Bull. Natn. Sci. Mus., Tokyo, Ser. D, **15**, December 22, 1989

Genetic Variability of Left-Right Asymmetries and Mirror Imagery in Nonmetric Tooth Crown Characters

By

Yuji Mizoguchi

Department of Anthropology, National Science Museum, Tokyo

Abstract In order to elucidate the degree of the genetic variability of asymmetries and the variability due to mirror imagery specific to monozygotic twins in nonmetric tooth crown characters, twenty-eight such characters were quantitatively analyzed using the tetrachoric correlation method on the basis of 347 Japanese monozygotic and dizygotic twin pairs. From the results and previous studies, it was concluded that the genetic variability of asymmetries and the mirror immagery specific to monozygotic twins seemed negligible in both metric and nonmetric dental characters.

Although not so many authors have investigated the genetic variability of dental asymmetries, most of them have shown or asserted, based mainly on the analyses of variance of familial data, that there is no or little evidence for genetic variability in the bilateral asymmetries of tooth crown diameters (Potter and Nance, 1976; Sharma and Corruccini, 1987; Mizoguchi, 1987; Corruccini *et al.*, 1988). Corruccini and Potter (1981) have reported similar findings also for the absolute left-right differences of molar cusp dimensions. Regarding other traits than human dental ones, Reeve (1960) estimated the genetic variance of the absolute left-right difference in the sternopleural hair number of *Drosophila* as about 2% of the phenotypic variance. Katayama *et al.* (1978) found no or little genetic variability for the magnitude of the fluctuating asymmetries of digital ridge-counts in Japanese. Further, concerning thirteen nonmetric cranial traits in rhesus macaques, McGrath *et al.* (1984) suggested that there was little evidence of a strong genetic influence on their bilateral asymmetries which were observed regardless of the directionality of the asymmetries, though the Falconer's method and phi coefficients used by them for estimating the heritability of all-or-none attributes are not necessarily the best.

While the above findings and assertions are based on the comparisons of familial data, there are other kinds of studies giving a hint for searching out the causes of dental fluctuating asymmetries. Adams and Niswander (1967) showed that such a congenital malformation as cleft lip increased the fluctuating asymmetry in the buccolingual crown diameter of the lower first molar. Barden (1980) also showed that the fluctuating asymmetries in the mesiodistal crown diameters of permanent teeth were consistently greater in Down syndrome patients than in normal subjects. In respect of a nonmetric dental character called Carabelli tarit, Townsend and Brown (1983) indicated that its bilateral asymmetry was greater again in Down syndrome individuals than in controls. These findings suggest, at least, that an increment of the dental fluctuating asymmetry can be caused directly and/or indirectly by genic factors. But it should be noticed here that such genic factors may not necessarily be the causes for the fluctuating asymmetry seen in normal controls. On the other hand, there are a series of reports based on laboratory rats by SIEGEL and co-workers showing that fluctuating asymmetries in bone and tooth size as well as in relative calcium concentrations are increased with noise, heat and cold stresses experimentally given during the developmental periods (SIEGEL and SMOOKLER, 1973; SIEGEL and DOYLE, 1975; MOONEY *et al.*, 1985; SIEGEL and MOONEY, 1987). On the basis of their results, SIEGEL and MOONEY (1987) have maintained a "stress-induced calcium-transport-disruption hypothesis" that the disruption in calcium transport due to an environmental stress is only a short-term, acute alteration during antimeric formation, and that the increase of such a stress leads to an increased magnitude of fluctuating asymmetry of relative calcium levels in various calcium-dependent systems, *i.e.*, long bones, membranous bones and dentition. This hypothesis may be reasonable as an explanation at least for the increment of fluctuating asymmetry induced experimentally, but may not be so for the originally existing part of the fluctuating asymmetry, as in the case of genetic diseases. Although the application of this hypothesis to general fluctuating asymmetries in normal subjects may also be reasonable in part, it should be confirmed, for the present, by the use of the data on relatives in natural conditions whether the causes for the general fluctuating asymmetry itself are genetic, environmental or both, as briefly sketched at the beginning.

As regards the genetic variability of dental size asymmetry, several workers including the present author have investigated it, as mentioned above. For dental minor variants, however, nobody seems to have carried out similar analyses except for a few molar cusps (CORRUCCINI and POTTER, 1981). In the present study, therefore, it was attempted to estimate the relative genetic variance of asymmetries in nonmetric tooth crown characters using the tetrachoric correlation method (PEARSON, 1900). As the data used here were those from twins, mirror imagery within twin pairs of the nonmetric characters was also examined simultaneously. On the mirroring of nonmetric dental characters, there have been a few investigations. According to them, the mirroring not only of CARABELLI trait (BIGGERSTAFF, 1973) but also of other molar and premolar cusps (STALEY and GREEN, 1974) tends to be minimal both in monozygotic and in dizygotic twin pairs.

