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An investigation of cervicovertebral morphology in different sagittal skeletal growth patterns

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SUMMARY The purpose of the present study was to examine and compare cervicovertebral morphology in subjects with different sagittal skeletal patterns. The material comprised lateral head films of 90 untreated subjects, 45 girls and 45 boys, aged 13–15 years. The radiographs were obtained in the natural head position using a fluid level method. The subjects were divided into three groups according to ANB angle: ANB angle between 1 and 5 degrees (skeletal Class I), larger than 5 degrees (skeletal Class II), and smaller than 1 degree (skeletal Class III). Each ANB group consisted of 30 subjects, 15 girls and 15 boys. Twenty-nine linear and four area measurements were used to assess cervicovertebral morphology. Differences between the ANB groups and between genders were assessed by means of analysis of variance and the least significant difference test. In addition, cephalometric measurements for all subjects were subjected to discriminant analysis.

The results of the analysis of variance showed that there were statistically significant differences in the measurements of the lumen length of C1, inferior depths of C2 and C4, anterior intervertebral spaces of C2 and C3, posterior intervertebral space of C3, and anterior and posterior body heights of C4 among the ANB groups. The total length of C1, inferior depths of C2–C5, anterior intervertebral spaces of C2–C4, posterior intervertebral space of C2, anterior body heights of C4 and C5, and posterior body heights of C3–C5 demonstrated significant gender differences. The results of the discriminant analysis indicated that 54.4 per cent of the original grouped cases were correctly classified in the total sample. The final discriminant model was able to classify correctly 20 of the 30 Class I subjects (66.7 per cent), 17 of the 30 Class II subjects (56.7 per cent), and 12 of the 30 Class III subjects (40.0 per cent).

Introduction

The introduction of cephalometric radiography as an orthodontic diagnostic tool permitted the accurate evaluation of the skeletal relationship of subjects with various types of malocclusion (Bishara *et al.*, 1983). The sagittal skeletal relationship of the maxillary and mandibular apical bases is an important factor evaluated during orthodontic diagnosis and treatment planning. This relationship is used to establish detailed treatment goals and treatment mechanics. From the orthodontic viewpoint, a patient's facial profile is best described by the relative antero-posterior jaw relationship with respect to the cranial anatomy (Bishara *et al.*, 1983; Chang, 1987; Kirchner and Williams, 1993; Yang and Suhr, 1995). The ANB angle is a measurement that is commonly used in evaluating the sagittal relationship of the apical bases (Kim and Vietas, 1978; Bishara *et al.*, 1983; Hussels and Nanda, 1984; Oktay, 1991).

Recently, a number of authors have described associations between head posture and craniocervical morphology that may affect the pattern of craniofacial growth (Solow and Tallgren, 1976; Solow and Greve, 1979; Solow *et al.*, 1982, 1984; Kylamarkula and Huggare, 1985; Solow and Siersbæk-Nielsen, 1986, 1992; Hellsing *et al.*, 1987; Tallgren and Solow, 1987; Huggare, 1987, 1991; Cooke and Wei, 1988; Özbek and Köklü, 1993; Sandıkçıoğlu *et al.*, 1994; Huggare and Cooke, 1994). These studies suggest that the posture of the head upon the cervical spine may influence the direction of craniofacial growth, possibly through the soft tissue stretching hypothesis of Solow and Kreiborg (1977).

Huggare and Houghton (1996) investigated the relationships between atlas morphology and cranial base dimensions and flexure. They concluded that some dimensions of the atlas and axis vertebrae were associated with the length and height of the mandible and the gonial angle.

Morphological features of the first cervical vertebra (particularly the height of its dorsal arch) have been found to be associated with mandibular growth direction (Huggare, 1989; Solow and Siersbæk-Nielsen, 1992; Huggare and Cooke, 1994). A relationship has also been reported between atlas morphology and head posture (Kylamarkula and Huggare, 1985).

Grave *et al.* (1999) compared cervicovertebral dimensions in Australian Aborigines and Caucasians. They found that there were statistically significant differences in cervicovertebral morphology between Aborigines and Caucasians. They also found some associations between the dimensions of the cervical vertebrae and craniofacial lengths, particularly those representing the posterior cranial base and mandible.

