain threshold. The patients had a lower pain threshold than the healthy individuals.* ***Conclusion:*** *This study indicates that patients with acute oral pain have lower Painmatcher pain thresholds than healthy individuals, suggesting a general decrease in nociceptive thresholds in these patients. The Painmatcher seems to be as valid as a VAS for acute oral pain assessment. The Painmatcher pain threshold is highly reproducible but associated with unpleasantness.*

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Key words: facial pain, pain, pain measurement, pain threshold, visual analog scale

The experience of pain is multidimensional and comprises, for example, pain intensity, unpleasantness, fear, and anxiety. In many acute and chronic pain conditions, there are in addition, peripheral or central sensitization and impairments in central nervous system (CNS) inhibitory pathways, which in turn are factors contributing to spontaneous pain, allodynia, and hyperalgesia.[1–4]

Most pain-intensity measures seem to be strongly related to one another statistically and most appear to be valid when used to assess current pain.[5] However, each different method has its advantages and disadvantages. The visual analog scale (VAS) offers a standard method widely used to assess, for example, pain intensity and degree of unpleasantness experienced.[6,7] However, the VAS has

Fig 1 The pain-intensity matching device (score 0 to 60) consists of a unit for application of electricity to the thumb and index finger. The Painmatcher creates an eventually noxious stimulus by progressively increasing electrical intensity.

limitations in the assessment of pain intensity, since patients have to compare and grade their present pain intensity against the memory of previous pain experienced or the worst imaginable pain.[8,9]

A recently developed pain-intensity matching device, the Painmatcher, allows a patient to match present pain intensity in a certain region of the body to a physical sensation between the right thumb and index finger caused by an increasing electrical current that eventually produces a painful stimulation.[10]

The aims of this study were to investigate the Painmatcher reproducibility, degree of pain intensity and unpleasantness experienced by healthy individuals upon pain threshold assessment, differences in pain threshold between healthy male and female individuals, as well as between these healthy individuals and patients with acute oral pain, and the relation between pain-intensity assessments by the Painmatcher and a VAS in the patients.

Materials and Methods

Subjects

Forty healthy individuals comprising 11 males and 29 females with a median age (interquartile range) of 44 (22) years were included. The subjects did not report any ongoing pain, use of pain or anti-inflammatory medication, or recent or ongoing dental treatment.

Twenty-eight patients, 14 males and 14 females, with a median age of 46 (22) years also participated in this study. The group consisted of consecutive patients who sought treatment for acute oral pain at the Institute of Odontology, Karolinska Institutet, Huddinge, Sweden. Inclusion criteria were acute pulpitis, osteitis, or periodontitis with ongoing pain over a period of not more than 2 weeks.

Methods

The Painmatcher prototype (score 0 to 60) used in this study is a microprocessor-controlled constant-current electrical stimulation unit that provides rectangular pulses with a frequency of 10 Hz and 10 mA pulse amplitude to electrodes held by the subjects between their right thumb and index finger. It produces an eventually noxious stimulus as intensity or stimulation is progressively increased (Fig 1). The stimulation increase is obtained by increasing the pulse width from 0 to a possible maximum of 450 ms in increments of 7.5 ms, ie, 60 steps in all. The rate at which the pulse width increases is randomly and automatically selected by the Painmatcher from 1 of 3 available rates when the start button is pushed by the operator. The Painmatcher automatically records the score when the subject releases the electrodes, and the score is then displayed for the operator.

The Painmatcher was used to assess the pain threshold in all subjects as well as the oral pain intensity in the patients. The pain threshold was defined as the score obtained when the sensation experienced in the index finger and thumb became painful. The ongoing oral pain intensity was defined as the score obtained when the pain intensity in the right hand due to the electrical stimulation corresponded to the patients' ongoing oral pain intensity. The pain threshold and Painmatcher score for pain intensity were recorded 3 times each, and the mean value of these was used in the analysis.

The 100-mm VAS scaled from 0 to 100 with end points marked with no pain or unpleasantness and with worst pain or unpleasantness ever experienced.

Experimental Protocol

All recordings with the Painmatcher and VAS were performed after introductory trials in order to accustom the subject to the procedures.

