Abstract: This study aimed to investigate masticatory function and taste and their possible relationship with salivary flow in young adults with good oral health. The study also examined whether anthropometric measurements and gender could influence the variables studied. A total of 171 subjects were selected (125 females, 46 males). Masticatory performance was evaluated with the sieve method, and perceived masticatory ability was measured using the visual analogue scale. Taste was evaluated using the drop test with four different flavors in three different concentrations, and unstimulated and stimulated saliva flows were measured. The anthropometric variables measured included body mass index (BMI) and waist circumference (WC). The independent variables studied could not predict masticatory performance. The independent variables, BMI, WC, and gender, predicted 14% of perceived masticatory ability, and BMI predicted 5% of taste. Masticatory performance was not related to salivary flow or anthropometric parameters in young healthy adults. Perceived masticatory ability was related to BMI, WC, and gender, whereas taste was only weakly related to BMI. The flow rate did not exhibit a statistically significant difference between males and females for the anthropometric groups.

Keywords: mastication; BMI; salivary flow; taste.

Introduction

A sufficient amount of saliva is important for appropriate masticatory function (1). Salivary secretion is mainly induced during eating, and the perception of food texture is mediated by saliva (2). Taste is also influenced by saliva through the distribution of taste substances to taste receptors, chemical interactions with taste substances, and alterations in the sensitivity of taste receptors (3). Saliva is an important agent in oral physiology (4). Most saliva is produced by three pairs of major glands: the parotid, submandibular, and sublingual glands (5). The flow and quality of saliva are important indicators of oral health.

Masticatory function can be objectively evaluated using comminution tests, which measure an individual’s capacity to break down food into particles in a specific number of chewing cycles by determining the sizes of test food samples that have been chewed (6,7). Another method for verifying masticatory function is subjective tests that measure the subject’s own perception of chewing, such as the ability test (8,9).

Taste is the sensory impression of food or other substances on the tongue. It is characterized as one of the five traditional senses and can be associated with food preferences (10,11). The taste receptors on the tongue are constantly bathed with saliva, which modulates a significant number of physiological processes. It has been reported that changes in taste are related to oral health factors, such as dry mouth, tongue coating, and the
loss or destruction of taste receptors (12). Furthermore, associations among oral conditions and various anthropometric measures, such as body mass index (BMI), have been identified in previous studies (13,14). Studies have also reported poor oral health in obese people (14). Gender-related differences are another important variable to study because sex hormones could influence salivary glands, taste perception, and muscle activity for mastication (15-17).

Considering the importance of masticatory function and taste and the role of saliva in these parameters, it is relevant to evaluate the relationships among them. Additionally, analyzing the influence of gender and anthropometric measurements on those factors is highly recommended to provide a basis for further studies. Saliva and chewing have been shown to be interrelated, although the relationship between the amount of saliva and masticatory function has not yet been fully elucidated (18). There are previous data regarding the association of salivary flow and masticatory performance in older individuals showing that a reduction in salivary flow was associated with a decline in masticatory performance (19). Moreover, normal-weight children had a better masticatory performance than overweight or obese children, and poor masticatory performance had a significant relationship with being underweight (20). Nonetheless, studies involving the role of saliva, masticatory function, and BMI in young healthy adults are scarce. Therefore, the aim of this study was to investigate the relationships between masticatory function, taste and salivary flow rate in young adults. Furthermore, the study examined whether gender and anthropometric measurements could be influenced by the other variables studied.

**Materials and Methods**

**Sample**
The present study included a convenience sample of 171 subjects, aged 18-33 years (125 females, 46 males), selected from public or private schools of higher education in Piracicaba, SP, Brazil. Both undergraduate and postgraduate students participated after they signed the informed consent forms. This study was approved by the Ethics Committee of the Piracicaba Dental School (Protocol number 110/2011).

**Clinical examination**
A clinical examination was performed to verify the normality of the oral tissues and the absence of tooth loss; occlusion was also checked to ensure that all participants had a normal occlusion, i.e., the first permanent molars in Angle’s Class I, a normal relationship between the canines, and an overjet and overbite ≤3 mm. These oral characteristics comprised the inclusion criteria. The exclusion criteria were the use of dental appliances, systemic illness, smoking, and the ingestion of medicines that could affect the central nervous system, muscular activity, or salivary secretion.

**Physical evaluation**
The anthropometric measurements included body weight (kg) and height (m), which were used to determine the BMI and waist circumference (WC; cm).

All measurements were made according to international standards (21). Body weight and height were obtained using an anthropometric scale (110CH, Welmy, Santa Bárbara D’Oeste, SP, Brazil), with an accuracy of 100 g, and a stadiometer, with an accuracy of 0.5 cm. BMI was calculated as BMI = kg / m². Furthermore, the following World Health Organization cut-offs for BMI were used: underweight, <18.5 kg/m²; normal weight, 18.5-24.9 kg/m²; overweight, ≥25 kg/m²; obese, ≥30 kg/m² (22).

