Bull. Natn. Sci. Mus., Tokyo, Ser. D, 9, December 22, 1983

Influences of the Earlier Developing Teeth upon the Later Developing Teeth

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In the dentition of the mouse, the compensatory growth of the later formed teeth has been suggested by some authors. Grüneberg (1965) stated that if the first molar of the mouse, which was the most variable tooth and normally by far the largest in the tooth row, was reduced to become the smallest, then the second and third molars tended to grow even larger than in a normal mouse. Sofaer (1969) asserted the stabilization of length of the tooth row. He said that the formation of a supernumerary tooth at the anterior end of the molar row could be regarded as a positive reaction to the small size of the developing tooth row, tending to restore it to its normal length, while a negative response could also occur in the reverse situation, where, for example, the third molar could be reduced in size and eventually completely suppressed with increasing size of the first two molars. Sofaer (1973) further showed on the basis of the first and second molars of the upper and lower jaws of the mouse that there was a slight though non-significant tendency for greater compensatory interaction to be associated with greater asymmetry of the later developing tooth in each jaw. Although not concerning the compensation within a single population, Kurtén (1967) argued that a negative phyletic correlation was observable between the canine size and that of the anterior premolars of the saber-toothed tiger as well as between the lengths of the lower second and third premolars of the cave hyena when comparing the two populations of different ages.

As regards human dentition, Robinson (1954) considered that the differential reduction of the third and second molars had been probably caused initially by the space shortage within jaws. Sofaer *et al.* (1971b) showed that when a lateral incisor was missing on one side, the central incisor adjacent to the missing tooth was larger than the central incisor on the other side. On the basis of a model for the size of developing teeth and jaws, Sofaer *et al.* (1971a) argued that there could be a tendency for the earlier developing tooth to remain large but for the later developing tooth to become reduced through selection for tooth to jaw size harmony. Recently, however, Townsend and Brown (1980) stated that no evidence was found for compensatory interactions between developing teeth in the permanent dentition of Australian Aboriginals. On the other hand, Mizoguchi (1981) suggested, using the canonical correlation analysis method, that there might be a portion of variation due to the compensatory growth of the later developing teeth within a variation unit which was associated with the anterior or posterior tooth group.

The purpose of this article is to make the existence of the compensatory interaction between teeth much clearer. The simplest method for carrying this out may seem to be estimation of the correlations between the teeth which are supposed to have compensatory interactions. However, even if there would be such an interaction between them, it might not be confirmed by the simple correlation method because the intensity of the interaction was considerably lower than that of the influence of a general size factor upon both of them (MIZOGUCHI, 1981). Here, therefore, the path analysis and principal component analysis methods were used to examine the interrelations in the rest of variation obtained by excluding the influence of the general size factor from the correlations between the relevant characters.

Materials

In the present study, two sorts of data were used. One of them is that from a set of dental plaster casts of 51 male and 52 female Japanese of twelve to fifteen years of age living in Tokyo. These casts were collected by Prof. K. HANIHARA of the Department of Anthropology, the University of Tokyo, in 1955. Their permanent teeth from central incisor to second molar on the right side of both jaws were intact enough to measure the mesiodistal crown diameters on the plaster casts. The measurements were performed by the present author using FUJITA's (1949) method with a sliding caliper with an accuracy of 0.05 mm.

The other is the data published by INOUE *et al.* (1983). This contains somatometric and X-ray cephalometric data in addition to odontometric one. The subjects are 43 male and 46 female Japanese of twenty-five to twenty-seven years old living in Kagoshima Prefecture. The measurement items selected are shown in Table 11 or 12. It should be noted that the data on the third molars of both jaws are nonmetric one, recorded as present or absent. In the present study, the category of "unerupted, impacted or unknown teeth" made up by INOUE *et al.* (1983) was treated as "absence" of a tooth, and all the other categories as "presence." As regards mesiodistal diameters, the data of the teeth on one side, right or left, where more teeth were available for measurement than on the other side, were employed as those representing the teeth of an individual.