Materials

On the basis of the dental plaster casts from Japanese monozygotic (MZ) and dizygotic (DZ) twin pairs who lived in Tokyo or the suburbs, twenty-eight nonmetric tooth crown characters (Table 1) were scored by the present author after MIZOGUCHI's (1977) grading system. The MZ twin sample (designated as the EZ series) is composed of 137 male and 135 female twin pairs, and the DZ twin sample (the ZZ series),

Table 1. Chi-square tests of the homogeneity in the frequencies of bilateral symmetry/asymmetry of nonmetric tooth crown characters between the samples used.[1)]

Character	Tooth	Sex	Sample size			OK/EZ		OK/ZZ		EZ/ZZ	
			OK[2)]	EZ[3)]	ZZ[3)]	df	χ^2	df	χ^2	df	χ^2
1. Shoveling	UI1	M	106	226	63	1	0.65	1	0.17	1	0.09
		F	106	230	60	1	0.12	1	0.11	1	0.07
2. Shoveling	UI2	M	114	210	66	2	2.19	1	0.09	2	0.65
		F	114	228	52	2	1.94	1	0.07	1	0.02
3. De Terra's tubercle	UP1	M	106	124	46	2	5.01	2	4.22	2	0.05
		F	106	146	50	2	1.49	2	9.91**	2	9.82**
4. De Terra's tubercle	UP2	M	98	90	14	2	2.45	1	0.00	1	0.38
		F	98	122	32	2	20.9	2	0.86	1	0.02
5. Carabelli's tubercle	UM1	M	114	236	70	2	6.40*	2	3.52	2	5.75
		F	114	188	46	2	1.03	2	2.93	2	4.03
6. Carabelli's tubercle	UM2	M	68	30	16	2	1.55	1	0.02	1	0.54
		F	68	54	4	2	1.77	1	0.05	1	0.18
7. Reduced hypocone	UM1	M	118	232	76	1	4.76*	1	1.32	1	0.04
		F	118	212	46	1	3.96	1	0.01	1	1.01
8. Reduced hypocone	UM2	M	46	30	8	1	0.00	1	1.44	1	1.82
		F	46	38	10	2	0.16	1	0.01	1	0.00
9. Mes. ling. acc. mar. tub.	UM1	M	66	150	44	2	3.12	2	0.30	2	4.41
		F	66	152	46	2	0.88	2	1.82	2	1.77
10. Mes. ling. acc. mar. tub.	UM2	M	78	40	16	2	1.28	1	0.03	1	0.07
		F	78	74	6	2	7.36*	1	0.48	1	0.05
11. Dist. buc. acc. mar. tub.	UM1	M	68	104	44	2	2.02	2	1.32	2	4.06
		F	68	106	30	2	3.50	2	3.77	2	0.43
12. Dist. buc. acc. mar. tub.	UM2	M	34	10	0	1	0.24	—	—[4)]	—	—[4)]
		F	34	12	8	1	0.01	1	0.13	1	0.28
13. Protostylid	LM1	M	90	138	54	2	1.31	2	4.62	2	2.53
		F	90	124	28	2	0.68	2	1.30	2	1.48
14. Protostylid	LM2	M	70	40	18	2	4.32	1	0.00	1	0.05
		F	70	86	6	2	3.44	1	0.42	1	0.18
15. Sixth cusp	LM1	M	94	122	44	2	6.70*	2	2.59	2	2.18
		F	94	136	22	2	1.96	1	1.81	1	1.56
16. Sixth cusp	LM2	M	44	22	2	1	0.21	1	0.43	1	2.37
		F	44	38	6	2	0.82	1	0.02	1	0.30
17. Seventh cusp	LM1	M	92	170	54	2	2.44	2	5.96	2	6.63*
		F	92	146	32	2	0.04	1	1.44	1	2.07
18. Seventh cusp	LM2	M	62	36	10	1	0.38	1	0.17	1	0.01
		F	62	68	12	1	1.88	1	0.30	1	0.16
19. Deflecting wrinkle	LM1	M	84	126	38	2	1.25	1	0.27	1	0.07
		F	84	110	18	2	3.01	1	0.21	1	0.07
20. Deflecting wrinkle	LM2	M	102	76	22	—	—[4)]	—	—[4)]	—	—[4)]
		F	102	134	26	—	—[4)]	—	—[4)]	—	—[4)]
21. Lingual acc. cusp	LP1	M	110	162	52	2	0.59	1	1.74	1	1.34
		F	110	218	52	1	0.01	1	0.00	1	0.09
22. Lingual acc. cusp	LP2	M	98	96	26	2	0.08	1	0.03	1	0.04
		F	98	154	28	2	0.10	1	0.03	1	0.09

Table 1. (Continued)

Character	Tooth	Sex	Sample size			OK/EZ		OK/ZZ		EZ/ZZ	
			OK[2)]	EZ[3)]	ZZ[3)]	df	χ^2	df	χ^2	df	χ^2
23. Reduced hypoconulid	LM1	M	106	172	62	2	1.58	1	4.65*	1	2.48
		F	106	152	32	2	1.68	1	0.11	1	0.23
24. Reduced hypoconulid	LM2	M	62	22	8	1	0.00	1	0.06	1	0.28
		F	62	68	10	2	1.79	1	1.79	1	3.39
25. Groove pattern	LM1	M	24	38	10	1	0.00	1	0.14	1	0.73
		F	24	14	0	1	0.13	—	—[4)]	—	—[4)]
26. Groove pattern	LM2	M	16	0	0	—	—[4)]	—	—[4)]	—	—[4)]
		F	16	34	8	1	0.00	1	0.43	1	0.30
27. Dist. buc. acc. mar. tub.	LM1	M	104	154	50	1	5.75*	1	0.10	1	1.07
		F	104	146	24	1	1.45	1	0.00	1	0.07
28. Dist. buc. acc. mar. tub.	LM2	M	62	24	4	1	0.01	1	0.62	1	1.08
		F	62	56	2	1	0.01	1	3.26	1	6.62*