For the WC measurement, a flexible tape measure (ES4010, Sanny anthropometric tape 2.0 m, American Medical Brazil, Ltd., São Paulo, Brazil) was used while the volunteers stood upright. The tape was placed at the narrowest point between the xiphoid process and the iliac crest (23).

**Masticatory performance**
Masticatory performance was assessed by determining the individual’s capacity for the fragmentation of a chewable test material called Optocal (24), which is composed of the following: silicon Optosil R plus, 58.3%; toothpaste, 7.5%; solid vaseline, 11.5%; common dental plaster powder, 10.2%; alginate powder, 4%; and catalyst paste, 20.8 mg/g. The components were blended and placed in metal molds with cubic compartments measuring 5.6 mm, and mechanical pressure was applied. The subjects received 17 cubes (3.6 g) and chewed them for 20 masticatory cycles, which were visually monitored by the examiner. The fragmented particles were then expelled from the oral cavity into plastic receptacles covered with filter paper. After drying, the particles were weighed and passed through a series of 10 granulometric sieves with meshes of range 0.71-5.60 mm, connected in decreasing order and closed with a metal base. The particles were placed in the first sieve in the series, and the set was vibrated for 20 min. The particles retained on each sieve were removed and weighed on an analytical scale with a precision of 0.001 g. The distribution of the particles by weight was described using a cumulative function...
(RosimRamler equation). The degree of fragmentation of the material was then described by the median particle size ($X_{50}$), which was the aperture of the sieve through which 50% of the weight of the fragmented material could theoretically pass (25). The formula is as follows:

$$QW (X) = 1 - 2 \left( \frac{X}{X_{50}} \right)^b$$

In this formula, $QW$ is the weight fraction of particles that are smaller than $X$ and variable $b$ represents the spread of the size distribution (broadness variable), reflecting the extent to which the particles were equally sized.

Perceived masticatory ability
Self-perceived chewing ability consists of the individual’s perception of his or her ability to grind food. This variable was measured using the visual analogue scale (VAS) (26), which consists of a horizontal line with extremes marked 0 and 10, corresponding to the classification “completely dissatisfied” (point 0) and “fully satisfied” (point 10). The volunteers were asked “How satisfied are you with your ability to chew food?” (9) and prompted to mark the point on the line that corresponds to his or her level of satisfaction.

Taste
To evaluate flavor thresholds, a modified methodology proposed by Mueller et al. was used (27). Four liquid solutions were used at three different concentrations: sweet: 0.2, 0.1, and 0.05 g/mL of sucrose; sour: 0.165, 0.09, and 0.05 g/mL of citric acid; salty: 0.1, 0.04, and 0.016 g/mL of sodium chloride; and bitter: 0.0024, 0.0009, and 0.0004 g/mL of quinine hydrochloride. Two drops of liquid were placed on the middle of the tongue approximately 1.5 cm from the tip using a dropper; the subjects were then allowed to close their mouths. The sequence of administration was randomized across trials. For each test, the participant chose one of the four options: sweet, salty, bitter, or acid (sour). There was no time limit for the test. The tests started with the lowest concentration. The subject’s task was to identify the correct taste. Between each test, the participants rinsed their mouths with a sip of tap water. Each correct taste was given a value of “1”. The result for the entire test was the sum of the results for the individual taste qualities (range, 0-12).

Salivary flow
The following parameters were considered to measure the salivary flow: stimulated and unstimulated salivary flow rates.

Saliva collection
Stimulated and unstimulated saliva were collected in the morning, and all subjects were asked to refrain from eating, drinking, or brushing their teeth for at least 2 h before collection. The subjects were comfortably seated, and after a few minutes of relaxation, they rinsed their mouths with distilled water. For the unstimulated saliva flow measurement, they were asked to avoid swallowing their saliva and to lean forward and spit all the saliva they produced over a 5-min period through a glass funnel into a cooled tube. After that, stimulated saliva was collected for 5 min by having the participants chew 0.3 g of an inert and tasteless material (Parafilm, Merifeld, EUA) for approximately 70 cycles/min. The stimulated and unstimulated flow rates were defined as the weight of the saliva secreted per min (g/min).

