Original Article

Bilateral Asymmetry in the Tooth Relationships of Orthodontic Patients

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ABSTRACT

Objective: To quantify the nature and extent of bilateral dentoalveolar asymmetries in routine adolescent orthodontic patients.

Materials and Methods: Eight left-right pairs of occlusal dimensions were measured from dental casts (n = 211 subjects) with proportionate samples of class I, II, and III malocclusions.

Results: Directional asymmetry is a subtle, but pervasive feature of the dental arches, with systematically larger dimensions on the left side. Prior studies attribute this sidedness to compensations for hemispheric laterality. Patient's sex did not influence the magnitude of asymmetry, but patients with class II malocclusion exhibited significantly greater asymmetries, particularly in the anterior segment. Inspection suggests that this is attributable to the lack of coupling and guidance of the teeth between the jaws. There is a significant association between the severity of class II buccal-segment relationship and the extent of left-right asymmetries.

Conclusion: Clinically, these lateralities need to be anticipated, particularly in class II malocclusions, and incorporated into the treatment plan.

KEY WORDS: Bilateral asymmetry; Laterality; Dentoalveolar malocclusion; Angle's classification

INTRODUCTION

It is well known that people's faces are not perfectly symmetric.[1,2] For example, facial expressions typically are more obvious on a person's left side due to right hemispheric dominance.[3] Clinically, left-right symmetry of the underlying skeletodental structures generally is a treatment goal,[4,5] and studies suggest that symmetric faces are deemed more attractive.[6,7]

Some asymmetries are acquired, for example, because of chewing side preference[8] or trauma,[9,10] but most left-right differences have no specific, identifiable etiology.[11,12] Most asymmetries are subtle, requiring precise bilateral comparisons for their detection. These are evident when comparing the measurements of paired structures, but go unnoticed on casual clinical appraisal.[13,14]

The purpose of the present study was to quantify left-right asymmetries in the dental relationships of samples of routine orthodontic patients studied according to Angle's classification of malocclusion. We assessed the kinds of asymmetry, their distributions and magnitudes in the dental arches, and correlations among them.

MATERIALS AND METHODS

Pretreatment dental casts of Angle class I, II, and III malocclusions were assembled from a cohort of orthodontic patients who met three criteria:

- —All had intact permanent dentitions (excluding third molars), and none had prior treatment.
- —All were whites living in the US Midsouth to reduce variation.[15,16]
- —No patient had a branchial arch syndrome, facial cleft, or any other condition known to enhance the risk of asymmetry.

Proportionate samples were collected by Angle class and sex. Total sample size was 211 individuals. Mean age at pretreatment was 14.0 years (SD = 2.1 years; range = 11 to 23 years).

Measurements were made using digital-readout sliding calipers on full-mouth dental casts. Interarch relationships were assessed with the casts in maximum

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Table 1. Side-specific descriptive statistics for the occlusal dimensions, by sex and Angle classification, along with 2-way analysis of variance results[a]

Variable	Class I				Class II			
	Males		Females		Males		Females	
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Midline deviation	0.06	0.24	0.29	0.21	0.28	0.26	0.11	0.22
Overjet Rt	4.26	0.42	3.82	0.36	6.59	0.46	5.25	0.37
Overjet Lt	4.16	0.40	3.77	0.35	6.69	0.44	5.48	0.36
Canine Rt	−1.56	0.28	−1.15	0.24	−4.72	0.31	−3.68	0.25
Canine Lt	−1.14	0.32	−0.74	0.28	−3.91	0.35	−2.74	0.29
BSR Rt	−0.03	0.26	−0.01	0.23	−2.73	0.29	−2.71	0.23
BSR Lt	0.17	0.30	0.06	0.26	−2.42	0.33	−1.65	0.27
Mx 1–3 chord Rt	22.98	0.25	22.45	0.26	21.8	0.29	23.77	0.29
Mx 1–3 chord Lt	22.72	0.23	22.47	0.23	22.28	0.26	24.06	0.26
Mx 1–6 chord Rt	44.39	0.37	43.16	0.39	42.64	0.43	46.21	0.43
Mx 1–6 chord Lt	44.08	0.35	44.12	0.37	43.41	0.41	46.69	0.41
Md 1–3 chord Rt	17.09	0.23	16.41	0.2	17.35	0.26	16.51	0.21
Md 1–3 chord Lt	17.33	0.21	16.54	0.18	17.14	0.23	16.55	0.19
Md 1–6 chord Rt	41.45	0.41	39.84	0.36	40.96	0.45	39.44	0.37
Md 1–6 chord Lt	41.98	0.38	40.02	0.33	41.01	0.42	39.72	0.34

