Buccolingual Size Asymmetry and Its Developmental Meaning

Stanley M. Garn, A.B., Ph.D.

Arthur B. Lewis, D.D.S., M.S.

Rose S. Kerewsky

Yellow Springs, Ohio

In a previous paper we considered bilateral asymmetry in the mesiodistal crown diameter, the magnitude of such asymmetry and the extent to which it was systematic throughout the permanent dentition.[5] We found that bilateral asymmetry for this dimension was not systematic, either within individuals or in the sample as a whole. However, the magnitude of asymmetry, averaging ±0.24 mm for all classes of teeth, was larger for boys than for girls, greater for larger teeth than for smaller teeth, and larger for the more distal tooth in each morphological class. Having further shown positive and significant correlations within morphological classes, it was clear that bilateral asymmetry is governed by developmental factors operating within morphological classes (but not between them) and affected both by sex and position within each class.

These findings on the nature of bilateral asymmetry in the mesiodistal dimension immediately directed attention to bilateral asymmetry in the buccolingual diameter. Not only was it important to ascertain whether the same principles were involved (sex, size and position in each class), but it was also important to discover whether the degree and direction of bilateral asymmetry in one crown dimension was related to left-right asymmetry in the other. Finally, having obtained information on buccolingual as well as mesiodistal asymmetry, it would be possible to review the implications of asymmetry to dental genetics and the controlling factors affecting tooth size within morphological classes and in the dentition as a whole.

Methods and Materials

This study of bilateral size asymmetry was based upon vernier caliper measurements of buccolingual and mesiodistal crown diameters made on plaster casts of one hundred eighteen Ohio White adolescents, all regular participants in the Fels Longitudinal Studies. Included for study well before birth, they were unselected with respect to occlusion.[3]

For each pair of corresponding teeth on opposite sides of the midline, size was recorded to the nearest 0.1 mm and punched on standard 80-column IBM punch cards. Thereafter, size asymmetry (d) was machine-calculated by the IBM 1620 Computer as the difference between individual pairs of teeth. The plus sign (+) was assigned when the tooth on the left side exceeded that on the right. Mean values of d were therefore indicative of any tendency towards sidedness within the sample as a whole.

Standard deviations of d (σd), that is the RMS or root mean square asymmetry, were also computer calculated. The greater the value of σd, the greater and more variable the extent of asymmetry for that particular tooth.

Using a specially-written computer program, the degree of left-right asym-

TABLE I

MEAN ASYMMETRY (d) AND RMS ASYMMETRY (σd) IN THE BUCCOLINGUAL DIMENSION OF THE PERMANENT TEETH

TOOTH	Boys				Girls			
	N	$\overline{X}_{d}$*	σd*	Rank*	N	$\overline{X}_{d}$	σd	Rank
Upper								
I 1	56	—0.05	0.25	9	57	—0.08	0.19	12
I 2	53	0.05	0.34	3	51	—0.02	0.31	3
C	34	—0.02	0.27	6	36	—0.08	0.21	9
P 1	54	—0.08	0.20	14	51	—0.07	0.18	13
P 2	55	—0.00	0.26	7	44	—0.01	0.26	4
M1	59	—0.05	0.22	12	55	—0.03	0.20	11
M2	30	—0.06	0.41	1	21	—0.11	0.39	1
Lower								
I 1	54	—0.00	0.22	11	57	0.03	0.18	14
I 2	54	—0.01	0.29	10	58	—0.01	0.20	10
C	50	0.12	0.34	2	48	0.03	0.24	6
P 1	55	—0.00	0.21	13	52	0.04	0.22	8
P2	50	—0.04	0.28	5	42	0.08	0.23	7
M1	54	0.05	0.25	8	57	0.08	0.25	5
M2	19	0.10	0.29	4	18	0.23	0.34	2
Mean		0.00	0.27			0.00	0.24	

*$\overline{X}$d is the average of all asymmetries, taking sign into account. σd is the root mean square (RMS) asymmetry, within which ± limits 66% of cases fall. Rank is the ranking of σd values from highest (1) to lowest (14). Signs retained after rounding from three digits.

metry (d) for each tooth was correlated with the degree of left-right asymmetry of every other tooth within the same jaw and between the jaws. The magnitude of the resulting correlations then indicated the extent to which asymmetry values tended to be related within individuals. In similar fashion the signs of the correlations provided indication as to whether, within individuals, asymmetries tended to be in the same direction.