Statistics
The collected data were analyzed using the SPSS software (SPSS 21.0 Inc., Chicago, IL, USA). Descriptive statistics were used for all variables, including means, medians, standard and interquartile deviations, and frequency. The normality of the data was calculated using the Shapiro-Wilk test. The data for males and females were compared using the Student $t$-test and Mann-Whitney and Wilcoxon tests. Chi-squared or Fisher’s exact tests were used to compare proportions among groups, and Spearman’s coefficients were determined to correlate masticatory function, taste, and unstimulated and stimulated salivary flow rates. Furthermore, to verify the possible factors associated with masticatory function and taste, three models of multiple linear regression analyses were built. Thus, masticatory performance, ability, and taste were entered into the models as dependent variables, and age, gender, BMI, WC, and unstimulated and stimulated salivary flow rates were entered as independent variables. Only variables with $P \leq 0.20$ for the bivariate linear regression were kept in the multivariable models as potential confounders. A significance level of 5% was adopted.

Results
The characteristics of the samples are presented in Table 1. The number of females was significantly higher than the number of males. In terms of anthropometry, the proportion of underweight females was significantly higher than that of underweight males, whereas the proportion of obese males was greater than that of obese females. The anthropometric variables, BMI and WC, were significantly higher for males, as expected. Masti-
The correlations between masticatory function, taste, and salivary flow were not significant. The correlations by gender showed similar results; thus, the data were pooled. The correlation between unstimulated and stimulated salivary flow was significant ($r = 0.54$, $P < 0.01$; Table 2).

Comparisons of masticatory function, taste, and salivary flow rate according to anthropometric status showed no significant differences. However, in the obese group, the stimulated flow rate did not correlate with the unstimulated rate, whereas the coefficients for the other three groups were significant. Moreover, there was no statistically significant difference in flow rate between males and females for any of the groups (Table 3).

A bivariate analysis (Table 4) was performed to select the independent variables that were eligible for inclusion in the regression model (i.e., the variables with a $P$ value $< 0.20$). Masticatory performance was not predicted by the independent variables. Gender, age, BMI, and WC were eligible for multiple regression analysis for the dependent variable ability, whereas for taste, the variables BMI and WC were eligible for multiple regression analysis. For ability, the multiple model was significant, and the independent predictive variables were gender, BMI, and WC (Table 5). For taste, the model was also significant, and the predictor was BMI (Table 6). The coefficient of determination ($R^2$) obtained from a regression analysis indicates how well the data fits a statistical model. The adjusted $R^2$, which is more reliable when extra explanatory variables are added to the model, was chosen to determine the percentages of ability and taste that were predicted by the independent variables.
Regarding perceived masticatory ability, 14% was predicted by the independent variables, BMI, WC, and gender, whereas with taste, 5% was predicted by BMI.

**Discussion**

This study aimed to investigate masticatory function and taste and their possible relationship with salivary characteristics in young adults. The study also examined whether anthropometric measurements and gender had an influence on the variables studied. The study sample was composed of young dentate adults with good oral health. The sample included a greater number of females than males, although the ages were similar between the gender groups. Masticatory performance was evaluated...
using the sieve method, which is considered as the standard method for evaluating masticatory function (28). The median X̄50 value found in the present study, 3.39 mm, can be considered to be good, in agreement with previous studies (6,7) and similar between genders, as previously reported (6,29). Nevertheless, no distinct findings between genders are clearly stated because some studies have found a better performance for males (17,30). Several parameters in masticatory function were found to be different between genders, such as a higher duration of chewing cycle for women (31) and higher electromyography (EMG) activities per cycle and per sequence for males (32). These findings could suggest better performance for men, which is different from the findings of the present study. The possible reason is that the method applied for masticatory performance in the present study did not consider the chewing time but a fixed number of chewing cycles to obtain the median particle size (6).

The perceived masticatory ability was assessed because it is an important tool to investigate masticatory function, especially in large samples, because of its simplicity of administration (33). Moreover, it is important to know about this perception in young adults, considering that masticatory function has an influence on food choice. Furthermore, VAS enables a range of abilities to be captured (9), with patient-based evaluations deemed valid (34). In this context, the findings of masticatory ability of the present study could indicate that the volunteers rated their ability confidently. This fact could be explained by the good oral health of the participants and the presence of all teeth. Similarly, Zhang et al. (35) verified that the chewing ability was strongly associated with dental conditions, adding that subjects with replaced teeth had a higher likelihood of chewing problems. Interestingly, although the masticatory performance and ability values in the present study indicated adequate masticatory function, the respective correlations were not significant, probably because of the nature of the tests. Functional tests, such as the comminution test, more directly estimates an individual’s mechanical chewing function because they are based on objective parameters. However, they may not correlate well with an individual’s own perception of his/her chewing ability (36).

Regarding taste, the subjects distinguished the flavor and respective concentrations very well, as indicated by the large ceiling effect and the absence of a floor effect. Ceiling effects exist when a score reaches a maximum extreme, whereas floor effects exist when a score reaches a minimum extreme. Only one female presented a score of “3”, indicating taste hyposensitivity, whereas another female had a score “6”, indicating moderate taste hyposensitivity. All other participants scored above “8”. Regarding gender, the statistical tests did not reveal any significant differences. Consistent with our results, Ohnuki et al. (37) studied students aged 15-18 years and found no significant differences in taste hyposensitivity between genders, although some authors suggest that gender hormonal variations can influence taste perception (38). This inconsistency may indicate the need for a more sensitive taste test for use in large samples. Taste was not correlated with masticatory function parameters.

