The Meaning Of Bilateral Asymmetry In The Permanent Dentition

STANLEY M. GARN, A.B., Ph.D.
ARTHUR B. LEWIS, D.D.S., M.S.
ROSE S. KEREWSKY
Yellow Springs, Ohio

The existence of size asymmetry within the dentition has long been recognized. A tooth on one side of the jaw may be larger or smaller than its antimere by 0.1 mm, 0.4 mm or even more. [1,2,10,12] Such bilateral asymmetries are of concern to the orthodontist in case evaluation and treatment planning. But how often and to what extent do bilateral asymmetries in tooth size occur?

Inseparable from the problem of prevalence and magnitude of size asymmetry in the dentition is the problem of causation. Why may a tooth on one side be larger than the corresponding tooth on the other side? Is this part of a syndrome of hemihypertrophy or hemiatrophy in which all teeth on one side of a jaw are comparably affected? Such a finding would point to independent growth factors affecting the dental anlage of each side of the jaws as a whole. Is a disproportionately large tooth on one side associated with an adjacent tooth of diminished size? Such a finding would point to purely local and reciprocal variations in odontogenesis. Are size asymmetries perceptibly greater for the more distal, more variable or "unstable" tooth in each class? Such a finding would point to the further action of a "field" known to be responsible for number reduction, size reduction and size variance of the more distal tooth of each type.[4-6]

The present study constitutes a report on bilateral asymmetry in 28 of the 32 permanent teeth. It relates, first, to the magnitude of such asymmetry; second, to the possible systematic nature of bilateral asymmetry within and between the jaws; third, to the relationship between bilateral asymmetry and hypodontia; and fourth, to systematic differences in the magnitude of bilateral asymmetry as related to overall tooth size and to position within each morphological class.

METHODS AND MATERIALS

This study of size asymmetry (*d*) in the unworn permanent dentition is based upon vernier caliper measurements of mesiodistal crown diameters made on plaster casts of 239 Ohio white adolescents. Monozygotic twins and triplets were excluded from the study because of the possibility of introducing mirroring due either to the development of laterality subsequent to cleavage, or to intra-uterine pressures.

For each pair of corresponding teeth on opposite sides of the midline, $\overline{I_1|}$ and $\overline{|I_1}$ etc., the size asymmetry *d* was recorded to the nearest 0.1 mm, the readout minimum of the vernier calipers used. The signs + and — reflected the direction of the size asymmetry, a plus value indicating that the tooth on the left side exceeded the corresponding tooth on the right. The mean values of *d* for each pair of teeth thus showed, by their signs, the extent to which crown size asymmetries tended to be systematic.

From individual values of *d*, the Root Mean Square asymmetry or σ_d was calculated for each pair of permanent teeth. The values of σ_d (the standard deviation of *d* value) showed the magnitude of asymmetries characteristic of each tooth in the maxilla and mandible respectively.

In addition to the mean *d* and the Root Mean Square asymmetry value or σ_d, the magnitude and direction of asymmetry values were correlated within individuals. To do this the raw asymmetry or *d* values were converted into normalized T-scores, using McCall's method,[8] by a special computer program. The resulting T-scored values of *d* were effectively free of skewness.[7,8,9] Intraindividual asymmetry correlations were then made using the IBM 16K 1620 computer at the Fels Computer Facility.

Clearly, any tendency for bilateral asymmetry of various teeth to occur in the same direction within individuals would be characterized by positive intra-individual asymmetry correlations. On the other hand a reciprocal relationship between the magnitude and direction of asymmetry values between adjacent pairs of teeth would be characterized by negative intra-individual correlations for the tooth pairs involved. In this way the correlation matrices could be examined to discover whether, *within individuals,* teeth on one side of the midline tended to be systematically larger or smaller. Similarly the correlations could be analyzed to determine whether asymmetries in the permanent dentition represented differential or compensating use of the dental anlage.