Methods

Correlation coefficients between metric characters were estimated by calculating product-moment correlation coefficients (FISHER, 1958). Only when estimating correlation coefficients between the maxillary and mandibular third molars as well as between the thrid molars and other metric characters, the tetrachoric correlation method (PEARSON, 1900; EVERITT, 1910; MIZOGUCHI, 1977) was used.

The way of contribution of the earlier developing teeth to a later developing tooth was examined by the path analysis (WRIGHT, 1934; LI, 1956, 1975; YASUDA, 1969; KEMPTHORNE, 1969). Further, the principal component analysis method (LAWLEY and MAXWELL, 1963; OKUNO *et al.*, 1971, 1976; TAKEUCHI and YANAI, 1972) was employed in order to grasp the whole interrelations between the above odontometric, cephalometric and somatometric characters.

All the calculations were carried out with a computer, HITAC M-200H/M-280H System (VOS3/JSS4), of the Computer Centre, the University of Tokyo. The programs used are TETRAC for tetrachoric correlation coefficients, PATHAN and PCAFPP for path analyses and principal component analyses, respectively, all written in FORTRAN by the present author.

Results and Discussion

It is a problem to determine the criterion after which a tooth is said to develop earlier than another. What is important in clarifying the compensatory interrelation between teeth is to know the developmental stage during which most of the variation in size of a tooth is caused. MIZOGUCHI (1980) suggested that the environmental variances of teeth were intensively associated with the relative lengths of the developmental period before commencement of calcification rather than those of the calcification period itself. Comparing the coefficients of variation for the mesiodistal

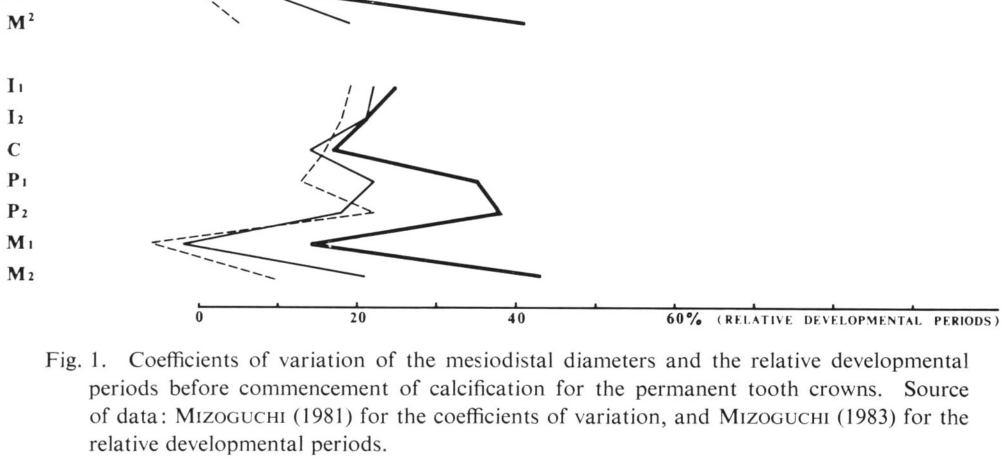

Fig. 1. Coefficients of variation of the mesiodistal diameters and the relative developmental periods before commencement of calcification for the permanent tooth crowns. Source of data: MIZOGUCHI (1981) for the coefficients of variation, and MIZOGUCHI (1983) for the relative developmental periods.

crown diameters (MIZOGUCHI, 1981) to the relative lengths of pre-calcification stage, which were calculated by MIZOGUCHI (1983) on the basis of the data of LOGAN and KRONFELD modified by MCCALL and SCHOUR as well as those of NOLLA (LOWREY, 1973), it seems that there is a proportional or parallel relation between these ratios, especially within each of the anterior and posterior tooth groups (Fig. 1). Therefore, all the permanent teeth were divided into two groups of earlier and later developing teeth by regarding the time of commencement of calcification as a critical point. As a result, classified into the earlier developing tooth group were the central incisor, canine and first molar in the maxillary dentition, while, the central and lateral incisors, canine, and first molar in the mandibular dentition. However, the mandibular central incisor was excluded in the following path analyses because the mandibular central and lateral incisors not only begin to calcify at nearly the same time (MIZOGUCHI, 1983) but also are considerably correlated to each other (MIZOGUCHI, 1981).