As noted above, the nature of the tests could be an influencing factor. In this context, it is important to incorporate the broader biological and sociological aspects of eating habits and taste sensations that are involved in diet choice into further studies on taste, as suggested by Ohnuki et al. (39).

In the present study, the unstimulated and stimulated salivary flow rates were similar between males and females. This finding is consistent with Smith et al. (40), who observed that the effect of gender was not significant for stimulated saliva. Nevertheless, Yamamoto et al. (41) affirmed that the total saliva flow rate of an individual should only be compared with data from those of the same gender. The different findings might be explained by differences in methodology, such as the period of saliva collection and stimulus type. Dawes (42) observed that the unstimulated whole-mouth saliva flow rate is regulated by a circadian variation being low at approximately 6 am and high at around 6 pm. Therefore, it is important to record the time of collection when undertaking analyses. Regarding the stimulus, the properties and composition of mixed saliva differ depending upon whether secretion is stimulated by tasting, smelling, and chewing food, or is unstimulated (43).

A correlation among salivary flow rate, masticatory function, and taste parameters was expected because saliva is an important agent in oral physiology (4). However, the respective coefficients were very low. This finding is quite interesting given that our study group, which comprised young adults, presented the same results that Ikebe et al. (19) observed in healthy older adults; however, they found significant correlations in people without posterior occlusal support. This might indicate that age per se is not the determinant factor in the association between saliva and masticatory function and other aspects, such as the remaining number of teeth, might influence this association more strongly.

It has been observed that oral conditions may be associated with anthropometric measurements (14,44). In this context, a high BMI has been associated with
hyposalivation (45). However, our results revealed that salivary flow rates did not correlate with anthropometric values. We also observed that only in the obese group, the unstimulated saliva flow rate uncorrelated with the rate after mechanical stimulation (table 3), agreeing with de Campos et al., 2014 (46). The salivary flow rates can be elicited by different types of stimulation, which might indicate that obese people may have differences in craving or conditioned anticipatory responses to food (47). Moreover, the small number of obese individuals in the present study could have been responsible for the lack of correlation between unstimulated and stimulated saliva, indicating caution in interpreting these findings.

The bivariate analysis showed that masticatory performance was not associated with the independent variables; thus, a regression model could not be built. Gender and anthropometric measurements could explain 14% of perceived masticatory ability. Consistent with our results, Östberg et al. (14) considered that perceived masticatory ability may have other factors (physical, social, and psychological) that could help explain this variable’s behavior among individuals. Makhija et al. (48) verified that masticatory ability was associated with BMI with obese participants rating their ability as poor and being more likely to avoid high-fiber foods in an older population. It is interesting to note in our results that anthropometric measurements were associated with masticatory ability in a sample consisting of young dentate adults. This result might suggest that factors, such as eating rate, should be considered, as reported by Karlopoulou et al. (49), showing that a higher self-reported eating rate was associated with weight gain. This indicates the need to further investigate this association in a larger sample. Gender presented a negative relationship in our data, which indicates that males perceived themselves as chewing better. This may be related to the fact that women are usually more worried about their health. It has been stated that women over-report minor health problems or report health problems at an earlier stage (50). This might explain why women evaluate their chewing more critically in the present study. However, this finding should be interpreted with caution because of the preponderance of females in the sample. According to the results of the third regression model, BMI and WC could explain 5% of taste. Obesity has been linked to diets containing high levels of fat and sugar, which may have implications for taste conditions (51,52); however, Donaldson et al. (53) argued that taste is only one factor among the complex causes of obesity, which corroborates with the percentage of taste predicted in our results.

Finally, it is possible to infer that in healthy young individuals, masticatory function and taste were considered adequate. Moreover, the salivary flow rate was normal for all subjects, probably indicating proper function, although no association was observed. The anthropometric measures had little influence on the studied variables. Nevertheless, some limitations must be noted, such as the greater number of females. These limitations indicate that the results should be interpreted with caution for other populations, although all clinical data were collected under standardized conditions. Moreover, the cross-sectional nature of this study does not permit conclusions about causal relationships.

Masticatory function and taste were weakly related to salivary flow in young healthy adults. Masticatory ability was related to BMI, WC, and gender, whereas taste was only weakly related to BMI. Masticatory function, taste, and salivary flow were similar between genders in young healthy individuals. The flow rate did not exhibit a statistically significant difference between males and females for the anthropometric groups.

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