[a] Sides are right (Rt) and left (Lt); BSR indicates buccal segment relation. Statistics are the arithmetic mean ($\bar{X}$) and standard error of the mean (SE). Maxillary is coded as Mx and mandibular as Md. Tooth numbers 1–3 and 1–6 refer to Palmer notation (1 is central incisor, 3 is canine and 6 is first molar). F is the F-ratio from 2-way analysis of variance, and *P* is the corresponding *P* value.

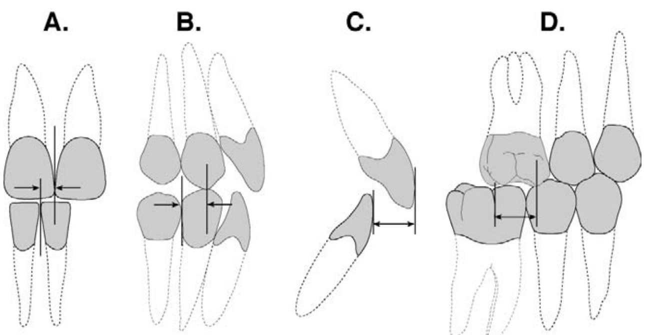

Figure 1. Schematic illustrations of (A) the incisor midline discrepancy (mandibular shifts to the right were scored as positive), (B) canine discrepancy (a class II canine relationship, as illustrated, was scored as negative), (C) overjet (an anterior crossbite was given a negative score), and (D) buccal segment relationship (a class III relation, with the mandibular molar malpositioned to the distal, was given a negative score).

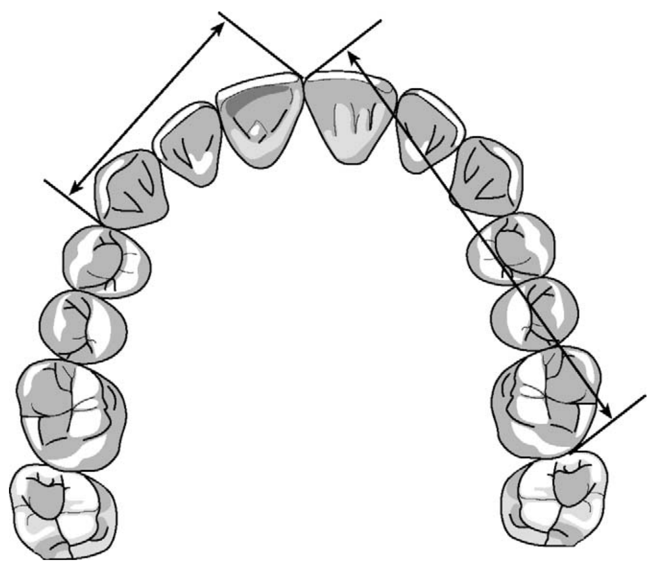

Figure 2. Illustration of the method of measuring arch chords: With one beak of the calipers on the labial interincisal papilla, the other was positioned at the distal-most aspect of the canine (yielding the 1-3 chord) and, independently, at the distal-buccal heel of the first molar (1-6 chord). The 1-3 and 1-6 chord measurements were made separately on the left and right sides of the maxillary and mandibular dental casts.

intercuspation.[17,18] Five sorts of variables were measured from each subject (Figures 1 and 2):

1. Deviation of the incisor midlines; a mandibular deviation to the right was given a positive sign.
2. Incisor overjet was measured separately on the left and right central incisors.
3. Canine deviation was the horizontal distance from the cusp tip of the maxillary canine to its normal position in the embrasure between the mandibular canine and first premolar.
4. Buccal segment relation (BSR) parallels Angle's molar classification,[19] but on a continuous scale, where the horizontal distance of the buccal groove of the mandibular first molar is measured relative to the mesiobuccal cusp tip of the maxillary first molar. An idealized Class I relationship has a BSR of 0 mm; Class II relationships are given a negative value.
5. Arch chords are the straight-line distances from the incisive interdental papilla measured to (A) the dis-

