Prevalence and Etiology of Asymmetries in Occlusion

RICHARD J. SMITH, D.M.D., M.S.
HOWARD L. BAILIT, D.M.D, PH.D.

Asymmetric molar relationships often result in difficult mechanical problems during treatment, and Angle[2] considered them sufficiently important and distinctive to include "subdivision" categories within each of his classes of malocclusion. Epidemiological studies of occlusion, however, have rarely measured the frequency of these subdivisions. Even less is known about esthetically important asymmetries in overjet and overbite.

Without data on prevalence and severity it has not been possible to evaluate alternative causes for asymmetries. Why do they occur? Can they be predicted or prevented?

In this paper we report on asymmetries in a group of orthodontic patients and in a population of natives from the island of Bougainville in the Solomon Islands, Papua New Guinea. Our objectives are to (1) provide basic data on the frequency and severity of asymmetries in a clinical population, (2) compare this group with an unindustrialized population to determine if differences in asymmetry between groups can be related to selected environmental factors, and (3) discuss some of the complex genetic problems involved in interpreting the etiology of asymmetries in occlusion and other structures.

MATERIALS AND METHODS

Subjects

All subjects in this study have complete permanent dentitions (with or without third molars), since asymmetries in adolescents with mixed dentitions and adults with missing teeth are frequently related to factors other than those of interest here. Asymmetries during the mixed dentition are often only a temporary consequence of asymmetric primary tooth loss, while adults with missing teeth often have large asymmetries because of asymmetric drift into unoccupied space in the dental arch. Since both of these types of asymmetries would confound the evaluation of other effects not understood as clearly, these individuals have been excluded from study.

The orthodontic sample consists of pretreatment casts of patients accepted for treatment in the graduate orthodontic clinic at the University of Connecticut School of Dental Medicine. Selection of 150 cases was made at random except for the requirement of complete permanent dentitions. All 68 males and 82 females are between 12 and 26 years of age, Caucasian, and of variable socioeconomic status. No patients referred to the clinic with craniofacial anomalies are included.

The Melanesian data come from natives living in 14 villages on the island of Bougainville in the Solomon Islands. Both the dentition and general biology of these people have been extensively studied.[3,7,11] The population is relatively unindustrialized. Sweet potatoes and taro are the dietary staples. Up oo age 35, less than 5% of individuals have lost any permanent teeth, and tooth decay is rare. Professional dental care is not available. A total of 351 males between 12 and 65 years of age and 412 females between 11 and 68 are included in the analysis.

Variables

Overjet, overbite, and the sagittal molar relationship are measured to the nearest 0.1 mm with Helios dial calipers or a groove micrometer (for overjet). Overjet is defined as the horizontal distance from the most labial point of a maxillary central incisor to the corresponding mandibular incisor, parallel to the occlusal plane.[5] If the lower incisors are labial to the maxillary incisors (i.e., in anterior crossbite), the measurement is negative.

Overbite is measured as the vertical distance from the incisal edge of a maxillary central incisor to the incisal edge of the corresponding mandibular central incisor.[5] When the incisors overlap (overbite), the distance is positive. When a space exists between the incisors in the frontal plane (openbite), the distance is negative.

A quantitative measurement of the sagittal molar relationship is made by determining the distance in the sagittal plane between the mesial contact points of the upper and lower first permanent molars.[10] When the lower molar is mesial to the upper molar, the distance is positive, when distal to the upper molar, negative.

Data Analysis

After data were keypunched, recording and measuring errors were checked with the Churchill Editing Program.[6] Measurements more than 2.50 standard errors from values predicted by multiple regression equations were remeasured. Less than 0.1% of all measurements were found to be in error.

Since the study of asymmetry is concerned with small differences, the evaluation of measurement error is important. Duplicate measurements on a series of 20 casts indicated that the magnitude of asymmetry was higher than that between duplicate measurements of the same side (for all variables, $p<.01$) indicating that random measurement errors would not confound the study of asymmetric variation. The standard error of measurement for each variable was about 0.1 mm. As a conservative estimate, we therefore consider asymmetries of 0.4 mm or less as possibly due to measurement error rather than actual anatomical asymmetry. Thus, only asymmetries of 0.5 mm or more will be considered in this study.

