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RESEARCH AND EDUCATION

The reliability of a visual analog scale for determining the preferred chewing side

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ABSTRACT

Statement of problem. Although the visual analog scale (VAS) is a simple tool for quantitatively measuring symptom perception, no studies have used the VAS to assess the degree of subjective masticatory laterality.

Purpose. The purpose of this study was to assess the reliability of the VAS for determining the preferred chewing side (PCS) and to compare it with other methods.

Material and methods. A cross-sectional study was conducted in which 42 adults with natural dentition performed 2 masticatory sessions. Eight different methods were used to determine the PCS by combining different definitions, food tests, measurements, and number of cycles assessed. A test-retest was performed in 10 participants to evaluate the reliability of each method using the intraclass correlation coefficient. To assess the validity of the different methods, the Pearson correlations were performed (α=.05) between the 8 methods.

Results. Self-assessment using the VAS had the highest reliability; it also had a positive and significant relationship with 6 of the 7 other methods. The method that showed the best validity used bagged silicone as the test food, determined the PCS by video recording, and assessed all masticatory cycles using the asymmetry index. Low reliability was found for methods using the location of gum bolus at standardized time intervals or electromyographic recordings.

Conclusions. The VAS provided a highly reliable means of assessing the degree of masticatory laterality perceived by the participant, with a positive and significant correlation with the majority of the other methods. (J Prosthet Dent 2015;■:■-■)

A major objective of prosthodontic treatment is to restore or improve masticatory function. Although mastication may occur bilaterally, most people have a preferred chewing side (PCS).[1-3] The restoration of missing dental units on the preferred side would therefore improve masticatory efficiency.[4-6] However, whether prosthodontic restoration on the nonpreferred side would improve masticatory performance remains unknown. This is partially because there is no Q1 consensus on whether the PCS is determined centrally or is related to peripheral factors; in the latter case, which peripheral factors are most closely related is unknown.[3,7,8] The discrepancies in the literature can be explained by differences in study populations, the definition of PCS, and the methods used.

The PCS has been defined as the side on which food is mostly chewed,[1,2,8,9] the side the jaw moves toward in the closing phase of mastication,[7,10,11] the side with more muscular activity during chewing,[12,13] or, subjectively, by patient perception.[3] Moreover, the 3 main methodologic aspects may influence the PCS, namely the type of test food used, the measurement technique, and the number of cycles assessed. Various test foods have been used to determine the PCS, including chewing gum,[1,8,9,14,15] natural food,[10,12,16-18] and artificial test food.[7,19] The PCS can be determined by direct visual inspection[7,16,18]

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Clinical Implications

To determine the preferred chewing side (PCS), the visual analog scale could be preferred for use in clinical practice and large observational studies. The method that uses bagged silicone as the test food, that determines the preferred chewing side by video recording, and that assesses all masticatory cycles using the asymmetry index would be the preferred research method.

or by indirect evaluation of images recorded with a video camera,[7,10] a kinesiograph,[11,15,17,19,20] or an electromyograph.[12,13] Some studies have assessed only the first masticatory cycle[8,18] while others have analyzed a random number of cycles[1,9,14,21] or all cycles.[7,11,16,19,20]

The ideal method for clinical use should be simple, reliable, and valid and should be able to determine the PCS quantitatively. The visual analog scale (VAS) is an easy and rapid method of effectively assessing pain intensity and the degree of nasal flow asymmetry[22]; however, no studies have used the VAS to assess the degree of subjective masticatory laterality. Furthermore, although several methods for determining the PCS have been compared, the results are inconclusive.[2,7,8,12,15]

The purpose of this study was to assess the reliability of the VAS for determining the PCS and for comparing it with other methods. The null hypothesis was that the VAS would not be reliable.