Table 1. Extended

Class III				Analysis of Variance					
Males		Females		Angle Class		Sex		Interaction	
$\overline{X}$	SE	$\overline{X}$	SE	F	*P*	F	*P*	F	*P*
0.27	0.27	−0.43	0.24	0.76	.4648	1.20	.2742	1.88	.1551
1.86	0.46	1.14	0.42	53.51	<.0001	6.04	.0148	0.65	.5237
1.96	0.44	1.01	0.40	62.81	<.0001	6.78	.0099	0.58	.5593
−0.36	0.31	0.43	0.28	114.49	<.0001	10.82	.0012	0.68	.5100
0.56	0.35	0.43	0.32	70.14	<.0001	3.51	.0623	2.01	.1372
2.30	0.29	1.90	0.26	162.55	<.0001	0.33	.5688	0.41	.6656
2.81	0.33	2.33	0.30	109.72	<.0001	0.06	.8039	2.18	.1158
23.28	0.32	23.32	0.32	4.08	.0184	19.07	<.0001	0.94	.3908
23.10	0.29	23.42	0.29	3.53	.0311	24.12	<.0001	1.08	.3403
45.12	0.47	44.93	0.47	7.08	.0011	33.10	<.0001	0.15	.8572
45.08	0.45	45.22	0.45	3.85	.0228	29.02	<.0001	2.17	.1170
17.25	0.26	16.58	0.23	0.37	.6905	14.57	.0002	0.08	.9226
17.22	0.23	16.54	0.21	0.11	.8976	15.90	<.0001	0.11	.8939
40.65	0.45	39.97	0.41	0.68	.5102	14.42	.0002	0.75	.4740
40.8	0.42	40.08	0.38	1.75	.1760	18.11	<.0001	1.35	.2610

tal-most aspect of the canine and (B) the distobuccal aspect of the first molar. Chords were measured from the midline to the canine (from central incisor through canine) and to the first molar (from central incisor through first molar) in each of the four quadrants.[20,21] The variables primarily assess dentoalveolar asymmetries.

The technical error of measurement was assessed using the conventional Dahlberg statistic,[22] namely

$$d = \sqrt{\frac{\sum_{i=1}^{n} (X_{1i} - X_{2i})^2}{2n}}$$

where X_{1i} and X_{2i} are the first and second measurements of specimen *i*. The unit of measurement does not cancel out, so d is expressed as the average millimetric difference attributable to measurement imprecision. Double determinations of 135 measurements yielded an average error of just 0.068 mm.

Two sorts of left-right asymmetry are examined,[23,24] namely fluctuating asymmetry (FA) and directional asymmetry (DA). FA occurs for homologous dimensions when the sample distribution of the left-right differences is centered on zero.[25] DA occurs when the mean of the distribution is shifted away from zero. DA is identified when the group average differs significantly from zero based on a one-sample *t*-test.[26] Preserving the signs of the left-minus-right (L − R) differences,

$$DA = \frac{\sum (L - R)}{n}$$

where n is the number of cases measured.

The magnitude of FA is expressed as the absolute value of the side difference of a variable within each case. DA will confound the measure of FA,[27] so the average DA for a sample is subtracted on a case-specific basis to center average L − R on zero:

$$FA = \frac{\sum |(L - R) - \bar{x}_{DA}|}{n}$$

Two-way analysis of variance was used to test for differences in the magnitude of asymmetry among Angle's three classes and between sexes.[28] Statistics were evaluated as two-tail tests at $\alpha = .05$.

RESULTS

Occlusal Dimensions

Dental relationships can vary because of differences in the tooth positions within the supporting bone and because of size differences of the supporting arches. This mixture of sources is shown in Table 1, where 10 of the 15 variables have statistically significantly different mean sizes among Angle's classes.

