Pressure Pain Threshold of the Posterior Aspect of the Temporomandibular Joint Measured with a Semi-Spherical Probe

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Aims: *To develop and test a probe for measurement of the pressure pain threshold (PPT) over the posterior aspect of the temporomandibular joint (TMJ) in healthy individuals, including determination of PPT levels, reliability, and the smallest detectable difference (SDD) between measurements.* ***Methods:*** *A semi-spherical probe was designed to measure PPT levels over the posterior aspect of the TMJ through the external auditory meatus. The probe was connected to an electronic algometer. Three consecutive measurements were performed with this probe over the posterior and lateral aspects of the left and right TMJs as well as over a reference point on the forehead (glabella) in 31 healthy subjects: 10 male and 21 female. Measurements were also performed for comparison with a conventional flat probe with a 1 cm² area over the lateral aspect of the TMJ and the reference point.* ***Results:*** *The PPT measured with the semi-spherical probe and the conventional probe showed similar degrees of interindividual variation and reproducibility. The relative SDD, expressed as the percentage of the mean PPT for 2 measurements, showed similar levels for the flat and semi-spherical probes, ie, 28% to 32% of the mean PPT at the TMJ.* ***Conclusion:*** *The semi-spherical probe shows similar reliability and relative SDD for measurement of PPT levels over the posterior aspect of the TMJ in healthy individuals as measurement over the lateral aspect with a flat probe. Measurement of the posterior PPT with a semi-spherical probe may be a useful adjunct to conventional lateral PPT measurements.*
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Key words: algometer probe, healthy, pressure pain threshold, smallest detectable difference, temporomandibular joint

The measurement of pressure pain threshold (PPT) with algometers has been introduced to quantify tenderness with better reliability than by digital palpation.[1–3] In patients, PPT measurements may be used for diagnostic purposes as well as a parameter for studies of treatment effect. The values of the PPT in healthy individuals have then to be used as a reference for the values in patients. However, a potential diagnostic problem is the considerable overlap of PPT values in patients and healthy individuals. Several studies have been published regarding pressure algometry of the temporomandibular joint (TMJ) with different instruments.[4–6] Reliability studies have shown good to excellent intraexaminer reproducibility and interexaminer agreement for the lateral aspect of the joint.[4,5]

Fig 1 Electronic algometer with the semi-spherical probe.

Fig 2 Measurement of pressure pain threshold on the posterior aspect of the temporomandibular joint.

Digital palpation through the external auditory meatus is commonly used to assess tenderness of the posterior aspect of the TMJ. There is a small distance between the distolateral part of the mandibular condyle and the anterolateral wall of the external auditory meatus when the teeth are kept together. However, digital palpation of the joint by this approach is difficult because of the small dimension of the external auditory meatus. Algometric measurement could be an alternative to palpation over the posterior aspect. Nonetheless, to reach the posterior part of the condyle with certainty, an approach via the external auditory meatus is necessary, which is impossible with a flat probe. In a study by Chung et al,[4] the PPT of the posterior aspect of the TMJ was measured with a flat probe on the skin in the pre-auricular area posterior to the TMJ with an anterior direction, and the subject keeping the mouth open. However, the authors described technical problems during these measurements, since the algometer tended to slip from the area during measurements, and the contact area is uncertain as well. It was therefore considered of interest to design and test a special probe for PPT measurements by the posterior approach.

The smallest detectable difference (SDD) between 2 measurements is another aspect of reliability and of major interest in PPT studies of treatment outcome. To the best of our knowledge, no SDD values have been reported for PPT of the TMJ regarding healthy individuals or patients. The SDD is the smallest detectable difference that can statistically be distinguished from the methodologic error of measurement. The methodologic error of PPT measurement can be regarded as a compound of variations in the measuring instrument, the biologic variation of the variable, variability in examiner experience, and psychologic variations between subjects. Although SDD is dependent on the observer, the context, and the individual being examined, it can be useful for evaluating treatment outcome. A statistically significant difference between measurements is the primary outcome measure, but the SDD is an important secondary step to account for the error inherent in the method.

