

Sexual dimorphism of human vallate papillae: an *in vivo* study of normative morphology

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The perimeters of vallate papillae (VP) house approximately half of the taste buds on the human tongue. However, little information exists regarding perimeter measurements of VP. Likewise, great diversity exists among reports of the number of VP and diameter of VP, in general. The research presents an analysis of the perimeters, counts, and diameters of VP in vivo. Endoscopic examination was performed on 79 individuals (40 females, 39 males) between 18 and 26 years of age. A total of 583 VP were counted, 565 of which were able to be measured. Data revealed a statistically significant difference between male and female VP count ($t(75.6) = 4.5$; $p = 0.00003$). Females had, on average, 2.22 more VP than males. Males were found to have larger mean VP diameter per person and mean VP perimeter per person than females ($t(58.9) = -2.4$; $p = 0.021$ and $t(59.3) = -2.4$; $p = 0.019$, respectively). The report demonstrates that VP are sexually dimorphic at the gross anatomical level. (Folia Morphol 2015; 74, 2: 245–251)

Key words: circumvallate papillae, gustation, gustatory papillae, lingual papillae, taste, taste buds, tongue

INTRODUCTION

Vallate papillae

The detailed structure of the tongue was first described by Casserius in 1609 and later, the lingual papillae of the tongue were further expounded by Marcello Malpighius and Lorenzo Bellini in 1664 and 1665, respectively [46]. Vallate papillae (VP), commonly referred to as circumvallate papillae, are lingual papillae, located at the posterior dorsum of the tongue, which form a V-shaped row immediately anterior to the sulcus terminalis [35]. The VP, unlike other lingual papillae, receive innervation from the glossopharyngeal nerves [35]. Developmentally, VP are among the first lingual papillae to form *in utero*, having been reported to develop as early as the 4th week of embryonic development [20]. Currently, the

earliest photographic evidence demonstrates that VP anlagen are well defined by the 6th embryonic week [45].

Among all of the gustatory papillae, VP are the largest and can be seen macroscopically with little effort. Therefore, it is unusual that little agreement has existed regarding the count of VP in humans (Table 1). Most descriptions of VP are found among textbooks and are likely arbitrary estimates of VP counts which document ranges of VP without also identifying important information including demographics such as sex, race, and age. Such demographical information has been documented to have influence over VP morphology. Age, for example, may contribute to the diversity among VP count ranges because, in the elderly, lateral VP undergo involution [2].

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Table 1. Reports of the estimated number of vallate papillae (VP) present in the human tongue

Author(s)	Range of VP [#]	
	Low	High
Cruveilheir*	16	20
Marjolin*	9	15
Sömmering*	12	14
Meckel*	3	20
Freudenreich (1833) [17]	7	9
Ridge (1844) [33]	9	15
Harrison (1848) [18]	12	16
Hassall (1849) [19]	7	8
Todd and Bowman (1850) [39]	8	10
Richardson (1854) [32]	15	20
Folsom (1863) [16]	7	15
Kirkes (1867) [23]	8	10
Flint (1889) [15]	7	12
M'Kendrick and Snodgrass (1893) [27]	8	15
Loveland (1897) [24]	7	10
Stöhr (1901) [36]	8	15
Ferguson (1909) [13]	8	12
Broomell and Fischelis (1913) [4]	6	12
Hollingsworth and Poffenberger (1917) [20]	8	16
Walmsley (1922) [40]	8	12
Cruzon-Miller (1922) [9]	10	13
Bödecker (1926) [3]	9	10
Kamath (1982) [22]	7	12
Miller and Bartoshuk (1991) [26]	3	13
Nelson (1998) [28]	12	15
Jung et al. (2004) [21]	7	9
Standring (2008) [35]	8	12

[#]Ranges were likely reported as estimates

*As documented by Todd (1852) *Cyclopedia of Anatomy and Physiology* [38]

As the name suggests, each VP is surrounded by a vallum, a small mound of tissues, which creates a sulcus around the papilla. The inner surface of the vallum (the perimeter of the VP) houses an average of 250 taste buds [35]. About 50% of the taste buds located on the tongue are located at the VP [30]. Despite the well-established existence of the many taste buds located along the perimeters of VP, little data exists regarding VP perimeter measurements. Likewise, other morphological data, including VP diameter, has been described, but most of these data are widely diverse and likely estimated, too (Table 2).