Additionally, 11 of the tests between the sexes are significant. These statistics are largely confirmatory of (1) the facial proportions that characterize the three Angle classes and (2) the larger mean skeletodental dimensions in males. Summarily, these results show that (1) overjet and canine discrepancies are largest in class II and smallest in class III cases and (2) BSR is negative in class II cases, near-zero in class I, and positive in class III cases, simply because this is the fundamental trait used to classify the malocclusions. "Sex" is included in these analyses to control for the

Table 2. Descriptive statistics for directional asymmetry, by sex and Angle classification, along with 2-way analysis of variance results[a]

	Class I				Class II				Class III				Analysis of Variance					
	Males		Females		Males		Females		Males		Females		Angle Class		Sex		Interaction	
Variable	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	F	*P*	F	*P*	F	*P*
Midline deviation	0.06	0.24	0.29	0.21	0.28	0.26	0.11	0.22	0.16	0.26	−0.43	0.24	1.12	.3281	0.83	.3638	1.47	.2324
Overjet	−0.09	0.18	−0.05	0.16	0.10	0.20	0.24	0.16	0.11	0.20	−0.13	0.18	0.94	.3913	0.01	.9174	0.55	.5784
Canine deviation	0.42	0.35	0.41	0.30	0.81	0.39	0.94	0.31	0.86	0.39	0.01	0.35	1.11	.3329	0.72	.3961	1.09	.3380
BSR	0.20	0.27	0.08	0.23	0.31	0.30	1.06	0.24	0.54	0.30	0.43	0.27	2.26	.1065	0.64	.4229	1.76	.1752
Mx 1–3 Chord	0.30	0.20	−0.27	0.18	−0.18	0.23	0.03	0.18	0.11	0.23	0.47	0.20	1.65	.1942	0.00	.9940	3.11	.0467
Mx 1–6 Chord	0.48	0.24	−0.31	0.21	−0.04	0.26	0.96	0.21	0.31	0.26	0.77	0.24	2.15	.1193	1.34	.2476	7.98	.0005
Md 1–3 Chord	0.23	0.21	0.13	0.18	−0.21	0.23	0.04	0.18	−0.12	0.23	−0.04	0.21	1.18	.3080	0.20	.6559	0.38	.6852
Md 1–6 Chord	0.53	0.24	0.18	0.21	0.05	0.26	0.29	0.21	−0.13	0.26	0.11	0.24	1.21	.2993	0.04	.8423	1.10	.3359

[a] These data (L-R) retain the sign of the side differences. Statistics are the arithmetic mean ($\bar{X}$) and standard error of the mean (SE). Maxillary is coded as Mx and mandibular as Md. Tooth numbers 1–3 and 1–6 refer to Palmer notation (1 is central incisor, 3 is canine and 6 is first molar). F is the F-ratio from 2-way analysis of variance, and *P* is the corresponding *P* value. BSR indicates buccal segment relation.

Table 3. Descriptive statistics and tests for directional asymmetry[a]

Variable	$\bar{X}$	SD	SE	*t*-test	*P* value
Midline deviation	0.080	1.406	0.097	0.82	.4113
Overjet	0.030	1.055	0.073	0.42	.6775
BSR	0.443	1.582	0.109	4.07	<.0001
Canine deviation	0.564	2.040	0.140	4.02	<.0001
Mx 1-3	0.063	1.208	0.083	0.76	.4495
Mx 1-6	0.364	1.452	0.100	3.64	.0003
Md 1-3	0.024	1.192	0.082	0.29	.7714
Md 1-6	0.187	1.380	0.095	1.99	.0401

[a] Data are the left-right side differences with signs retained; the 1-sample *t*-tests evaluated whether mean asymmetry deviated significantly from zero (2-tail tests). Sample size is 211 for each test. SD indicates standard deviation; BSR, buccal segment relation; SE, standard error of the mean. Maxillary is coded as Mx and mandibular as Md. Tooth numbers 1–3 and 1–6 refer to Palmer notation (1 is central incisor, 3 is canine and 6 is first molar).