The aim of this study was to develop and test a probe for measurement of the PPT of the posterior aspect of the TMJ in healthy individuals as well as to determine PPT levels, reliability, and SDD between repeated measurements.

Materials and Methods

Probe Design

Forty silicone impressions of the external auditory meatus were used to determine the position of the lateroposterior part of the mandibular condyle and to measure the dimensions of the lateral part of the auditory meatus. A probe with a length of 10 mm and a semi-spherical tip with 6 mm diameter was made according to the data obtained. The probe was connected to an electronic algometer (Figs 1 and 2). The algometer (Somedic) includes a handpiece with a digital display that indicates the amount of pressure applied as well as the rate of increase in pressure. A switch with a button operated by the patient is connected to the algometer. The patient is instructed to press the button when the sensation of pressure turns into pain. The current PPT level, which then remains displayed, is

recorded. When the conventional flat probe is used with this algometer, the force is converted to pressure (kPa), the area being 100 mm^2. The area of the semi-spherical surface was 57 mm^2.

This surface is not always identical with the contact area in the auditory meatus, and the force is distributed with a concentration toward the center of the area. The values on the display are shown in units of force per area but not recalculated to kPa. Thus, direct comparison should not be made between numerical values of pressure obtained with the semi-spherical and flat probes.

Subjects

Ten healthy male and 21 healthy female subjects, without pain from the TMJ, were recruited to the study. Seven of the individuals were dental students, 13 were staff members at the Institute of Odontology, and 11 were attending their annual recall visits in a private dental office. Pain at maximum voluntary mouth opening and joint tenderness to palpation of the lateral or posterior aspect of the TMJ were additional criteria for exclusion. The mean age of the males was 50 years (SD = 15) and of the females 45 years (SD = 19).

Measurements

The PPTs over the posterior and lateral aspects of the left and right TMJs as well as a reference point (glabella) on the forehead were determined with the semi-spherical probe, and the pressure applied by the probe was increased at a rate of 50 kPa/s. During the measurement at the posterior aspect, the subjects were asked to keep their teeth together without clenching. The PPTs at glabella and the lateral aspect of both joints were also determined, using a standard probe with a flat 1 cm^2 circular surface and increasing the pressure at 50 kPa/s. The sites were measured in the same order in all subjects. The test procedure consisted of 3 cycles with 8 measurements in each, 3 with the flat probe followed by 5 with the semi-spherical probe, for a total of 24 measurements. The interval between the beginning of each measurement was 2 minutes, resulting in a total time for the 3 cycles of 48 minutes. The sites were measured in the following order with the flat probe: glabella, TMJ lateral right, TMJ lateral left; and with the semi-spherical probe: glabella, TMJ lateral right, TMJ lateral left, TMJ posterior right, TMJ posterior left. All measurements were performed by the same examiner (SN).

Before being recruited to the study, the subjects had been informed about the procedure and had given their informed consent. The study was approved by the Ethical Committee at Huddinge University Hospital (application no. 40/2000).

Statistics

The Kolmogorov-Smirnov test was used to test for normal distribution of the variables, and all variables were found to be normally distributed. For the TMJ, lateral and posterior aspects, the PPT was expressed as the mean values for the right and left side. The differences between the 3 consecutive measurements were tested by 1-way analysis of variance (ANOVA) for repeated measures with the Bonferroni test for correction of multiple comparisons. The differences in the PPT between genders were analyzed by the independent Student t test. A significance level of $P < .05$ was chosen. The measurement error was estimated by the standard deviation (SD) of repeated measurements on the same subject and its coefficient of variation (CV) in percent of the mean of 2 consecutive measurements