In the last computational step, left-right asymmetry in the buccolingual diameter was correlated with left-right asymmetry in the mesiodistal dimension, tooth by tooth, and for each sex separately. In this way it was possible to discover whether bilateral asymmetry existed within teeth or whether mesiodistal and buccolingual size asymmetries were essentially different phenomena and (by implication) causally unrelated.

Findings

As shown in Table I, where mean values for bilateral asymmetry ($\overline{X}$d) in the buccolingual diameter are set forth for boys and girls separately, there is no evidence for one side or the other to be systematically larger in this crown dimension. Mean values for bilateral asymmetry average close to 0.00 for both sexes. By sign test the distribution

TABLE II

COMPARISON OF NORMAL TOOTH SIZE VARIABILITY (σ) AND RMS ASYMMETRY (σd) IN THE MESIODISTAL AND BUCCOLINGUAL DIAMETERS

	NORMAL VARIABILITY (σ)				RMS ASYMMETRY (σd)			
	Mesiodistal		Buccolingual		Mesiodistal		Buccolingual	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Upper								
I^1	±0.57	±0.57	±0.49	±0.52	±0.28	±0.19	±0.25	±0.19
I^2	.59	.67	.66	.55	.27	.28	.34	.31
C	.46	.43	.68	.50	.24	.19	.27	.21
P^1	.47	.41	.58	.52	.19	.18	.20	.18
P^2	.46	.42	.61	.52	.22	.21	.26	.26
M^1	.49	.59	.52	.57	.26	.26	.22	.20
M^2	.59	.62	.76	.72	.31	.42	.41	.39
Lower								
I^1	.37	.38	.43	.47	.15	.16	.22	.18
I^2	.42	.40	.46	.47	.15	.15	.29	.20
C	.40	.41	.70	.54	.17	.20	.34	.24
P^1	.47	.39	.57	.52	.18	.17	.21	.22
P^2	.46	.40	.58	.49	.20	.19	.28	.23
M^1	.54	.66	.49	.54	.24	.31	.25	.25
M^2	.62	.59	.58	.57	.34	.35	.29	.34
Mean	0.49	0.50	0.58	0.54	0.23	0.23	0.27	0.24

of negative and positive values of $\overline{X}$d (18:10) does not differ significantly from expectancy (14:14). Thus, with neither the right side nor the left systematically larger, mean values for tooth size employed in orthodontic studies may either be side-specific or combined-side. The latter procedure undoubtedly gives the better estimate of tooth size with numerically small samples.

Although there is no systematic sidedness in asymmetry as shown by the $\overline{X}$d values, RMS asymmetry in the buccolingual dimension is considerable for every tooth, upper or lower and in both sexes. As shown by the measure σd, the root mean squared (RMS) buccolingual asymmetry is not much less than ±0.2 mm and may be as large as ±0.4 mm for the second molar teeth. In general, RMS asymmetry is smallest for the upper first premolar and largest for the upper second molar. Beyond this, RMS asymmetry values tend to be systematically larger for the more distal tooth in each class, without exception, as shown in Figure 1. The more distal tooth, traditionally the more "unstable" tooth, thus has the greater asymmetry as well. Further, RMS asymmetry is systematically larger for boys than for girls (14 of 14 paired values, $\chi^2 > 6.0$). Overall, RMS buccolingual asymmetry amounts to ±0.27 for boys and ±0.24 mm for girls. These RMS asymmetry values (0.27 and 0.24 mm) are roughly half of the magnitude of normal variability of tooth size (σ) for the same teeth and dimensions, 0.58 and 0.54 mm respectively (see Table II).

