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Indicators of jawbone asymmetry through analysis of panoramic radiographs

ABSTRACT

Aim *To assess the degree of jawbone asymmetry by drawing vertical lines on digital panoramic radiographs of paediatric patients with right or left unilateral cross-bite.*
Materials and methods *Study Design: The sample consisted of 217 paediatric patients of both genders, aged 6-9 years. A set of vertical lines was drawn on the side of the mandible with the cross-bite and on the side without the cross-bite, using software program tpsDigs version 2. Subsequently, the differences in the measurements of the two sides were determined through statistical analysis..*
Results *Analysis of the vertical jaw lines on the radiographic bite indices indicated, in every case, quantifiable differences between the side with the cross-bite and the side without the cross-bite. The differences between vertical variables, related to the heights of the mandible body and the condyle, were statistically significant ($p<0.005$) for the whole sample and both genders. Statistically significant differences in the heights of the mandible body were found for all the age groups (6 to 9 years old), except for the 9-year-old group, which registered differences in the variables of condylar height.*
Conclusion *Throughout the sample and regardless of the side affected by cross-bite, the vertical variables corresponding to the total height of the ramus were always smaller on the side with the cross-bite. Gender did not affect the results obtained and age influenced some of the mandible's vertical heights.*

Keywords *Asymmetry; Children; Mandibular joint disorders; Orthopantomography; Posterior cross-bite.*

Introduction

Patients with unilateral cross-bite develop bone asymmetry, unilateral mastication, diminished bite strength and asymmetrical muscle activity. They also have joint problems and exhibit changes in jaw position and movements [Neto et al., 2007]. For this reason, early diagnosis and treatment are important not only to prevent long-term effects on jawbone growth and development [Neto et al., 2007; McNamara, 2002; Hesse et al., 1997; Sonnesen et al., 2001; Rilo et al., 2007], but also to modify neuromuscular patterns [Sonnesen et al., 2001] and to benefit the condyle's physiological position, muscle balance and the correct occlusal relationship [Throckmorton et al., 2001; Egermark el al., 2003; Farella et al., 2007; Alamoudi, 2000; Berg et al., 2008]. Throughout the years, numerous researchers have attempted to make the most of panoramic radiography by taking measurements for the diagnosis, treatment and prognosis of various pathologies, including the determination of bone and condyle asymmetry [Maber et al., 2006; Dhanjal et al., 2006; Cameriere et al., 2006; Güler et al., 2005; Habets et al., 1987; Habets et al., 1988; Kilic et al., 2008; Kjellberg et al., 1994]. In our study, we attempted to determine if, by drawing vertical lines on panoramic radiographs, it is possible to identify measureable and quantifiable changes in bone structure which, in clinical practice, could indicate the degree of malocclusion.

Materials and methods

Sample

The study subjects consisted of 645 girls and boys treated at a Radiology Diagnostic Centre in Madrid during the years 2006 to 2010. General medical information, photos and X-rays were collected for all of them. Their parents or guardians signed an authorisation document for research purposes, in accordance with data protection laws. Study subjects were recruited at random, as their information became available, based on the following inclusion criteria: healthy patients who had never received orthodontic treatment, between the ages of 6 and 9 years, in the first phase of mixed dentition, with photographic records supporting the precise diagnosis of unilateral cross-bite, and X-ray records with sufficient quality for evaluation. We excluded patients with orofacial pathologies, malformations or any condition that could result in alterations in the individual's development or normal growth, dental/periodontal alterations that could affect or interfere in the diagnosis of cross-bite, and using any permanent or removable dental appliance.

Photographic and radiographic diagnostic protocol

A single examiner took the whole series of digital photographs using the same technical standards and verbal instructions for all patients. A maximum of 20 patients per session were subsequently evaluated by a single examiner using a 30" computer monitor, with optional computer magnification. An anterior or posterior tooth was considered to have a cross-bite when at least half of its width was in this position and when the jaw's midline had deviated toward the cross-bite. Digital panoramic radiographs were made with Siemens orthopantomographic model Orthophos. A maximum of 20 patients per session were subsequently evaluated by a single examiner using a 30" computer monitor and tpsDigs version 2, allowing for 10% enlargement or reduction of the image, thus facilitating the recognition of anatomical structures. Then the following anatomical points were identified, on the left and right.

- Co: the condyle's highest point.
- Go: the point bisecting the angle formed by tangents, on the ramus of the mandible's posterior border (RL) and the lower border of the body of the mandible (RM).
- INC: the deepest point between the coronoid process and the condyle.
- AgMe: the highest point of the mental formen.
- 46 and 36: the highest point of the first permanent molar's distal surface, right and left, respectively.