Table 2. Data documenting the diameter of vallate papillae present in the human tongue

Author(s)	Range of diameter [mm] [§]	
	Low	High
Todd and Bowman (1850) [39]	1/20 th in*	1/12 th in*
Todd ed. (1852) [38]	—	1/8 th in [†]
Kirkes (1867) [23]	1/20 th in*	1/12 th in*
Cunningham (1903) [10]	1	2.5
Hollingsworth and Poffenberger (1917) [20]	1.0	1.5
Broomell and Fischelis (1913) [4]	—	1/4 th in [†]
Standring ed. (2008) [35]	1	2

[§]Ranges were likely reported as estimates; *1/20th in = 1.27 mm; 1/12th in = 2.17 mm; [†]1/8th in = 3.18 mm; [†]1/4th in = 6.35 mm

Gustation

Despite the paucity of well-documented gross anatomical information regarding VP, there is a large body of knowledge regarding taste function and the importance of taste, in general. Taste, especially bitter taste perception, allows for the evaluation of foods that may contain poisons such as plant alkaloids and fermentation products resulting from bacterial contamination [11, 31]. Likewise, taste is linked to human health by way of biased food selection [1, 29, 37, 47]. Biased food selection and differences in eating behaviour, in general, have been linked to differences in sex [6, 7, 12, 34, 41, 42, 44, 48]. Similarly, numerous studies have noted differences in taste perception between males and females, especially with regard to bitter taste [5, 8, 14, 43].

Purpose and rationale

The following report formally documents VP count and gross morphology and accounts for salient details including demographics, methods of data acquisition, and statistical analysis. The relationship between VP count and diameter is explored, as well. Because prior reports have documented differences in gustatory physiology between sexes, the authors rationalised that, likewise, males and females may have apparent sexual differences in gustatory anatomy. Therefore, the report also compares VP morphology between sexes.

MATERIALS AND METHODS

Sample

Research was approved by the West Liberty University Human Subjects Committee. Individuals

participated in the study voluntarily. A total of 79 Caucasian individuals (40 females and 39 males) with an average age of 20.6 ± 1.6 years (mean \pm standard deviation) volunteered for participation in the study. The female and male age ranges were the same (18–26 years). Similarly, the average age of each sex was approximately the same, the female average age was 20.3 ± 1.6 years and the male average age was 20.9 ± 1.5 years. Data, including VP count, was collected from all 79 individuals; however, researchers were not capable of collecting adequate morphological measurements from all participants (1 female and 1 male, respectively). A total of 583 VP were counted and 565 VP were measured.

Methods

In vivo endoscopy was performed with an intraoral camera (Dentamerica Cammy, 1.3 Megapixels) and photographs were taken to assess the morphological characteristics of the VP. Each participant opened their mouth and protruded their tongue to allow access to the posterior dorsum of the tongue. The intraoral camera, sleeved for infection control, was inserted into the oral cavity with care not to touch surrounding anatomy, in order to avoid subject discomfort. Vallate papillae were identified on a computer screen and counted (Fig. 1).

A flattened probe, curved to negotiate the contour of the tongue (convex dorsally, concave ventrally), with a circular reference dot of known diameter (6.25 mm; 0.25 in) located at its tip was utilised as a reference. Intraoral camera sleeves were used to cover the probe for infection control. The probe was manipulated to position the reference dot next to the VP so that both the reference dot and VP could be photographed together. VP morphology was then measured with ImageJ software, utilising the known diameter of the circular dot as a reference for pixel calibration.

Placing the reference dot near the papillae was accomplished with the most ease at the VP located most anterolaterally. In most of the subjects, the probe was not able to be positioned next to the posterior-most papillae due to discomfort (i.e., the gag reflex). In these cases, the diameters of the anterolateral papillae, which had been measured with the reference dot, were then calibrated as references for the posteromedial papillae.