To investigate the Painmatcher reproducibility, the pain threshold was assessed twice with a 5-minute interval in all subjects. In the healthy individuals, a VAS was used to record the pain intensity as well as unpleasantness experienced in the hand during pain-threshold assessment by the Painmatcher. In the patients, the oral pain intensity was assessed with the VAS. The pain threshold

Table 1 Intra- and Interindividual Coefficients of Variation in Pain Threshold Assessed with Painmatcher in 40 Healthy Individuals and 28 Patients with Acute Oral Pain

	Assessment	
	First	Second
Healthy individuals		
Intraindividual variation		
Median	11	8
IQR	6	7
Interindividual variation		
First measurement	75	60
Second measurement	59	55
Third measurement	56	58
Patients		
Intraindividual variation		
Median	6	8
IQR	8	8
Interindividual variation		
First measurement	107	98
Second measurement	103	100
Third measurement	101	99

The Painmatcher (score 0 to 60) was used to assess the pain threshold 2 times, 5 minutes apart (first and second assessment). Each assessment comprised 3 measurements of the pain threshold. For the intraindividual variation, the Table shows the median and interquartile range (IQR) for the group's individual coefficient of variation between the 3 measurements. Regarding the interindividual variation, the Table shows the coefficient of variation of the Painmatcher scores at each measurement.

Table 2 Pain Threshold, Pain Intensity, and Degree of Unpleasantness as Assessed by a Pain-Intensity Matching Device (Painmatcher) and a Visual Analog Scale (VAS) in 40 Healthy Individuals and 28 Patients with Acute Oral Pain

	Assessment		
	Median	IQR	n
Healthy individuals			
Pain threshold (Painmatcher)	13	10	40
Pain intensity when pain threshold was assessed with the Painmatcher (VAS)	19	30	38
Degree of unpleasantness when pain threshold was assessed with the Painmatcher (VAS)	31	38	38
Patients			
Pain threshold (Painmatcher)	8	8	28
Current pain intensity (Painmatcher)	7	5	28
Current pain intensity (VAS)	33	41	28
Pain intensity of Painmatcher stimuli when matched to oral pain intensity (VAS)	37	38	28
Degree of unpleasantness of Painmatcher stimuli when matched to oral pain intensity (VAS)	38	49	28

The Painmatcher (score 0 to 60) was used to assess the pain threshold. The VAS (score 0 to 100) was used to assess the degree of pain intensity and unpleasantness elicited by the Painmatcher when pain threshold was assessed in the healthy individuals as well as the ongoing oral pain in the patients. IQR = interquartile range.

and oral pain intensity were then recorded with the Painmatcher. Finally, a VAS was used to record the pain intensity and degree of unpleasantness experienced in the hand during the Painmatcher assessment of the oral pain intensity. The ratios between the Painmatcher score for ongoing pain and pain threshold were used in the analyses comparing the Painmatcher and VAS.

Statistics

Nonparametric statistical methods were used and included median and interquartile range (IQR = 75th percentile to 25th percentile) for descriptive statistics. However, the parametric coefficient of variation (CV = 100 × standard deviation/mean) was used to describe the degree of intra- and interindividual variation. The significance of differences within groups was evaluated with the sign test. The significance of differences between patients and healthy individuals was assessed with the Mann-Whitney *U* test. The significance of correlations between measurements within each group was tested with the Spearman rank correlation test. Relative operating characteristic (ROC) curves were used for illustration of systematic disagreement between the 2 pain threshold assessments, where the axes represented the cumulative proportions of the 2 Painmatcher assessments. To evaluate the reliability between the first and second observation, the random individual changes (RV) and systematic change for the group in position (RP) were calculated.[11] Values of RV and RP close to 0 indicate absence of random or systematic differences, respectively, and the corresponding ROC curve will be close to the main diagonal.[11] A probability level of less than .05 was considered as significant.

Results

Painmatcher Reproducibility

Table 1 shows the intra- and interindividual variation of pain-threshold assessment in the healthy individuals and in the patients, and Table 2 shows the Painmatcher and VAS scores for both groups. The Painmatcher scores for the 2 pain-threshold assessments did not differ significantly, neither in the healthy individuals (P = .200) nor in the patients (P = .523). There were positive correlations

