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Resemblance of Tongue Anatomy in Twins

Andrew I. Spielman,[1] Joseph G. Brand,[2] Yvonne Buischi[3] and Walter A. Bretz[3]

[1] *Department of Basic Science and Craniofacial Biology, New York University College of Dentistry, United States of America*
[2] *Monell Chemical Senses Center and Department of Biochemistry, School of Dental Medicine, University of Pennsylvania, United States of America*
[3] *Department of Cariology and Comprehensive Care, New York University College of Dentistry, United States of America*

This study compared the anatomical features of the tongue in nine pairs of twins — six monozygotic and three dizygotic. The aim of the project was to determine if tongues, like any other anatomical structure, could be used to reliably predict relatedness given that tongue shape, presentation and surface can be influenced by environment. Using the method of forced choice, 30 subjects were asked to match the photographs of tongues from twins. Our data indicate that, based on visual assessment, monozygotic twins have highly similar tongues (60% matches); similarly, dizygotic twins were matched 31% of the time, which is a higher probability than would be expected from random selection. This study should help identify baseline and control data in future behavioral studies of taste, which has a genetic basis.

■ **Keywords:** twins, concordance, anatomy, tongue

Studies that compare individual differences in monozygotic (MZ) versus dizygotic (DZ) twins are often designed to distinguish those characteristics that are genetically controlled from those that show a high-environmental impact. With few exceptions, such studies have not focused on internal structures, such as the oropharyngeal tissues. For instance, a few twin studies have examined the role of genetics in tooth anatomy. In a study of 34 pairs of twins, it was shown that the mesiodistal dimension for all permanent teeth in MZ twins was more concordant than in DZ twins (Kabban et al., 2001). Similarly, a moderate genetic influence is partly responsible for the high phenotypic variation of the intercuspal distance (Townsend et al., 2003). Morphological features, such as the Carabelli's trait, have higher concordance in MZ twins than in DZ twins (Boraas et al., 1988; Biggerstaff, 1973). Only a single study has provided a detailed map of the occlusal surface topography of the first permanent molars of MZ and DZ twins and singletons (Boraas et al., 1988). That study, however, only examined nine pairs of maxillary first molars and concluded that a significant genetic contribution to occlusal topography was apparent. A recent study assessed the occlusal morphology of mandibular primary first molar teeth from dental casts of 9 MZ twin pairs and 12 DZ twin pairs that were digitized by a contact-type three-dimensional scanner (Su et al., 2008). The heritability estimates of occlusal surface areas for right and left mandibular primary first molars were 97.5% and 98.2%, respectively.

Earlier studies by Rao (Rao & Lew, 1978) revealed that complex segregation analysis of tongue pigmentation in 493 nuclear families failed to indicate significant evidence for incomplete recessivity, polygenic variation, or an effect of sibship environment, thus establishing simple Mendelian inheritance for tongue pigmentation. To date, no studies have analyzed the resemblance rates of tongue topography in human twins.

Usually, individuals of each species show a species-specific and readily identifiable structure of the tongue. For example, the tongue of an aardvark is different from that of a horse. These are two extreme cases where tongue usage contributes to their morphological disparity, because the aardvark's tongue plays an active role in searching for and capturing food. Yet, after a single training session, it is quite easy to segregate tongues of horses from those of pigs or cows. Additional information on comparative

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ADDRESS FOR CORRESPONDENCE: Walter. A. Bretz, DDS, PhD, New York University College of Dentistry, Department of Cariology & Comprehensive Care, 345 East 24th Street, Room 1005, New York, NY, 10010. E-mail: wb36@nyu.edu

tongue topography in humans and animals can be found in Bradley (1971).

The purpose of this study was to determine if MZ twins have discernable similarities in the anatomy of their tongue that would allow them to be distinguished from DZ twins.