Morphological measurements included papilla perimeter and width. Previous reports have documented estimated VP diameter; however, VP are not

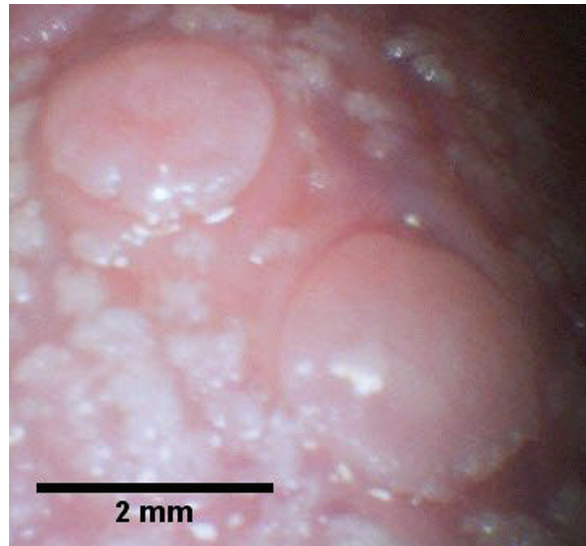


Figure 1. *In vivo* endoscopic presentation of two vallate papillae (VP). The VP are non-keratinised, and therefore appear pink in colour. Surrounding the VP are numerous filiform papillae which appear white due to their keratinisation. The VP are easily identified and differentiated from surrounding structures based on colour, size, and shape.

perfectly circular. Because VP are not perfectly circular, measurements were taken at the widest and narrowest widths of each papilla and averaged for a 'diameter' measurement.

Statistical analysis

The statistical software, Statistical Package for the Social Sciences (IBM SSPS Statistics 20) was used for all of the statistical analyses depicted herein except for the D'Agostino-Pearson omnibus K2 test for normality, which was accomplished via GraphPad Prism software (Version 6). Likewise, all graphical representations included in this report were produced via GraphPad Prism.

RESULTS

Count

A total of 583 VP were counted and 565 VP were measured (96.9%). The average number of VP among all individuals ($n = 79$) was 7.38 ± 2.46 VP per person. Males had an average of 2.22 VP less than females (6.26 ± 2.02 per male, $n = 39$; 8.48 ± 2.37 per female, $n = 40$, respectively). The lowest count of VP was in a male who had a complete absence of VP. A female had the highest count of VP with a total of 15. As assessed by the D'Agostino-Pearson omnibus K2

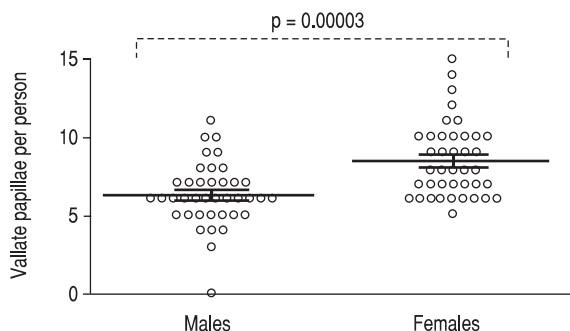


Figure 2. Scatter dot plot demonstrating the statistically significant difference between male and female vallate papillae (VP) counts ($t(75.6) = 4.5$; $p = 0.00003$). Males ($n = 39$) had an average of 6.26 ± 0.32 (mean \pm SEM) VP per person and females ($n = 40$) had an average of 8.48 ± 0.38 , respectively. Most males and females were found to have six VP (mode = 6).

test, both male and female VP counts fit a normal distribution ($K2 = 4.17$, $p = 0.124$ and $K2 = 5.9$, $p = 0.052$, respectively). The Student's t test was performed to explore differences between sexes. There was a statistically significant difference between total number of VP per person between sexes ($t(75.6) = 4.5$; $p = 0.00003$) (Fig. 2).

Perimeter

The average total perimeter of VP per person was 32.22 ± 12.85 mm. The average total perimeter of male ($n = 38$) VP was 30.63 ± 14.44 mm per male, whereas the female ($n = 39$) average was 33.77 ± 11.07 mm (Table 3). No significant differences were

found between the total VP perimeter per person among sexes ($t(69.4) = 1.1$; $p = 0.29$). However, a significant difference was found between male and female mean VP perimeter per person ($t(59.3) = -2.4$; $p = 0.019$) (Table 4). On average, females had a mean VP perimeter per person 0.85 mm less than that of males (Fig. 3).