1) The three categories (left > right, left = right, and left < right) of two samples were compared. When the expected absolute frequencies of less than five were over 20% or when there were one or more expected absolute frequencies of less than unity, two contiguous categories were incorporated after COCHRAN's recommendation (SIEGEL, 1956). When the degree of freedom was unity, YATES' correction (SIEGEL, 1956) was made.

2) The double observations of the OK series, composed of males and females, were combined.

3) The EZ and ZZ series are MZ and DZ twins, respectively. In each series, two members of a twin pair were pooled.

4) The chi-square test was not carried out because the sample size of at least one sample was zero or because the frequencies of both samples for a certain category were 100%.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$.

of 42 male and 33 female like-sexed twin pairs. The dental plaster casts of these twins were collected during 1950's by the project team for general twin studies supported by the Grant-in-Aid for Scientific Research from the Ministry of Education of Japan, and are now stored in the University Museum, the University of Tokyo.

For assessing intraobserver error in scoring, the dental plaster casts of the OK series were employed. This series consists of 61 male and female Japanese singletons from Okinawa. The plaster casts had been collected by Prof. K. HANIHARA of International Research Center for Japanese Studies, Kyoto, and are now housed also in the University Museum, the University of Tokyo.

Methods

The number of the grades set for the degree of development in each nonmetric tooth crown character is in principle four: absence (0), slightly developed (1), relatively well developed (2) and highly developed (3) grades (For the details, see MIZOGUCHI, 1977). The condition of symmetry/asymmetry of a bilateral nonmetric character in an individual is expressed using the sign of the difference between the grades of the right (R) and left (L) sides, *i.e.*, (R minus L). This asymmetry measure, therefore, discontinuously ranges from -1 (R<L) through 0 (R=L) to 1 (R>L). It should be noted that this asymmetry measure is not an absolute left-right difference but a measure with the directionality of asymmetry.

As the purpose was to assess the genetic variability of asymmetries and mirror imagery within twin pairs, the concordance and discordance rates in the above asymmetry measure between two members of a twin pair were firstly calculated. Mirror imagery can be defined as the condition in which one twin of a twin pair has a positive value in respect of the asymmetry measure and the other twin has a negative value. In order to confirm the genetic variability of asymmetry or the existence of mirror-image mechanism in MZ twinning (NEWMAN *et al.*, 1937; TORGERSEN, 1950), the frequencies of concordant and discordant pairs in the asymmetry measure were compared between the OK, EZ and ZZ series. The frequencies relating to the OK series are from the double observations of the right and left sides in the same individuals obtained at an interval of about eight months. The frequencies of "mirror imagery" in this series, therefore, are those completely caused by the intraobserver error in the scoring of the present author. The comparisons of concordance and discordance rates within pairs between the three samples, however, require the premise that the incidences of bilateral symmetry/asymmetry are the same in the samples to be compared because the former concordance and discordance rates can be affected by the latter symmetry/asymmetry incidences. Homogeneity tests in frequencies between different samples were performed using the chi-square test.

The above procedure is for qulitatively inferring the existence, if any, of the genetic variability of asymmetries or the mirror-image mechanism specific to MZ twins. In the present study, furthermore, the quantification of such variability was undertaken by the use of the tetrachoric correlation method (PEARSON, 1900; EVERITT, 1910; MIZOGUCHI, 1977) in the same way as in ordinary metric characters on the assumption of underlying continuous variates with an abrupt threshold. It goes without saying that tetrachoric correlation coefficients within twin pairs on left-right differences are not affected by the incidences of bilateral symmetry/asymmetry unlike the case of the direct comparisons of concordance and discordance rates. But it should be noticed that there is another source of errors more or less affecting the estimation of a tetrachoric correlation coefficient in the present study. It is the inequality of the intervals of grades for the development of a nonmetric character. This problem would not emerge if the all-or-none scoring method were adopted. In this case, however, an extremely high or low incidence might make it difficult to find individuals with asymmetric conditions in the trait.

All the calculations were executed with the HITAC M680H/M682H (VOS3) System of the Computer Centre, the University of Tokyo. The programs used are X2TST for chi-square tests and TETRAC for tetrachoric correlation coefficients. These were written in FORTRAN by the present author.

Table 2. Percent frequencies of twin pairs with asymmetries in the same direction and with mirror imagery in respect of nonmetric tooth crown characters.