Subsequently, the following vertical measurements were drawn (Fig. 1).

- V0: the axis of the panoramic radiograph.
- V1 and V2: the height of the body of the mandible, right and left respectively, at the most anterior point of the mental foramen, right and left.
- V3 and V4: the height of the body of the mandible, right and left respectively, at the highest point of the first permanent molar's right and left distal surfaces.
- V5 and V6: condylar height of the body of the mandible, right and left respectively; this refers to the distance from the highest point of the condyle to the lowest point of the sigmoid notch, right and left.
- V7 and V8: total height of the ramus of the mandible, right and left respectively. The distance between the highest point of the condyle, right and left respectively, to the right and left mandibular angle.

Statistical analysis

The software SPSS (SPSS Inc. Chicago, IL, USA) for Windows, version 17.0, was used. All the results had a 95% level of confidence ($p<0.05$). The mean and standard deviation were calculated for each of the sample's measurements. Mean comparisons were made using the Student's t-test.

Results

The final sample consisted of 217 girls and boys distributed by age group. The mean age was 7.5 years (Table 1). Analysis revealed that the vertical variable lengths of the total sample of patients with right cross-bites were greater in variables V1 and V3, and shorter in V5 and V7. The differences among variables V1-V2, V3-V4 and V5-V6 were statistically significant. In the sample of left cross-bites, variables V1, V3 and V7 had greater length, while in V5 they were shorter. The differences among variables V1-V2 and V3-V4 were statistically significant. In the sample of boys with right cross-bites, V1 and V3 had the greatest lengths, with the shortest in V5 and V7. The differences among V1-V2, V3-V4 and V5-V6 were statistically significant. In the left cross-bite sample, V1, V3 and V7 showed greater length, and V5 was shorter. Only the difference in variables V3-V4 was significant. In the sample of girls with right unilateral cross-bite, there was greater length in V1 and V3, and variables V5 and V7 were shorter. The differences among V1-V2, V3-V4 and V5-V6 were statistically significant. In the sample of left unilateral cross-bites, V1, V3 and V7 were longer than variables V2, V4 and V8. Those of V5 were shorter than those of V6. The differences between V1-V2 and V3-V4 were statistically significant.

In the 6-7 years age group for right unilateral cross-bites, V1 and V3 were longer than V2 and V4. Variables V5 and V7 were shorter than V6 and V8. Only the difference among variables V1-V2 were statistically significant. In the sample of left unilateral cross-bites, V2, V6 and V8 were greater than V1, V5 and V7, with V4 less than V3. In this sample, no statistical significance was found. In the 7-8 years age group of right unilateral cross-bites, variables V1 and V3 showed greater lengths than V2 and V4, while V5 and V7 were shorter than V6

FIG. 1 Vertical measurements.

AGE (y)	RUCB (m)	RUCB (f)	LUCB (m)	LUCB (f)	Total
6-7	20	19	7	15	61
7-8	22	24	6	13	65
8-9	16	16	9	10	51
9-10	7	13	10	10	40
TOTAL	65	72	32	48	217

TABLE 1 Sample distribution by age group, gender and side with cross-bite.

and V8. In the sample of left unilateral cross-bites, the variables V1, V3 and V5 were greater than V2, V4 and V6, and variable V7 was less than V8. In this range only the difference in variables V3-V4 was statistically significant. In the 8-9 years age group of right unilateral cross-bites, variable V3 showed greater length than V4, while V1, V5 and V7 were shorter than V2, V6 and V8. The difference in variables V3-V4 was statistically significant.

No significant differences were found in the sample of left unilateral cross-bites (Tables 2, 3 and 4).

Discussion

There are few studies in the literature evaluating symmetry and quantifiable skeletal changes based on