Taking data from Table I, there is reasonable agreement between the sexes

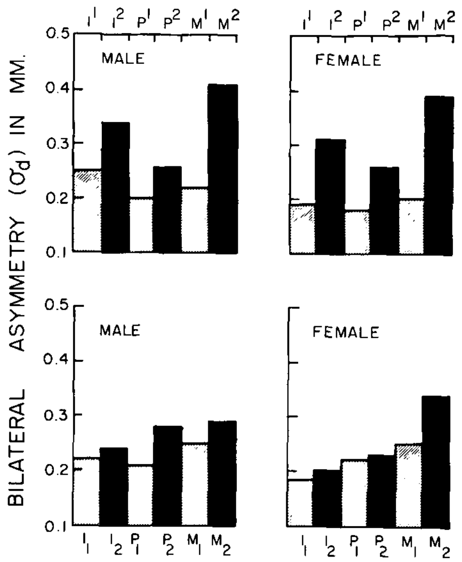

Fig. 1 RMS buccolingual size asymmetry (σd) in the more mesial tooth (shaded bars) and the more distal tooth (solid bars) of each morphological class. Here, as with mesiodistal size asymmetry previously reported by us, RMS size asymmetry is larger for the more distal tooth of each class, suggesting systematic relaxation of genetic control.

in the ranking of RMS asymmetry values for specific teeth, the upper second molar having the largest such asymmetry (rank 1) in both sexes and the upper first premolar tending to the lowest (rank 13-14). The rank-order correlation between the sexes (rho) is 0.8 for RMS bilateral asymmetry in the buccolingual dimension. However, in both sexes taken separately the relationship between tooth size *per se* and the magnitude of bilateral asymmetry in the buccolingual diameter is at best low, rho being 0.05 for boys and 0.36 for girls, respectively. Unlike the mesiodistal diameter, then, where RMS asymmetry is more clearly related to size of individual teeth (the comparable values of rho being 0.73 and 0.63) tooth size is not a systematic determinant of buccolingual size asymmetry.

It is of interest, therefore, to compare RMS asymmetries in the buccolingual and mesiodistal diameters. As summarized from Table II, these two crown dimensions — buccolingual and mesiodistal — yield quite comparable RMS asymmetry values, averaging 0.27 and 0.23 mm for boys and 0.24 and 0.23 mm for girls. Thus, although the buccolingual dimension tends to be larger than the mesiodistal crown diameter of most teeth, RMS asymmetry for the two tooth dimensions is not very different. By sign test (using 3-digit values of σd before rounding off) the observed distribution is almost exactly chance; buccolingual asymmetry is therefore no greater than asymmetry in the mesiodistal diameter.

Turning then to the correlations that relate the degree of buccolingual asymmetry for one tooth with that for all other teeth, upper and lower, it is clear that there is no systematic tendency for such asymmetries to be associated within individuals. Were there such a trend, the distribution of the signs would be systematically positive, whereas no such systematic trend exists, as shown in Table III. Just as on a group basis where there is no uniform tendency for teeth on one side to be larger than the other, within *individuals,* there is also no tendency for buccolingual asymmetries to add or "sum." As with the mesiodistal crown diameter, it is of clinical interest to the practitioner to know that within individuals systematic size asymmetries do not commonly exist.