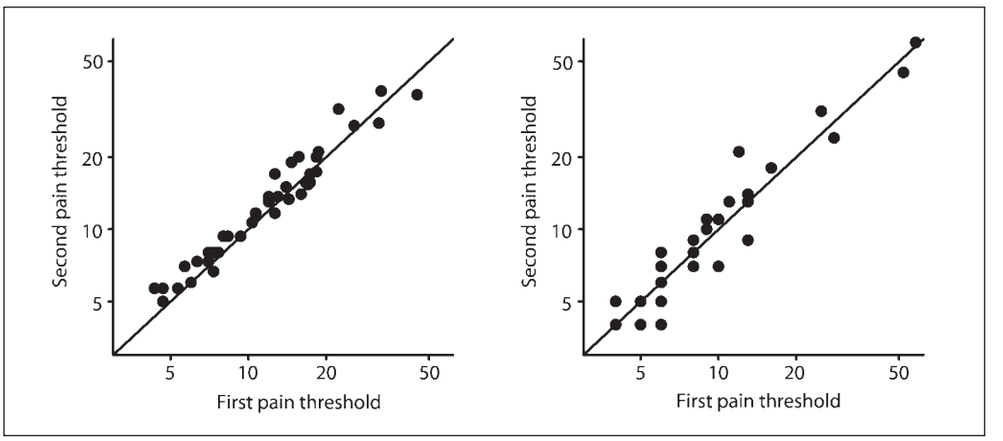

Fig 2 Scatter-plot panel showing the relations between the pain threshold at the first and second assessment with the Painmatcher in 40 healthy individuals *(left)* and 28 patients with acute oral pain *(right)*. The correlations between the assessments were significant for both the group of healthy individuals (r_s = 0.97, n = 40, $P < .001$) as well as for the patients (r_s = 0.93, n = 28, $P < .001$). The solid line represents complete agreement between the assessments. There was a lower random individual difference between the assessments for the healthy individuals (RV = 0.033) than for the patients (RV = 0.078).

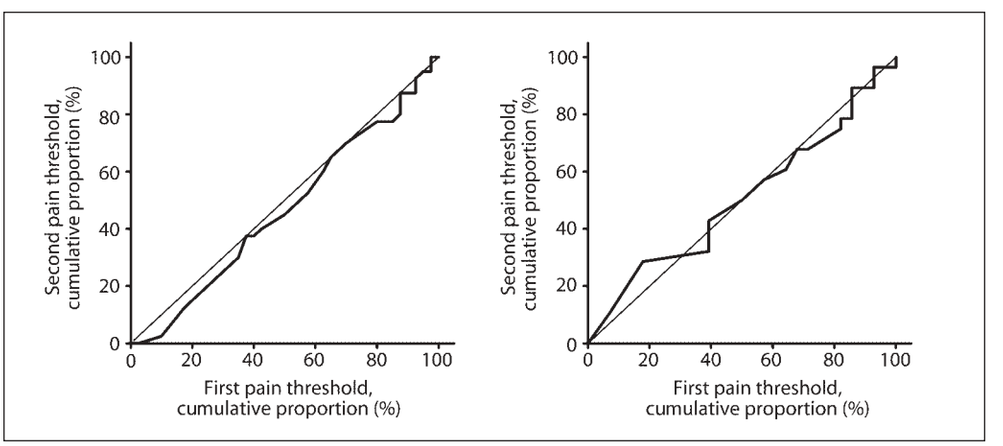

Fig 3 Panel of relative operating characteristics (ROC) curves showing the systematic difference in position and concentration between the first and second assessment of pain threshold with the Painmatcher in 40 healthy individuals *(left)* and 28 patients with acute oral pain *(right)*. The thin solid line represents complete agreement between the assessments. The systematic difference between the assessments for the healthy individuals (RP = 0.002) and patients (RP = –0.001) were similar. For the healthy individuals, however, the first pain threshold assessment tended to be systematically higher than the second (the ROC is below the solid thin line for the major part of the range).

between these assessments in both the healthy individuals as well as in the patients (r_s = 0.97, n = 40, $P < .001$ and r_s = 0.93, n = 28, $P < .001$, respectively; Fig 2). There was a lower random individual change for the healthy individuals (RV = 0.033) than for the patients (RV = 0.078), while the systematic change in position was similar (RP = 0.002 and RP = –0.001, respectively; Fig 3).

Pain Thresholds

There were no gender differences in pain threshold (healthy individuals: $P = .413$; patients: $P = .799$). The patients had lower pain thresholds than the healthy individuals ($P = .045$; Fig 4).