TABLE 1

Demographics of the Twin Subjects

Parameters	Age, years	Gender		Zygosity (pairs)	
Total *n* = 18	Mean ± *SD* (range)	M	F	MZ	DZ
	18.2±5.1 (13–28)	*n* = 8	*n* = 10	*n* = 6	*n* = 3

Materials and Methods

Demographics

We compared the tongue morphology of nine pairs of twins (six MZ and three DZ pairs). The twins were recruited from the Twins Institute for Genetics Research at Montes Claros, Minas Gerais, Brazil. The twins were raised together and were still living in the same household. Table 1 provides the demographic data of the study participants. The twins were on average 18 years old and were equally distributed regarding gender.

Consent was obtained following New York University and Universidade Estadual de Montes Claros Institutional Review Boards' guidelines, which are in compliance with the Declaration of Helsinki.

Tongue Pictures

Tongue pictures were taken with a Fuji S2Pro camera (Fuji Co., Japan) using a 55-mm macro lens; the distance between the tongues and the camera was about 12–18", and it was adjusted to provide adequate focus. The digital images were printed out on regular white paper and were provided to the volunteers.

Zygosity

To determine the zygosity type of the twins, DNA was extracted from peripheral venous blood samples and all individuals were genotyped using eight highly polymorphic DNA loci (Bretz et al., 2005). Briefly, short, tandem repeat DNA markers were PCR-amplified by standard methods, and the alleles were determined using an ABI-377 automated DNA sequencer and scored using GENESCAN 2.1 (Applied Biosystems, Foster City, CA, USA). The individuals that differed in one or more alleles were considered dizygotic. This zygosity determination procedure confirmed six pairs of MZ twins and three pairs of DZ twins.

Identification of Tongue Anatomy in Twins

Identification of anatomical similarities was done in a blind fashion. Nine pairs of pictures of tongues from twins were selected. Care was taken to ensure that the sizes of the tongues and pictures were identical. We excluded additional anatomical features from the image (lips, teeth, and uvula) to avoid additional clues that could influence the selection of the appropriate pairs. The nine pairs of pictures were mixed and presented to 30 volunteers who had never seen the pictures before. Half of the volunteers were health care workers in the field of dentistry or sensory neuroscience with prior exposure to images of taste papillae, while the other half were not affiliated with any biomedical institution. No differences in matching rates were found between these two groups. The volunteers were presented with the 18 pictures arranged randomly, and they had 3–4 minutes to assemble them into twin pairs. One of the authors (AIS) administered the test and was 'blind' to the zygosity of the twin pairs. The 18 pictures were coded with a set of random numbers for subsequent decoding.

Results

Figure 1 shows the 18 tongue pictures, which were numbered from 1 to 18 in random order. Before we present the results of the study in Figure 2, we ask the reader to perform the matching of tongues in the same way as it was performed in our study. The reader is asked to look at the 18 photos and to pair them up in 3–4 minutes. Subsequently, the reader is asked to identify which pair of photos is matched by zygosity. The readers' results can be compared to those presented in Figure 2 and Tables 2 and 3. We suggest the reader not look at our results before completing his/her assessment. We would deeply appreciate if the readers' results be sent to the corresponding author in the following pairing format: '2–16, 1–13, 3–18, etc'. For a detailed description of the methods, please see the Methods section.

Figure 2 shows the photos belonging to the nine pairs of twins, their zygosity and the per cent of correct pairing by the 30 volunteers. When the test was performed, the test administrator (AIS) was unaware that six out of the nine sets were MZ twins. The identity of MZ and DZ twins was revealed after the test administration.

A detailed account of the photos that were matched by the volunteers is shown in Table 3. The number of matches ranged from 0 to 6, with an average of 4.5. The volunteer who matched zero pairs was a taste neuroscientist. Most volunteers identified the MZ pairs, while one DZ pair (pictures #13 and 14) was also matched at a 75% rate. The MZ pairs were matched with an average of 60% (range 30–83%).