In our previous study[5] we found evidence for intraclass similarity in mesiodistal crown asymmetry values. That is to say, within each tooth class the degree of left-right asymmetry in one tooth was slightly correlated with the degree of left-right asymmetry in the second tooth. Inspection of the buccolingual asymmetry intercorrelations in Table III revealed a slight tendency for the same intraclass asymmetry correlations. For clarity, we have removed the relevant intraclass asymmetry correla-

TABLE III

BUCCOLINGUAL ASYMMETRY CORRELATIONS (*rd*)
FOR THE MAXILLA AND MANDIBLE

Tooth	I1	I2	C	P1	P2	M1	M2
				maxilla			males
I^1		—.05	.12	—.22	—.01	.09	—.07
I^2	—.06		—.36	—.02	—.01	—.06	—.44*
C	.02	—.03		.01	.12	.00	.18
P^1	.06	—.06	—.05		.26	—.01	—.43*
P^2	—.11	—.10	—.10	.11		.01	—.23
M^1	—.29*	.04	—.07	.08	.37*		—.05
M^2	—.14	—.05	—.21	—.17	—.25	—.01	
	females						
				mandible			males
I^1		.33*	.18	.24	.03	.24	.31
I^2	.19		.14	—.15	—.06	.11	.40
C	.18	.27		.06	.36*	.31*	—.09
P^1	—.11	.04	—.02		.19	.04	—.18
P^2	.24	—.05	.13	.16		.35*	—.15
M^1	.08	.23	.03	.25	.13		.04
M^2	.05	.00	—.10	—.20	.16	.36	
	females						

*Statistically significant at p=.05 or better. Four would be expected by chance alone.

tions from Table III, and have put them together in Table IV. Summarizing the combined-sex data in Table IV, it would appear there is a low, barely significant, intraclass asymmetry correlation (of the order of 0.15-0.20). Teeth of the same morphological class, and within the same jaw, slightly tend toward asymmetry in the same direction.

TABLE IV

ASSOCIATION OF BUCCOLINGUAL ASYMMETRIES
WITHIN TOOTH CLASSES

Asymmetry correlation (*rd*)	Males		Females		Combined	
	N	*r*	N	*r*	N	*r*
I^1 with I^2	50	—0.05	50	—0.06	100	—0.05
I_1 with I_2	51	0.33*	57	0.19	108	0.26*
P^1 with P^2	53	0.26	42	0.11	95	0.19
P_1 with P_2	50	0.19	41	0.16	91	0.18
M^1 with M^2	30	—0.05	21	—0.01	51	—0.03
M_1 with M_2	19	0.04	18	0.36	37	0.20

*Significant at p=.05 or better.

We have also investigated the relationship between buccolingual and mesiodistal size asymmetry within individuals, tooth by tooth and for boys and girls separately. For 28 such rd correlations (14 for boys, 14 for girls), the number of correlations significant at p=.05 was exactly chance, indicating no relationship. By sign test, however, a slight but statistically significant association was observed (20:8, $\chi^2 > 5.0$). So, buccolingual and mesiodistal size asymmetries are barely related variables. For all practical purposes, however, developmental factors that are responsible for left-right size asymmetry in the two most used crown dimensions may be viewed as nearly independent.

Discussion

This study of bilateral asymmetry in the buccolingual crown dimension further extends our previous findings on bilateral asymmetry in the mesiodistal diameter. It shows no evidence of "sidedness," no tendency for the teeth on one side to be consistently larger than the teeth on the other side, either for the sample as a whole or for individuals of either sex within the sample population. For the buccolingual crown diameter, RMS bilateral asymmetry (σd) is of the order of ±0.25 mm, closely approximating values previously obtained for the mesiodistal dimension. These σd values are in accord with other published data when the results are properly analyzed and presented.[1,5,9-11] Though absolutely small, RMS size asymmetry (averaging close to ±0.25 mm) is relatively large compared with normal variability in tooth size (σ) which approximates ±0.55 mm. So a substantial proportion of normal size variability, calculated in the usual way, is due to left-right asymmetry, and all correlations involving tooth size are reduced thereby.*

