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Highlights:

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Alternate unilateral chewers masticate more efficiently than consistent unilateral chewers.

Alternate unilateral chewers can masticate as or more efficiently when they chew unilaterally.

Title: Is the side with the best masticatory performance selected for chewing?

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Running title: Chewing side and masticatory performance

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Abstract

Objective: This study assessed the degree of relationship between masticatory laterality and lateral asymmetry of masticatory performance using silicon pieces enclosed in a latex bag.

Design: Forty-two young adults with natural dentition participated in this cross-sectional, observational study. They performed four different masticatory assays, each consisting of five trials of chewing three pieces of silicon for 20 cycles. In one assay, they were asked to masticate unbagged silicon free-style, whilst in the three other assays they were asked to masticate bagged silicon free-style, unilaterally on the right-hand side and unilaterally on the left-hand side. The preferred chewing side was determined by calculating the asymmetry index for both the free-style assays. Masticatory performance was determined by sieving the silicon particles and the cycle duration was also recorded. Data were analysed using independent samples or paired t-test and linear regression.

Results: Masticatory function using the bagged silicon was similar to that using the unbagged silicon. A significant and positive relationship was observed between the preferred chewing side expressed as the asymmetry index and the side with better masticatory performance. Alternate unilateral chewers demonstrated better masticatory performance than unilateral chewers. However, when free-style and unilateral chewing were compared for each subject, unilateral chewing was found to be as efficient as - or even more efficient than - free-style chewing.

Conclusions: There is a positive association between the preferred chewing side and the more efficient side. Alternate unilateral mastication *per se* does not promote better masticatory performance than consistently unilateral mastication.

Introduction

One of the main objectives of dental treatment is to restore or improve masticatory function, which is evaluated by self-assessment of chewing ability and/or objective masticatory performance measured using laboratory tests.¹ Whereas masticatory function can be studied recording the chewing pattern simultaneously with the muscular activation of the masticatory muscles,² masticatory performance can be determined by quantifying the degree of fragmentation of an artificial test food after a set number of chewing cycles.³ Number of teeth, occlusal contact area, bite force and salivary flow, are all factors that can affect masticatory performance.⁴

Although mastication may occur bilaterally or alternating both sides, it is thought that the majority of people chew more on one particular side, i.e. they have a preferred chewing side (PCS).⁵⁻⁷ The proportion of children or adults with a PCS ranges from 45% to 98%,⁷⁻¹¹ and there is no agreement on whether the right side is used more frequently than the left side.^{8-10,12,13} Furthermore, it is still unknown whether the PCS is centrally determined or related to peripheral factors, nor which peripheral factors are most closely related to the PCS.^{7,10,11}

Although natural foods can be used to assess masticatory function, artificial test food can be easily standardised and its physical properties remain the same over time.¹⁴ Consequently, the use of artificial test foods such as silicon impression material is

reliable.¹⁵ It has been shown that tough and hard foods, as well as materials with high cohesiveness that do not disintegrate are more appropriate to determine the PCS.^{9,16-18} Real food placed in a latex bag has also been used to assess the masticatory function.^{19,20} Theoretically, the best test food to assess the PCS would be one which formed an artificial, hard and cohesive (non-committable) bolus. Placing the artificial test food in a latex bag seems to be the method that best guarantees the bolus cohesiveness.

Bite force and occlusal contact area are the best predictors of variation in masticatory performance,²¹⁻²³ and lateral differences in these parameters are positively correlated with masticatory laterality.^{9,10} It has been reported that masticatory performance tends to be better on the preferred side; however, no significant correlation has been found between chewing side preference and masticatory performance.²⁴ Although it seems plausible that side efficiency could affect chewing side preference, to our knowledge no studies have demonstrated a direct relationship between asymmetry of masticatory performance and chewing side preference. Although bilateral chewers seem to present better masticatory performance than unilateral chewers,¹⁸ no direct association has been demonstrated.