Diameter

The average VP diameter per person was 1.41 ± 0.49 mm. There was a statistically significant difference between male and female average VP diameter per person ($t(58.9) = -2.4$; $p = 0.021$) (Table 4). On average, females had a mean VP diameter per person 0.26 mm narrower than that of males (Fig. 4). The mean VP diameter per person was found, via Pearson's r , to have a weak negative statistically significant correlation with VP count per person among the total population ($r = -0.29$, $p = 0.011$, $n = 76$). Likewise, females had a moderate negative statistically significant correlation between VP diameter per person and VP count per person ($r = -0.36$, $p = 0.025$, $n = 39$). However, no correlation existed between male VP diameter per person and VP count per person ($r = -0.10$, $p = 0.573$, $n = 37$).

DISCUSSION

Little morphological information, aside from estimated ranges of both VP count and diameter, has been documented regarding VP gross anatomy.

Table 3. Descriptive statistics of vallate papillae (VP) per person among the sample population and sexes

VP parameter	Population	Range		Median	Mean	\pm SD	\pm SEM
		Min	Max				
Count per person	Total population ($n = 79$)	0	15	7	7.38	2.46	0.28
	Males ($n = 39$)	0	11	6	6.26	2.02	0.32
	Females ($n = 40$)	5	15	8	8.48	2.37	0.38
Total perimeter [mm] per person	Total population ($n = 77$)	0	71.4	30.07	32.22	12.85	1.46
	Males ($n = 38$)	0	71.4	27.61	30.63	14.44	2.34
	Females ($n = 39$)	17.1	62.6	30.68	33.77	11.07	1.77
Mean perimeter [mm] per VP per person	Total Population ($n=76$)	1.7	11.9	4.3	4.52	1.56	0.18
	Males ($n = 37$)	2.29	11.9	4.86	4.96	1.83	0.30
	Females ($n = 39$)	1.71	7.32	4.09	4.11	1.13	0.18
Mean papilla diameter [mm] per person	Total population ($n = 76$)	0.52	3.81	1.32	1.41	0.49	0.06
	Males ($n = 37$)	0.71	3.81	1.53	1.55	0.58	0.10
	Females ($n = 39$)	0.52	2.23	1.26	1.28	0.35	0.06

Min — minimum; Max — maximum; SD — standard deviation; SEM — standard error of the mean

Table 4. Comparison of vallate papillae (VP) count, perimeter, and diameter between sexes

VP parameter	Mean \pm SEM		t	df	P	Mean difference	95% CI	
	Males	Females					Lower	Upper
Count per person	6.26 \pm 0.32	8.48 \pm 0.38	4.7	75.6	0.00003*	2.22	1.23	3.21
Total perimeter [mm] per person	30.63 \pm 2.34	33.77 \pm 1.77	1.1	69.4	0.29	3.13	-2.72	8.99
Mean perimeter [mm] per person	4.96 \pm 0.30	4.11 \pm 0.18	-2.4	59.3	0.019*	-0.85	-1.54	-0.14
Mean papilla diameter [mm] per person	1.55 \pm 0.10	1.28 \pm 0.06	-2.4	58.9	0.021*	-0.26	-0.49	-0.04

*Denotes statistical significance ($p < 0.05$); CI — confidence interval; SEM — standard error of the mean

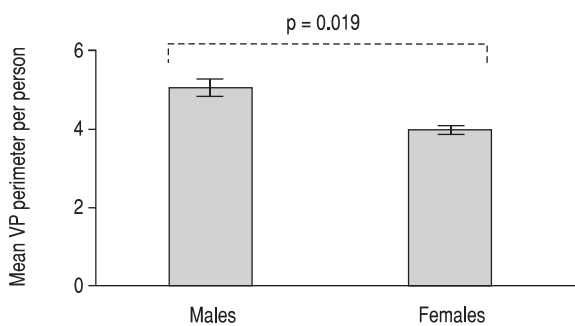


Figure 3. Bar chart demonstrating the statistically significant difference between male and female mean vallate papillae (VP) perimeter per person ($t(59.3) = -2.4$; $p = 0.019$). Males ($n = 37$) had a mean VP perimeter per person of 4.96 ± 0.30 mm (mean \pm SEM) and females ($n = 39$) had an average of 4.11 ± 0.18 mm, respectively.