Character	Tooth	Zygosity	Sex	Total no. of pairs	Asym-metries in the same direction	Symmetry in one or two twins	Mirror imagery
1. Shoveling	UI1	D. Obs.[1)]		53	0.00	100.00	0.00
		MZ	M	113	0.00	98.23	1.77
			F	115	0.87	99.13	0.00
		DZ	M	34	0.00	100.00	0.00
			F	30	0.00	100.00	0.00
2. Shoveling	UI2	D. Obs.		57	3.51	96.49	0.00
		MZ	M	105	1.90	96.19	1.90
			F	114	1.75	96.49	1.75
		DZ	M	33	3.03	96.97	0.00
			F	26	0.00	96.15	3.85
3. DE TERRA's tubercle	UP1	D. obs.		53	11.32	88.68	0.00
		MZ	M	62	9.68	88.71	1.61
			F	73	8.22	89.04	2.74
		DZ	M	23	4.35	91.30	4.35
			F	25	12.00	84.00	4.00
4. DE TERRA's tubercle	UP2	D. Obs.		49	12.24	87.76	0.00
		MZ	M	45	2.22	93.33	4.44
			F	61	6.56	93.44	0.00
		DZ	M	7	14.29	85.71	0.00
			F	16	6.25	87.50	6.25
5. CARABELLI's tubercle	UM1	D. Obs.		57	21.05	78.95	0.00
		MZ	M	118	6.78	88.98	4.24
			F	94	6.38	87.23	6.38
		DZ	M	35	5.71	88.57	5.71
			F	23	21.74	65.22	13.04
6. CARABELLI's tubercle	UM2	D. Obs.		34	23.53	76.47	0.00
		MZ	M	15	20.00	73.33	6.67
			F	27	11.11	77.78	11.11
		DZ	M	8	0.00	87.50	12.50
			F	2	0.00	100.00	0.00
7. Reduced hypocone	UM1	D. Obs.		59	5.08	93.22	1.69
		MZ	M	116	1.72	97.41	0.86
			F	106	0.94	98.11	0.94
		DZ	M	38	0.00	100.00	0.00
			F	23	4.35	95.65	0.00
8. Reduced hypocone	UM2	D. Obs.		23	13.04	82.61	4.35
		MZ	M	15	0.00	100.00	0.00
			F	19	5.26	89.47	5.26
		DZ	M	4	0.00	75.00	25.00
			F	5	20.00	80.00	0.00
9. Mes. ling. acc. mar. tub.	UM1	D. Obs.		33	30.30	69.70	0.00
		MZ	M	75	2.67	90.67	6.67
			F	76	6.58	82.89	10.53
		DZ	M	22	18.18	77.27	4.55
			F	23	4.35	95.65	0.00
10. Mes. ling.	UM2	D. Obs.		39	15.38	82.05	2.56

Table 2. (Continued)

Character	Tooth	Zygosity	Sex	Total no. of pairs	Asym-metries in the same direction	Symmetry in one or two twins	Mirror imagery
acc. mar. tub.		MZ	M	20	5.00	85.00	10.00
			F	37	2.70	94.59	2.70
		DZ	M	8	12.50	87.50	0.00
			F	3	0.00	100.00	0.00
11. Dist. buc.	UM1	D. Obs.		34	17.65	82.35	0.00
acc. mar. tub.		MZ	M	52	11.54	78.85	9.62
			F	53	9.43	88.68	1.89
		DZ	M	22	4.55	90.91	4.55
			F	15	0.00	100.00	0.00
12. Dist. buc.	UM2	D. Obs.		17	11.76	82.35	5.88
acc. mar. tub.		MZ	M	5	0.00	100.00	0.00
			F	6	0.00	100.00	0.00
		DZ	M	0	—	—	—
			F	4	25.00	75.00	0.00
13. Protostylid	LM1	D. Obs.		45	15.56	82.22	2.22
		MZ	M	69	5.80	86.96	7.25
			F	62	12.90	83.87	3.23
		DZ	M	27	3.70	92.59	3.70
			F	14	0.00	85.71	14.29
14. Protostylid	LM2	D. Obs.		35	31.43	65.71	2.86
		MZ	M	20	10.00	85.00	5.00
			F	43	6.98	83.72	9.30
		DZ	M	9	11.11	88.89	0.00
			F	3	33.33	66.67	0.00
15. Sixth cusp	LM1	D. Obs.		47	31.91	68.09	0.00
		MZ	M	61	9.84	88.52	1.64
			F	68	13.24	79.41	7.35
		DZ	M	22	13.64	86.36	0.00
			F	11	0.00	90.91	9.09
16. Sixth cusp	LM2	D. Obs.		22	9.09	90.91	0.00
		MZ	M	11	9.09	90.91	0.00
			F	19	0.00	94.74	5.26
		DZ	M	1	0.00	100.00	0.00
			F	3	0.00	100.00	0.00
17. Seventh cusp	LM1	D. Obs.		46	8.70	91.30	0.00
		MZ	M	85	1.18	95.29	3.53
			F	73	2.74	95.89	1.37
		DZ	M	27	3.70	85.19	11.11
			F	16	6.25	81.25	12.50
18. Seventh cusp	LM2	D. Obs.		31	12.90	87.10	0.00
		MZ	M	18	0.00	100.00	0.00
			F	34	0.00	100.00	0.00
		DZ	M	5	0.00	80.00	20.00
			F	6	0.00	100.00	0.00
19. Deflecting	LM1	D. Obs.		42	14.29	85.71	0.00
wrinkle		MZ	M	63	6.35	90.48	3.17
			F	55	0.00	98.18	1.82
		DZ	M	19	5.26	94.74	0.00
			F	9	0.00	100.00	0.00