Most studies of the cervical column have been concerned with general descriptions or specific associations between head posture, craniofacial morphology, and the upper cervical vertebrae. However, the relationships between overall cervicovertebral morphology and sagittal skeletal pattern have not so far been investigated in detail.

Therefore, the aims of this study were to:

1. examine the relationships between cervicovertebral morphology and sagittal skeletal pattern;
2. compare cervicovertebral morphology in subjects with different sagittal skeletal patterns.

Material and methods

The material comprised the natural head position lateral cephalograms of 90 subjects, 45 girls and 45 boys, aged 13–15 years obtained from all subjects routinely prior to orthodontic treatment. The natural head position was determined using the fluid level method described by Showfety *et al.* (1983). A metal chain was suspended in front of the film cassette to indicate the true vertical.

All of the subjects were nose breathers with complete dentitions, no history of orthodontic treatment, no wound, burn, or scar tissue in the face and neck region, and no signs of functional disturbances of the masticatory system.

The subjects were divided into three groups according to ANB angle, using Gazilerli's (1976) norms for Turkish children: ANB angle between 1 and 5 degrees (skeletal Class I), larger than 5 degrees (skeletal Class II), and smaller than 1 degree (skeletal Class III). Each ANB group comprised 30 subjects (15 girls and 15 boys).

Twenty-nine linear and four area measurements were used to assess cervicovertebral morphology in different sagittal skeletal patterns. The cephalometric measurements used in the study are described in Figure 1.

The area measurements were made with an electronic planimeter (Ushikata X-plan 360-i, Ushikata Mfg Co, Tokyo, Japan). Each area was measured on three successive occasions and the mean value of the three measurements was computed.

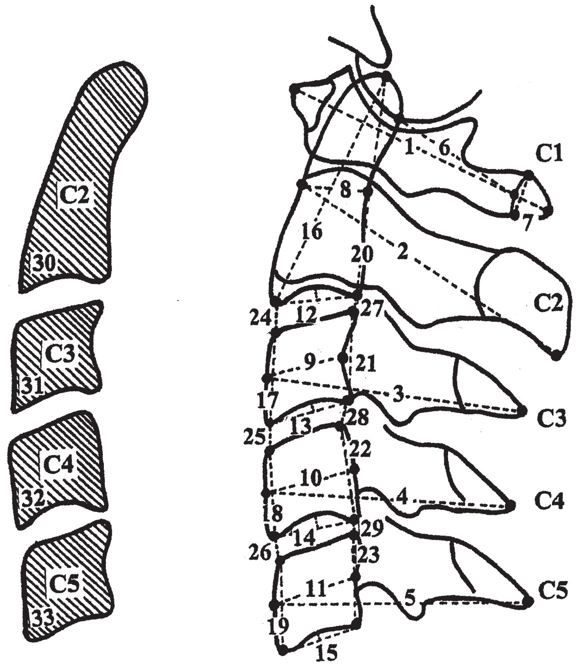

Figure 1 Cephalometric measurements used in the study. Linear measurements: (1)–(5) TLC1–C5 (total length of the cervical vertebrae): the maximum antero-posterior length of C1–C5; (6) LLC1 (lumen length of the atlas): the distance from the dorsal border of the odontoid process of C2 to the anterior border of the dorsal arch of C1; (7) DAHC1 (dorsal arch height of the atlas): the maximum vertical height of the dorsal arch of C1; (8)–(11) BLC2–C5 (body length of the cervical vertebrae): the distance between the midpoints of the antero-superior and antero-inferior points of the bodies of C2–C5 and the midpoints of the postero-superior and postero-inferior points of C2–C5; (12)–(15) IDC2–C5 (inferior depth of the cervical vertebrae): the perpendicular distance between the extreme superior points of the inferior border of the bodies of C2–C5 and the tangent line to the antero-inferior and postero-inferior points of the bodies of C2–C5; (16)–(19) ABHC2–C5 (anterior height of the bodies of the cervical vertebrae): the distance between the antero-superior and antero-inferior points of the bodies of C2–C5; (20)–(23) PBHC2–C5 (posterior height of the bodies of the cervical vertebrae): the distance between the postero-superior and postero-inferior points of the bodies of C2–C5; (24)–(26) AISC2–C4 (anterior intervertebral space of the cervical vertebrae): the anterior distance between the bodies of C2–C5; (27)–(29) PISC2–C4 (posterior intervertebral space of the cervical vertebrae): the posterior distance between the bodies of C2–C5. Area measurements: (30)–(33) AC2–C5: the area of the bodies of C2–C5.