RIGHT UNILATERAL CROSS-BITE									
RIGHT HEMI-MANDIBLE					LEFT HEMI-MANDIBLE				
	Mean (pixel)	SD	MIN (pixel)	MAX (pixel)		Mean (pixel)	SD	MIN (pixel)	MAX (pixel)
TOTAL SAMPLE									
V1	231.01	24.067	174	326	V2	227.78	25.537	166	316
V3	211.88	24.395	148	280	V4	204.89	26.360	121	285
V5	108.34	20.443	59	164	V6	117.07	37.652	61	396
V7	377.56	51.267	90	520	V8	383.41	39.417	270	499
SAMPLE OF BOYS									
V1	237.58	21.901	184	326	V2	235.34	22.116	183	316
V3	215.89	23.008	167	273	V4	206.26	25.742	121	284
V5	108.38	18.739	68	156	V6	120.34	50.004	78	396
V7	377.86	62.927	90	505	V8	3888.78	41.584	270	499
SAMPLE OF GIRLS									
V1	225.08	24.535	174	314	V2	220.96	26.624	166	303
V3	208.26	25.194	148	280	V4	203.65	27.025	125	285
V5	108.31	22.000	59	164	V6	114.11	21.048	61	169
V7	377.29	38.276	304	520	V8	378.56	36.972	293	494
6-7 AGE GROUP									
V1	225.08	24.535	174	314	V2	220.96	26.624	166	303
V3	208.26	25.194	148	280	V4	203.65	27.025	125	285
V5	108.31	22.000	59	164	V6	114.11	21.048	61	169
V7	377.29	38.276	304	520	V8	378.56	36.972	293	494
7-8 AGE GROUP									
V1	234.35	22.364	194	314	V2	231.33	23.195	192	303
V3	213.67	21.680	174	280	V4	206.83	22.590	178	285
V5	108.30	17.966	74	156	V6	124.33	57.242	75	396
V7	375.00	70.504	90	520	V8	389.67	38.995	304	494
8-9 AGE GROUP									
V1	236.25	20.735	210	301	V2	237.44	21.941	206	303
V3	222.69	21.643	185	277	V4	210.00	25.836	121	247
V5	113.00	19.817	79	163	V6	116.56	18.558	83	169
V7	387.78	31.976	332	473	V8	388.94	33.125	337	476
9-10 AGE GROUP									
V1	228.55	24.682	178	278	V2	224.10	23.830	178	269
V3	218.85	24.182	183	273	V4	214.45	25.180	176	273
V5	115.30	22.259	70	145	V6	122.35	18.977	89	158
V7	398.65	28.792	350	472	V8	297.40	27.854	345	469

TABLE 2 Statistical description. Vertical bone measurements for the whole RUCB sample.
SD: Standard deviation.
Min: Minimum value. Max: Maximum value.

LEFT UNILATERAL CROSS-BITE									
RIGHT HEMI-MANDIBLE					LEFT HEMI-MANDIBLE				
	Mean (pixel)	SD	MIN (pixel)	MAX (pixel)		Mean (pixel)	SD	MIN (pixel)	MAX (pixel)
TOTAL SAMPLE									
V1	230.18	26.111	175	328	V2	226.61	25.345	170	324
V3	216.06	29.171	154	341	V4	209.80	28.801	121	342
V5	111.35	20.213	64	151	V6	112.25	19.420	74	169
V7	387.73	39.110	319	506	V8	386.80	38.599	326	511
SAMPLE OF BOYS									
V1	277.84	21.911	187	306	V2	224.38	20.351	187	309
V3	210.38	25.862	154	283	V4	201.91	24.466	121	263
V5	110.00	21.577	79	151	V6	111.13	19.041	82	163
V7	387.66	35.816	325	468	V8	386.66	32.129	335	459
SAMPLE OF GIRLS									
V1	231.73	28.690	175	328	V2	228.10	28.299	170	324
V3	219.85	30.861	157	341	V4	215.06	30.475	156	342
V5	112.25	19.432	64	145	V6	113.00	19.833	74	169
V7	387.77	41.531	319	506	V8	386.90	42.700	326	511
6-7 AGE GROUP									
V1	212.59	17.465	187	264	V2	214.77	20.171	172	261
V3	199.73	28.464	154	260	V4	197.36	23.413	154	254
V5	106.09	22.151	77	155	V6	109.68	21.138	74	153
V7	363.95	29.991	319	455	V8	364.64	28.878	326	448
7-8 AGE GROUP									
V1	234.95	14.695	216	270	V2	230.42	12.937	204	266
V3	218.47	21.214	177	256	V4	206.21	27.363	121	247
V5	105.11	17.084	64	129	V6	103.89	16.031	79	141
V7	375.58	28.652	321	433	V8	376.05	28.428	340	443
8-9 AGE GROUP									
V1	238.63	30.622	187	306	V2	228.58	32.498	180	309
V3	222.37	24.568	189	283	V4	216.21	21.781	188	263
V5	114.37	21.887	81	145	V6	114.21	20.520	86	169
V7	403.89	44.544	352	495	V8	403.11	46.089	357	493
9-10 AGE GROUP									
V1	236.95	30.067	175	328	V2	234.15	28.664	170	324
V3	225.75	34.511	171	341	V4	220.80	36.385	169	342
V5	120.20	16.234	83	151	V6	121.15	16.349	95	163
V7	410.05	33.470	345	506	V8	405.90	34.069	351	511