Table 2. (Continued)

Character	Tooth	Zygosity	Sex	Total no. of pairs	Asym-metries in the same direction	Symmetry in one or two twins	Mirror imagery
20. Deflecting wrinkle	LM2	D. Obs.		51	0.00	100.00	0.00
		MZ	M	38	0.00	100.00	0.00
			F	67	0.00	100.00	0.00
		DZ	M	11	0.00	100.00	0.00
			F	13	0.00	100.00	0.00
21. Lingual acc. cusp	LP1	D. Obs.		55	1.82	98.18	0.00
		MZ	M	81	4.95	95.06	0.00
			F	109	0.00	100.00	0.00
		DZ	M	26	3.85	96.15	0.00
			F	26	3.85	96.15	0.00
22. Lingual acc. cusp	LP2	D. Obs.		49	6.12	93.88	0.00
		MZ	M	48	2.08	89.58	8.33
			F	77	9.09	88.31	2.60
		DZ	M	13	0.00	92.31	7.69
			F	14	7.14	78.57	14.29
23. Reduced hypoconulid	LM1	D. Obs.		53	3.77	96.23	0.00
		MZ	M	86	1.16	96.51	2.33
			F	76	1.32	98.68	0.00
		DZ	M	31	0.00	100.00	0.00
			F	16	0.00	100.00	0.00
24. Reduced hypoconulid	LM2	D. Obs.		31	19.35	80.65	0.00
		MZ	M	11	9.09	72.73	18.18
			F	34	11.76	82.35	5.88
		DZ	M	4	0.00	100.00	0.00
			F	5	20.00	80.00	0.00
25. Groove pattern	LM1	D. Obs.		12	8.33	91.67	0.00
		MZ	M	19	0.00	94.74	5.26
			F	7	14.29	85.71	0.00
		DZ	M	5	0.00	80.00	20.00
			F	0	—	—	—
26. Groove pattern	LM2	D. Obs.		8	25.00	62.50	12.50
		MZ	M	0	—	—	—
			F	17	0.00	88.24	11.76
		DZ	M	0	—	—	—
			F	4	0.00	100.00	0.00
27. Dist. buc. acc. mar. tub.	LM1	D. Obs.		52	3.85	94.23	1.92
		MZ	M	77	1.30	98.70	0.00
			F	73	0.00	98.63	1.37
		DZ	M	25	0.00	100.00	0.00
			F	12	0.00	100.00	0.00
28. Dist. buc. acc. mar. tub.	LM2	D. Obs.		31	6.45	93.55	0.00
		MZ	M	12	0.00	100.00	0.00
			F	28	0.00	96.43	3.57
		DZ	M	2	0.00	100.00	0.00
			F	1	0.00	100.00	0.00

[1] Double observations of the OK series.

Results

The homogeneity tests for the samples used (Table 1) showed that in only 10 (6%) of the 168 comparisons there were significant between-sample differences at the 5% level in the frequencies of bilateral symmetry/asymmetry, *i.e.*, "right>left," "right= left" and "right<left" categories. This means that the EZ, ZZ and OK series have the same proportion in respect of the symmetry/asymmetry of almost all the nonmetric tooth crown characters dealt with here, and, therefore, allows of comparing the frequencies of the pairs with asymmetries in the same directions within pairs or with mirror imagery among the OK, EZ and ZZ series. These comparisons are shown in Table 2. The between-sample differences in the concordance and discordance rates listed in this table, however, could not be tested because mainly of the small sample sizes and/or the small number of the grades, *i.e.*, four or three, adopted for the nonmetric characters. But, at least, it seems probable that the frequencies of MZ and DZ twin pairs with mirror imagery are higher than those of the mirroring in the OK series, *i.e.*, the asymmetries due to intraobserver error, in most of the characters, as was expected.

In Table 3, the tetrachoric correlation coefficients within twin pairs on the left-right differences of the nonmetric tooth crown characters are shown. Also in this correlation analysis, there were many cases in which a tetrachoric correlation coefficient could not be estimated because chiefly of the small sample size. If the correlation coefficients based on over twenty pairs are regarded as relatively successful estimates, such successfully obtained coefficients from both MZ and DZ twin pairs can be found for ten cases in Table 3. They are those for the shoveling (male UI2), DE TERRA's tubercle (male and female UP1), CARABELLI's tubercle (male and female UM1), reduced hypocone (female UM1), mesiolingual accessory marginal tubercle (male and female UM1), sixth cusp (male LM1) and seventh cusp (male LM1). Most (70%) of these successfully obtained correlation coefficients are less than about twice the standard error in each both in MZ and in DZ twin pairs, implying that such coefficients are not significantly different from zero. Of the ten cases, however, two, *i.e.*, the CARABELLI's tubercle of females and the mesiolingual accessory marginal tubercle of males revealed significantly greater within-pair correlation coefficients in DZ twin pairs than in MZ. In the remaining eight cases, no significant differences were found between the within-pair correlations of the MZ and DZ twin pairs at the 5% level.