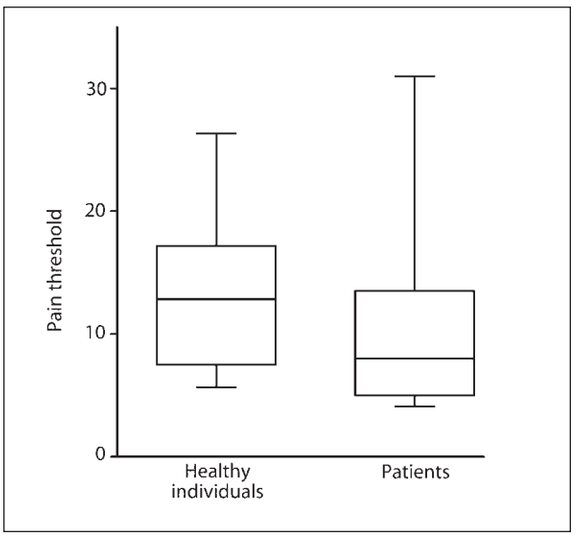

Fig 4 Box plot (10th, 25th, 50th, 75th, and 90th percentile) showing the electrical pain threshold as assessed with the Painmatcher in 40 healthy individuals and 28 patients with acute oral pain. The patients had significantly lower electrical pain thresholds ($P = .045$).

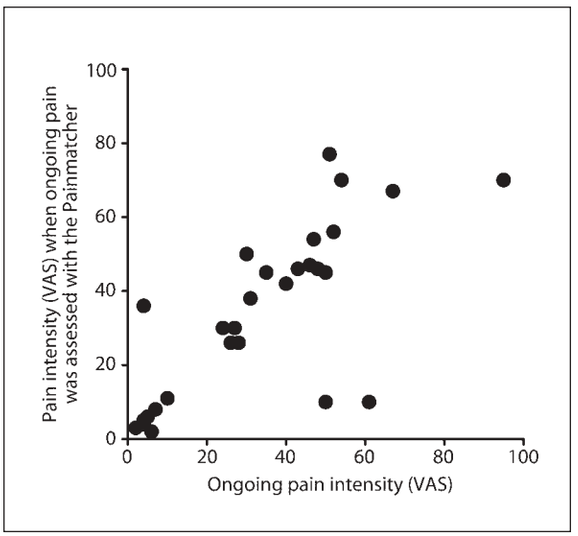

Fig 5 Scatter plot showing the relation between the visual analog scale (VAS) scores for ongoing pain intensity and VAS scores for pain intensity experienced when the ongoing pain intensity was assessed with the Painmatcher in 28 patients with acute oral pain ($r_s = 0.76$, n = 28, $P < .001$).

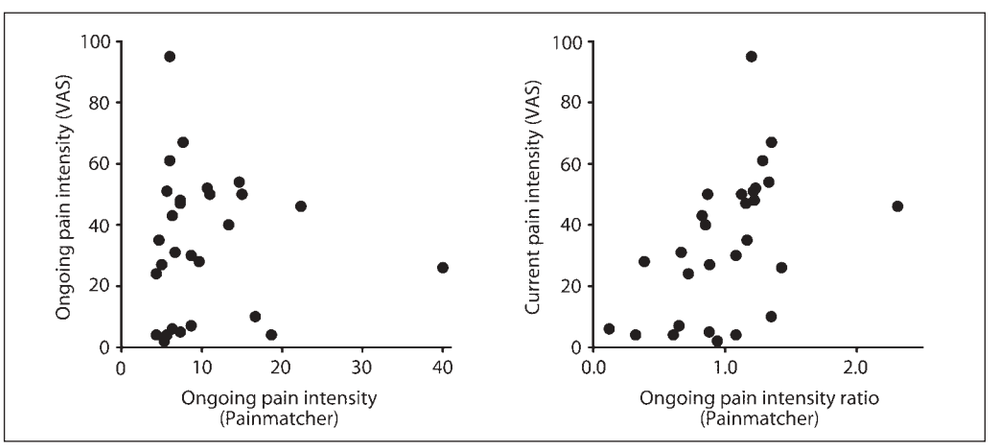

Fig 6 Scatter-plot panel showing *(left)* relation between the ongoing pain intensity as assessed with the Painmatcher and a visual analog scale (VAS; $r_s = 0.18$, n = 28, $P = .354$) and *(right)* the relation between ongoing pain ratio (ongoing pain-intensity score/pain threshold score) as assessed with the Painmatcher and the ongoing pain intensity as assessed with a VAS in 28 patients with acute oral pain ($r_s = 0.63$, n = 28, $P = .004$).