Besides testing the hypotheses of (a) sidedness, (b) reciprocal directions of asymmetry between adjacent teeth, and (c) differential susceptibility of certain teeth to left-right asymmetry, attention was also given to (d) the possible relationship between tooth number reduction and the magnitude of bilateral asymmetry. Accordingly, subjects in the total group lacking one or more third molar teeth, as roentgenologically confirmed after the age of 14, were separately studied as previously described.[4-6]

Findings

As shown in Table I, bilateral asymmetry in the permanent dentition showed no systematic tendency toward sidedness on a group basis. The distribution of signs of the mean *d* was essentially chance, both for the total group and for the group of adolescents characterized by tooth number reduction.

The RMS asymmetry values (σ_d), however, evidenced clear-cut and reasonable trends. Values of σ_d were greater for the maxillary teeth as a whole, approximately $\pm$ 0.25 mm, than for the mandibular teeth as a whole, approximating $\pm$ 0.20 mm. In a general way the meaning of the magnitude of the RMS asymmetry values was shown by simple rank order correlations (rho) between the mean size of individual teeth and the corresponding values of σ_d. With values of rho between 0.6 and 0.8 it was clear that larger teeth were characterized by greater side-to-side asymmetry, as also shown graphically in Figure 1.

Despite this expectable general relationship between the size of individual classes of teeth and the magnitude of size asymmetry (σ_d), it was also true that the more distal tooth of each class tended to a larger RMS asymmetry value than the more mesial tooth of the same class. Such a trend was observed for 10 out of 12 possible pairs in the total group, and in a corresponding proportion of pairs in the third molar agenesis group (Table I and Figure 2). Further, the RMS asymmetry tended to be slightly larger in subjects characterized by third molar agenesis. Paired for tooth and sex, σ_d in the third molar agenesis group exceeded the corresponding σ_d in the total group in 20 out of 28 pairings ($\chi^2 = 5.14$ against the chance or 14:14 hypothesis).

Therefore, while tooth size *per se* is closely related to the magnitude of left-

TABLE I

BILATERAL ASYMMETRY (*d*) IN THE PERMANENT DENTITION IN MM

	TOTAL GROUP						THIRD MOLAR AGENESIS GROUP					
	Boys			Girls			Boys			Girls		
TOOTH	N	$\bar{X}_d$*	σ_d**	N	$\bar{X}_d$	σ_d	N	$\bar{X}_d$	σ_d	N	$\bar{X}_d$	σ_d
Upper												
I^1	103	0.02	0.275	131	0.02	0.191	33	–0.03	0.376	43	0.02	0.205
I^2	98	–.01	.268	124	–.01	.276	28	.03	.261	39	–.02	.288
C	88	–.06	.240	117	–.06	.190	32	–.12	.284	41	–.05	.193
P^1	95	–.01	.190	126	.03	.178	30	–.04	.172	42	.06	.189
P^2	92	–.01	.218	114	.04	.210	29	.04	.244	37	.07	.198
M^1	102	–.03	.260	130	–.03	.261	34	–.07	.268	43	–.08	.238
M^2	68	.01	.309	93	.001	.415	25	–.07	.303	31	–.02	.452
Lower												
I_1	100	.03	.147	127	.02	.159	34	.04	.161	39	.04	.175
I_2	106	.04	.151	129	.01	.152	35	.07	.167	42	.01	.148
C	101	.05	.174	127	.06	.195	33	.08	.175	43	.05	.195
P_1	98	.02	.180	125	.02	.168	32	.02	.186	42	.02	.187
P_2	84	–.02	.200	115	.01	.190	23	–.04	.218	39	–.02	.193
M_1	98	.003	.236	128	.03	.307	33	–.01	.266	41	.04	.247
M_2	56	.09	.340	70	–.17	.352	22	.04	.308	23	–.11	.287

* Average negative and positive asymmetries ($\bar{X}_d$)