Discussion

In the present study, it was suggested from the comparisons of discordance rates of asymmetries in the twin and double observation samples that at least part of the mirror imagery within twin pairs was not due to observational errors (Table 2), though its significance was not confirmed because of the small sample size. The within-pair

Table 3. Tetrachoric correlation coefficients within twin pairs of left-right differences in nonmetric tooth crown characters.

Character	Tooth	Sex	Within-pair Cor. coef. ± S.E. (*n*)			Normal deviate[1]		
			D. Obs.[2]	MZ	DZ	D. Obs./MZ	D. Obs./DZ	MZ/DZ
1. Shoveling	UI1	M	— (53)[3]	— (113)[3]	— (34)[3]	—	—	—
		F		— (115)[3]	— (30)[3]	—	—	—
2. Shoveling	UI2	M	— (57)[3]	.24 ± .25 (105)[3]	.66 ± .33 (33)[3]	—	—	−1.01
		F		.04 ± .29 (114)[3]	— (26)[3]	—	—	—
3. DE TERRA's	UP1	M	.88 ± .11 (53)[3]	.66 ± .18 (62)	.19 ± .43 (23)[3]	1.06	1.56	1.02
tubercle		F		.38 ± .22 (73)[3]	.22 ± .36 (25)[3]	2.01*	1.76*	0.38
4. DE TERRA's	UP2	M	.71 ± .18 (49)[3]	−.15 ± .33 (45)[3]	.48 ± .54 (7)[3]	2.29*	0.41	−0.99
tubercle		F		.14 ± .28 (61)[3]	— (16)[3]	1.70*	—	—
5. CARABELLI's	UM1	M	.71 ± .15 (57)	.22 ± .19 (118)	.28 ± .32 (35)[3]	2.03*	1.21	−0.17
tubercle		F		−.36 ± .23 (94)[3]	.52 ± .30 (23)[3]	3.94***	0.59	−2.35*
6. CARABELLI's	UM2	M	.61 ± .22 (34)[3]	−.20 ± .44 (15)[3]	— (8)[3]	1.64	—	—
tubercle		F		.57 ± .27 (27)[3]	— (2)[3]	0.10	—	—
7. Reduced	UM1	M	.90 ± .11 (59)[3]	.98 ± .04 (116)[3]	— (38)[3]	−0.73	—	—
hypocone		F		.77 ± .23 (106)[3]	.91 ± .17 (23)[3]	0.50	−0.03	−0.47
8. Reduced	UM2	M	.31 ± .43 (23)[3]	— (15)[3]	— (4)[3]	—	—	—
hypocone		F		.24 ± .45 (19)[3]	1.00 (5)[3],[4]	0.12	—	—
9. Mes. ling.	UM1	M	.93 ± .08 (33)[3]	.02 ± .26 (75)[3]	.77 ± .20 (22)[3]	3.35***	0.76	−2.31*
acc. mar. tub.		F		.08 ± .24 (76)[3]	−.04 ± .41 (23)[3]	3.40***	2.32*	0.25
10. Mes. ling.	UM2	M	.77 ± .16 (39)[3]	.12 ± .44 (20)[3]	.83 ± .30 (8)[3]	1.38	−0.18	−1.33
acc. mar. tub.		F		.17 ± .38 (37)[3]	— (3)[3]	1.46	—	—
11. Dist. buc.	UM1	M	.63 ± .22 (34)[3]	.16 ± .24 (52)	— (22)[3]	1.44	—	—
acc. mar. tub.		F		.37 ± .26 (53)[3]	— (15)[3]	0.77	—	—
12. Dist. buc.	UM2	M	.56 ± .34 (17)[3]	— (5)[3]	— (0)[3]	—	—	—
acc. mar. tub.		F		— (6)[3]	.68 ± .53 (4)[3]	—	−0.19	—
13. Protostylid	LM1	M	.45 ± .24 (45)[3]	.40 ± .22 (69)[3]	— (27)[3]	0.16	—	—
		F		.06 ± .24 (62)[3]	— (14)[3]	1.17	—	—
14. Protostylid	LM2	M	.87 ± .10 (35)[3]	.74 ± .26 (20)[3]	.84 ± .28 (9)[3]	0.48	0.08	−0.29
		F		.22 ± .31 (43)[3]	1.00 (3)[3]	1.99*	—	—
15. Sixth cusp	LM1	M	.83 ± .12 (47)[3]	.52 ± .20 (61)	.17 ± .43 (22)[3]	1.32	1.47	0.73