Relation Between Ongoing Oral Pain Intensity Assessments by the Painmatcher and a VAS

The ongoing pain intensity, as assessed with the VAS, was positively correlated to the VAS rating of pain intensity when the ongoing pain intensity was assessed with the Painmatcher ($r_s = 0.76$, n = 28, $P < .001$; Fig 5).

The ongoing pain intensity assessed with the Painmatcher and that assessed with the VAS were not significantly correlated ($r_s = 0.18$, n = 28, $P = .354$; Fig 6). The ratio between the Painmatcher score for ongoing pain and pain threshold was positively correlated with the VAS score for ongoing pain ($r_s = 0.63$, n = 28, $P = .004$; Fig 6). This ratio was also correlated with the pain intensity caused by the Painmatcher when the ongoing pain was assessed ($r_s = 0.60$, n = 28, $P = .007$).

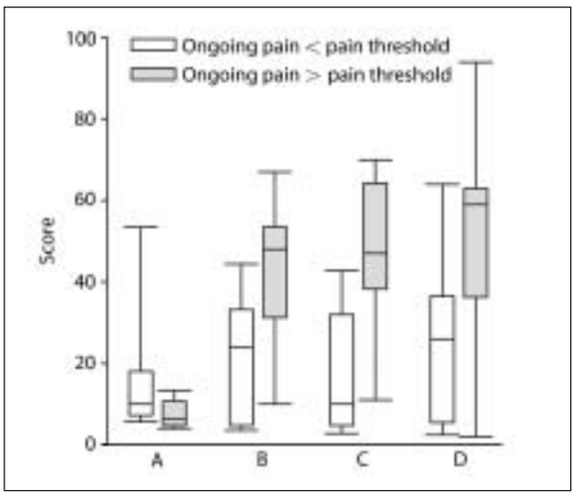

Fig 7 Box plot (10th, 25th, 50th, 75th, and 90th percentile) showing the distributions of Painmatcher scores for pain threshold (A) and visual analog scale (VAS) scores for ongoing pain intensity (B) as well as pain intensity (C) and unpleasantness (D) experienced when the ongoing pain intensity was assessed with the Painmatcher in patients reporting ongoing pain intensity lower than their pain threshold (n = 13) and patients with ongoing pain intensity higher than their pain threshold (n = 15). Patients reporting lower ongoing pain intensity than pain threshold had higher pain threshold (A; $P = .041$) and lower ongoing pain intensity (B; $P = .004$) as well as pain intensity and unpleasantness (C; $P < .001$ and D; $P = .038$, respectively) than the other patients.

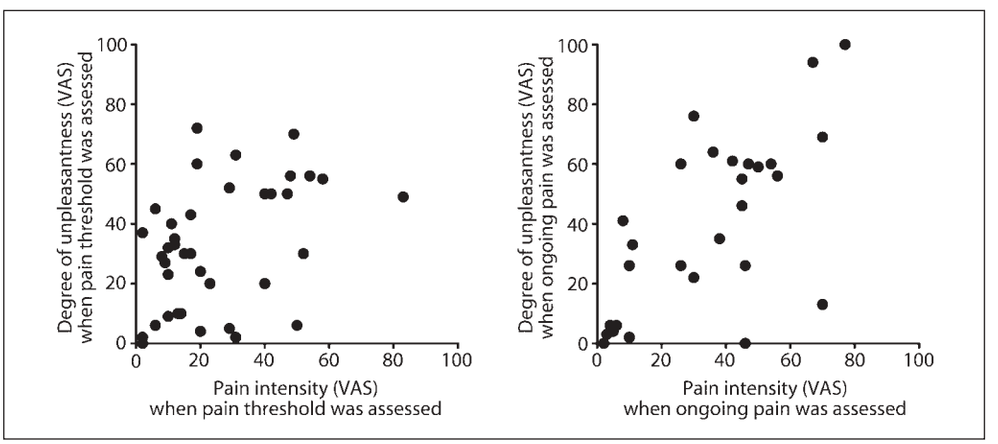

Fig 8 Scatter-plot panel showing the relations between the visual analog scale (VAS) scores for pain intensity and unpleasantness experienced when the pain threshold was assessed with the Painmatcher in 40 healthy individuals (*left*; $r_s = 0.42$, n = 40, $P = .009$) and when the ongoing pain intensity was assessed with the Painmatcher in 28 patients with acute oral pain (*right*; $r_s = 0.62$, n = 28, $P < .001$).