The first aim of this study was to assess the degree of relationship between masticatory laterality and lateral asymmetry of masticatory performance, using silicon tablets enclosed in a latex bag as a test food in young adults with natural dentition. The second aim was to determine whether free-style mastication achieves better efficiency than unilateral mastication.

Material and Methods

Subjects

Forty-two young adults (23 women and 19 men) with natural dentition were selected from volunteer students and staff at the University of Barcelona Faculty of Dentistry (Barcelona, Spain) to participate in this cross-sectional study. Their ages ranged from 21 to 45 years old with a mean age of 26.8 (SD=4.9) years. Among the participants, thirty-one had Angle class I bilaterally and eleven had unilaterally or bilaterally class II. No subject had severe malocclusion. Subjects with fewer than 24 natural teeth, those undergoing active orthodontic treatment, or those suffering orofacial pain were excluded. Sample size was calculated considering a Type I error of 0.05, a power of 0.80 and a Pearson correlation between asymmetry of bite force and masticatory laterality of 0.40.¹⁰ Subjects were fully informed and signed an informed consent form 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

Masticatory assays

Each subject performed four different masticatory assays, each consisting of five trials of 20 cycles each chewing 2 g of silicon. Optosil tablets (5 mm thick, 20 mm diameter) (Optosil P Plus; Heraeus Kulzer, Hanau, Germany) were made as described by Albert et al.¹⁵ and were cut into four quarters. Two types of chewing test food were used: three quarter tablets (2 g) without a bag (unbagged silicon) and three quarter tablets placed in a latex bag which was sealed with cyanoacrylate adhesive (bagged silicon).¹⁹ Two assays consisted of free-style mastication: in one, subjects chewed the unbagged silicon

test food and in the other, the bagged silicon, in order to assess the influence of the type of test food in the PCS, the MPS and the cycle duration. For the other two assays, subjects were asked to chew bagged silicon unilaterally, using only the right-hand side in one assay and only the left-hand side in the other. The order of the trials was alternated between unbagged and bagged chewing tests for free-style mastication and between right and left for unilateral mastication.

Masticatory performance was evaluated for each masticatory assay by assessing the degree of comminution of the silicon test food.^{21,23} For each assay, particles from five trials (10 g) were dried for 24 h and passed through a series of eight sieves (0.25, 0.425, 0.85, 2, 2.8, 3.15, 4, and 5.6 mm) while being shaken for 1 min. After cumulative weight distribution of the sieve contents had been determined, median particle size was calculated for each subject using the Rosin–Rammler equation [$Q_w(X) = 1 - 2E-(X/X_{50})^b$], where $Q_w(X)$ is the fraction of particles by weight with a diameter smaller than X , the median particle size (MPS or X_{50}) is the size of a theoretical sieve through which 50% of the weight can pass, and b describes the breadth of particle size distribution.²⁶ The total duration of each of the five trials was used to calculate the duration of the average chewing cycle.²⁷

A video camera (Sony HDR-UX7E, Japan) recorded mandible displacement while closing during each free-style mastication assay. The side of mandible lateralisation while closing was counted for each chewing cycle using a slow-speed playback mode to calculate masticatory laterality. The asymmetry index (AI) for each free-style mastication of bagged or unbagged silicon, was calculated according to Mizumori et

al,¹⁷ as

$$AI = \frac{(\text{number Right strokes} - \text{number of Left strokes})}{(\text{number Right strokes} + \text{number of Left strokes})}$$

Data analysis

The side difference of masticatory performance was calculated as absolute difference between the MPS obtained chewing unilaterally on the right-hand side and the MPS obtained chewing on the left-hand side ($MPS_R - MPS_L$). Similarly, the side difference in cycle duration was calculated ($TIME_R - TIME_L$).