Error of measurements

Twenty randomly selected radiographs were re-traced and re-measured by the same investigator 2 weeks after the initial analysis. The error of the method was examined using the coefficient of reliability, calculated for each measurement:

$$\text{coefficient of reliability} = 1 - Se^2/St^2$$

where Se^2 is the variance due to random error, and St^2 is the total variance of the measurements (Houston, 1983).

Statistical analysis

Data were analysed using SPSS for Windows, version 10.0 (SPSS Inc., Chicago, IL, USA). The means and standard deviations were calculated for all variables in each ANB group and for gender. Analysis of variance was used to determine statistically significant differences between the ANB groups and between genders. The least significant difference (LSD) multiple comparison test (Keppel, 1973) was applied to the measurements at which *F*-values were found to be statistically significant. In addition, cephalometric data for all patients were

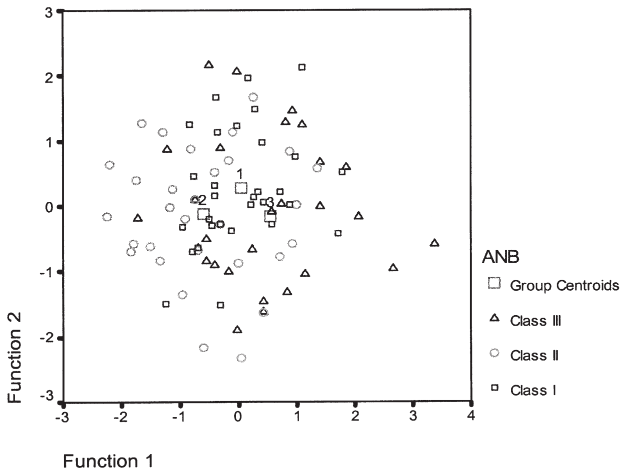

Figure 2 Discriminant function scores using the stepwise method for the total sample.

subjected to a discriminant analysis. Using the stepwise method of Wilk's, all cephalometric variables were included in the analysis. Excluding those measurements that contributed the least to the overall model progressively reduced the number of parameters. Once variable selection was complete, a discriminant model was generated comprising a number of factors. The discriminant scores were calculated for each subject. These scores automatically allocated subjects to one of the three groups and these are presented diagrammatically in Figure 2. Because of the significant gender differences, these analyses were carried out for each sex and for the total sample separately. $P \leq 0.05$ was considered statistically significant.

Results

The value of the coefficient of reliability was above 0.90 (range 0.90–0.99) for all cephalometric measurements, except the inferior depths of C5 measurement (0.87). The mean chronological ages of the subjects were 13.76 ± 0.58, 13.56 ± 0.60, and 13.90 ± 0.77 years for skeletal Class I, II, and III, respectively. No statistically significant age differences were found between the

Table 1 Means and standard deviations (SD) of all variables used in the study for each group of girls.