Discussion

The morphological appearance of the tongue can be described by several parameters, such as size, shape, color, and surface features of the tongue, as well as by the density and pattern of filiform and fungiform papillae. In general, tongue comparisons are problematic because the tongue is a highly muscular structure that, unlike facial structures, is subject to changes in its overall shape. Furthermore, the

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TABLE 2

Concordance Rates for Pictures Correctly Selected by Visual Assessment (n = 30)

Matching of Pairs	Zygosity	% Concordance
1–4	MZ	50
2–12	MZ	30
3–9	MZ	80
5–18	MZ	63
6–8	DZ	7
7–10	MZ	83
11–16	DZ	10
13–14	DZ	75
15–17	MZ	52

features of the tongue are usually not visible and are rarely, if ever, compared in twins.

This study demonstrates that the volunteers were able to match the pictures 60% of the time on average for MZ twins and 31% of the time on average for DZ twins. Both of these percentages are higher than the expected probability of selecting the correct pairs by chance. There are 3,060 possibilities of randomly pairing 18 photos [$^{18}C_2$ = (18 x 17)/2]. Considering chance alone, the expected correct-pairing rate is 22%. We observed a higher correct-pairing rate, clearly demonstrating that the appearances of the tongues are similar, particularly in MZ pairs.

The features that can be used to describe tongues might not be obvious to an untrained eye, but there were no significant differences in the matching abilities between trained (dentists, sensory neuroscientists) and untrained volunteers. Indeed, the tongue is a rather difficult anatomical structure to describe because of its inconsistent characteristics, such as color, shape, overall appearance, presence or absence of grooves, central crevice, and color and length of filiform papillae, among other features. Unlike facial features, which do not considerably change with muscle contraction, the tongue is a highly muscular organ, and contraction or relaxation of the tongue can double or halve its size and roll up or flatten its appearance. In this respect, tongue-rolling might be relevant because the musculature of the tongue, which is associated with the ability to roll it up, might be apparent in its physical appearance at rest.

Hereditary sensory and autonomic neuropathy type IV show a decrease in fungiform papillae or taste sensation