		F		.51±.20 (68)	— (11)[3]	1.39	—	—
16. Sixth cusp	LM2	M	.86±.17 (22)[3]	1.00 (11)[3),4]	— (1)[3]	—	—	—
		F		— (19)[3]	— (3)[3]	—	—	—
17. Seventh cusp	LM1	M	.99±.03 (46)[3]	.02±.30 (85)[3]	.04±.40 (27)[3]	3.17***	2.34**	−0.04
		F		.24±.33 (73)[3]	.51±.43 (16)[3]	2.23*	1.11	−0.50
18. Seventh cusp	LM2	M	.93±.10 (31)[3]	— (18)[3]	— (5)[3]	—	—	—
		F		— (34)[3]	— (6)[3]	—	—	—
19. Deflecting wrinkle	LM1	M	.99±.02 (42)[3]	.69±.20 (63)[3]	— (19)[3]	1.56	—	—
		F		— (55)[3]	— (9)[3]	—	—	—
20. Deflecting wrinkle	LM2	M	— (51)[3]	— (38)[3]	— (11)[3]	—	—	—
		F		— (67)[3]	— (13)[3]	—	—	—
21. Lingual acc. cusp	LP1	M	.62±.31 (55)[3]	.91±.09 (81)[3]	— (26)[3]	−0.90	—	—
		F		— (109)[3]	— (26)[3]	—	—	—
22. Lingual acc. cusp	LP2	M	.00±.34 (49)[3]	−.06±.34 (48)[3]	— (13)[3]	0.13	—	—
		F		.07±.26 (77)[3]	−.09±.47 (14)[3]	−0.15	0.15	0.29
23. Reduced hypoconulid	LM1	M	.28±.36 (53)[3]	.14±.32 (86)[3]	— (31)[3]	0.29	—	—
		F		.37±.33 (76)[3]	— (16)[3]	−0.18	—	—
24. Reduced hypoconulid	LM2	M	.95±.07 (31)[3]	.38±.50 (11)[3]	— (4)[3]	1.11	—	—
		F		.27±.33 (34)[3]	.26±.68 (5)[3]	2.02*	1.00	0.01
25. Groove pattern	LM1	M	1.00 (12)[3),4]	— (19)[3]	— (5)[3]	—	—	—
		F		1.00 (7)[3),4]	— (0)[3]	—	—	—
26. Groove pattern	LM2	M	.83±.30 (8)[3]	— (0)[3]	— (0)[3]	—	—	—
		F		— (17)[3]	— (4)[3]	—	—	—
27. Dist. buc. acc. mar. tub.	LM1	M	.84±.16 (52)[3]	.94±.11 (77)[3]	— (25)[3]	−0.49	—	—
		F		— (73)[3]	— (12)[3]	—	—	—
28. Dist. buc. acc. mar. tub.	LM2	M	.92±.15 (31)[3]	— (12)[3]	— (2)[3]	—	—	—
		F		— (28)[3]	— (1)[3]	—	—	—

1) A normal deviate for the difference between two tetrachoric correlation coefficients was estimated directly using the correlation coefficients and their standard errors.

2) Double observations of the OK series which is composed of males and females.

3) One or more of the four absolute frequencies in the fourfold correlation table were less than five.

4) There were no discordant pairs.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by the one-tailed test for "D. Obs./MZ" and "D. Obs./DZ," and by the two-tailed test for "MZ/DZ."

correlations of left-right differences were found, in general, to be lower in twin pairs than in the pairs of double observations (Table 3), suggesting the existence of some symmetry disturbing factors except observational errors. And, among the ten sets of the relatively successfully estimated within-pair correlation coefficients for MZ and DZ twin pairs, the correlation coefficients of only two characters, *i.e.*, the CARABELLI's tubercle of females and the mesiolingual accessory marginal tubercle of males were found to be significantly greater in DZ twin pairs than in MZ (Table 3), as mentioned above. But the within-pair correlation coefficients of the other eight cases including the above two characters in the opposite sex did not show any significant differences between MZ and DZ twin pairs at the 5% level. Further, the correlation coefficients themselves in most of the ten cases are suggested not to be different from zero. Although there may be several ways of explaining these facts, the simplest but most likely interpretation is that there is no genetic variability of asymmetries nor mirror imagery specific to MZ twin pairs at least in those nonmetric tooth crown characters. But there is also an alternative possibility that the variability due to mirror imagery specific to twinning processes cancels the genetic variability of asymmetries, resulting in no correlation of asymmetries within twin pairs. Intuitively, however, this possibility seems not to be so high.

The present results with respect to the genetic variability of asymmetries seem compatible with those on the absolute left-right size differences of molar cusps by CORRUCCINI and POTTER (1981) as well as with those on the tooth crown dimensions by POTTER and NANCE (1976), MIZOGUCHI (1987) and CORRUCCINI *et al.* (1988). Also regarding mirror imagery, the present results appear to be consistent with the frequencies of mirroring in CARABELLI trait obtained by BIGGERSTAFF (1973) and with those on the hypoconulid (LM1), seventh cusp (LM1) and the number of cusps (LP1 and LP2) by STALEY and GREEN (1974).

After all, it would be better for the present to consider that the genetic variability of asymmetries and the variability due to the mirror-image mechanism specific to MZ twinning are practically negligible in both metric and nonmetric dental characters, or that the variability of dental asymmetries including spurious mirror imagery within twin pairs is caused largely by accidental environmental factors, some of which may be common to two members of a twin pair.

Acknowledgments

I wish to express my grateful thanks to Dr. Bin YAMAGUCHI of the Department of Anthropology, National Science Museum, Tokyo, for his invaluable comments on the manuscript. I would also like to thank Prof. Kazuro HANIHARA of International Research Center for Japanese Studies, Kyoto, as well as Prof. Tadahiro OOË and Prof. Toshiro KAMIYA who formerly managed the dental plaster casts of twins in the Department of Anatomy, the University of Tokyo, for having made arrangements for my study.