MATERIAL AND METHODS

This was a cross-sectional study of 42 young adults—23 women and 19 men, aged 27 (range 21 to 45) years—with natural dentition recruited among volunteer students and staff at the Faculty of Dentistry, University of Barcelona, Spain, who had participated in an earlier research project.[23,24] Individuals with fewer than 24 natural teeth, those undergoing active orthodontic treatment, and those suffering orofacial pain were excluded. Among the participants, 31 had Angle class I bilateral, and 11 had unilateral or bilateral class II. No participant had severe malocclusion or temporomandibular disorders that could affect mandibular movement. A test-retest was performed in 10 participants (6 women and 4 men, mean age 26 years), chosen based on their availability 1 to 2 weeks after the first measurements. Participants provided informed and signed consent. The study was approved by the Ethics Committee of the Barcelona University Dental Hospital (Code 17/12). All experiments were carried out in accordance with the principles of the Helsinki Declaration.[25]

Each participant performed 2 masticatory sessions separated by several days. The test food used was either chewing gum (Trident; Cadbury Adams) or bagged silicone (Optosil P Plus; Heraeus Kulzer GmbH). In the second case, the participant was asked to chew to comminute the pieces. Tablets of Optosil (5-mm thick, 20-mm diameter) were made in accordance with the description by Albert et al and were cut into quarters.[6,26] Three one-quarter tablets (2 g) were placed in a latex bag that was sealed with cyanoacrylate adhesive.[23]

The first masticatory session comprised 1 masticatory assay with bagged silicone (5 trials of 20 masticatory cycles each) and 1 with chewing gum (5 trials for 25 seconds each), separated by a 5-minute rest period. The surface electromyographic (EMG) activity of the anterior temporal muscles was recorded during all masticatory assays using the ARCUSdigma II EMG adapter (KaVo Dental GmbH). After preparing and cleaning the skin, the self-adhesive bipolar AG/AgCl electrodes (#272; Noraxon USA Inc) were placed in accordance with the manufacturer's instructions. The silicone masticatory assay was recorded by video camera (HDR-UX7E; Sony Corp) and the masticatory laterality of all cycles was evaluated using its slow-speed playback. For the chewing gum assay, each participant was asked to place the chewing gum on the center of the tongue, and 1 operator observed the direction toward which the tongue moved the gum for the first cycle. The participant continued to chew the gum until stopped at 15, 20, and 25 seconds to observe the site of the gum.

The second masticatory session comprised 1 masticatory assay using bagged silicone. Participants completed 5 trials of 20 masticatory cycles each, and jaw movements were recorded using the ARCUSdigma II system in an upright position with the measuring bow placed around their head. The ARCUSdigma transmitter was affixed to the mandibular arch using the mandibular attachment, which was previously adapted to the labial surfaces of the mandibular anterior teeth by acrylic (Trim; Bosworth Company) and fixed using cyanoacrylate. Participants were asked to perform right- and left-sided lateral guidance movements, starting and ending in the intercuspal position. They were then asked to chew bagged silicone, as per the first session.

The PCS was determined by 8 methods (Table 1). The first 4 methods have been described elsewhere.[1,8,11,18] Briefly, the first method (M1) was based on the definition of PCS as the "direction toward which the gum was moved by the tongue for the first cycle of mastication."[8] The second method (M2) was defined as "the location of the gum bolus at standardized time intervals."[1] In the third method (M3), PCS was defined as the mandibular side favored during the closing phase for the first mastication cycle,[18] measured 5 times using a lateralization index of (LI) as follows: LI = (right − left) / (right + left). The fourth method (M4) used all masticatory cycles to calculate the asymmetry index (AI), as follows: AI =

Table 1. Description of different methods used to determine preferred chewing side with main aspects of methodology

Method	Test Food	Measurement	Cycles Assessed	Data Analysis: Each Cycle	Data Analysis: Data Per Participant	Definition of the PCS and Reference
M1	Chewing gum	Direct vision	1st	Dichot	5	The direction toward which the gum was moved for the first cycle[8]
M2	Chewing gum	Direct vision	Random	Dichot	15	The location of gum bolus at 15, 20, and 25 seconds[1]
M3	Bagged silicone	Video camera	1st	Dichot	5	The side of the mandible on the closing phase for the first cycle of mastication[18]
M4	Bagged silicone	Video camera	20	Trichot	100	The side on which the participant chewed in the frontal plane[11]
M5	Bagged silicone	Kinesiography	20	Quant	100	Maximum lateral displacement of kinesiographic records (Fig. 1)
M6	Bagged silicone	EMG	20	Quant	100	The lateral asymmetry of the relative muscular activity (Fig. 2)
M7	Hard food	Subjective		Trichot	1	Self-assessment of the PCS[3]
M8	Hard food	Subjective/VAS		Quant	1	Self-assessment on a VAS of the degree of lateral preference for chewing