TABLE 4

	RUCB	LUCB
	T-TEST Signif	T-TEST Signif
TOTAL SAMPLE		
V1-V2	0.001	0.007
V3-V4	0.000	0.001
V5-V6	0.004	0.554
V7-V8	0.052	0.545
SAMPLE OF BOYS		
V1-V2	0.022	0.105
V3-V4	0.000	0.027
V5-V6	0.047	0.669
V7-V8	0.075	0.692
SAMPLE OF GIRLS		
V1-V2	0.001	0.035
V3-V4	0.001	0.017
V5-V6	0.003	0.688
V7-V8	0.399	0.653
6-7 AGE GROUP		
V1-V2	0.000	0.422
V3-V4	0.070	0.429
V5-V6	0.101	0.111
V7-V8	0.256	0.800
7-8 AGE GROUP		
V1-V2	0.057	0.102
V3-V4	0.000	0.046
V5-V6	0.055	0.750
V7-V8	0.083	0.902
8-9 AGE GROUP		
V1-V2	0.565	0.000
V3-V4	0.005	0.049
V5-V6	0.184	0.969
V7-V8	0.585	0.806
9-10 AGE GROUP		
V1-V2	0.052	0.173
V3-V4	0.094	0.090
V5-V6	0.029	0.679
V7-V8	0.720	0.140

TABLE 3 Statistical description. Vertical bone measurements for the whole LUCB sample.
SD: Standard deviation. Min: Minimum value. Max: Maximum value.
TABLE 4 Comparative analysis of the symmetry of vertical measurements in the sample with RUCB and LUCB. T-TEST: Significance.

panoramic radiographs, using a sample of children with unilateral cross-bites. Initially the scarcity of such research was due to the poor quality offered by conventional X-ray images. As for metric variables, not all authors utilise the same type of vertical variables. The most commonly used method is that of Habets et al. [1987] and we have incorporated other variables described by other authors [Hintze et al., 1990; Larheim and Svanaes, 1986; Kubota et al., 1999; Ongkosuwito et al., 2009; Piedra, 1995].

Studies carried out on samples of adult patients found significant differences between the two sides, with greater lengths in the sample of women with jaw anomalies [Habets et al., 1988]. In our study, the only statistically significant differences were in condylar height, in the whole sample, in both genders and in the 9-10 years age group. Other authors, in longitudinal studies of a sample of children in the phase of early mixed dentition without malocclusions, observed that the length of all the measurements increased, with significant differences between right and left in some variables.

In our study, regardless of the malocclusion, all the measurements increased with age; there were also significant differences among some variables. Using other radiographic points of study, some authors evaluated mandible asymmetry in patients between the ages of 7 and 16 years without malocclusions. Contrary to our research, they found statistically significant differences in condylar height between the right and left sides, in the 7-8 years age group [Tsai, 2002; Liukkonen et al., 2005].

Using the Habets method and a sample of patients with posterior bilateral cross-bites, some authors found statistically significant differences between the left and right sides in the heights of the condyle and the ramus of the mandible, in the control group as well as the group with posterior bilateral cross-bites. We only found significant differences among the variables that determine condylar height [Kiki et al., 2007]. Other authors, applying the same method, studied the effects of different types of occlusions on mandible asymmetry [Sezgin et al., 2007]. Unlike our study, they did not find any statistically significant difference.

Subsequently, applying the Habets method on the orthopantomograms of adult patients with unilateral cross-bites and others with normal occlusion, studies revealed the presence of asymmetrical condyles in patients with unilateral cross-bites, with the shorter heights of the condyle and the ramus of the mandible on the side of the unilateral cross-bite [Kilic et al., 2008]. In our study, throughout the sample for both genders and all age groups, condylar height is also smaller, except for age groups 7-8 and 8-9 years. The ramus of the mandible's total length did not vary according to the side of the cross-bite. In more recent studies of a sample with normal occlusions, unilateral cross-bites and posterior bilateral cross-bites, no significant differences were found among any of the age groups or either gender [Uysal et al., 2009]. Contrary to our results, they evidenced statistically significant differences in the condylar heights of the whole sample, both genders and 6-year-olds when the unilateral cross-bite was on the right.

Conclusions

1. Throughout the sample, regardless of the side with the cross-bite, vertical variables corresponding to the total height of the ramus were always shorter on the side with the cross-bite. Gender had no effect on the results obtained. The age range influenced the height of the mandible.
2. Skeletal development in the sample of unilateral cross-bites presents quantifiable anatomical differences in vertical variables, but it is difficult to determine the degree of asymmetry. Nonetheless, we believe that orthopantomography can be used as a diagnostic aid in the study of mandible symmetry.

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