Measurements	Class I (n = 15)		Class II (n = 15)		Class III (n = 15)	
	Mean	SD	Mean	SD	Mean	SD
Linear (mm)						
1. TLC1	47.06	3.30	47.00	2.62	47.0	2.65
2. LLC1	19.18	2.08	19.31	2.18	18.61	2.33
3. DAHC1	9.03	1.28	9.39	2.02	9.15	1.51
4. TLC2	48.15	2.90	48.39	3.03	49.19	2.33
5. BLC2	12.56	1.14	12.64	1.08	12.81	1.23
6. IDC2	1.85	0.34	1.36	0.52	1.77	0.26
7. ABHC2	39.03	2.75	38.72	2.57	38.27	2.83
8. PBHC2	34.65	2.29	34.90	2.25	33.96	2.73
9. AISC2	3.38	1.13	4.50	1.23	3.00	1.12
10. PISC2	1.35	0.93	1.68	0.70	1.27	0.78
11. TLC3	44.18	2.02	43.57	2.48	45.62	2.92
12. BLC3	14.32	1.09	14.86	1.20	14.58	1.57
13. IDC3	1.71	0.59	1.39	0.59	1.77	0.39
14. ABHC3	13.09	1.75	11.75	2.00	13.92	1.72
15. PBHC3	14.47	1.15	13.86	1.48	14.73	0.99
16. AISC3	3.24	1.12	4.18	1.28	2.96	0.88
17. PISC3	1.25	0.81	1.61	1.07	1.58	0.79
18. TLC4	43.94	2.05	44.64	2.67	44.42	2.10
19. BLC4	14.03	1.01	14.50	1.16	14.69	1.55
20. IDC4	1.53	0.62	1.09	0.48	1.81	0.48
21. ABHC4	12.38	1.75	10.93	2.11	12.96	1.48
22. PBHC4	14.62	1.36	13.68	1.88	14.39	0.82
23. AISC4	3.41	1.20	3.79	0.98	3.23	10.50
24. PISC4	1.43	0.83	1.63	0.91	1.46	0.66
25. TLC5	45.15	1.48	44.75	3.32	47.05	2.33
26. BLC5	14.09	1.02	14.43	1.05	14.19	1.16
27. IDC5	1.27	0.71	0.89	0.45	1.46	0.52
28. ABHC5	11.71	1.70	11.00	1.72	12.23	1.83
29. PBHC5	13.82	1.21	13.36	1.54	14.08	1.19
Area (mm^2)						
30. AC2	430.44	46.15	433.82	35.59	434.56	54.42
31. AC3	180.01	21.52	173.25	35.33	187.01	29.22
32. AC4	175.11	25.28	166.60	32.12	181.81	22.55
33. AC5	170.07	21.66	167.31	26.59	177.21	23.47

Table 2 Means and standard deviations (SD) of all variables used in the study for each group of boys.

Measurements	Class I (n = 15)		Class II (n = 15)		Class III (n = 15)	
	Mean	SD	Mean	SD	Mean	SD
Linear (mm)						
1. TLC1	49.42	2.60	48.71	2.67	47.57	2.80
2. LLC1	20.25	2.49	20.39	1.44	18.89	2.01
3. DAHC1	9.06	1.55	8.68	2.03	9.32	1.35
4. TLC2	49.42	2.60	48.11	3.54	51.07	5.31
5. BLC2	12.75	0.96	12.50	1.14	12.71	1.19
6. IDC2	1.25	0.52	1.00	0.59	1.21	0.51
7. ABHC2	37.83	2.18	37.39	2.94	37.39	3.34
8. PBHC2	34.06	2.05	33.43	3.03	34.07	2.65
9. AISC2	4.75	1.41	5.50	1.14	5.00	1.61
10. PISC2	2.04	1.05	2.23	0.82	1.48	0.96
11. TLC3	44.31	2.87	43.89	3.47	44.50	3.12
12. BLC3	15.00	1.20	15.07	1.41	14.43	1.28
13. IDC3	1.01	0.42	0.79	0.57	0.89	0.53
14. ABHC3	16.11	23.49	9.75	2.17	10.57	2.59
15. PBHC3	13.25	1.07	12.89	1.71	13.82	2.40
16. AISC3	5.11	1.38	5.61	1.20	5.07	1.43
17. PISC3	1.42	0.67	2.29	0.55	1.64	0.77
18. TLC4	44.00	3.07	44.11	3.16	44.75	4.26
19. BLC4	15.03	1.29	14.96	1.31	14.46	1.14
20. IDC4	0.74	0.43	0.52	0.45	0.71	0.58
21. ABHC4	10.42	1.70	9.32	2.05	10.36	2.31
22. PBHC4	13.67	1.10	12.57	1.27	13.68	2.00
23. AISC4	4.72	1.72	5.29	1.19	4.57	1.48
24. PISC4	1.29	0.89	1.89	0.40	1.25	0.75
25. TLC5	45.25	3.94	44.75	3.71	44.96	2.68
26. BLC5	14.81	1.42	14.86	1.28	14.68	1.27
27. IDC5	0.54	0.41	0.52	0.52	0.50	0.58
28. ABHC5	10.47	1.91	9.25	1.97	9.89	2.11
29. PBHC5	13.47	1.35	12.29	1.33	12.79	2.11
Area (mm^2)						
30. AC2	432.46	42.18	420.59	58.84	421.26	62.66
31. AC3	167.54	22.57	158.31	31.60	166.84	42.32
32. AC4	169.35	22.33	155.85	26.99	163.83	35.92
33. AC5	168.47	23.97	154.78	27.82	160.66	35.51