Buccolingual crown asymmetry (σd) further agrees with mesiodistal crown asymmetry in the tendency for such asymmetry to be larger for boys than for girls, larger for the lower molar teeth than for the incisors, and larger for the more distal tooth in each morphological class, without exception. But while thus demonstrating lawful and meaningful properties, buccolingual size asymmetry does not appear to be related to tooth size. In this respect, therefore, the systematically larger RMS buccolingual size asymmetry in boys cannot be attributed to their 4-5% larger crown diameters alone[6] but may represent a tendency for all crown dimensions to be less effectively under genetic control in the human male. From studies on other developmental parameters, ossification timing, bone lengths, etc., this appears to be part of a general trend. Compared with girls, boys are less consistent *intra se*,[4,7,8] whether in developmental timing or in size attainment. One might even suspect that the course of crowding-spacing and prognosis with or without orthodontic treatment would be less tidily predictable in boys than in girls of comparable developmental level.

It is to this latter consideration that particular attention must now be directed. In a way, tooth size asymmetry represents failure of the genetic code, i.e., incomplete penetrance. Asymmetry is greater within boys than within girls, possibly because the paired X chromosomes in females make for more effective dimensional control. The greater RMS asymmetry (σd) in males further helps to explain systematically lower intratooth size communalities in that sex.[3] That is to say, because of dimen-

*RMS buccolingual size asymmetry (σd) averages ±0.25 for both sexes (as shown in this study) and mesiodistal size asymmetry averages ±0.23 mm, as we have previously shown. While readout error (±0.1 mm) and measuring error ±0.10-0.15 mm) contribute to these values, it is not now practicable to estimate the "true" value of σd.

sional asymmetry, tooth size in males represents the genetic potential a little less. Further, the greater RMS asymmetry for the more distal teeth of all classes (I2, P2 and M2) explains some of the other observations on tooth size.[3] The more distal tooth shows greater RMS asymmetry than the more mesial or "key" tooth, because it is less effectively controlled. Therefore size variance of the more distal tooth is increased and therefore tooth size correlations involving the more distal teeth are lower than tooth size correlations involving the more mesial teeth of each class. Partly because of such RMS variations in the size of paired teeth (more so for boys than for girls) brother-sister difference correlations are probably lower than they might otherwise be, and size differences between brothers are undoubtedly exaggerated as compared with size differences between sisters. The study of left-right size asymmetry thus provides illumination into many other aspects of tooth size and tooth-size relationships within individuals and between siblings of like and unlike sex.

There remains, of course, an intriguing technical problem. Granted that combined left and right teeth provide the best possible estimate of average tooth size, is this necessarily the best estimate of the intention of the genes? It could be that the *larger* tooth in each pair more nearly approximates the genetic potential, and that resulting intercorrelations based on the larger tooth (rather than the combined-side average) would be systematically higher, particularly for the more distal teeth and in sibling comparisons. This suggestion is operationally simple, quite susceptible to testing. It would provide added insight into the meaning of left-right asymmetry and further understanding of the mechanisms by which tooth size is controlled.

We are interested, after all, in the functional meaning of size asymmetry in the permanent dentition. Evidence that σd is greater in the more distal tooth is in accordance with the stated hypothesis that genetic control is more effective for the mesial or "key" tooth in each morphological class. Evidence that σd is systematically greater in the male than in the female (for all teeth and both crown dimensions) is in accordance with the notion that the male, lacking the replicate X chromosome, is therefore more susceptible to noninformational or random "noise," less neatly programmed than the female by the genetic code for such X-mediated continuous variables. The hypothesis that the smaller tooth of an isometric pair represents the greater deviation from the genetic code, affords us an exact test, one that would be confirmed by higher intraindividual, interindividual, co-twin, sibling, and brother-sister tooth size correlations. If that were so, we would then recommend considering the larger tooth, rather than one-side or combined-side dimensions, in attempting to ascertain the intentions of the genes with respect to the mesiodistal and buccolingual crown diameters commonly measured.

Summary

1. Bilateral asymmetry in permanent tooth size was ascertained for both mesiodistal and buccolingual crown diameters of one hundred eighteen Ohio White adolescents.