** σ_d Root Mean Square asymmetry. 66% of cases fall within $\pm\sigma_d$ values shown.

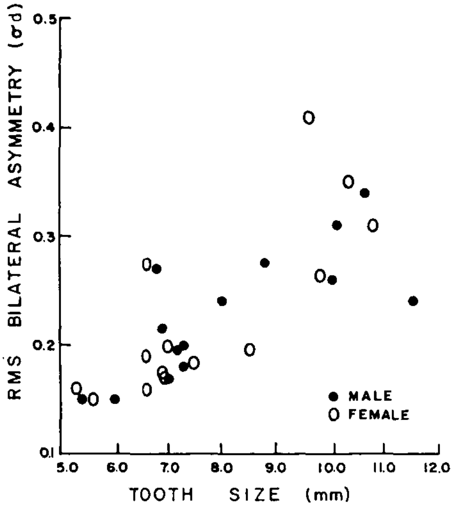

Fig. 1 Relationship between mean size of various tooth classes (abscissa) and the Root Mean Square asymmetry or σ_d (ordinate). For the 14 pairs of teeth shown for each sex in the total group, it is clear that the bigger teeth have the greater size asymmetry. The rank order correlation (rho) is 0.73 in males and 0.63 in females. Comparable rank order correlations hold for the subgroups with third molar agenesis.

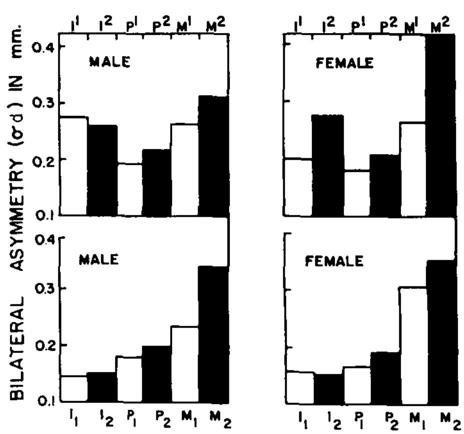

Fig. 2 Comparison of the RMS size asymmetry (σ_d) in the more mesial tooth and the more distal tooth of each morphological class in the total group. In general, the more distal tooth, though slightly smaller on the average, has the larger RMS size asymmetry. The same trend obtains for those subjects with third molar agenesis (see Table I).

right asymmetry in the permanent dentition, the more distal and traditionally more "unstable" tooth of each class is separately subject to disproportionate size asymmetry. Further size asymmetry throughout the dentition is systematically but slightly greater in those subjects characterized by tooth number reduction, primarily agenesis of M3.

Turning from the purely group trends for tooth size asymmetry to intra-individual asymmetry correlations, complete correlation matrices for the total group of 239 subjects are given in Table II. Sex-specific intercorrelation values for asymmetries in the maxillary teeth are shown in the top half, and those for mandibular teeth in the lower half.

Either for maxillary teeth or for mandibular teeth as a whole there is no evidence that within individuals left-right asymmetries of different classes of teeth are in the same direction. Reviewing the signs of the total of 84 correlations tabulated in the second table, it it seen they are essentially at random. Were asymmetries to be systematic within individuals, such that one individual tends to have the larger teeth on the left throughout, and another individual tends to have the teeth larger on the right, the intra-individual asymmetry correlations would then generally be positive. So the complete intra-individual intertooth asymmetry correlations provided in Table II enable us to reject this simple hypothesis of sidedness. Since asymmetry correlations involving adjacent teeth of different morphological classes do not systematically show negative values, the notion of differential or reciprocal competition for segments of the dental anlage may be rejected at this time.