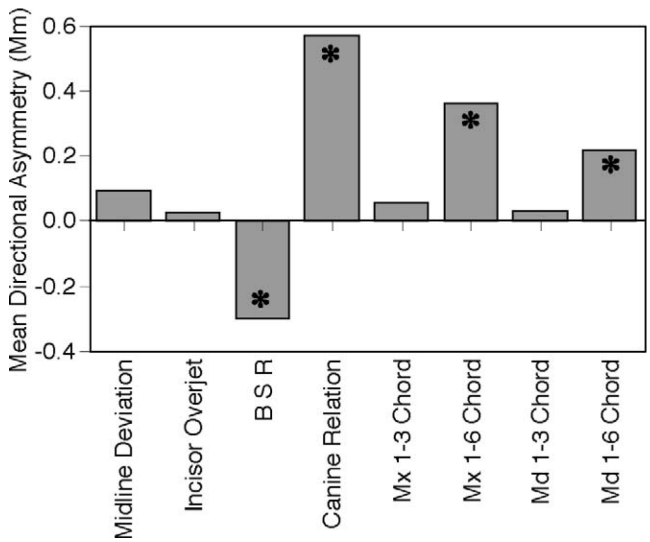

Figure 3. Plot of mean directional asymmetries for the eight paired arch dimensions. Of the eight variables, four (flagged with asterisks) are significantly different from zero. All four variables are systematically larger on the left side (L > R); mean BSR is negative because of the way it was coded.

well-documented issue that men's arch dimensions tend to be larger than women's.[29,30]

Directional Asymmetry

DA occurs when there is a systematic trend for subjects to have larger dimensions on one side, so the average L − R difference is offset away from zero.[27] Table 2 shows that DA does not depend on Angle's class or on the subject's sex; none of the analysis of variance tests is significant. This warranted pooling the sample, and Table 3 shows that four of the eight variables exhibit directional asymmetry (Figure 3), namely the (1) canine relationship, (2) BSR, (3) maxillary 1-6 chord, and (4) mandibular 1-6 chord. In all four instances, the left dimension tends to exceed the right. Note that these small group averages obscure the considerable interindividual variation, where some asymmetries are quite obvious. Statistically, by repeated-measures analysis of variance, all four variables exhibit the same magnitude of DA ($P = .08$), with a grand mean of about half a millimeter (but with ranges exceeding a centimeter).

Table 4 lists the correlation matrix for the eight measures of DA, and roughly half of the associations (13/28) are significantly different from zero. With DA, the sign of the difference is retained, so positive correlations mean that both direction and magnitude of the

Table 4. Correlation matrices for the 8 measures of left-right asymmetry[a]

Variable	Midline	Overjet	BSR[b]	Canine	Mx 1-3 Chord	Mx 1-6 Chord	Md 1-3 Chord	Md 1-6 Chord
Midline	—	0.03	0.16*	0.48*	0.27*	0.39*	0.32*	0.26*
Overjet	−0.1	—	−0.13	−0.06	0	−0.04	0.08	0.08
BSR	0.28*	−0.08	—	0.44*	0.1	0.21*	0.03	−0.04
Canine	0.63*	−0.11	0.61*	—	0.13	0.22*	0.04	0.17*
Mx 1-3 chord	−0.38*	−0.02	0.22*	0.07	—	0.62*	0.14*	0.15*
Mx 1-6 chord	−0.48*	0.06	0.28*	−0.02	0.73*	—	0.21*	0.18*
Md 1-3 chord	0.53*	−0.12	−0.07	0.11	−0.12	−0.12	—	0.67*
Md 1-6 chord	0.48*	−0.20*	−0.11	0.23*	−0.03	0.02	0.75*	—

[a] Pearson product-moment correlation coefficients for directional asymmetry are listed below the diagonal; correlations for the measures of fluctuating asymmetry are listed above the diagonal. Maxillary is coded as Mx and mandibular as Md. Tooth numbers 1–3 and 1–6 refer to Palmer notation (1 is central incisor, 3 is canine and 6 is first molar).

[b] BSR indicates buccal segment relation.

* Correlation coefficient significantly different from zero ($P < 0.05$). Degrees of freedom are 210 for each test.

TABLE 5. Magnitudes of fluctuating asymmetry, by sex and Angle classification, and analyses of variance[a]