Path analysis

In all the path analyses performed, the mesiodistal crown diameters of the earlier developing teeth were assumed to be exogenous variables and those of the later de-

Table 1. Path coefficients of each later developing tooth on the earlier developing teeth in the maxillary permanent dentition based on a Japanese sample from Tokyo.

Later developing teeth		Earlier developing teeth		
		I1	C	M1
Male:	I2	0.51	0.11	−0.08
	P1	−0.02	0.54	0.26
	P2	−0.23	0.58	0.22
	M2	−0.29	0.17	0.56
Female:	I2	0.41	0.22	0.22
	P1	0.20	0.39	0.31
	P2	0.25	0.22	0.39
	M2	0.04	−0.03	0.65

Table 2. Path coefficients of each later developing tooth on the earlier developing teeth in the mandibular permanent dentition based on a Japanese sample from Tokyo.

Later developing teeth		Earlier developing teeth		
		I2	C	M1
Male:	P1	0.05	0.47	0.22
	P2	−0.24	0.44	0.41
	M2	−0.01	0.08	0.54
Female:	P1	0.17	0.54	0.17
	P2	0.09	0.17	0.46
	M2	0.05	0.22	0.52

Table 3. Coefficients of determination in the path analysis of the maxillary permanent teeth based on a Japanese sample from Tokyo.

Later developing teeth		Earlier developing teeth			Joint effect	Residual variable
		I1	C	M1		
Male:	I2	0.26	0.01	0.01	0.02	0.70
	P1	0.00	0.29	0.07	0.14	0.51
	P2	0.05	0.33	0.05	−0.06	0.63
	M2	0.09	0.03	0.31	−0.11	0.68
Female:	I2	0.17	0.05	0.05	0.23	0.51
	P1	0.04	0.16	0.10	0.26	0.45
	P2	0.06	0.05	0.15	0.23	0.51
	M2	0.00	0.00	0.42	0.00	0.57

Table 4. Coefficients of determination in the path analysis of the mandibular permanent teeth based on a Japanese sample from Tokyo.

Later developing teeth		Earlier developing teeth			Joint effect	Residual variable
		I2	C	M1		
Male:	P1	0.00	0.22	0.05	0.12	0.60
	P2	0.06	0.20	0.17	−0.02	0.60
	M2	0.00	0.01	0.29	0.03	0.67
Female:	P1	0.03	0.29	0.03	0.25	0.41
	P2	0.01	0.03	0.21	0.14	0.62
	M2	0.00	0.05	0.27	0.16	0.52

Table 5. Significance tests for the differences between the observed and the estimated correlation coefficients between the maxillary later developing teeth, i.e. endogenous variables, based on a Japanese sample from Tokyo.

		Correlation coefficient		Normal deviate
		Observed	Estimated	
Male:	I2—P1	0.2370	0.2438	−0.07
	—P2	0.1283	0.1370	−0.07
	—M2	0.1124	0.0250	0.61
	P1—P2	0.6950	0.4093	2.90**
	—M2	0.3306	0.2909	0.28
	P2—M2	0.4204	0.2688	1.18
Female:	I2—P1	0.5613	0.5039	0.53
	—P2	0.4895	0.4766	0.09
	—M2	0.3714	0.3290	0.32
	P1—P2	0.8241	0.5082	4.23***
	—M2	0.3026	0.3677	−0.54
	P2—M2	0.3659	0.3898	−0.22

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

Table 6. Significance tests for the differences between the observed and the estimated correlation coefficients between the mandibular later developing teeth, i.e. endogenous variables, based on a Japanese sample from Tokyo.