EMG, electromyography; Dichot, dichotomous variable; PCS, preferred chewing side; Trichot, trichotomous variable; Quant, quantitative variable; VAS, visual analog scale.

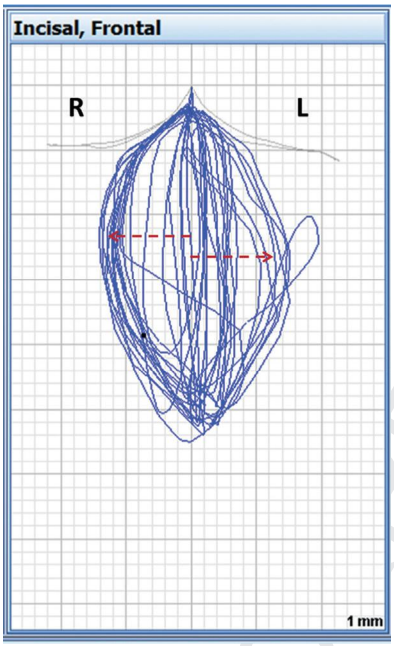

Figure 1. Frontal view of mandibular tracing at incisal level. Tracing during 20 cycles when bagged silicone was chewed to determine preferred chewing side (method 5). Dashed arrows signify maximum lateral displacement or amplitude for right and left cycles.

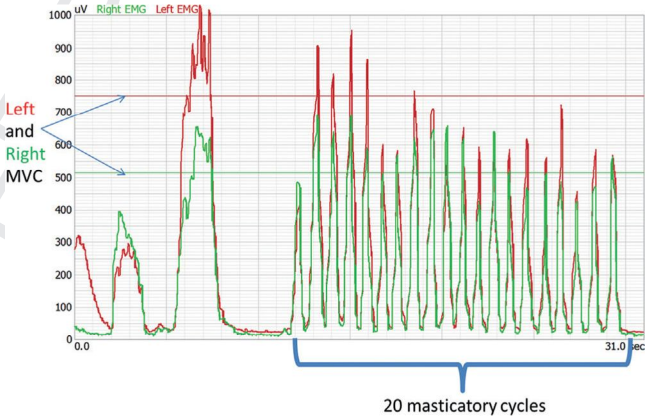

Figure 2. Example electromyographic (EMG) recording. EMG shows activity of right (green line) and left (red line) anterior temporal muscles during maximum voluntary contraction (MVC) and during the 20 cycles of chewing bagged silicone. MVC was measured by using horizontal line displayed by software as reference, after asking participant to close as hard as possible onto 2 dental cotton rolls placed on posterior molars of both sides for 3 seconds.

(number right strokes − number of left strokes) / (number right strokes + number of left strokes). The PCS was defined as the side on which the participant chewed in the frontal plane.[11]

The fifth method (M5) aimed to determine the amount of maximum lateral displacement per cycle in the frontal plane of kinesiographic records (Fig. 1).[27] The mean value was related to the maximum lateral value and obtained a relative value between −1 and +1. The sixth method (M6) aimed to determine the PCS by the lateral asymmetry of the relative muscular activity during silicone chewing (Fig. 2). The muscular activity of the anterior temporal muscles was measured in each cycle and related to each maximum voluntary contraction (MVC). The absolute difference between the right and the left side was calculated, and the mean of these 100 values was obtained.

