Relationship Between Cervical Lordosis and Facial Morphology in Caucasian Women with a Skeletal Class II Malocclusion: A Cross-Sectional Study

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Relationship Between Cervical Lordosis and Facial Morphology in Caucasian Women with a Skeletal Class II Malocclusion: A Cross-Sectional Study

Felice Festa, M.D., D.D.S., M.S. Ph.D.; Simona Tecco, D.D.S.; Marco Dolci, M.D.; Fabio Ciufolo, D.D.S.; Silvio Di Meo, D.D.S.; Maria R. Filippi, D.D.S.; Anna L. Ferritto, D.D.S.; Michele D'Attillio, D.D.S.

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Address for reprint requests:
Dr. Simona Tecco
Via Le Mainarde, 26
65121, Pescara
Italy
E-mail: simtecco@tin.it

ABSTRACT: Several published studies show a relationship between craniofacial morphology and head posture. The aim of this study was to evaluate the association between cervical lordosis angle and mandibular length from lateral skull radiographs, and to investigate the relationship between mandibular retrusion and cervical lordosis angle decreasing. The sample comprised 70 Caucasian adult women, average 27.4, in skeletal class II and Angle class II. Lateral skull radiographs were obtained in natural head position (mirror position). Ten morphological variables were individuated on tracings. In order to assess errors due to landmark identification, double measurements were made in ten randomly selected radiographs and were compared with Dahlberg's formula. A Sperman's rank correlation test showed a negative correlation ($P<0.01$) between cervical lordosis and mandibular length (compensatory curvature of the cervical spine) and positive correlation between anterior cranial base and maxillary length ($P<0.05$). Based upon the cross-sectional method, no conclusion was possible about the mechanism concerning these results. Future longitudinal studies in growing patients should be directed to understanding the extent of environmental and genotype influences on cervical lordosis angle.

Dr. Felice Festa *is director of the Department of Orthodontics and Gnathology, School of Dentistry and a professor of Orthodontics at the University of Chieti, Italy. He is also Director of the Post Graduate program in Clinical Gnathology and Orthodontics at the same university. He received his M.D. degree and D.D.S. degree at the University of Rome in 1979 and 1982 respectively. He earned a M.S. degree in orthodontics in 1985 at the University of Cagliari. In 2001 he was nominated National Referee Professor in Orthodontics at the Professor National College. Dr. Festa has authored many clinical and research articles in his field.*

Craniofacial biologists and orthodontists described associations between head posture and craniofacial morphology. There are *longitudinal studies* done to show the influence of head posture on the pattern of craniofacial growth. Schwarz[1,2] attributed the development of Class II malocclusion to hyperextension of the head relative to the cervical column during sleep. Also Gresham and Smithles[3] noted vertical development of the face and a large prevalence of Class II malocclusion in subjects with *poor neck posture*. Bjork[4] observed raised head position and facial retrognathism in subjects with flat base angle.

Solow and Tallgren[5,6] noticed a systematic set of associations between morphologic and postural variables. Among postural variables, the position of the head in relation to the cervical column (that is craniocervical angulation) showed more correlation with facial morphology than the conventional measure of head posture—the position of the head in relation to true vertical. Among morphologic characteristics of subjects with high craniocervical angulation were reduced facial prognathism, large mandibular plane inclination, and large lower anterior facial height. These findings were supported by Thompson[7] and similar findings were made by Opdebeek[8], et al. and many other authors.[9-19] These studies suggest that head posture upon the cervical column may influence the direction of craniofacial growth, possibly through soft-tissue stretching, a hypothesis of Solow and Kreiborg.[20]

Recently, a correlation was also established between Class II occlusion, forward head posture, and craniomandibular dysfunction: forward head posture could influence craniofacial growth and determine morphoskeletal and neuromuscular patterns, leading to a dysfunctional condition.[21] Also Huggare[22] showed a correlation between dysfunctional condition and cervical posture: in subjects affected with craniomandibular disorders (CMD), he showed a cranial base flattening and a modest increasing of cervical lordosis, which tended to disappear after therapy of CMD.

Metric studies about the cervical column have been concerned with general descriptions or specific associations between head posture, craniofacial morphology, and upper cervical vertebrae. These metric studies aimed to quantify the extent of sexual dimorphism in dimension of cervical vertebrae within a group, to compare cervical vertebral dimensions in different ethnic and age groups, and to examine linear relationships between selected cervicovertebral and craniofacial dimensions. Regarding ethnic differences, Huggare and Houghton[23] drew particular attention to reports of relationships between the morphology of atlas and cranial base dimensions and flexure. They examined skeletal remains of prehistoric Polynesian and Thai people to show that height dimensions of the atlas were negatively correlated with cranial base flexure, while some dimensions of the atlas and axis vertebrae were associated with length and height of the mandible and gonial angle.The results indicated ontogenetic and functional relationships between cranial base and atlas, as well as common growth factors affecting the atlas and the mandible.[23]

Solow,[24] et al. also compared head posture, craniofacial morphology, and selected dimensions of the cervical column in young Danish and Australian Aboriginal males. The results showed natural head posture lower in the Aborigines, so that their upper cervical columns inclined more anteriorly.