		Correlation coefficient		Normal deviate
		Observed	Estimated	
Male:	P1—P2	0.7029	0.3585	3.43***
	—M2	0.4153	0.2882	0.99
	P2—M2	0.4995	0.3155	1.52
Female:	P1—P2	0.6342	0.4240	2.04*
	—M2	0.6394	0.4716	1.68
	P2—M2	0.5673	0.4278	1.28

$^{*}P<0.05$; $^{**}P<0.01$; $^{***}P<0.001$.

veloping teeth to be endogenous variables. The results of path analyses based on the sample derived from Tokyo are shown in Tables 1 to 6. In every path analysis, there was no path coefficient with the negative sign and large absolute value (Tables 1 and 2), if the value whose coefficients of determination were more than 10% in Tables 3 and 4 were regarded as large. The path coefficient with the largest absolute value of every later developing tooth had the positive sign, and, besides, was on the nearest one of the earlier developing teeth to the relevant tooth in position within the jaw. Significance tests for the differences between the observed correlation coefficients and those estimated through path analyses showed that most of the results of the path analyses were reasonable (Tables 5 and 6). As an exception, however, the observed correlation coefficients between the first and second premolars tended to be higher than the estimated ones in both maxilla and mandible of males and females. This suggests that there are some other common factors to the premolars than the exogenous variables which were set up.

The path analyses based on the sample from Kagoshima (INOUE *et al.*, 1983) also indicated nearly the same trend as the above case except for the thrid molars (Tables 7 and 8), though the sample sizes for pairs of variables varied from 22 to 43 in males and from 19 to 46 in females.

These results suggest that the later developing teeth except the third molars are influenced more intensively by morphogenetic fields than by the earlier developing teeth which provide a local environment of the later developing teeth. Therefore, the compensatory growth of these later developing teeth, if any, seems very little, though SOFAER *et al.* (1971b) and MIZOGUCHI (1981) suggested the compensatory interaction even between the teeth excluding the third molars. From the facts that unerupted teeth are crowded and overlapped one another within jaws and that the relative positions of the teeth change from the earliest development of the permanent tooth germ at birth to the completed resorption of the deciduous tooth and its replacement by the permanent tooth (LOGAN and KRONFELD, 1933), it might be expected that there was no or little compensatory interaction in mesiodistal crown dimensions be-

Table 7. Path coefficients of each later developing tooth on the earlier developing teeth in the maxillary permanent dentition based on a Japanese sample from Kagoshima[1].

Later developing teeth		Earlier developing teeth		
		I1	C	M1
Male:	I2	0.41	0.36	−0.22
	P1	0.20	0.45	0.01
	P2	0.16	0.17	0.44
	M2	0.05	0.20	0.36
	M3	−0.44	0.31	−0.16
Female:	I2	0.23	0.09	0.08
	P1	0.33	0.36	0.20
	P2	0.35	0.27	0.25
	M2	−0.17	0.21	0.76
	M3	0.37	−0.46	−0.22

[1] Source of data: INOUE *et al.* (1983).

Table 8. Path coefficients of each later developing tooth on the earlier developing teeth in the mandibular permanent dentition based on a Japanese sample from Kagoshima[1].

Later developing teeth		Earlier developing teeth		
		I2	C	M1
Male:	P1	0.10	0.29	0.24
	P2	−0.00	0.27	0.58
	M2	0.08	0.11	0.53
	M3	0.04	−0.15	−0.49
Female:	P1	0.11	0.48	−0.08
	P2	0.30	0.28	−0.05
	M2	0.36	0.09	0.02
	M3	0.29	−0.09	−0.62

[1] Source of data: INOUE *et al.* (1983).

tween the teeth except the third molars.

The influences of the earlier developing teeth upon the third molars, however, were different from those upon other later developing teeth (Tables 7 and 8). The path coefficients with the largest absolute value of the third molars had the negative sign in all the analyses of male and female maxillary and mandibular teeth. In particular, the path coefficients of the mandibular third molars on the first molars were as high as −0.49 in males and −0.62 in females. Most of these results seem reasonable because the significance tests showed no differences between the observed and estimated correlation coefficients (Tables 9 and 10). It is possible to interpret this as evidence suggesting that the third molars which are formed last of all are intensively influenced by the earlier developing teeth, in other words, that the third molars grow to compensate the dentition. If so, this is consistent with the view of stabilization of length of the tooth row in the mouse by SOFAER (1969). It should be noted, however, that

Table 9. Significance tests for the differences between the observed and the estimated correlation coefficients between the third molar and the other teeth in the maxilla based on a Japanese sample from Kagoshima[1].