A number of statistical techniques have been used to measure asymmetry, perhaps the simplest being $1-r^2$, where r is the Pearson product-moment correlation coefficient between the two sides of an individual.[12] Nevertheless, $1-r^2$ as a measure of asymmetry provides no more information than the correlation coefficient, r, as a measure of symmetry. For the Bougainville sample this value is calculated within-groups, so that it is not inflated by differences among villages.

Results

The distributions of absolute values for asymmetries are given in Tables I and II for males and females of both populations. Because the sample of orthodontic patients is nonrandom with regard to both age and sex, we consider only the Bougainville sample to be of interest concerning age changes and sex differences in asymmetry.

On Bougainville the most symmetric variable is incisor overbite with over 70% of both males and females exhibiting no measurable (less than 0.5 mm) asymmetry. The sagittal molar relationship is the most asymmetric variable, only about 40% of individuals in each sex having differences less than 0.5 mm between sides.

Although small asymmetries are common, large discrepancies are infrequent. Except for the molar relationship in males, less than 3% of the Bougainville population has more than 2.5 mm of asymmetry for any variable.

Correlation coefficients for each variable are listed separately by sex in Table III. In both sexes, correlations for overbite and overjet are .80 or greater, while for the molar relationship it is less than .70. Overbite is the least asymmetric as determined by correlation as well as by absolute frequencies.

The amount of asymmetry on Bougainville increases with age (Tables IV and V). Except for the molar relationship in females, the greatest asymmetry is in one of the two oldest age groups (40-49 or 50-69) while the lowest asymmetry occurs in a group between 10 and 29 years of age.

Frequency of Asymmetries in Occlusion, Males

Millimeters of Asymmetry	Bougainville (N=351)						Connecticut (N=68)					
	Overjet		Overbite		Molar Relationship		Overjet		Overbite		Molar Relationship	
	N	%	N	%	N	%	N	%	N	%	N	%
0.0 - 0.4	220	63	253	72	145	41	39	57	50	74	20	29
0.5 - 1.4	106	30	78	22	154	44	22	32	16	24	24	35
1.5 - 2.4	16	5	11	3	31	9	4	6	1	2	6	9
2.5 - 3.4	6	2	6	2	14	4	2	3	1	2	7	10
3.5 - 4.4	1	<1	2	1	4	1	-	-	-	-	6	9
4.5 - 5.4	-	-	-	-	3	1	1	2	-	-	1	2
5.5 - 6.4	1	<1	1	<1	-	-	-	-	-	-	4	6
6.5 - 7.4	1	<1	-	-	-	-	-	-	-	-	-	-

Table I

Frequency of Asymmetries in Occlusion, Females

Millimeters of Asymmetry	Bougainville (N=412)						Connecticut (N=82)					
	Overjet		Overbite		Molar Relationship		Overjet		Overbite		Molar Relationship	
	N	%	N	%	N	%	N	%	N	%	N	%
0.0 - 0.4	286	69	319	77	179	43	58	71	65	79	19	23
0.5 - 1.4	103	25	73	18	187	45	19	23	14	17	28	34
1.5 - 2.4	19	5	14	3	37	9	2	2	2	2	13	16
2.5 - 3.4	3	1	5	1	7	2	3	4	1	1	12	15
3.5 - 4.4	1	<1	-	-	1	<1	-	-	-	-	6	7
4.5 - 5.4	-	-	1	<1	1	<1	-	-	-	-	3	4
5.5 - 6.4	-	-	-	-	-	-	-	-	-	-	-	-
6.5 - 7.4	-	-	-	-	-	-	-	-	-	-	1	1

Table II

TABLE III

Correlation Coefficient (r) Between Sides
Bougainville population

	Males	Females
overjet	.80	.83
overbite	.90	.91
molar relationship	.64	.67

There is conflicting evidence regarding sex differences in asymmetry. The frequency data suggest that males are more often highly asymmetric for all variables. The correlation coefficients, however, do not bear out this tendency. Following a Fisher's z transformation, none of the sex differences in correlation coefficients are found to be statistically significant at the .05 level.