However, intra-individual and intraclass asymmetry correlations are systematically positive throughout. Asymmetries of I_1 do go with asymmetries of I_2, P_1 with P_2, M_1 with M_2, etc., for both sexes in the total group and both

TABLE II

INTERTOOTH ASYMMETRY CORRELATIONS(r_d) FOR MALES AND FEMALES*

Tooth	I1	I2	C	P1	P2	M1	M2
				maxilla			
							males
I^1		.08	–.06	–.08	.07	.10	.02
I^2	.02		.14	.23**	.06	–.12	.04
C	.08	–.07		.12	–.25**	–.16	.28**
P^1	–.06	–.04	–.03		.03	–.13	–.15
P^2	–.20**	–.09	.05	.28**		.14	–.04
M^1	–.02	.07	.05	.08	.14		.10
M^2	–.01	.02	.04	–.05	.17	.09	
	females						
				mandible			
							males
I_1		.20**	.11	.00	–.03	.02	.02
I_2	.01		–.05	.10	.03	.01	.09
C	–.12	.01		.10	–.05	.09	–.16
P_1	.18**	.08	–.05		.19	.11	.03
P_2	–.03	.05	–.05	.06		–.05	–.02
M_1	–.14	–.01	–.04	.12	–.05		.21
M_2	–.13	.05	–.06	.07	.23	.26**	
	females						

* Total group.
** Statistically significant at $p = .05$ or better.

TABLE III

ASSOCIATION IN THE MAGNITUDE OF BILATERAL ASYMMETRY WITHIN MORPHOLOGICAL CLASSES

Correlation (r_d)	Males N	Males r	Females N	Females r	Combined N	Combined r
I^1 with I^2	95	0.08	120	0.20	215	0.05
I_1 with I_2	99	.20*	123	.01	222	.09
P^1 with P^2	85	.03	109	.28*	194	.17*
P_1 with P_2	82	.19	109	.06	191	.13
M^1 with M^2	66	.10	91	.09	157	.10
M_1 with M_2	51	.21	68	.26*	119	.20*

* Significant at $p = .05$ or better. Note that all signs are positive.

sexes in the third molar agenesis (hypodontia) group. For clarity this is shown in Table III where intraclass asymmetry correlations alone are tabulated. Besides the systematic direction of the 18 intraclass asymmetry correlations, the 5 correlations significant at $p = .05$ or better is considerably in excess of expectancy (i.e. 1).

From these 84 correlations involving intra-individual asymmetry values, it is clear that factors in common tend to affect the magnitude and direction of left-right asymmetries within particular morphological classes. Thus, if $\overline{I_1|}$ exceeds $\overline{|I_1}$, $\overline{I_2|}$ will tend to exceed $\overline{|I_2}$. Such a trend does not occur between morphological classes. Local rather than general factors therefore appear to influence side-to-side asymmetries within individuals, though tooth size, tooth position and hypodontia are all meaningfully related to the magnitude of side-to-side asymmetry.

Discussion

The results of this study go far toward answering many questions about size asymmetry throughout the permanent dentition. As previously reported by Lundström[10] and Moorrees,[12] they show that neither the left side nor the right is systematically larger in the size of permanent teeth. They show that the RMS or Root Mean Square size asymmetry approximates ± 0.25 mm for individual pairs of maxillary teeth and ± 0.20 mm for pairs of mandibular teeth. They show that size asymmetry is moderately correlated with tooth size *per se* (rho = 0.6 - 0.8) such that larger teeth are generally characterized by greater side-to-side size discrepancies and vice versa.

The RMS values for bilateral asymmetry (σ_d) given in the first table of this paper are actually in reasonable accord with the earlier published work of Ballard,[1] despite the 0.25 mm measurement intervals employed by him, and his decision to exclude cases where asymmetry values were less than 0.25 mm. If Ballard's *excluded* cases are taken into account (66% - 75% of his sample, depending on the tooth considered) and the difference in the measurement intervals are considered, it will be seen that the majority of his 500 cases and the majority of ours fall within the ± 0.25 mm asymmetry range for individual pairs of teeth.*

Fortunately for the orthodontist, size asymmetry does not ordinarily involve an entire side. One side of a jaw is not systematically larger in mesiodistal tooth diameters than the other. Therefore, we need not look for developmental factors affecting tooth size throughout the right side or the left. Unlike the supporting jaws, or the skull or the postcranial skeleton, hemihypertrophy or hemiatrophy does not commonly characterize the dentition.[11] Genetic factors seem to outweigh intra-uterine pressure and postnatal asymmetries in controlling tooth size within any one of the four dental quadrants.