		Correlation coefficient		Normal deviate[2]
		Observed ± S.E. (n)	Estimated	
Male:	M3—I1	−.3227 ± .2523 (39)	—	—
	—I2	−.7235 ± .1695 (39)	−.1060	−3.64***
	—C	−.0355 ± .2743 (41)	—	—
	—P1	−.3605 ± .2562 (38)	−.0812	−1.09
	—P2	−.0067 ± .2908 (34)	−.1342	0.44
	—M1	−.1754 ± .2818 (32)	—	—
	—M2	−.2071 ± .2719 (38)	−.0874	−0.44
Female:	M3—I1	−.0461 ± .2584 (37)	—	—
	—I2	−.1929 ± .2574 (36)	−.0595	−0.52
	—C	−.3458 ± .2171 (44)	—	—
	—P1	−.1696 ± .2569 (36)	−.1840	0.06
	—P2	−.2154 ± .2503 (37)	−.1637	−0.21
	—M1	−.2201 ± .2570 (35)	—	—
	—M2	−.4910 ± .2163 (37)	−.2337	−1.19

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

[1] Source of data: INOUE *et al.* (1983).

[2] Normal deviates were obtained for the observed tetrachoric correlation coefficients by using their standard errors under the assumption that an estimate obtained from the sum of compound path coefficients was the correlation coefficient in the population.

Table 10. Significance tests for the differences between the observed and the estimated correlation coefficients between the third molar and the other teeth in the mandible based on a Japanese sample from Kagoshima[1].

		Correlation coefficient		Normal deviate[2]
		Observed ± S.E. (n)	Estimated	
Male:	M3—I1	−.0619 ± .2659 (40)	—	—
	—I2	−.0947 ± .2515 (43)	—	—
	—C	−.0757 ± .2529 (43)	—	—
	—P1	.2240 ± .2480 (42)	−.1412	−0.33
	—P2	−.1804 ± .2756 (35)	−.2876	0.39
	—M1	−.4629 ± .2489 (30)	—	—
	—M2	−.4784 ± .2486 (33)	−.2638	−0.86
Female:	M3—I1	−.2671 ± .2273 (45)	—	—
	—I2	.0268 ± .2396 (44)	—	—
	—C	.0000 ± .2348 (46)	—	—
	—P1	−.2291 ± .2359 (42)	.0466	−1.17
	—P2	−.2244 ± .2637 (34)	.0363	−0.99
	—M1	−.5492 ± .2592 (24)	—	—
	—M2	−.1107 ± .2582 (38)	−.0012	−0.42

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

[1] and [2] See the footnote to Table 9.

the dimensions of the erupted third molars were assumed to be greater than those of the "unerupted, impacted or unknown" (INOUE *et al.*, 1983) third molars. This assumption seems reasonable because the mean values of mesiodistal crown diameters of the erupted third molars were, in fact, statistically not different from those of the second molars in the Kagoshima sample (INOUE *et al.*, 1983).

Principal component analysis

In the preceding section, it was suggested that there was no or little compensa-

Table 11. Factor loadings in the principal component analysis of the correlation matrix on the somatometric, cephalometric and odontometric characters in males[1].