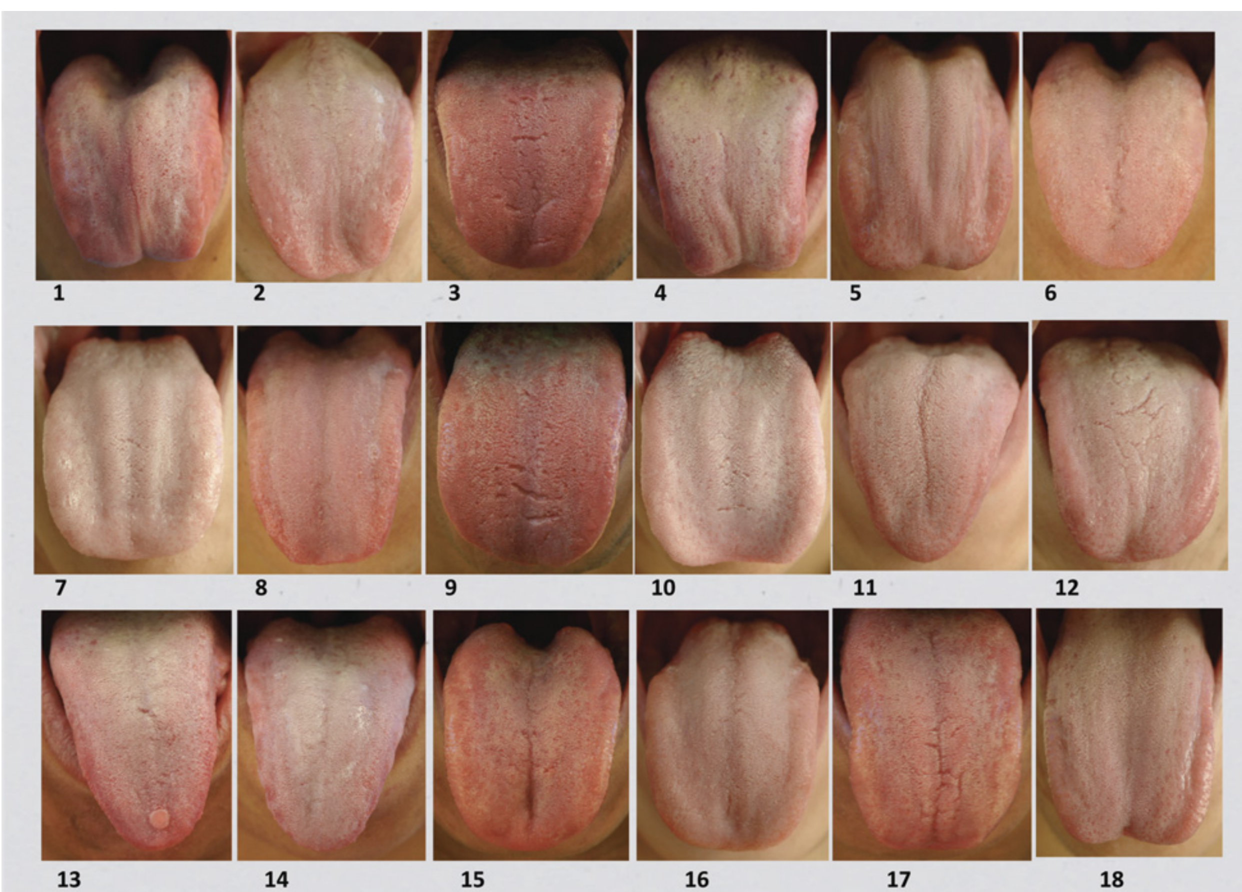

FIGURE 1

Pictures of the tongues used in the study arranged randomly. The reader is asked to match nine pairs of tongues in 3–4 minutes. For the correct matching and results of our study, please see Figure 2 and Table 2.