$$CV = \frac{SD \times 100}{\bar{\chi}}$$

The SDD between 2 consecutive PPT measurements at the same site was calculated by 2 different formulas: $SDD = 1.96\sqrt{2}\ SEM_p$, where SEM = standard error of the measurement $s\sqrt{(1-r)}$, r = Pearson's product-moment correlation coefficient, s = standard deviation; as well as the 95% limits of agreement (LOA) method. The LOA was calculated as $mean_{diff} \pm 2s_{diff}$, where $mean_{diff}$ is the mean of the differences between measurements and s_{diff} is the standard deviation of these differences.[7] For each method, the SDD was also calculated as percentage of the mean of the 2 measurements (SDD%)

$$SDD\% = \frac{SDD \times 100}{\bar{\chi}}$$

Results

Reliability of PPT Levels

Table 1 shows the results of 3 consecutive measurements with the semi-spherical probe and with the flat probe at all tested sites for the 2 genders. There was no significant difference between the 3 measurements at the posterior aspect of the TMJ. The measurement error for both probes, expressed

Table 1 Pressure Pain Thresholds (PPTs) and the Interindividual Variation in 31 Healthy Subjects (Mean of 3 Consecutive Measurements in Units of Force with Flat [F] and Semi-Spherical [S] Probes)

		Females						Males						
Site	Probe	Mean	SD	CV	10th p	90th p	n	Mean	SD	CV	10th p	90th p	n	*P*
Glabella	F	408	121.1	30	242	559	21	576	192.4	33	333	869	10	.006
TMJ lat	F	273	71.8	26	200	400	21	364	133.7	37	210	632	10	.069
TMJ post	S	167	39.3	26	110	226	21	200	73.0	37	112	326	10	.207

TMJ lat = lateral aspect of the temporomandibular joint, TMJ post = posterior aspect of the temporomandibular joint.
SD = standard deviation, CV = coefficient of variation in percent, 10th p = 10th percentile, 90th p = 90th percentile, *P* = *P* value for difference between genders.

Table 2 Measurement Error for Pressure Pain Thresholds (PPTs) Obtained with Flat and Semi-Spherical Probes Over Glabella and the Lateral and Posterior Aspects of the Temporomandibular Joint in 31 Healthy Individuals

	M1 – M2			M2 – M3		
	Mean	SD	CV	Mean	SD	CV
Flat probe						
Glabella	465	95.8	21	456	89.9	20
TMJ lat	304	48.5	16	295	47.0	16
Semi-spherical probe						
TMJ post	178	28.9	16	179	25.9	15

TMJ lat = lateral aspect of the temporomandibular joint, TMJ post = posterior aspect of the temporomandibular joint.
For the TMJ the mean of the right and left TMJ is shown. The measurement error is calculated as the standard deviation of repeated measurements on the same subject (SD) and the coefficient of variation (CV) in percent for 2 consecutive measurements (M1 – M2 and M2 – M3).

as the standard deviation of repeated measurements on the same subject, is shown in Table 2. The interindividual variation of the PPT (as expressed by CV) was similar for the semi-spherical probe and the flat probes (Table 1).

Gender Difference

The male subjects showed higher PPT values at the glabella with the flat probe than the female subjects ($P = .006$). The 10th percentile, which here is considered as the lower limit for healthy individuals, thus differed between genders for the flat probe at the glabella, but not at the TMJ. No gender difference was found at the posterior aspect of the TMJ with the semi-spherical probe.

SDD

The SDD and SDD% values are shown in Table 3. The relative SDD expressed as the percentage of the mean PPT for 2 measurements showed similar levels for the flat and semi-spherical probes, ie, 28% to 32% of the mean PPT at the TMJ. For the PPT measured with the semi-spherical probe, at least a difference of 56 units was necessary for the change between 2 consecutive measurements to be significantly different from methodologic error in the measurement. For the flat probe at the lateral aspect of the TMJ, the difference had to be 91 units.