Thirteen (46%; Fig 6) of the patients had a lower Painmatcher score for ongoing pain than pain threshold. These patients reported or showed lower ongoing pain as assessed with the VAS ($P = .004$), higher pain threshold ($P = .041$), as well as lower pain intensity and unpleasantness when the oral pain intensity was assessed with the Painmatcher ($P < .001$ and $P = .038$, respectively) compared to the patients with an oral pain intensity score higher than the pain threshold (Fig 7). There were no significant differences between these groups regarding any other variable.

Relation Between Ratings of Pain Intensity and Unpleasantness

The VAS score for degree of unpleasantness was higher than the VAS score for pain intensity experienced when the pain threshold was assessed with the Painmatcher ($P = .045$), and these variables were positively correlated ($r_s = 0.42$, n = 38, $P = .009$; Fig 8) in the healthy individuals.

For the patients, the VAS scores for pain intensity and unpleasantness experienced when the ongoing pain intensity was assessed with the Painmatcher were positively correlated ($r_s = 0.62$, n = 28, $P < .001$; Fig 8). The VAS score for pain intensity was not significantly different from the degree of unpleasantness experienced when the ongoing pain intensity was assessed ($P = .103$).

Discussion

This study has shown that patients with acute oral pain have lower pain thresholds than healthy individuals, as assessed with the Painmatcher, suggesting that these patients have a general decrease in nociceptive thresholds. The Painmatcher appears to be as valid as a VAS for assessing ongoing acute oral pain, and the assessment of electrical pain threshold with the Painmatcher is highly reproducible but associated with unpleasantness.

Lower electrical pain thresholds were found in the patients with acute oral pain than in the healthy individuals. Several studies have shown that patients with various pain conditions may develop a generalized decrease in nociceptive thresholds. This has been suggested to be due to central sensitization induced by the nociceptive input.[3,12–15] Moller and Pinkerton[16] showed that patients with chronic pain had lower electrical skin-pain thresholds than did healthy individuals. Likewise, decreased pressure-pain thresholds at a remote nonpainful site have been found in patients with long-term pain conditions such as chronic trapezius myalgia,[13] rheumatoid arthritis,[14] tension-type headache,[17] or temporomandibular disorder,[18] suggesting widespread altered central processing of nociceptive input in these conditions. Indeed, increased pain sensitivity in nonpainful regions has been proposed to be a disorder of pain modulation in conditions with long pain durations.[15,18,19] However, the patients in our study had acute pain with a maximum duration of no more than 2 weeks. Our results thus suggest that acute pain of relatively short duration may also influence central nociceptive processing in nonpainful areas. Minor nerve injury and/or inflammation have been found to be able to initiate and maintain central processes that increase sensitivity to electrical stimuli.[20] However, those changes were only found in the painful areas but it indicates that also minor peripheral changes may alter central processing of nociceptive input, which is supported by our results. Another explanation for the lower pain thresholds in the patients could be that the ongoing pain influenced the pain threshold by causing difficulties for the patients to focus their attention on the Painmatcher sensation. However, the similar and high degrees of pain-threshold reproducibility in both patients and healthy individuals indicate that this explanation is less likely.

In healthy individuals, noxious stimulation in one region may increase pain thresholds in another region. This phenomenon has been explained by activation of so-called 'diffuse noxious inhibitory controls' (DNIC) that cause widespread inhibition of wide dynamic range neurons in the CNS by noxious stimulation.[21–23] However, in patients with chronic trapezius myalgia or short- or long-term rheumatoid arthritis, no raised pressure-pain thresholds could be detected in nonpainful areas as might be expected if DNIC mechanisms were operative as a result of the pain caused by the disease[13,14]; one explanation suggested was that the ongoing pain was of too low an intensity to induce DNIC mechanisms. The overall pain intensity was similar and overlapping in these studies and the present study, suggesting that the degree of pain intensity was too low to induce DNIC mechanisms in the patients in the present study as well.