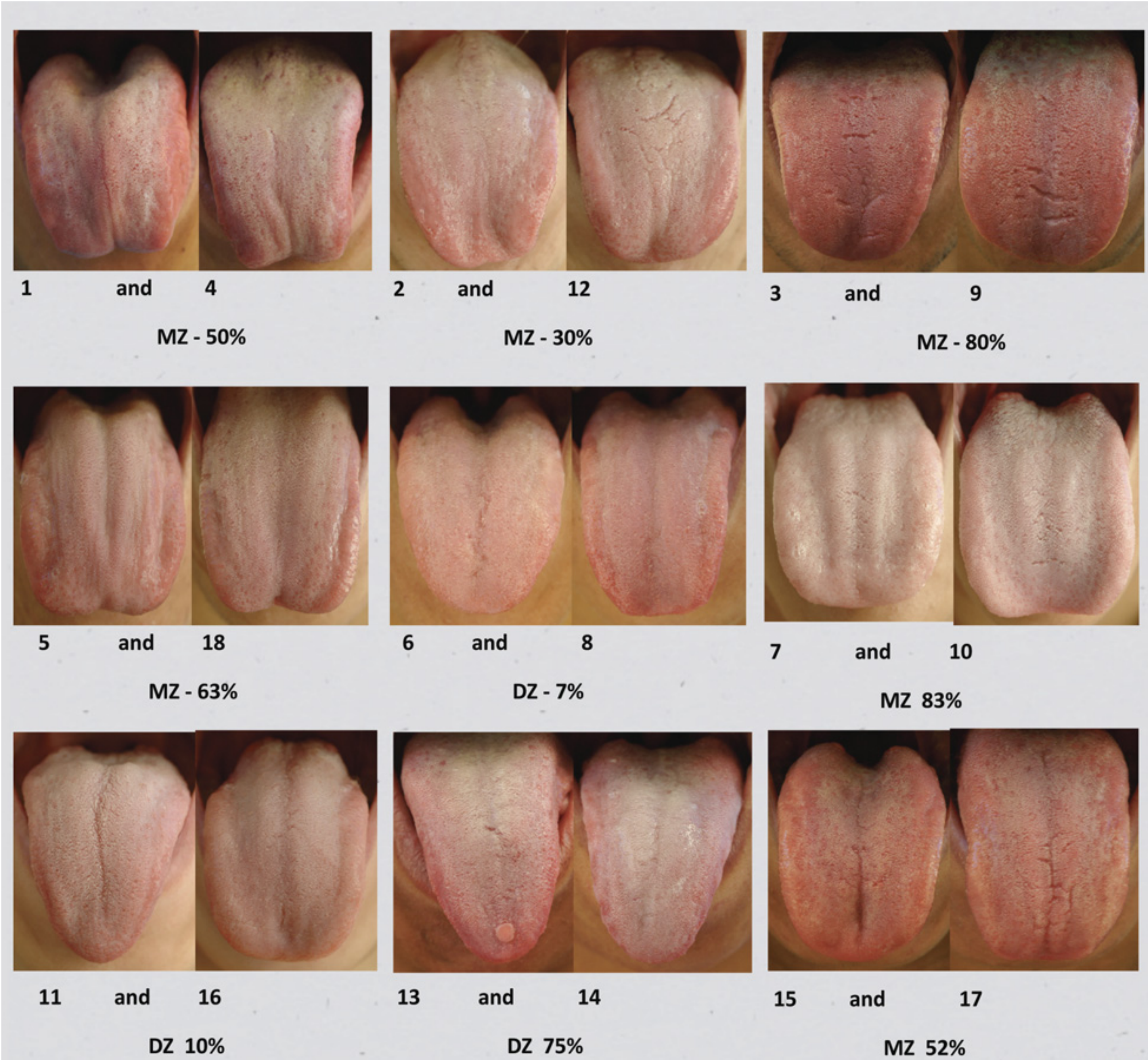

FIGURE 2
Correctly paired tongue photographs used in the study. Nine pairs of pictures, zygosity (MZ = monozygotic, DZ = dizygotic), and the per cent of the time the particular pair was matched by the 30 volunteers.

(Gardner et al., 2008). Initially, we attempted to analyze the number and the distribution pattern of fungiform papillae of the tongues. However, counting the fungiform papillae by placing a grid on top of the tongue pictures proved unreliable. In addition to the inability to verify if a specific feature on the tongue is a fungiform papilla, their density varies from region to region of the tongue, making the grid method misleading (Miller, 1986). Therefore, the characteristics of the fungiform papillae were not a trustworthy attribute to identify the twins. Moreover, untrained personnel may not focus on any particular papillae at all. Rather, they may concentrate on the overall impression that an image conveys (shape, size, density, grooves, and appearance of the filiform rather than the fungiform papillae). Hence, we pursued the picture-matching method in this study.

Before undertaking this study, we hypothesized that MZ twins would have similar patterns of papilla distribution, even though the density of fungiform papillae greatly varies among subjects. In general, most animals have a random pattern of fungiform papillae, while the number and location of circumvallate papillae are rather predictable. One very striking exception to the apparent random placement of fungiform papillae occurs in the pig tongue, where these taste papillae lie in parallel rows running from the anterior to the posterior end of the tongue.