ANB groups or between genders. Descriptive statistics including means and standard deviations of all measurements in each ANB group are presented in Tables 1 and 2 for girls and boys, respectively. The results of the analysis of variance are given in Table 3. These showed that there were statistically significant differences in the measurements of the lumen length of C1, inferior depths of C2 and C4, anterior intervertebral spaces of C2 and C3, posterior intervertebral space of C3, anterior and posterior body heights of C4 among the ANB groups. The total length of C1, inferior depths of C2–C5, anterior intervertebral spaces of C2–C4, posterior intervertebral space of C2, anterior body heights of C4 and C5, and posterior body heights of C3–C5 measurements demonstrated significant gender differences. In addition, the area of the third cervical vertebra showed significant interaction effects between gender and ANB groups. According to the results of the LSD test, the most significant differences among the ANB groups were concentrated between the skeletal Class II and III groups and between the skeletal Class I and II groups. No significant differences were found between the Class I and III groups (Table 4).

The results of the discriminant analysis are shown in Table 5. According to these results, 66.7 per cent of the boys, 33.3 per cent of the girls, and 66.7 per cent of the pooled group were identified correctly in the skeletal Class I group. For the Class II and III groups, the results were: 86.7, 73.3 and 56.7 per cent and 26.7, 66.7 and 40.0 per cent, respectively.

The discriminant model provided a success rate of 60.03 per cent for boys including two variables (the posterior intervertebral spaces of C3 and C4), 57.8 per cent for girls including four variables (the lumen length of C1, anterior intervertebral space of C2, total length and inferior depth of C5), and 54.5 per cent for the total sample including three variables (the lumen length of C1, total length of C2 and anterior body height of C4). The final model was able to classify correctly 20 of the 30 Class I subjects (66.7 per cent), 17 of the 30 Class II subjects (56.7 per cent), and 12 of the 30 Class III subjects (40.0 per cent).

Table 3 The results of the analysis of variance.

Measurements	ANB	Gender	ANB × gender
Linear (mm)			
1. TLC1	0.88	6.80*	0.78
2. LLC1	3.54*	1.48	0.38
3. DAHC1	0.14	0.75	0.59
4. TLC2	2.27	1.76	0.76
5. BLC2	0.20	0.00	0.21
6. IDC2	4.56*	21.72***	0.48
7. ABHC2	0.38	3.99	0.60
8. PBHC2	0.15	1.59	0.73
9. AISC2	5.42**	28.45***	1.06
10. PISC2	2.90	6.53*	0.55
11. TLC3	1.57	0.14	0.54
12. BLC3	0.92	0.82	0.80
13. IDC3	2.39	42.98***	0.48
14. ABHC3	1.03	0.12	0.78
15. PBHC3	2.12	8.94**	0.83
16. AISC3	4.05*	47.47***	0.55
17. PISC3	4.71*	3.30	1.23
18. TLC4	0.35	0.00	0.15
19. BLC4	0.22	2.43	1.85
20. IDC4	5.89**	56.42***	1.78
21. ABHC4	5.24*	25.82***	0.48
22. PBHC4	4.34*	8.95**	0.13
23. AISC4	1.75	25.0***	0.44
24. PISC4	2.61	0.02	0.79
25. TLC5	1.31	1.16	1.29
26. BLC5	0.27	4.51	0.13
27. IDC5	1.90	35.36***	2.03
28. ABHC5	2.56	20.43***	0.68
29. PBHC5	2.54	8.35**	0.89
Area (mm^2)			
30. AC2	0.07	0.59	0.25
31. AC3	0.98	0.12	5.95*
32. AC4	1.60	3.82	0.37
33. AC5	0.89	3.27	0.66

$^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$.