The present study did not find any gender difference in pain threshold, neither in healthy individuals nor in patients. Other studies have shown lower pain thresholds in healthy females evoked, for example, by mechanical, thermal, or electrical stimuli.[24–26] Edwards et al[25] found lower cutaneous thermal pain thresholds in healthy females but did not observe any gender difference in patients with acute pulpitis. While this latter observation is in agreement with our results in the patients, the lack of a gender difference in the healthy individuals is difficult to explain. Sjölinger et al found with the Painmatcher (personal communication), lower pain thresholds in 14 young (19 to 25 years) healthy females than in 14 males of similar age, indicating that females, in fact, have lower Painmatcher pain thresholds even though it was undetectable in the present study. Our patient group was equally balanced gender-wise, but most of the healthy individuals were females. The difference in gender distribution between the groups should not influence our results regarding pain thresholds since the patients had lower pain thresholds despite the large female proportion in the healthy group, regardless of the fact that females nevertheless might have lower pain thresholds than males.

The patients estimated the pain intensity caused by the Painmatcher to be equal to the ongoing oral pain when the ongoing acute pain was assessed with the Painmatcher. The Painmatcher thus seems to have a similar degree of validity as a VAS in this situation. However, there was no significant correlation between the VAS and Painmatcher scores for ongoing pain intensity. On the other hand, the relevance of the significant association between a high VAS score and a high ratio between the ongoing pain and pain threshold is interesting. The use of this ratio, however, needs to be further investigated since almost half of the subjects ranked the ongoing

oral pain lower than the pain threshold with the Painmatcher. This was another unexpected finding and is difficult to explain at present although there were differences between these patients and the other patients regarding some of the investigated variables. Possibly, the degree of unpleasantness experienced from the Painmatcher may be involved, as indicated by the difference in degree of unpleasantness between these patient groups. The degree of unpleasantness relative to the pain intensity has been found to differ between different types of experimental noxious stimuli; ischemic exercise and cold-pressor pain evoke higher estimates of unpleasantness, and contact heat stimuli provoke less unpleasantness.[27] How the Painmatcher stimuli relate to these modalities is not known. The high degree of unpleasantness experienced when the pain threshold was assessed suggests a high relative unpleasantness, which has been suggested to mimic chronic pain.[27] The Painmatcher stimuli could thus be better suited for assessment of chronic pains than acute pains, but this has to be further investigated. Nevertheless, pain threshold and intensity assessment with a Painmatcher has some advantages. Compared to the use of a VAS, Painmatcher recordings are performed with the subjects blinded to the readings. Assessment of ongoing pain intensity is made by comparison of the actual pain intensity to a painful stimuli experienced at the same time, which in theory could be a superior method to the comparison to memories of 'no pain' and 'worst pain ever experienced' used with a VAS. In addition, the Painmatcher has been found to be at least as reliable and responsive as a VAS and a numerical rating scale regarding detection of pain-treatment results, ie, the Painmatcher might be capable to detect individual changes in pain intensity with time.[10]

According to the definition, the pain threshold should correspond to a very low pain intensity, ie, the lowest VAS score. However, 47% of the healthy individuals reported pain intensities higher than 20 mm on the VAS, and the higher pain intensity the assessment caused, the higher degree of unpleasantness that was experienced. This indicates that the assessment of the pain threshold with the Painmatcher is associated with pain and unpleasantness in healthy individuals. The high VAS scores were unexpected but could be due to the subjects' difficulties in responding exactly when the sensation in the fingers changed to pain.

The 2 assessments of the pain threshold showed low intraindividual variation. Reliability coefficients were 0.97 for the healthy individuals and 0.93 for the patients, coefficients that demonstrate high reproducibility for pain threshold assessment with the Painmatcher.[28] This is further supported by the similar low degrees of systematic differences between the assessments. The patients showed a higher random individual difference between assessments than did the healthy subjects. One explanation for this could be that the pain threshold is affected by their ongoing oral pain, which also may explain the tendency to a larger variation of pain thresholds in the patients. The clinical relevance for this must, however, be considered insignificant since there was no difference between the 2 pain threshold assessments. This is confirmed by the rather small deviation of the ROC from the main diagonal which, taken together, show that pain threshold assessments are stable over this time interval.

In conclusion, this study indicates that the assessment of electrical pain threshold with the Painmatcher is highly reproducible but is associated with unpleasantness. Furthermore, patients with acute oral pain have lower pain thresholds than healthy individuals, as assessed with a Painmatcher, suggesting that these patients have a general decrease in nociceptive thresholds. The Painmatcher seems to be as valid as a VAS for assessing ongoing acute oral pain.

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