The seventh method (M7) involved asking, “Do you prefer 1 side for chewing hard food?”, with 3 options: “on the right” (+1), “on the left” (−1), “alternate/simultaneously, or I do not know” (0).[3] The last method (M8) consisted of using a VAS assessment after the masticatory assays, making 1 mark on a 10-cm line with “always left” (−1) and “always right” (+1) at either end and with “no preference” (0) in the middle. These 2 last methods were applied in the first session just before the masticatory assays were started (Fig. 3).

The sample size was determined by considering a type I error of 0.05 and a power of 0.8 in order to find a correlation between methods of r= 4. The values per participant for each of the 8 methods would theoretically range from −1 (extreme left chewer) to +1 (extreme right chewer). Test-retest reliability was assessed by the

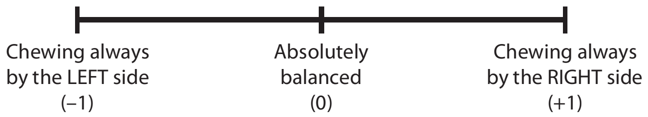

Figure 3. Visual analog scale. Scale is labeled with extremes as masticatory asymmetry and with central point as completely symmetrical mastication.

Table 2. Reliability of 8 methods used to determine preferred chewing side

Method	ICC (CI 95%)	Variability	
		Inter-participant	Intra-participant
M1	0.64 (0.17 ; 0.88)	0.36	0.15
M2	0.12 (-0.48 ; 0.65)	0.01	0.07
M3	0.79 (0.40 ; 0.94)	0.46	0.12
M4	0.77 (0.37 ; 0.93)	0.14	0.04
M5	0.75 (0.32 ; 0.92)	0.1	0.03
M6	0.16 (-0.32 ; 0.58)	0	0.01
M7	0.86 (0.58 ; 0.96)	0.63	0.09
M8	0.93 (0.77 ; 0.98)	0.22	0.02

Intraclass coefficient correlation (ICC), and inter- and intra-participant variability from test-retest analysis (n=10).

intraclass correlation coefficient (ICC) using a mixed model with a random effect for the individual. The Pearson correlations were performed to assess validity between the 8 PCS methods. All analyses were performed using software package IBM Statistics for Windows v20.0 (IBM Corp) (α=.05).

RESULTS

One of the 43 participants who initially participated in this study was excluded because of tooth sensitivity during the masticatory assays. Therefore, the final sample comprised 42 participants, of which 10 also underwent test-retest analysis.

The methods that subjectively assessed the perception of PCS via a question (M7) or the VAS (M8) had the highest ICC values, indicating a high discrimination between participants (high interparticipant variability) and a strong agreement between sessions (low intraparticipant variability) (Table 2). Low reliability was evident for M1 that used chewing gum to assess random chewing cycles and for the M6 that assessed asymmetric muscle activity.

A matrix of the correlation coefficients between the 8 methods is shown in Table 3. Except for M6, which determines the PCS by assessing asymmetric masticatory muscular activity, all other methods showed a significant and positive relationship. M4, which used the AI, had the highest correlation values.

Electromyographic activity during the MVC showed no significant differences between the 5 trials of bagged silicone and the 5 trials of chewing gum (data not shown). Therefore, the sequence of the trials did not affect MVC activity. The mean electromyographic activity of the right and left sides of all 42 participants while chewing bagged silicone was double, while that of chewing gum was $P<.001$; 1-way ANOVA; Duncan post hoc test. No time effect was observed on electromyographic activity during the trials.

Table 3. Pearson correlation coefficient matrix for different methods used to determine preferred chewing side

	M1	M2	M3	M4	M5	M6	M7	M8
M1	1.00							
M2	0.48[c]	1.00						
M3	0.64[c]	0.46[b]	1.00					
M4	0.65[c]	0.57[c]	0.79[c]	1.00				
M5	0.54[c]	0.52[c]	0.47[b]	0.68[c]	1.00			
M6	0.30	0.17	0.41[b]	0.32[a]	0.01	1.00		
M7	0.62[c]	0.51[c]	0.73[c]	0.65[c]	0.47[b]	0.32[a]	1.00	
M8	0.62[c]	0.58[c]	0.71[c]	0.65[c]	0.56[c]	0.20	0.82[c]	1.00

[a] $P<.05$.
[b] $P<.01$.
[c] $P<.001$.