Grave, et al.[25] compared cervicovertebral dimensions in 60 young adult Australian Aborigines and 60 Caucasians from Adelaide. The results confirmed the relative shortness of the cervical spine in Australian Aboriginals. They indicated ethnic dimorphism and an association between dimensions of the cervical vertebrae and craniofacial lengths, particularly those representing the posterior cranial base and the mandible with the posterior arch heights of the upper two vertebrae.

Huggare and Houghton[23] reported a correlation between sagittal length of atlas and mandibular length and ramus height, indicating a close association in growth mechanism of the two regions.

The aim of this cross-sectional investigation has been to examine the relationship between variables describing cervical lordosis and facial morphology (most of mandibular dimensions) without considering the effect linked to ethnic origin, gender dimorphism, age, or mandibular inclination. This is why in this study the populations were homogeneous for those factors (Caucasian adult women in skeletal class II).

Materials and Methods

The sample was comprised of 70 women, aged 25-35 years (average 26.8 years) admitted to the Department of Orthodontics and Gnathology, University of Chieti, for treatment of TMJ disorders. The criteria for selection were European ethnic origin, confirmed birthdate, skeletal class II, normal angle of mandibular rotation (GoGn/SN angle). None of the women was receiving or had undergone orthodontic treatment and/or orthognathic surgery prior to their selection.

TMJ bilateral internal derangement was assessed according to the Tanaka approach.[26] Muscle palpation revealed tenderness and pain upon palpation of the jaw closure muscle bilaterally. Bruxism was not assessed.

Cervical muscle pain upon palpation, assessed according to the Travell[27] approach, was considered inclusion criteria in the sample. However, subjects were not matched for different levels and types of pain.

Lateral skull radiographs were taken using an Orthopantomograph OP100 (Instrumentarium Imaging). Exposure data were 70 kV and 20 mA per second. The distance between the head and radiological tube was 1.5 m. High-speed intensifying screens were used. The radiographs were exposed with the subjects standing in the orthoposition[28] defined as the intention position from standing to walking, looking into a mirror.[29]

In order to minimize external influences, no ear rods were used in the cephalostat, as shown in **Figure 1**.The radiologist was asked to register on lateral skul1 radiographs all the neck and the sixth cervical vertebra.

Twenty-two reference points, described in **Table 1** and depicted in **Figure 2** on a diagram of a lateral skull-neck radiograph, were marked and thirteen reference lines, described and depicted in **Table 2**, were taken. Nine craniofacial morphological variables have been studied, as described in **Table 3** and **Figure 2**. Lordosis of the cervical spine was measured on the lateral skull radiographs according to Hellsing.[15] The morphological variables,

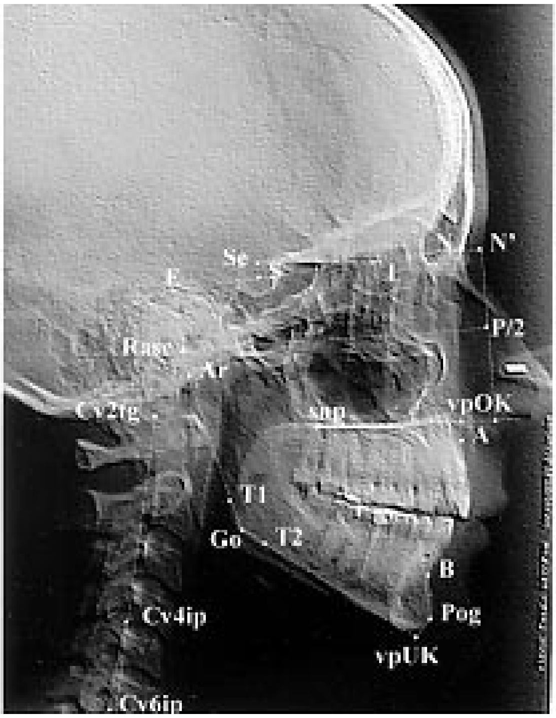

Figure 1
Radiographs of lateral skull showing location of reference points.