	PC I	II	III	IV	V	Communality
Cubic root of weight	.10	.63*	−.40*	−.18	.11	.6021
Height	−.24	.51*	−.18	.46*	.37*	.6967
Sitting height	−.37*	.23	−.26	.36*	.65*	.8103
Head length	.15	.30*	.07	.44*	.03	.3182
Head breadth	.16	.53*	−.32*	−.37*	.23	.5941
Bizygomatic breadth	.35*	.56*	−.17	−.50*	.31*	.8110
Bigonial breadth	.27	.42*	−.28	−.34*	.33*	.5556
Morph. face height	−.06	.53*	−.09	.27	−.52*	.6345
N-ANS	.03	.57*	.28	−.18	−.46*	.6493
ANS-ME	−.14	.36*	−.01	.37*	−.50*	.5367
N-S	.12	.25	.56*	.14	.27	.4799
ANS-PTM	.02	.43*	.39*	−.35*	−.18	.4908
POG-GO	−.15	.40*	.27	.43*	.20	.4755
CD-GO	.01	.53*	.42*	.01	.01	.4574
M-D diameter of UI1	−.70*	.20	−.20	−.40*	−.11	.7544
UI2	−.66*	−.10	−.30*	.04	−.39*	.6847
UC	−.71*	.21	.06	.12	−.18	.5979
UP1	−.77*	.19	−.19	.22	.00	.7028
UP2	−.61*	.03	.26	−.14	.01	.4603
UM1	−.71*	.09	.37*	−.22	.22	.7381
UM2	−.60*	−.07	.26	−.11	−.05	.4446
UM3	.50*	.42*	.62*	−.11	.02	.8224
LI1	−.49*	.25	−.12	−.52*	−.19	.6135
LI2	−.59*	.09	−.14	−.15	−.27	.4652
LC	−.49*	.32*	−.51*	.17	−.03	.6320
LP1	−.69*	.01	−.11	.19	.08	.5295
LP2	−.67*	.18	.22	−.11	.24	.5962
LM1	−.61*	−.30	.53*	−.20	.10	.7943
LM2	−.69*	−.05	.35*	.11	.30*	.7071
LM3	.41*	.52*	.21	.35*	−.27	.6772
Total contribution (%)	22.56	12.92	9.64	8.29	7.69	61.11
Cumulative proportion (%)	22.56	35.49	45.13	53.42	61.11	61.11

1) Source of data: INOUE *et al.* (1983).

* Factor loading of over 0.30 in absolute value.

Table 12. Factor loadings in the principal component analysis of the correlation matrix on the somatometric, cephalometric and odontometric characters in females[1].

	PC I	II	III	IV	V	VI	Communality
Cubic root of weight	.26	.73*	−.02	.22	−.13	.25	.7275
Height	.16	.67*	−.07	−.13	.23	−.31*	.6505
Sitting height	.20	.65*	.01	−.00	.04	−.51*	.7264
Head length	.10	.30	.04	−.08	−.05	.56*	.4212
Head breadth	.34*	.14	−.50*	.56*	−.30*	.05	.7941
Bizygomatic breadth	.35*	.38*	−.15	.51*	−.48*	−.06	.7828
Bigonial breadth	.45*	.18	−.15	.32*	−.04	−.01	.3608
Morph. face height	.21	.74*	−.16	−.18	.27	−.14	.7425
N-ANS	−.18	.13	−.29	−.26	.43*	.30*	.4797
ANS-ME	.11	.61*	.06	−.43*	.00	−.23	.6240
N-S	.17	.36*	−.34*	.08	.01	.63*	.6703
ANS-PTM	.17	−.18	.22	−.46*	−.29	−.08	.4201
POG-GO	.14	.27	.20	.11	−.06	.05	.1523
CD-GO	−.07	.20	.44*	−.08	−.36*	−.04	.3729
M-D diam. of UI1	.74*	−.09	.29	−.30*	.23	.12	.7967
UI2	.37*	−.35*	−.08	.34*	.47*	−.22	.6468
UC	.82*	−.06	.03	.05	.02	.19	.7130
UP1	.81*	.00	.13	−.20	.19	.03	.7499
UP2	.77*	.14	.04	−.08	.29	.32*	.7976
UM1	.78*	−.00	−.11	.19	.11	−.10	.6772
UM2	.72*	−.10	−.36*	.00	.10	−.18	.7010
UM3	−.29	.32*	.83*	.30*	−.03	−.14	.9931
LI1	.71*	−.09	.14	−.30*	−.19	−.11	.6731
LI2	.70*	−.10	.28	.07	−.24	.25	.6980
LC	.66*	−.20	.28	.12	−.03	.18	.6093
LP1	.76*	−.03	.27	−.05	.14	−.11	.6917
LP2	.74*	−.22	.09	.15	−.23	−.14	.7039
LM1	.28	.03	−.21	−.61*	−.67*	.02	.9458
LM2	.71*	−.22	.09	.05	.08	−.21	.6177
LM3	−.32*	.24	.72*	.25	.17	.31*	.8687
Total contribution (%)	26.07	11.29	8.62	7.45	6.46	6.15	66.03
Cumulative proportion (%)	26.07	37.35	45.97	53.42	59.88	66.03	66.03