Size asymmetry in the dentition does make developmental sense, however. Larger teeth, as mentioned above, are certainly subject to larger side-to-side discrepancies in tooth size. The RMS asymmetry, or size variance (σ_d), is also greater in children lacking one or more third molar teeth. The RMS asymmetry is expectably larger for the more distal tooth in each morphological class, I_2, P_2 and M_2, in accordance with our previous findings on increased size variance and lower size communalities for the more distal teeth of each class.[4-6]

* Although Ballard is quoted by Bolton[2] and others as having found that 90% of teeth show asymmetry in excess of 0.25 mm, what Ballard reported was that in 90% of individuals, size asymmetries for at least *one* of twelve pairs of teeth exhibited bilateral asymmetries of this order of magnitude. For any given pair of antimeres, RMS size asymmetry fell below ±0.3 mm, as a critical review of Ballard's paper[1] shows.

Clearly, factors responsible for numerical and dimensional instability in the dentition carry through to size asymmetry, especially when the lateral incisor, the second premolar and the second molar are concerned. Apparently any tendency toward number reduction is reflected by increased dimensional variance throughout the dentition, as we have previously shown. And the more distal tooth of each class, traditionally known as the "unstable tooth," reflects dimensional instability in the systematically greater range of bilateral asymmetry values.

Taking the dentition of a child as a whole, a given direction of size asymmetry in one pair of teeth is not reflected in other tooth pairs. Just as the left side or the right is not systematically bigger within the group as a whole, a given degree of asymmetry is not repeated within individuals. If $\underline{I^1|}$ is greater than $\underline{|I^1}$, $\underline{C|}$ will not necessarily be greater than $\underline{|C}$. Factors responsible for size asymmetry do not affect entire quadrants, as shown by the matrix of intra-individual correlations, as well as by group averages.

However, there is convincing evidence that factors in common do affect asymmetries *within* morphological classes. If $\underline{I^1|}$ is larger than $\underline{|I^1}$, then $\underline{I^2|}$ will tend to be larger than $\underline{|I^2}$ and so on. Unlike interclass asymmetry correlations that are essentially random in sign and distribution, intraclass asymmetry correlations are systematically positive. This is true for all three morphological classes, incisors, premolars and molars. Either more of the anlage goes into *both* of the teeth of a class on one side, or *both* are similarly affected in the course of later development.**

** The existence of fused teeth involving a single morphological class, as well as high intraclass correlations for tooth size, further support the concept that local factors involving a single class may operate differentially on one side or the other.

The interclass asymmetry correlations involving teeth of adjacent classes (I_2 with C, C with P_1, P_2 with M_1, etc.) provide us a partial answer to this problem. Were bilateral (size) asymmetry caused by a disproportionately large (or small) share of the anlage on one side for one morphological class, then the adjacent teeth of other morphological classes might be expected to show reverse size asymmetry, and hence *negative* correlations. But no such evidence comes from this study. Intraclass size asymmetries are positively correlated, but interclass asymmetries, even though involving adjacent teeth, are not systematically related. Thus, factors that cause asymmetry are clearly class-limited.

The magnitude of size asymmetries, under ± 0.3 mm for the majority of each sex for each pair of teeth considered, does not show bilateral asymmetry to be a common problem. Except in rare cases such asymmetries do not sum. However, such asymmetries are relatively large compared with the normal size variation (σ) of the teeth involved. They raise the operational question of whether tooth size is best represented as the average of the two sides, as frequently done, by the size of the teeth on the left side alone (as we have done in many of our studies) or by employing the size of the bigger tooth of each pair.