	Class I				Class II				Class III				Analysis of Variance					
	Males		Females		Males		Females		Males		Females		Angle Class		Sex		Interaction	
Variable	$\overline{X}$	SE	$\overline{X}$	SE	$\overline{X}$	SE	$\overline{X}$	SE	$\overline{X}$	SE	$\overline{X}$	SE	F	*P*	F	*P*	F	*P*
Midline deviation	0.96	0.17	0.97	0.15	1.24	0.19	1.08	0.15	0.8	0.19	1.02	0.17	1.15	.319	0.03	.8667	0.64	.528
Incisor overjet	0.89	0.12	0.94	0.1	0.83	0.13	0.72	0.11	0.89	0.13	0.37	0.12	2.94	.049	3.93	.0487	2.95	.0547
Canine relation	1.22	0.23	1.29	0.2	2.58	0.25	1.73	0.21	1.22	0.25	1.62	0.23	8.77	.0002	0.43	.5131	3.81	.0238
BSR	0.64	0.19	0.48	0.16	1.62	0.21	1.49	0.17	1.19	0.21	1.59	0.19	16.91	<.0001	0.06	.8071	1.32	.2696
Mx 1–3 chord	0.69	0.15	0.69	0.13	1.13	0.17	0.79	0.14	0.7	0.17	1.02	0.15	1.81	.1661	0.01	.9409	2.33	.0998
Mx 1–6 chord	1.07	0.17	0.98	0.15	1.19	0.19	1.15	0.16	0.82	0.19	1.41	0.17	0.39	.6773	1.14	.2862	2.33	.1
Md 1–3 chord	0.79	0.16	0.8	0.14	0.84	0.17	0.68	0.14	0.73	0.17	0.78	0.16	0.04	.9563	0.07	.7975	0.25	.7791
Md 1–6 chord	0.94	0.17	0.94	0.15	1.09	0.19	1.02	0.15	1.01	0.19	0.96	0.17	0.23	.7947	0.08	.782	0.02	.9802

[a] These descriptive statistics are based on the absolute side differences, namely left-right. Statistics are the arithmetic mean ($\overline{X}$) and standard error of the mean (SE). Maxillary is coded as Mx and mandibular as Md. Tooth numbers 1–3 and 1–6 refer to Palmer notation (1 is central incisor, 3 is canine and 6 is first molar). F is the F-ratio from 2-way analysis of variance, and *P* is the corresponding *P* value. BSR indicates buccal segment relation.

asymmetries covary. The strongest correlations are between the arch chords within each jaw. The asymmetries in arch chords coincide with shifts of the dental midline. The 1-6 chord is defined by teeth that emerge at much younger ages than teeth in the midarch,[31] suggesting that the asymmetries are already established once the incisors and first molars emerge. The correlations between the midline deviation and the 1-3 chords are of the same magnitude as for the 1-6 chords, so asymmetric positions of the late-emerging canine do not seem to affect the midline shift.

Fluctuating Asymmetry

FA is the *magnitude* of difference between the sides (Table 5). Of the eight variables, three differ significantly by Angle class, although some differences are a bit complex (Figure 4). The interaction term is statistically significant for canine relationship, disclosing that the pattern of variation across Angle's classes is different in the two sexes. The canine relationship is statistically the same—about 1.2 mm—across all three Angle classes in females, but, in males, FA is significantly higher (about 2.6 mm) in the class II sample. Overjet FA differs among Angle's classes in that the average is significantly smaller in the class III sample, especially for females (though the interaction term is not strictly significant).

The third interclass difference is for BSR, but this is an artifact of sample selection. The class I sample was selected on the basis that both left and right BSR were close to zero, so these are contrived ''special cases'' where asymmetries in BSR were explicitly diminished.