The distribution of asymmetries for the orthodontic sample is similar to the Bougainville population in several respects. Overbite is again the least asymmetric and the molar relationship the most asymmetric of the variables. Even though all the orthodontic patients were considered to need orthodontic treatment, the magnitude of asymmetry and the correlations for overbite and overjet are very

TABLE IV

Correlation Coefficient Between Sides, by Age Groups
Bougainville males

	10-14 N=45	15-19 N=72	20-29 N=63	30-39 N=101	40-49 N=52	50-69 N=18
overjet	.88	.95	.87	.74	.49	.86
overbite	.94	.96	.91	.87	.84	.91
molar relationship	.76	.52	.80	.65	.48	.31

TABLE V

Correlation Coefficient Between Sides, by Age Groups
Bougainville females

	10-14 N=60	15-19 N=75	20-29 N=100	30-39 N=100	40-49 N=56	50-69 N=21
overjet	.92	.94	.81	.79	.90	.31
overbite	.98	.96	.93	.82	.94	.81
molar relationship	.68	.67	.65	.74	.61	.57

similar to those on Bougainville. The greatest difference between groups is found in the molar relationship. Whereas over 25% of orthodontic patients have asymmetries greater than 2.5 mm, only 6% of males and 3% of females on Bougainville exhibit asymmetries of this magnitude.

Discussion

The most interesting results of this study concern the great similarity in the amount of asymmetry for overjet and overbite in the two samples, and the large difference in asymmetry for the molar relationship. Even though one group consists of individuals all of whom have malocclusions and the other a random sample with only 20-30% judged to have malocclusions,[11] asymmetric incisor occlusion is equally common. The most likely explanation for this is related to the widespread habit of pipe-smoking (by both males and females) on Bougainville.[9] The natives habitually place the pipe on one side of the mouth, usually in the canine-lateral incisor region, resulting in considerable attrition of these teeth and asymmetric overjet and overbite.[4] For many individuals with malocclusion on Bougainville, pipe-smoking is clearly the etiologic basis. On the other hand, finger-sucking, which would be the leading cause of incisal asymmetries in the orthodontic sample, is only one of many factors responsible for malocclusions in this latter group.

Although both the Connecticut and Bougainville samples consisted only of individuals with complete dentitions, the large difference in molar asymmetries is probably related to differences in premature tooth loss in the primary dentition. Tooth decay and loss on Bougainville are low at all ages (95% of adults under age 35 have all teeth, as do 81% of all individuals observed through age 68), so that space loss in the primary dentition would be uncommon. For the orthodontic patients, however, it is likely that many individuals had early asymmetric loss of primary molars.

Genetic Implications of Asymmetries

There are a number of problems with general explanations for the etiology of asymmetries. If, as is commonly assumed for many structures, the genetic information is identical for each side, the interpretation of small differences within an individual depends on whether or not environmental conditions are also the same on each side. When environmental effects are bilaterally identical, minor asymmetries indicate a lack of precision in the developmental process.[1] Alternatively, if there are environmental differences between sides, the interpretation of asymmetries is difficult and need not indicate a laxity in the genetic mechanisms controlling morphogenesis. Functional variations in structure could depend on highly localized environmental differences, the genotype being precise within environments but allowing for adaptive modifications between environments.

Theoretically, asymmetry in dental occlusion could reflect either or both imprecise genetic control and adaptation to asymmetric environmental effects. During prenatal development the dental arches and tooth germs mature within a reasonably symmetrical environment, and we can assume that the magnitude of asymmetries reflect the degree of genetic canalization. Postnatally, however, asymmetric effects, such as thumb sucking (or pipe-smoking on Bougainville), sleeping position,[8] or masticatory habits result in highly asymmetric environments for the dentition. These are at least partly responsible for the increasing asymmetry of occlusion with age. On present evidence we cannot determine whether asymmetry in occlusion indicates a lack of developmental control or a carefully controlled system allowing for functional adjustments to environmental variation.