Discussion

Previous investigations have reported the existence of morphological associations between the first and second cervical vertebrae and craniofacial structures (Sandıkçıoğlu *et al.*, 1994; Huggare and Houghton, 1996). In addition, correlations have been demonstrated between atlas morphology and head posture, a short posterior arch height being found in conjunction with an extended head posture (Kylamarkula and Huggare, 1985; Huggare, 1991). The direction of mandibular growth has also been related to morphology of the atlas and axis (Huggare, 1989; Huggare and Cooke, 1994). However, until now, relationships between overall cervicovertebral morphology and sagittal skeletal growth pattern have not been investigated in detail. In the present study, therefore, the relationships between the morphology of the cervical vertebrae and sagittal skeletal growth patterns were investigated.

The results show that there were some statistically significant differences in cervicovertebral morphology among subjects with different sagittal skeletal growth patterns. The lumen length of C1, anterior intervertebral spaces of C2 and C3, posterior intervertebral space of C3 in subjects with skeletal Class II were greater than those in the other groups, whereas the inferior depths of C2 and C4, and the anterior and posterior body heights of C4 were smaller than those in the other Classes.

In the present study, it was found that the total length, body height, inferior depth, and area of the cervical vertebrae had a general tendency to decrease in the Class II group, whereas the body length and the intervertebral space of the cervical vertebrae tended to increase in this group for both sexes. However, these differences were not statistically significant.

Kylamarkula and Huggare (1985) reported that the vertical height of the dorsal arch of the atlas was significantly smaller in children with enlarged adenoids and a retrognathic mandible, while there was no difference in the height of the anterior arch or in the antero-posterior dimension.

The results of the present study show that the atlas lumen length in the Class II group was longer than in the other groups, whereas no statistically significant

Table 4 The results of the least significant difference test.

Measurements	Class					
	I	II	III	I–II	I–III	II–III
Linear (mm)						
2. LLC1	19.71	20.25	18.75	NS	NS	1.50**
6. IDC2	1.55	1.18	1.49	0.37**	NS	0.31*
9. AISC2	4.07	5.00	4.00	0.93**	NS	1.00**
16. AISC3	4.17	4.90	4.02	0.72*	NS	0.88**
17. PISC3	1.33	1.95	1.61	0.61**	NS	NS
20. IDC4	1.13	0.80	1.26	0.33*	NS	0.46**
21. ABHC4	11.40	10.13	11.66	1.28**	NS	1.53**
22. PBHC4	14.14	13.13	14.03	1.02**	NS	0.91*

$^{*}P < 0.05$; $^{**}P < 0.01$.
NS, not significant.

Table 5 The results of the discriminant analysis using the stepwise method.

Actual group	Group	Predicted to be in Class I group	Predicted to be in Class II group	Predicted to be in Class III group
Class I	Boy $n = 15$	10 (66.7%)	5 (33.3%)	0
	Girl $n = 15$	5 (33.3%)	5 (33.3%)	5 (33.3%)
	Total $n = 30$	20 (66.7%)	7 (23.3%)	3 (10%)
Class II	Boy $n = 15$	2 (13.3%)	13 (86.7%)	0
	Girl $n = 15$	4 (26.7%)	11 (73.3%)	0
	Total $n = 30$	7 (23.3%)	17 (56.7%)	6 (20%)
Class III	Boy $n = 15$	6 (40%)	5 (33.3%)	4 (26.7%)
	Girl $n = 15$	3 (20%)	2 (13.3%)	10 (66.7%)
	Total $n = 30$	8 (26.7%)	10 (33.3%)	12 (40%)

Eigenvalues: 0.314, 1.048 and 0.228 for boys, girls and the total group, respectively.
Canonical correlations: 0.489, 0.715 and 0.431 for boys, girls and the total group, respectively.
Of the original grouped cases, 54.4 per cent were correctly classified in the total sample.

difference in the total (antero-posterior) length and height of the dorsal arch of the atlas was found between the groups.