Finally there is the question of the anatomical source of the side-to-side discrepancy in tooth size. Much of the discrepancy may be in the thickness of the enamel. Alternatively, the size discrepancy may be in the dentin. Bilateral asymmetry in the permanent dentition may also be a product of variations in both enamel thickness and variations in the size of the dentinal structures. Further studies of size asymmetry need to be qualitative.

Summary

1. The degree of bilateral asymmetry

(d) in mesiodistal crown diameters was investigated in 14 pairs of permanent teeth in each of 239 Ohio white adolescents.

2. Bilateral asymmetry ($\bar{X}_d$) proved to be randomly distributed with respect to side. The Root Mean Square (RMS) asymmetry value σ_d approximated ± 0.25 mm for individual maxillary teeth and ± 0.20 mm for individual mandibular teeth..
3. The RMS asymmetry was markedly related to tooth size *per se* (rho = 0.6 - 0.8).
4. Apart from tooth size, RMS asymmetry was also greater for the more distal tooth of each morphological class, and was slightly greater for all tooth classes and positions in subjects characterized by third molar agenesis.
5. Within individuals, teeth of the same morphological class tended to exhibit similar degrees and direction of asymmetry as shown by intraclass correlations (r_d). Interclass correlations were randomly distributed.
6. Accordingly, bilateral asymmetry in the permanent dentition was seen to be of purely local origin and probably postembryonic in timing. Asymmetry was shown to affect teeth of the same morphological class at most, with the probability and magnitude of asymmetry closely related to tooth size, tooth position, and tooth number reduction. Rarely do asymmetries "sum" as to produce a side-to-side discrepancy of major orthodontic concern.

Fels Research Institute

ACKNOWLEDGMENTS

Research support under grant DE-01294 from the National Institute of Dental Research, National Institutes of Health, and computer support under grant FR-00222 made the present study possible. We appreciate the assistance of Karen Jegart, Christabel G. Rohmann and that of Dean Smith of the Fels Computer Facility.

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. Bolton, W. A.: Disharmony in Tooth Size and Its Relation to the Analysis and Treatment of Malocclusion, *Angle Orthodont.*, 28: 113-128, 1958.
3. Fisher, R. A.: *Statistical Methods for Research Workers*, Edinburgh, Oliver and Boyd, 1958 ed.
4. Garn, S. M. and Lewis, A. B.: The Relationship Between Third Molar Agenesis and Reduction in Tooth Number, *Angle Orthodont.*, 32: 14-18, 1962.
5. Garn, S. M., Lewis, A. B. and Kerewsky, R. S.: Third Molar Agenesis and Size Reduction of the Remaining Teeth, *Nature*, 200: 488-489, 1963.
6. Garn, S. M., Lewis, A. B. and Kerewsky, R. S.: Third Molar Agenesis and Variation in Size of the Remaining Teeth, *Nature*, 201: 839, 1964.
7. Garn, S. M., and Shamir, Z.: *Methods for Research in Human Growth*, Springfield, Illinois, Charles C Thomas, 1958.
8. Johnson, P. O.: *Statistical Methods in Research*, New York, Prentice-Hall, Inc., 1949.
9. Lacey, J. I.: The Evaluation of Autonomic Responses: Toward a General Solution, *Ann. N.Y. Acad. Sci.*, 67: 125-163, 1956.
10. Lundström, A.: Asymmetries in the Number and Size of the Teeth and Their Aetiological Significance, *Trans. Europ. Orthodont. Soc.*, 167-185, 1960.
11. ———— Some Asymmetries of the Dental Arches, Jaws and Skull, and Their Etiological Significance, *Amer. J. Orthodont.*, 47: 81-106, 1961.
12. Moorrees, C. F. A., and Reed, R. B.: Correlations Among Crown Diameters of Human Teeth, *Arch. Oral Biol.*, 9: 685-697, 1964.