Experimental studies have clearly demonstrated that the magnitude of asymmetry in individuals of a population can be modified by artificial selection. Waddington[13,14] has appropriately argued that asymmetry should also be subject to natural selection. If so, one evolutionary trend in organisms would be a tendency to remove genes which make the animal sensitive to disturbing (but not to adaptive) environmental effects and select for genes which improve the phenotype even under stressful circumstances. The extent to which this canalizing selection would operate for any trait depends on the selective advantage of symmetry and precise morphology for the structure in question. While there is no evidence regarding differences in the degree of developmental homeostasis for individual occlusal traits, it appears that dental occlusion as a whole displays a high magnitude of asymmetry and is probably a relatively poorly canalized system. There is some evidence that over the last several thousand years, human dental occlusion has become more variable. It is possible that this is partly due to decreased selection pressures on the genes responsible for developmental canalization resulting in an increased susceptibility to random environmental effects.

Department of Orthodontics
Dental School
University of Maryland
Baltimore, Maryland 21201

ACKNOWLEDGMENTS

We thank Dr. Edward Harris for helpful comments on the manuscript. Supported by USPHS Grants DE 00136, DE 03729 and DE 05134 from the National Institute of Dental Research.

REFERENCES

1. Adams, M. S. and Niswander, J. D.: Developmental "noise" and a congenital malformation. *Genet. Res.*, 10:313-317, 1967.
2. Angle, E. H.: *Treatment of Malocclusion of the Teeth*, 7th ed. Philadelphia, S. S. White, 1907.
3. Bailit, H. L., DeWitt, S. J. and Leigh, R. A.: The size and morphology of the Nasioi dentition. *Am. J. Phys. Anthrop.*, 28:271-288, 1968.
4. Barrett, M. J.: Masticatory and non-masticatory uses of teeth. In: *Stone Tools as Cultural Markers: Change, Evolution and Complexity*, R. V. S. Wright, ed. Canberra, Australian Inst. Aboriginal Studies, 1977. pp. 18-23.

5. Baume, L. J., Horowitz, H. S., Summers, C. J., Backer Dirks, O., Brown, W. A. B., Carlos, J. P., Cohen, L. K., Freer, R. J., Harvold, E. P., Moorrees, C. F. A., Salzmann, J. A., Schmuth, G., Solow, B. and Taatz, H.: A method for measuring occlusal traits. *Int. Dent. J.*, 23:530-537, 1973.

6. Churchill, E.: The modern computer and physical anthropology (abstract). *Am. J. Phys. Anthrop.*, 21:426, 1963.

7. Friedlaender, J. S.: *Patterns of Human Variation. The Demography, Genetics and Phenetics of Bougainville Islanders.* Cambridge, Harvard Univ. Press, 1975.

8. Lear, C. S. C.: Variability of head posture during sleep and considerations relating to palate and dental arch form. *Arch. Oral Biol.*, 12:1229-1240,1967.

9. Lombardi, A. V. and Bailit, H. L.: Malocclusion in the Kwaio, a Melanesian group on Malaita, Solomon Islands. *Am. J. Phys. Anthrop.*, 36:283-294, 1972.

10. Seipel, C. M.: Variation of tooth position. *Svensk. Tandlaek. Tidskr.*, 39: (Suppl.), 1946.

11. Smith, R. J. and Bailit, H. L.: Variation in dental occlusion and arches among Melanesians of Bougainville Island, Papua New Guinea. 1. Methods, age changes, sex differences and population comparisons. *Am. J. Phys. Anthrop.*, 47:195-208, 1977.

12. Van Valen, L.: A study of fluctuating asymmetry. *Evolution*, 16:125-142, 1962.

13. Waddington, C. H.: *The Strategy of the Genes.* London, George Allen & Unwin, 1957.

14. ———— Experiments on canalizing selection. *Genet. Res.*, 1:140-150, 1960.