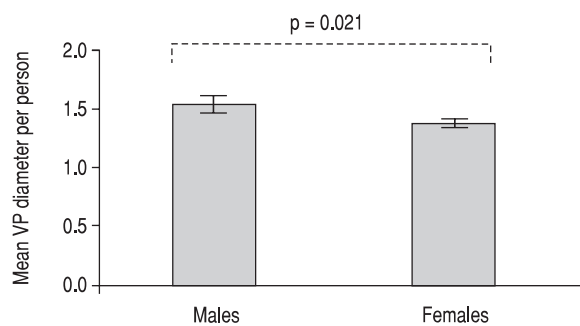


Figure 4. Bar chart demonstrating the statistically significant difference between male and female mean vallate papillae (VP) diameter per person ($t(58.9) = -2.4$; $p = 0.021$). Males ($n = 37$) had a mean VP diameter per person of 1.55 ± 0.10 mm (mean \pm SEM) and females ($n = 39$) had an average of 1.28 ± 0.06 mm, respectively.

Salient information including demographics and measurement techniques have been largely absent from prior reports. The research presented herein has included details of VP count, perimeter, and diameter. The report also identifies demographics (including race, sex, and age), sampling methods, measurement techniques, and statistical methodology. To the authors' knowledge, this report is the first to identify statistically significant differences between VP count, mean diameter per person, and mean perimeter per person between males and females.

In 1999, Mavi and Ceyhan compared the VP of young and elderly males and females in a Turkish population [25]. They counted VP by visual inspection with a tongue depressor. With respect to both sex and age, they noted no differences in VP number. Conversely, this report identifies a significant difference between male and female VP count. A comparison of Mavi and Ceyhan's [25] findings with the findings of this report can be found in Table 5.

Mavi and Ceyhan [25] noted an inverse relationship between VP count and diameter; however, they correlated arbitrary VP count groupings of < 6 , 6 , or > 6 VP with arbitrary diameter groupings ≤ 1 mm, $\geq 1-2$ mm, and ≥ 2 mm, with no description of statistical methods or results aside from " $(p < 0.05)$ ". Conversely, the diameter data from this report (Zdilla et al.) was assessed as parametric data. Among the total sample population of this report, there was a weak statistically significant negative correlation between VP diameter and VP count. When examining the relationship between VP diameter and count in each respective sex, a moderate negative statistically significant correlation was found among females but not among males. At least partially, the results of this study corroborate those of Mavi and Ceyhan [25] with regard to VP count and diameter.

Numerous studies have noted differences in taste acuity between males and females, especially with regard to bitter taste [5, 8, 14, 43]. Similarly, sex has

Table 5. The comparison of the number of vallate papillae (VP) between Turkish young and elderly females and males with the young females and males of this study

Author(s)	Sample				Mean VP count	Standard deviation
	Sex	Sample size	Age range	Mean age		
Mavi and Ceyhan (1999) [25]	Female	15	18–25	20.2	6.3	2.0
		10	60–80	66.6	6.4	1.2
	Male	15	17–20	19.3	5.4	1.1
		14	60–85	71.2	5.9	1.8
Zdilla et al. (current study)	Female	40	18–26	20.3	8.5	2.4
	Male	39	18–26	20.9	6.3	2.0

been demonstrated to contribute to biased food preference and differences in eating behaviour [6, 7, 12, 34, 41, 42, 44, 48]. While gustation is multifaceted, the difference between male and female VP count described herein may be of potential influence to sexual differences in taste acuity, hedonics, and biased food preference. One could hypothesize that if females have an average of 2.22 VP more than males, and each VP possesses an average of 250 taste buds, then females would have an average of 555 taste buds more than males along their VP. However, because no studies have yet determined the number of taste buds per VP perimeter length or the number of taste buds per VP tissue area, the sexual dimorphism of average VP perimeter per person is difficult to translate into gustatory function. Future studies should explore taste bud density in VP and the relationship between VP anatomy and taste physiology, in general, with special attention toward sexual dimorphism.

CONCLUSIONS

Vallate papillae house approximately half of the taste buds on the human tongue. However, little information, aside from estimated ranges of both VP count and diameter, has been documented regarding VP gross anatomy. Likewise, great diversity exists among reports of the number of VP and diameter of VP, in general. Salient information including demographics and measurement techniques have been largely absent from prior reports. This report has documented demographic information as well as measurement techniques. To the authors' best knowledge, this report is the first to identify sexual dimorphism of VP. Females tended to have more VP per person than males; however, males tended to have larger mean VP diameter and perimeter per person than females.

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