The determinants of the distribution pattern or density of the papillae have recently been identified. A quantitative

TABLE 3
Pairs of Coded Photographs Correctly Identified by Volunteers (*n* = 30)

Volunteer #	Pairs								
1	1 and 4		13 and 14	3 and 9	7 and 10		5 and 18		
2	1 and 4			3 and 9	7 and 10		5 and 18	2 and 12	15 and 17
3	1 and 4			3 and 9	7 and 10		5 and 18	2 and 12	15 and 17
4	1 and 4		13 and 14	3 and 9	7 and 10	6 and 8	5 and 18		15 and 17
5		11 and 16	13 and 14	3 and 9					
6	1 and 4		13 and 14	3 and 9	7 and 10	6 and 8	5 and 18		
7	1 and 4			3 and 9	7 and 10		5 and 18		15 and 17
8				3 and 9	7 and 10		5 and 18	2 and 12	15 and 17
9									
10			13 and 14	3 and 9					
11			13 and 14	3 and 9	7 and 10				15 and 17
12			13 and 14	3 and 9					
13	1 and 4		13 and 14	3 and 9	7 and 10		5 and 18	2 and 12	15 and 17
14			13 and 14		7 and 10		5 and 18		15 and 17
15	1 and 4		13 and 14	3 and 9	7 and 10		5 and 18	2 and 12	15 and 17
16	1 and 4		13 and 14	3 and 9	7 and 10		5 and 18	2 and 12	15 and 17
17	1 and 4	11 and 16	13 and 14	3 and 9	7 and 10		5 and 18		15 and 17
18			13 and 14	3 and 9	7 and 10				15 and 17
19			13 and 14	3 and 9	7 and 10		5 and 18		
20			13 and 14		7 and 10				
21	1 and 4		13 and 14		7 and 10		5 and 18		
22			13 and 14	3 and 9				2 and 12	15 and 17
23			13 and 14	3 and 9	7 and 10			2 and 12	15 and 17
24	1 and 4			3 and 9	7 and 10		5 and 18		
25			13 and 14		7 and 10		5 and 18		
26	1 and 4				7 and 10		5 and 18		
27			13 and 14	3 and 9	7 and 10		5 and 18		
28	1 and 4		13 and 14	3 and 9	7 and 10				
29	1 and 4		13 and 14	3 and 9	7 and 10		5 and 18		
30		11 and 16	13 and 14	3 and 9	7 and 10				
# of times a pair was matched	15	3	23	24	25	2	19	8	14
% frequency picked correctly	50%	10	75	80	83	7	63	30	52
Zygosity	MZ	DZ	DZ	MZ	MZ	DZ	MZ	MZ	MZ

trait locus (QTL) study in sets of 23 BXD recombinant inbred mice found several genes that influence tongue size and taste papilla layout and number (Reiner et al., 2008). Two QTLs that affect tongue length were found on chromosome 5 and 7, and a QTL that influences the number of fungiform papillae was found on chromosome 19. The candidate gene controlling the number of fungiform papillae codes for a nebulin-related anchoring protein and the actin-binding LIM protein 1.

Furthermore, we have performed studies on breath malodor in 50 pairs of twins, and we observed a striking concordance in the presence of tongue coatings (bacterial mats covering the tongue surface) in MZ twins (67%) as opposed to DZ twins (11%) (unpublished data). Besides genetic background, which can conceivably mediate microbial colonization of the tongue surface, it remains to be determined if tongue anatomy also dictates the patterns of bacterial mat accumulation on tongue surfaces.

The results of this study can be used in investigations of whether the pattern of taste papillae changes over time with or without changes in taste sensations. One way to answer this question would be to use these data as a baseline and those from the MZ twin pairs as a control. Similarly, MZ twin data could be used as a control to monitor the recovery of tasting ability following chemotherapy or radiation treatment to the head and neck because these treatments severely impair the ability to taste. If papilla patterns and tasting ability are monitored within an affected subject, a MZ twin pair control may act as an outside reference, especially if baseline data are available. Finally, twin data may be used to determine the role of environmental factors (food/drink exposure) in changes in taste sensitivity. The sets of twins in this study lived together and, presumably, were raised on the same types of food, which provides an opportunity to obtain baseline data on food preferences and taste sensitivity.

Future studies could include food and taste preferences in MZ and DZ twins to aid in taste-associated behavioral studies. Furthermore, this study constitutes a basis for future studies on heritability estimates of tongue anatomy and patterns in larger cohorts.

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