In order to evaluate the reproducibility of the parameters used in this study, the assays were all repeated with ten of the subjects 2–4 weeks after the first measurements were taken. Intraclass correlation coefficients and the smallest detectable difference in the main parameters were determined as measures of reliability and agreement, respectively (Table 1). Reliability relates the measurement error to variability between subjects, and agreement assesses how close the results of the repeated measurements are by estimating the measurement error.²⁸

The normal distribution fit of the data was tested by means of a Kolmogorov–Smirnov test. Comparisons were performed using Students t-tests, for related or independent samples, as appropriate. Pearson correlation coefficients were calculated to evaluate the correlation between variables.

To determine whether each subject had a chewing side preference, the threshold was set at 33%, so that the subject was considered an alternate unilateral chewer if the AI value for PCS ranged from - 0.33 to 0.33, and a consistent unilateral chewer if the AI value was less than -0.33 or more than 0.33. This threshold was selected in order to obtain three balanced groups and according to other studies.^{16,17}

Statistical analysis was performed using the spss software package (version 20.0; SPSS, Chicago, IL, USA) and *P*-values below 0.05 were considered significant.

Results

All the variables tested showed a normal distribution ($p > 0.415$; Kolmogorov Smirnov). For PCS, MPS and cycle duration, no significant differences were found between the unbagged and bagged free-style mastication chewing tests ($P = 0.71$; $P = 0.78$ and $P = 0.24$ respectively; Paired t-test). The intraclass correlation coefficients of masticatory assessment using unbagged silicon or bagged silicon ranged from 0.90 to 0.97 (Table 2).

A significant and negative relationship was observed between the preferred chewing side expressed as AI (range -1 to +1) and the side difference obtained for MPS ($r = 0.40$; $p = 0.004$; lineal regression) (Figure 1). This means that the more the right side is used to chew, the more efficient this side is compared to the left side. However, the chewing cycle duration side difference was not related to the preferred chewing side ($r = 0.027$; $p = 0.43$, linear regression).

Using the threshold of 33%, 19 subjects were classified as consistent unilateral chewer (5 left side and 14 right side) and 23 as alternate unilateral chewer. The MPS obtained from free-style mastication by consistent unilateral chewers (MPS=5.65 mm; SD=1.4) was significantly higher ($P = 0.05$, Independent Samples t-test) than the MPS of alternate unilateral chewers (MPS=4.75 mm; SD=1.5). That means than the higher MPS, the poorer masticatory performance. When masticatory performance was analysed for each

subject with paired data, the MPS obtained from free-style mastication (mean: 5.16 mm; SD=1.5) was similar to the MPS observed for unilateral mastication on the preferred side (mean: 5.14 mm; SD=1.6) and higher ($P=0.035$, Paired Samples t-test) than the MPS yielded by unilateral mastication on the more efficient side (mean: 4.96 mm; SD=1.5).

Discussion

Young adults with natural dentition showed better masticatory performance on the PCS. However, the side difference in masticatory performance only explained 16% of the variation in chewing side preference. In another study, no significant relationship between the side difference in masticatory performance and masticatory laterality was found,²⁴ probably due to the use of a small sample and also the use of different test foods to assess masticatory laterality and masticatory performance. The high intra- and inter-subject variability of the AI for the PCS supports the idea that a complex interplay of factors affects the selection of a PCS. Moreover, different studies have yielded apparently contradictory data on the factors related to PCS. These discrepancies in the literature can be explained by differences in the study population, in the definition of PCS, and consequently, in the methods used to determine the PCS.^{7,10} New research should focus on finding new factors than can explain the high variability of the PCS and on comparing the reliability of different methods to determine PCS.

Mastication of silicon tablets placed in a latex bag showed a similar laterality, efficiency and duration to mastication of silicon without a bag, and a high intra-subject correlation

was observed. Moreover, the high ICC values of masticatory function with bagged silicon obtained in the test-retest analysis demonstrated that this is a reliable method for assessing masticatory function. The main advantages of this type of test food are that chewing becomes easier and more comfortable for the volunteer, no pieces of silicon are lost, and it is easier for the operator to assess the PCS.¹⁹ This type of artificial test food placed in a latex bag is a reliable method for assessing masticatory function in dentate young adults and could be used in future studies.