2. There was no tendency for either left or right teeth to be systematically larger.

3. Buccolingual crown diameter asymmetry (σd) was greater for the more distal tooth of each morphological class, larger for boys than for girls, with RMS asymmetry values (σd) half of the magnitude of normal variability of tooth size (σ).

4. Males and females agreed in the tooth-specific ranking of asymmetry values ($\rho=0.8$), the maxillary second molars showing the most asymmetry and the maxillary first premolars the least.

5. Unlike mesiodistal tooth size asymmetry, buccolingual asymmetries showed little relationship to tooth size *per se*.

6. Although buccolingual dimensions tended to be larger than mesiodistal measurements, RMS asymmetry values were quite comparable for both dimensions.

7. Within individuals as within the group as a whole, there was no tendency for buccolingual asymmetries to by systematic and thus affect an entire side.

8. Within morphological classes there was a low, barely significant association between the amount of buccolingual asymmetry in one tooth and the amount of asymmetry in another tooth.

9. A slight but statistically significant association was observed between buccolingual and mesiodistal size asymmetry within individuals.

10. Systematically greater RMS asymmetry values for boys was attributed to less effective genetic control of tooth size in the XY as compared to the XX, thus accounting for lower intraboy than intragirl size correlations previously noted, as well as lesser brother-brother than sister-sister similarity in tooth size.

Fels Research Institute

ACKNOWLEDGMENTS

This report was supported in part by research grant DE-01294 from the National Institute of Dental Research and computer grant FR-00222, National Institutes of Health, Bethesda, Maryland. We are indebted to Mae Eyman and James Van Doren of the Fels Computer Facility for computational assistance, to Gail Blasingame for Figure 1 and to Christabel G. Rohmann for assistance in programming and data reduction.

BIBLIOGRAPHY

1. Ballard, M. L.: Asymmetry in Tooth Size: A Factor in the Etiology, Diagnosis and Treatment of Malocclusion, *Angle Orthodont.*, 68: 67-70, 1944.
2. Fisher, R. A.: *Statistical Methods for Research Workers*, Edinburgh, Oliver and Boyd, 1958.
3. Garn, S. M., Lewis, A. B. and Kerewsky, R. S.: Size Interrelationships of the Mesial and Distal Teeth, *J. Dent. Res.*, 44:350-354, 1965.
4. ———, X-Linked Inheritance of Tooth Size, *J. Dent. Res.*, 44:439-441, 1965.
5. ———, The Meaning of Bilateral Asymmetry in the Permanent Dentition, *Angle Orthodont.*, 36:55-62, 1966.
6. ———, Sexual Dimorphism in the Buccolingual Tooth Diameter, *J. Dent. Res.*, 45: 18-19, 1966.
7. Garn, S. M. and Rohmann, C.G.: X-Linked Inheritance of Developmental Timing in Man, *Nature*, 196: 695-696, 1962.
8. Garn, S. M., Rohmann, C. G. and Davis, A. A.: Genetics of Hand-Wrist Ossification, *Amer. J. Phys. Anthrop.*, 21:33-40, 1963.
9. Lundstrom, A.: Asymmetries in the Number and Size of the Teeth and Their Aetiological Significance, *Trans. Europ. Orthodont. Soc.*, 167-185, 1960.
10. ———, Some Asymmetries of the Dental Arches, Jaws and Skull, and their Etiological Significance, *Amer. J. Orthodont.*, 47:81-106, 1961.
11. Neff, C. W.: The Size Relationship Between the Maxillary and Mandibular Anterior Segments of the Dental Arch, *Angle Orthodont.*, 27:138-147, 1957.
12. Rohmann, C. G., Garn, S. M. and Davis, A. A.: Parent-Child, Sibling and Twin Similarities in Hand-Wrist Ossification, Fels Research Institute Publication 409, 1962.