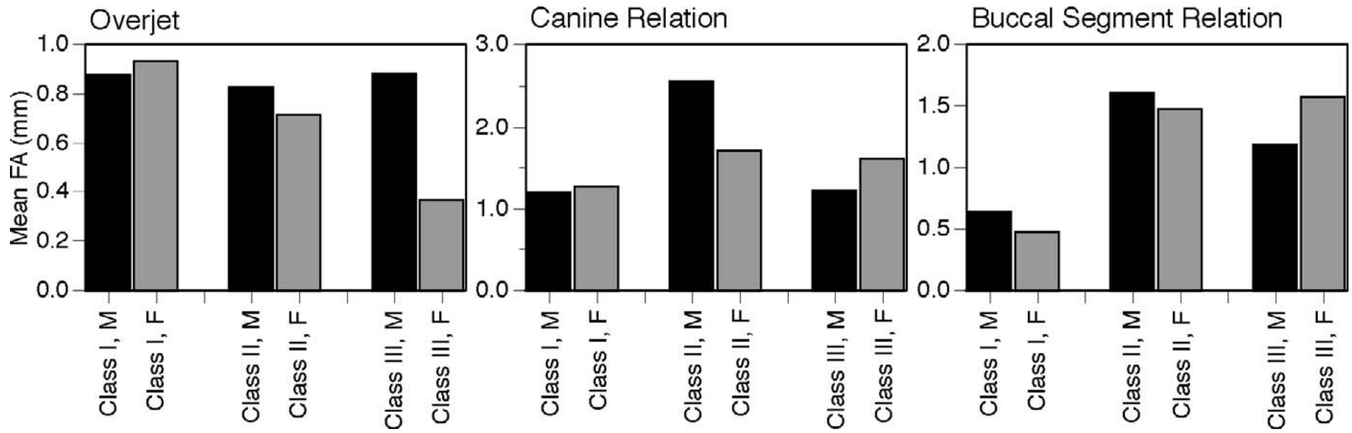

Figure 4. Histograms of the three dimensions with significant differences in the magnitudes of fluctuating asymmetry among Angle's categories. (See text for descriptions.)

This classification bias is obvious in Table 5 where it accounts for the highly significant difference for BSR. Of note, this bias does not discernibly affect the magnitudes of asymmetry across the other variables.

Table 4 lists the matrix of correlations for FA (upper right of matrix). The question here is whether the magnitude of asymmetry in one variable is associated with the magnitude in another. Of the 28 correlations, 16 are significant. The two largest correlations are between arch chords 1-3 and 1-6 in the maxilla ($r = .62$) and the mandible ($r = .67$). These correlations are intuitive as the 1-3 chord is incorporated in the 1-6 chord, and Solow[32] and others have commented on the geometrically dependent associations of overlapping dimensions. Two other, highly significant correlations involve deviations of the dental midline with BSR and with the canine relationship. In both situations, a deviation of the dental midline to one side corresponds to canine and molar deviations to the opposite side.

Kula et al[33] found that malocclusions with greater anteroposterior (AP) discrepancies—specifically greater overjet—tend to have greater left-right asymmetries, and the present study shows this as well. Two measures of AP discrepancy are assessed to emphasize this point, overjet and BSR. Table 6 lists the correlations (Spearman's ρ) between the severity of the AP discrepancy and magnitude of the $L - R$ asymmetries. As overjet increases, so does its $L - R$ asymmetry ($P < .0001$) and, likewise, asymmetry of the canine relationship ($P = .008$). Kula's study[33] focused on class II malocclusions; the present analysis generalizes the associations to the whole range of AP disharmonies. Associations are also significant for BSR, but the relationships are negative (simply because of the way BSR is coded). Across the spectrum of BSR (about -6 to $+8$ mm), the smaller the BSR (ie, more class II) the greater the (A) midline deviations, (B) overjet asymmetry, and (C) canine asymmetry. The association between the magnitude of BSR and the extent of canine asymmetry is representative of these relationships (Figure 5). We speculate that the principle underpinning these associations is the lack of intercuspation and occlusal guidance in cases where overt AP discrepancies leave the anterior teeth susceptible to greater left-right variations.

Table 6. Rank correlations between the anteroposterior severity of the malocclusion and magnitude of asymmetry

Left-Right Asymmetry	Spearman ρ	*P* value
	Mean Overjet	
Midline deviation	0.09	.1830
Overjet	0.29	<.0001
Canine deviation	0.18	.0079
BSR[a]	−0.04	.6082
Mx 1-3 Chord	−0.13	.0635
Mx 1-6 Chord	−0.08	.2199
Md 1-3 Chord	0.11	.1054
Md 1-6 Chord	0.11	.1007
	Mean BSR	
Midline deviation	−0.14	.0361
Overjet	−0.14	.0453
Canine deviation	−0.24	.0004
BSR	−0.07	.2943
Mx 1-3 chord	−0.08	.2546
Mx 1-6 chord	−0.13	.0546
Md 1-3 chord	0.05	.4549
Md 1-6 chord	−0.03	.6736

[a] BSR indicates buccal segment relation.