Alternate unilateral chewers were observed to chew more efficiently than consistent unilateral chewers, a finding also reported by Farias Gomes et al.¹⁸ However, when free-style and unilateral chewing were compared in each subject, consistent unilateral chewing was found to be as efficient as - or even more efficient than - free-style mastication, if the side considered was the preferred or the more efficient one. This apparent contradiction can be explained by the fact that people who chew simultaneously or alternately on both sides could chew efficiently even on one side. The present results do not support the idea that bilateral or mastication *per se* promotes higher masticatory performance, but there is a confounding factor that leads to a spurious relationship between bilateral or alternate unilateral style of mastication and high masticatory performance. In the present study this confounding factor was controlled for using the paired data analysis. Future studies should be conducted in order to determine the variables that affect the PCS and masticatory performance.

One of the limitations of the present study is that only one test food was used to assess masticatory function and the results are thus only applicable to this type of food. Another weakness of this study was the low sample size and the high intra- and inter-

subject variability of the AI for the PCS. The more efficient masticatory side was more likely to be used for chewing. However, due to the cross-sectional design of this study we cannot demonstrate whether an increase in masticatory performance on one side would be the result or the cause of preferring this side for chewing. Longitudinal studies are needed to clarify the cause-effect of these correlations. Nevertheless, restoration of missing teeth on the non-preferred side would improve masticatory performance but to a lesser extent than prosthodontic restoration on the preferred side.

In conclusion, there is a positive association between the preferred chewing side and the more efficient side. Alternate unilateral chewers masticate more efficiently than consistent unilateral chewers. However, alternate unilateral chewers can masticate as or more efficiently when they chew unilaterally.

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Figure Caption

Figure 1. Correlation between preferred chewing side and lateral asymmetry of median particle size ($MPS_R - MPS_L$) (mm)

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Table 1. Reproducibility estimated from intraclass correlation coefficients (ICC) with confidence interval (95% CI) coefficients and the smallest detectable difference (SDD) for the variables (n=10)

	ICC	SDD
PCS-Unbagged (AI)	0.958 (0.83-0.99)	0.39
PCS-Bagged (AI)	0.887 (0.54-0.97)	0.52
MPS-Unbagged-Free	0.859 (0.43-0.97)	1.44 mm
MPS-Bagged-Free	0.940 (0.76-0.99)	0.93 mm
MPS-Unilateral-Right	0.969 (0.88-0.99)	0.71 mm
MPS-Unilateral-Left	0.901 (0.60-0.98)	1.52 mm
MPS-Asymmetry	0.806 (0.22-0.95)	1.46 mm
Time- Unbagged-Free	0.918 (0.67-0.98)	130 msec
Time-Bagged-Free	0.963 (0.85-0.99)	86.3 msec
Time-Unilateral-Right	0.898 (0.59-0.98)	144 msec
Time- Unilateral-Left	0.911 (0.64-0.98)	133 msec
Time-Asymmetry	0.819 (0.27-0.96)	41.2 msec

PCS= Asymmetry Index of the Preferred Chewing Side. MPS=Median particle size. Time expressed as cycle duration

Table 2. Comparison of masticatory function data obtained using the unbagged and bagged test food during free-style mastication

	TEST FOOD		Difference of Means (95% CI; t-test)	ICC (95% CI)
	Unbagged Mean (SD)	Bagged Mean (SD)		
PCS (AI)	0.14 (0.5)	0.16 (0.5)	-0.02 (-0.11:0.07)	0.90 (0.81-0.95)
MPS (mm)	5.13 (1.5)	5.16 (1.5)	-0.03 (-0.23:0.17)	0.95 (0.91-0.97)
Time (msec)	733 (114)	740 (106)	-7.33 (-19.7:5.03)	0.97 (0.94:0.98)

ICC= Intraclass Correlation Coefficient. CI Confidence Interval. PCS= Asymmetry Index of the Preferred Chewing Side.

MPS=Median particle size. Time expressed as cycle duration