To write this paper, I utilized the NROFF program developed by the Computer Centre, the University of Tokyo, as a word-processor.

Literature cited

ADAMS, M. S., and J. D. NISWANDER, 1967. Developmental 'noise' and a congenital malformation. *Genet. Res., Camb.*, **10**: 313–317.

BARDEN, H. S., 1980. Fluctuating dental asymmetry: A measure of developmental instability in Down syndrome. *Am. J. Phys. Anthrop.*, **52**: 169–173.

BIGGERSTAFF, R. H., 1973. Heritability of the Carabelli cusp in twins. *J. Dent. Res.*, **52**: 40–44.

CORRUCCINI, R. S., and R. H. Y. POTTER, 1981. Developmental correlates of crown component asymmetry and occlusal discrepancy. *Am. J. Phys. Anthrop.*, **55**: 21–31.

CORRUCCINI, R. S., K. SHARMA and R. H. Y. POTTER, 1988. Comparative genetic variance of dental size and asymmetry in U.S. and Punjabi twins. *In*: Teeth Revisited: Proceedings of the VIIth International Symposium on Dental Morphology, Paris 1986, ed. D. E. RUSSELL, J.-P. SANTORO and D. SIGOGNEAU-RUSSELL. *Mem. Mus. natn. Hist. nat., Paris, (serie C)*, Tome 53. pp. 47–53.

EVERITT, P. F., 1910. Tables of the tetrachoric functions for fourfold correlation tables. *Biometrika*, **7**: 437–451.

KATAYAMA, K., Y. TAMAKI and A. TAGAYA, 1978. Genetic study of asymmetry and diversity in digital ridge-counts. *Bulletin of the Osaka Medical School*, **24**: 1–6.

McGRATH, J. W., J. M. CHEVERUD and J. E. BUIKSTRA, 1984. Genetic correlations between sides and heritability of asymmetry for nonmetric traits in rhesus macaques on Cayo Santiago. *Am. J. Phys. Anthrop.*, **64**: 401–411.

MIZOGUCHI, Y., 1977. Genetic variability in tooth crown characters: Analysis by the tetrachoric correlation method. *Bull. Natn. Sci. Mus., Tokyo, Ser. D*, **3**: 37–62.

MIZOGUCHI, Y., 1987. Mirror imagery and genetic variability of lateral asymmetries in the mesiodistal crown diameters of permanent teeth. *Bull. Natn. Sci. Mus., Tokyo, Ser. D*, **13**: 11–19.

MOONEY, M. P., M. I. SIEGEL and T. R. GEST, 1985. Prenatal stress and increased fluctuating asymmetry in the parietal bones of neonatal rats. *Am. J. Phys. Anthrop.*, **68**: 131–134.

NEWMANN, H. H., F. N. FREEMAN and K. J. HOLZINGER, 1937. Twins: A Study of Heredity and Environment. Chicago, University of Chicago Press.

PEARSON, K., 1900. I. Mathematical contribution to the theory of evolution: VII. On the correlation of characters not quantitatively measurable. *Phil. Trans. R. Soc., A*, **195**: 1–47.

POTTER, R. H., and W. E. NANCE, 1976. A twin study of dental dimension: I. Discordance, asymmetry, and mirror imagery. *Am. J. Phys. Anthrop.*, **44**: 391–395.

REEVE, E. C. R., 1960. Some genetic tests on asymmetry of sternopleural chaeta number in *Drosophila*. *Genet. Res., Camb.*, **1**: 151–172.

SHARMA, K., and R. S. CORRUCCINI, 1987. Genetic variance of dental asymmetry in Punjabi twins. *Am. J. Phys. Anthrop.*, **72**: 253.

SIEGEL, M. I., and W. J. DOYLE, 1975. The differential effects of prenatal and postnatal audiogenic stress on fluctuating dental asymmetry. *J. Exp. Zool.*, **191**: 211–214.

SIEGEL, M. I., and M. P. MOONEY, 1987. Perinatal stress and increased fluctuating asymmetry of dental calcium in the laboratory rat. *Am. J. Phys. Anthrop.*, **73**: 267–270.

SIEGEL, M. I., and H. H. SMOOKLER, 1973. Fluctuating dental asymmetry and audiogenic stress. *Growth*, **37**: 35–39.

SIEGEL, S., 1956. Nonparametric Statistics for the Behavioral Sciences. Tokyo, McGraw-Hill Kogakusha.

STALEY, R. N., and L. J. GREEN, 1974. Types of tooth cusp occurrence asymmetry in human monozygotic and dizygotic twins. *Am. J. Phys. Anthrop.*, **40**: 187–196.

TORGERSEN, J., 1950. Situs inversus, asymmetry, and twinning. *Am. J. Hum. Genet.*, **2**: 361–370.

TOWNSEND, G. C., and R. H. BROWN, 1983. Tooth morphology in Down's syndrome: evidence for retardation in growth. *J. ment. Defic. Res.*, **27**: 159–169.