Grave *et al.* (1999) investigated and compared cervicovertebral dimensions in Australian Aborigines and Caucasians. They reported that ethnic differences in cervicovertebral morphology were evident, particularly in the upper segment of the column. They also found that there were significant correlations between the dimensions of the cervical vertebrae and craniofacial lengths, particularly those representing the posterior cranial base and mandible. Similarly, Huggare and Houghton (1996) reported that the height of the atlantal posterior arch was associated with mandibular length, ramal height and gonial angle. Thus, in general, a high arch was seen in conjunction with a long, high and square-shaped mandible, whereas a low arch was usually found together with a short and low mandible. They also reported that the anterior height of the axis was significantly associated with mandibular length and ramal height.

Discriminant analysis was performed to test the validity of the cervicovertebral cephalometric measurements used to identify subjects with different sagittal skeletal patterns. The stepwise variable selection model examines each variable and selects those with the highest predictive value. The posterior intervertebral spaces of C3 and C4 for boys, the lumen length of C1, anterior intervertebral space of C2, total length and inferior depth of C5 for girls, and the lumen length of C1, total length of C2 and anterior body height of C4 for the total sample were selected as the parameters with the highest predictive values in the model. The two variables for girls alone were successful in classifying five of the 15 (33.3 per cent) Class I subjects, 11 of the 15 (73.3 per cent) Class II subjects, and 10 of the 15 (66.7 per cent) Class III subjects. In the boys, four variables alone were successful in classifying 10 of the 15 (66.7 per cent) Class I subjects, 13 of the 15 (86.7 per cent) Class II subjects, and four of the 15 (26.7 per cent) Class III subjects. The discriminant model including three variables for the total sample was able to classify correctly 20 of the 30 (66.7 per cent) Class I subjects, 17 of the 30 (56.7 per cent) Class II subjects, and 12 of the 30 (40.0 per cent) Class III subjects. The final model offered an overall success rate of 54.4 per cent for the total sample. Therefore, the discriminant model failed to identify clearly between the skeletal Class I, II, and III subjects, indicating the difficulty in distinguishing cephalometric features between the groups.

It has been stated that although the sagittal skeletal pattern seems to influence cervicovertebral morphology, many other factors must also influence cervicovertebral morphology. The morphogenesis of the cervical vertebrae is obviously related to their main functions of protecting the spinal cord, supporting the head and facilitating its mobility (Kylamarkula and Huggare, 1985). In view of the early completion of central nervous system growth (Knutsson, 1961), especially in the case of the upper vertebrae (Tulsi, 1971), it could be expected that the part supporting and protecting the spinal cord would remain largely unaffected by later environmental influences (Kylamarkula and Huggare, 1985).

On the contrary, several authors have reported significant sexual dimorphism in cervicovertebral dimensions, and that the majority of vertebral dimensions were larger in males than females (Tulsi, 1972; Solow *et al.*, 1982; Kylamarkula and Huggare, 1985; Grave *et al.*, 1999). Similarly, significant gender differences in the majority of cervicovertebral dimensions were found in the present study. However, the general tendency for boys to exhibit larger cervicovertebral dimensions than girls was not observed. This inconsistency could be attributable to the difference between the age groups. The age range of the subjects was 13–15 years, while other studies were performed on adult subjects.

Conclusions

This study demonstrated that there were some differences in cervicovertebral morphology in subjects with different sagittal skeletal patterns. The lumen length of C1 and the intervertebral spaces of C2 and C3 in subjects with Class II malocclusion were greater than in the other groups, while the inferior depths of C2 and C4 and the body height of C4 were smaller than in the other Classes. In addition, significant gender differences in cervicovertebral dimensions were found. As a result of discriminant analysis, the lumen length of C1, total length of C2, and anterior body height of C4 measurements for the total sample were selected as parameters with the highest predictive values, and 54.4 per cent of the original grouped cases were correctly classified in the final model. The evaluation of certain morphological features of cervical vertebrae would seem to be of some prognostic value regarding sagittal skeletal pattern.

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