Table 1
Reference Points*

Se:	Middle point of sella opening
S:	Stella point
A:	A point
B:	B point
Pog:	Pogonion
Me:	Menton
N:	Nasion
Ar:	Articulare
Gn:	Gnation
cv2tg:	The tangent point of the superior, posterior extremity of the odontoid process of the second cervical vertebra
cv4ip:	The most inferior-posterior point on the body of the fourth cervical vertebra
cv6ip:	The most inferior-posterior point on the body of the sixth cervical vertebra
Go:	According to Schwarz[2], the point of intersection between RL (ramus line) and ML (mandibular line)
T1:	The posterior tangent point of mandibular line and anterior to the gonial area
T2:	The lower tangent point of ramus line and superior to the gonial area
E:	Orthogonal projection of the posterior point of the condylar head on SN plane
L:	Orthogonal projection of pogonion on the SN plane
vpUK:	Orthogonal projection of pogonion on the mandibular line
vpOK:	Orthogonal projection of A point on the spinal plane
Rasc:	The point of intersection between ramus line and H line, according to Schwarz[2]
snp:	Posterior spinal point
sna:	Anterior spinal point

*Table indicates the reference points marked on lateral skull.

shown in **Figure 2** and **Table 3**, comprised facial prognathism of maxilla (SNA angle) and mandible (SNB angle); cranial mandibular angle (GoGn/SN angle); mandibular length, according to Schwarz (Go-vpUK) and to Steiner (E-L); maxillary length, according to Schwarz (spp-vpOK); anterior cranial base length, according to Schwarz (Se-N) and mandibular ramus height (Go-Rasc), according to Schwarz.[30,31] The results of mandibular and maxillary length and ramus height were compared to those described by Schwarz as ideal values and reported in **Table 4**. Previously, Schwarz reported ideal values of maxillary length, anterior basal cranial length, and ramus height, according to a specific mandibular length, as shown in **Table 4**.[30]

To assess errors due to landmark identification, duplicate measurements were made of ten radiographs in the same way as described by Hellsing[15] and shown in **Figure 2**, **Table 2**, and **Table 3**. Cephalometric variables were compared for each registration and the error variance calculated using Dahlberg's[32] formula:

$$\delta=\sqrt{(\Sigma d^2/2\mathbf{N})}$$

where d is the difference between the first and the second measurement and **N** the number of double registration. A Sperman's rank correlation was performed to evaluate the association between clinical parameters.

Results

Intraobserver method error variance for all variables was found to be less than 5% of biological variance of the whole sample, as shown in **Table 5**. **Table 6** shows mean values and standard deviations for the variables describing cervical column (CVT/EVT) and craniofacial morphology. **Table 7** describes the results of the correlation analysis for the variables studied in the whole sample. The results showed a negative significant correlation (r=-.342; p<0.01) between cervical lordosis (CVT/EVT) and mandibular length (Go-vpUK). A highly positive correlation was found between anterior cranial base length and maxillary length (r=.243; p<0.05).

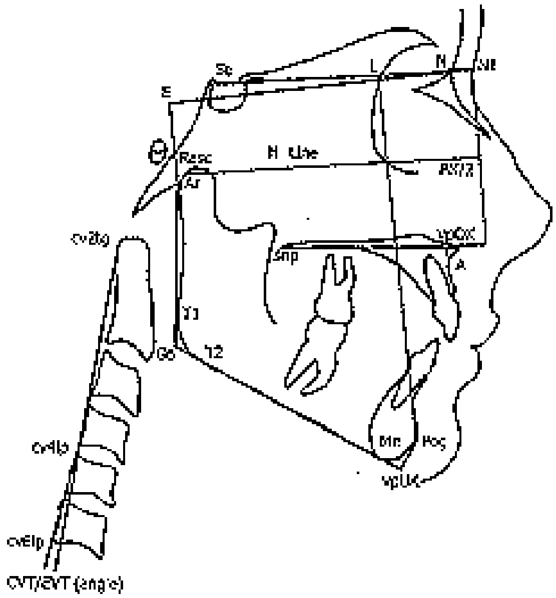

Figure 2
Indicates the morphological variables considered.

Table 3
Variables Considered*

SNA:	Angle between S point, N point, and A point
SNB:	Angle between S point, N point, and B point
CVT/EVT:	Cervical lordosis. The downward opening angle between CVT line and EVT line
GoGn-SN:	Craniomandibular angle. The angle between GoGn and SN
E-L:	Mandibular length, according to Steiner.[31] The distance between E point and L point
Go-vpUK:	Mandibular length, according to Schwarz[1]. The distance between Go and vpUK
snp-vpOK:	Maxillary length, according to Schwarz[1]. The distance between snp and vpOK
Rasc-Go:	Ramus height, according to Schwarz.[1] The distance between Rasc and Go
Se-N:	Anterior cranial base length according to Schwarz[1]. The distance between Se and N

*Table indicates variables considered.