DISCUSSION

The use of the VAS to describe the amount of lateral preference in mastication was among the methods that showed the highest reliability, and therefore the null hypothesis was rejected. Despite not being an objective method, it benefits from being able to assess the PCS quantitatively, providing a simple and quick assessment that does not require excessive training. This method could therefore be preferable for use in clinical practice and large observational studies. Because the volunteers in this study were young adults linked to a dental school, these data cannot be extrapolated directly to other populations. Future research should assess the reliability and validity of this method in specific patient groups, such as children and dental patients.

The method that showed the closest relationship with the other methods was the M4, which assessed the PCS while chewing bagged silicone over all 20 cycles and calculated the AI. Although this method used a video camera, a high level of concordance also existed when determining the PCS by using direct vision.[7] M4 would be the preferred method for use in research because it demonstrated a high validity and provides an objective assessment of PCS. To know whether a restoration of missing posterior teeth on the nonpreferred side would change masticatory laterality and improve masticatory performance, a prospective analytical study using this method to determine the PCS in partially edentulous patients is warranted. The analysis of only the first cycle with silicone (M3) was strongly correlated (r=0.79) with the analysis of all cycles (M4), and both demonstrated a positive and significant correlation with all the other methods studied. However, the analysis of only the first cycle showed better agreement but less ability to discriminate between the different participants compared with M4.

The results suggest that the choice of both the test food and the cycles assessed may not only influence repeatability but also agreement and the ability to discriminate among participants. Among the methods that used chewing gum, the method that considered the first cycle had acceptable reliability, whereas the method that assessed 3 random cycles had low reliability. The neuromuscular system explores the bolus during the first cycle and may choose the preferred side, while the side chosen for chewing is influenced by other factors during subsequent cycles, especially with chewing gum. These results are consistent with those of other studies reporting that harder foods are more appropriate for examining masticatory laterality.[7,10,11,19] Although bolus cohesiveness seems to play a role in chewing side preference, no great differences in masticatory function have been reported between unbagged and bagged silicone.[23] Therefore, bagged silicone is recommended as a test food for assessing the PCS, and because chewing is easier and more comfortable, no pieces of silicone are lost, and it is easier for the operator.

The use of ARCUSdigma II as a kinesiograph to record mandibular movements during chewing not only identified laterality in the closing phase of each cycle but also provided a quantitative measurement of the amplitude of each cycle, as demonstrated by M5. This technique required sophisticated equipment and a trained operator and, in the case of the ARCUSdigma, may interfere with natural chewing function. Consequently, the use of ARCUSdigma II to assess the PCS is not recommended.

The results suggest that asymmetric electromyographic activity of the anterior temporalis partially reflects the PCS and that several unknown factors might influence this asymmetry. Therefore, the activity of muscles on the working and nonworking side may show relatively high intraparticipant and interparticipant variability, as stated elsewhere.[28]

This study has some limitations. First, the different methods used to determine the PCS were not randomized, which may have resulted in some bias. However, electromyographic activity was neither time-dependent nor trial-dependent in this study. Second, the 2 methods that used chewing gum as the test food also used the bolus position to determine the PCS, whereas the silicone-based methods determined the PCS by mandibular position or asymmetry in muscular activity. Thus, the differences found between those groups might not be attributed to the test food alone. New studies are needed to assess the reliability and validity of methods using natural foods. Because no "gold standard" method is available, the validity assessed using the correlation coefficient matrix for the different methods could be taken with caution. A further limitation is the small sample size in the test-retest, and, although it was sufficient to know which methods are reliable, it was probably insufficient to know the actual magnitude of reliability.

CONCLUSIONS

To determine the PCS in a population of young adults with natural dentition, the VAS was highly reliable when assessing the degree of subjective masticatory laterality. Moreover, it demonstrated a positive and significant correlation with most of the other methods studied.

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