[1] Source of data: INOUE *et al.* (1983).
* Factor loading of over 0.30 in absolute value.

tory growth of the later developing teeth in the tooth row excluding the third molars. However, the third molars tended to erupt when the earlier developing teeth were small. Then, it was examined by principal component analysis on the basis of the data of INOUE *et al.* (1983) as to what interrelations there were between tooth, jaw and body sizes. The results are shown in Tables 11 and 12, where the sample sizes for pairs of variables varied from 22 to 43 in males and from 19 to 46 in females. From these, it is clear that the first principal component has high correlations with the teeth from central incisors to second molars of both jaws[1] and, at the same time, the reverse correlations with the third molars of both jaws not only in males but also in females. This is consistent with the results of the path analyses. The second principal component which had high correlations with the third molars of both jaws had considerably high correlations in the same direction with the cubic root of body weight, stature, head length, bizygomatic breadth, morphological face height, and lower face height (ANS-ME) in both sexes. The third principal component had relatively high correlations with the third molars of both jaws as well as mandibular ramus height (CD-GO) both in males and in females.

GRÜNEBERG (1965) and SOFAER (1969) asserted the stabilization of length of the tooth row due to the compensatory growth of the later developing teeth in the case of the mouse. ROBINSON (1954) and others argued that the reduction of the human third molars had been probably caused initially by the space shortage within jaws. In human dentition, however, the sizes of jaws seem not to completely control the sizes of all teeth in the ontogenetic process because there is clear evidence for the presence of tooth to jaw size disharmony (HANIHARA *et al.*, 1981). According to the principal component analyses in the present study, the effect of the compensatory growth of the later developing teeth on the whole dentition and that of the space shortage within jaws may be considered to be separate ones. When the compensatory growth of the later developing teeth is taken into account, a premise that the appropriate size of tooth row has been determined in advance with adaptive demands must be set up. If the first principal component obtained here suggests this kind of compensatory growth of the third molars, such a premise is confirmed to be reasonable. However, it should be noted that this component may simply indicate the third molars to vary partly independent of the other teeth, though most of the original correlations between the third molars and the other teeth had the negative sign (Tables 9 and 10). On the other hand, the second or third principal component, independent of the first principal component, suggests that part of the variation in the third moalrs is associated with that of jaws or body. In other words, it is possible to infer that in the variation of the third molars, there are at least two independent parts, of which one is caused by the compensatory growth for completing the dentition of certain size, and the other is influenced by the sizes of jaws and/or body. If so, the former part of variation must be primarily an evolutionary or adaptive phenomenon, while the latter is probably a secondary phenomenon in the sense that what are directly under the control of adaptive demands are jaws and/or body. If this hypothesis is accepted, it will also explain the presence of the tooth to jaw size disharmony mentioned above.

[1] The mesiodistal crown diameter of the mandibular first molar in one of the female individuals reported by INOUE *et al.* (1983) was extraordinarily smaller than the mean value, resulting in the small factor loading of the first principal component on the mandibular first molar in Table 12. The value for this mesiodistal diameter may be misprinted.

Summary and Conclusions

The path analyses of the earlier and later developing teeth suggested that there was no or little compensatory growth of the later developing teeth in the tooth row consisting of the teeth from central incisor to second molar in each jaw, but only the third molar grew to compensate a whole dentition of certain length. The principal component analyses of odontometric, cephalometric and somatometric data indicated the existence of at least two independent parts in the variation of the third molars, one of them being due probably to the compensatory growth of the third molar itself and the other depending upon the size of jaws and/or body.

Acknowledgments

I am very grateful to Professor Kazuro HANIHARA of the Department of Anthropology, the University of Tokyo, and Drs. Bin YAMAGUCHI and Hajime SAKURA of the Department of Anthropology, the National Science Museum, Tokyo, for their frank criticism and advice to this paper. I would also like to thank Associate Professor Sadao SHIMAGUCHI of the Department of Anatomy, School of Medicine, Kitasato University, for his kindly permitting me to use his program ADBMS1 in preparing this article. Further, my gratitude is to Miss Akiko NAKATSUKA who drew the excellent figure.

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