DISCUSSION

Fluctuating Asymmetry

FA is thought to result from the accumulation of minor stochastic events during development.[34] The two sides of the body are assumed to have the same genetic information, so phenotypic asymmetries result

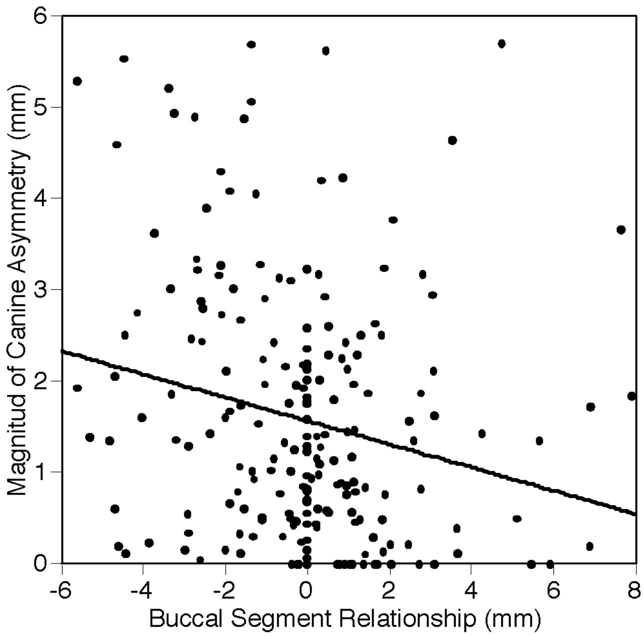

Figure 5. The buccal segment relationship (sides averaged) is plotted against the magnitude of asymmetry (|L − R|) for the canine. This plot is representative (Table 6), where more severe class II malocclusions have greater asymmetries in the anterior segment. Class III cases, in contrast, present with malocclusions, but generally not a lack of coupling.

from the accumulation of minor differences between teeth in the two quadrants of an arch. During development any number of environmental issues may cause FA, such as side differences in times of primary tooth exfoliation (or extraction), position and orientation of the developing successor's tooth buds, differences in eruptive tempos and pathways, differences in tooth emergence and sequence, positions of antagonists, and so on.

Analyses (Table 5) show that the amounts of asymmetry for overjet and canine relationship differ among Angle's classes, but asymmetries of the chord distances do not. Overjet itself is small or even negative in class III malocclusions, and the present study shows that the left-right differences in overjet are significantly smaller in class III cases, especially in females, and most discordant in class II malocclusions. In severe cases of class III malocclusions, the incisors are in crossbite so the maxillary anterior region becomes the "contained arch," which helps adjust the left and right central incisors symmetrically, so they are less asymmetric (though in crossbite).

Canine relationships are less symmetric in class II malocclusions because the maxillary canines are relatively forward and do not have the mandibular canine-premolar embrasure for guidance and stability, thus freeing them to exhibit greater asymmetry. Aside from the incisor and canine relationships, the other measures of FA are independent of Angle's class, which agrees with previous studies.[4,14,35,36]

Directional Asymmetry

There are four variables (Figure 3) where the left quadrant characteristically exceeds the size of the right, a situation termed DA.[37] In a classic craniometric study of human skulls by Woo,[38] 25 left-right paired dimensions were measured in some 900 skulls and tested for DA. Woo found that the skull is a collage of compensating side differences. In the midface (mandibles were not measured) there were significant L > R asymmetries—just as found here for arch chords. Neurobiologists attribute the facial directionalities to compensatory adjustments for right hemispheric dominance.[39,40]

Few orthodontic studies have measured the same variables on both sides of the arch, so the comparative data are meager. Biggerstaff and Wells[41] used a Cartesian coordinate system applied to occlusal views of dental casts. They offered no explanation for their finding that average arch length was longer on the left side (L > R), just as found here. Cassidy et al[42] also measured the dental arches of orthodontic patients. They too found that "the left side of the arch is slightly but systematically larger than the right."

Dentoalveolar asymmetries tend to be intercorrelated, probably because of dental compensations—asymmetries in one part of the arch contribute to other asymmetries because of the geometry of the dentition.[43]

CONCLUSIONS

- Bilateral asymmetry is prevalent in the occlusion of routine orthodontic patients.
- The magnitudes of most asymmetries are equivalent across all three categories of Angle's classification.
- There are few sex differences in the magnitude of bilateral asymmetry.
- Asymmetries are greatest in severe class II malocclusions, probably because their anteriors have no functioning antagonists for guidance and stability.
- DAs, where the left arch dimensions are larger than the right, are confirmed in these data, and the cause may be hemispheric size differences in the central nervous system.

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