Discussion

The semi-spherical probe showed low but acceptable reproducibility regarding measurements of the PPT over the posterior aspect of the TMJ and the same measurement error as the flat probe. The gender difference at the posterior aspect also seems to be small according to our results. The PPT values measured with the flat probe at the lateral aspect of the TMJ were higher in our study than those found by Chung et al[4] for males as well as for females. We did not find it appropriate to make comparisons with our results regarding the PPT levels of the posterior aspect, since we used a probe with a smaller contact area that was inserted into the external auditory meatus. However, the contact area of the semi-spherical probe can be expected to be approximately the same for measurements in the same area and in the same patient at different time points. A similar kind of approximation occurs during measurement with the flat probe, since the angle of the probe toward the skin surface cannot be determined in the clinical setting.

According to our results, the SDD means that an individual change in PPT at the posterior aspect of the TMJ has to be more than 56 units to be distinguished from the methodologic error of the measurements. At the lateral aspect and with the flat probe, the corresponding value has to be more than 91 units. For both probes this corresponds to

Table 3 The Smallest Detectable Difference (SDD) Between 2 Consecutive Measurements of Pressure Pain Thresholds (PPTs) in 31 Healthy Individuals Obtained with Flat and Semi-Spherical Probes

	Mean	SD	*r*	SEMp	SDD	SDD%	Mean diff	SD diff	SDD_{LOA}	SDD%
Flat probe										
M1 – M2										
Glabella	465	166.4	0.84	67	184	40	18	95.8	–173 to 210	41
TMJ lat	304	108.9	0.92	31	85	28	24	48.5	–73 to 121	32
M2 – M3										
Glabella	456	172.9	0.87	62	172	38	–2	89.9	–181 to 178	39
TMJ lat	295	104.6	0.90	33	91	31	–7	47.0	–94 to 87	32
Semi-spherical probe										
M1 – M2										
TMJ post	178	54.5	0.86	20	56	32	–5	28.9	–62 to 53	32
M2 – M3										
TMJ post	179	56.7	0.90	18	50	28	4	25.9	–48 to 56	29

TMJ lat = lateral aspect of the temporomandibular joint, TMJ post = posterior aspect of the temporomandibular joint; M1 = measurement 1; M2 = measurement 2; M3 = measurement 3; SD = standard deviation of PPT; *r* = Pearson's correlation coefficient; $mean_{diff}$ = mean of the difference between pairs of measurements; SD diff = standard deviation of the difference between pairs of measurements.
The SDD is shown calculated by 2 methods: *(1)* by standard error of the procedure (SEMp), *(2)* by the 95% limits of agreement (LOA = $mean_{diff}$ ± 2SD diff). The relative SDD (SDD%) is shown calculated as percentage of the mean of the 2 measurements.

a relative SDD of 32% of the mean PPT. Few studies have dealt with the SDD for measurements of clinical variables in healthy individuals or patients. The SDD for maximal mouth opening was reported by Kropmans et al.[8] They calculated the SDD from earlier studies by Agerberg[9] and Stegenga et al[10] and reported an SDD value of 5 mm, corresponding to 9% to 11% of the mean maximal mouth opening.

To our knowledge no studies have shown the SDD for pain on palpation for the TMJ, but for general joint pain the SDD of rheumatoid arthritis patients has been presented by Lassere et al.[11] For pain measured by a visual analog scale (VAS), the SDD was found to be 30% of maximum values, which if recalculated to SDD% for mean values corresponds to 52%. Whether a relative SDD of 32% for PPT as found in our study is high in comparison to that of VAS and palpation of the TMJ calls for further study.

The practical advantage with the semi-spherical design is the possibility of carrying out measurements at the posterior aspect of the joint where there is a modest amount of tissue between the probe and the joint components. It also has the same contact area regardless of different angles of the probe against the skin surface. However, it is only intended to be used for comparison of the PPT obtained in the same individual at different time points by one and the same examiner. The clinical value of the method has to be validated by comparisons with patient samples.

In conclusion, the semi-spherical probe shows reliability for measurement of PPT values at the posterior aspect of the TMJ in healthy individuals, which is similar to the reliability of measurements at the lateral aspect with a flat conventional probe. Measurements of the PPT at the posterior aspect of the TMJ with a semi-spherical probe may be a useful adjunct to conventional lateral PPT measurements.

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