Table 2
Reference Lines*

SN:	Nasion-sella line. The line through N and S
SeN:	Anterior cranial base line. The line through Se and N
NA:	The line through N and A
NB:	The line through N and B
PN:	Nasal perpendicular line, according to Schwarz[2] The perpendicular line to SeN through N1
PN/2:	The middle point of PN from N1 to sna-snp
sna-snp:	Spinal plane. The line between sna and snp
GoGn:	The line through Go (anatomical point) and Gn (anatomical point)
ML:	Mandibular line. The line through Me and T2
RL:	Ramus line. The line through Ar and T1
H line:	The parallel line to SeN through PN/2
CVT:	The upper part of the cervical spine. The line through cv2tg and cv4ip
EVT:	The lower part of the cervical spine. The line through cv4ip and cv6ip

*Table indicates the reference lines marked on lateral skull.

Discussion

Radiographic Technique

In this study, the radiographs were exposed with the subjects standing in orthoposition while looking into a mirror.[28,29] In order to minimize external influences, no ear rods were used in cephalostat. Previously, Hellsing analyzed the error inherent in the radiographic technique with or without ear rods in 14 adults.[15] Two series of duplicate radiographs were taken of each subject in natural head position over an eight months period. The first series of exposures was made without ear rods and the second series was taken with the head stabilized using ear rods. Hellsing concluded that omission of ear rods would not have any detrimental effect on the results. The morphological variables of head (in this study, SNA, SNB, GoGn/SN, ES, SL, Se-N, Go-Rasc, Go-vpUK, spp-vpOK) and a greater error variance for the cervical variables (in this study, CVT/EVT) were found in the group using ear rods when compared to the group not using ear rods.

Based on Hellsing's conclusions[15] and also Solow,[29] Bjerin,[33] Moorrees and Kean,[34] Carlsoo and Leijon,[35] no ear rods were used in the cephalostat in this study.

The Population

The aim of the present investigation was to examine the relationship between the variables of cervical lordosis

Table 4
Schwarz[1] Values*

Go-vpUK	spp-vpOK	Go-Rasc
56	37	40
57	38	40.5
58	39	41
59	39	42
60	40	43
61	40.5	43.5
62	41	44
63	42	45
64	42.5	45.5
65	43	46
66	44	47
67	44.5	47.5
68	45	48
69	46	44.9
70	46.5	50
71	47	50.5
72	48	51
73	48.6	52
74	49	53
75	50	53.5
76	50.5	54
77	51	55
78	52	55.5
79	52.5	56
80	53	57
81	54	58
82	54.5	58.5
83	55	59
84	56	60
85	57	60.5

*Table designates Schwarz's ideal values of maxillary length and ramus height according to a measurement of mandibular length.

and craniofacial morphology (mandibular length, maxillary length, anterior cranial base length, mandibular inclination, etc.) without considering the systematic effects of race, gender, and age.

Variations in the cervical column based on ethnicity have been reported previously. Solow[24] compared head posture, craniofacial morphology, and selected dimensions of the cervical column in young adult Danish and Australian Aboriginal males. It was found that the upper cervical column was inclined more anteriorly in the Aborigines. Grave[25] compared cervical vertebral dimensions in young adult Australian Aborigines with those of a similarly-aged group of Caucasian dental students. Ethnic differences in cervicovertebral morphology were evident, particularly in the upper segments of the column. Those studies considered anatomical size of cervical vertebrae and not the angle of cervical lordosis, as in this study, but in order to eliminate the possible effect of ethnic origin and all systematic influence, we comprised our sample of only Caucasian patients.

Table 5
Intraobserver Method Error

Variable	Error
SNA	2.6
SNB	1.7
CVT/EVT	0.3
GoGn-SN	1.6
E-L	1.0
SeN	0.9
spp-vpOK	4.5
Go-vpUK	2.5

Gender dimorphism in dimensions of the cervical column was found in both Caucasian and Australian groups in Grave's[25] study.

Grave[25] revealed that the majority of vertebral dimensions were larger in males than in females and that gender dimorphism was considerably more marked in Caucasians (values ranging up to 20%) as compared to Aborigines (value was about 10%). The difference was explained by a relatively lower homogeneity of the Caucasian group, which represented a wide range of ethnic diversity, including backgrounds from Anglo-Saxon and several other European populations. In order to eliminate the systematic effect of gender, our sample was comprised of only women.

Table 6
Results

Variables	N	X	Var.	SD	Median
SNA	70	80.7	5.4	3.9	81.0
SNB	70	76.3	7.0	3.5	76.0
CVT/EVT	70	9.4	19.2	5.9	8.0
Go-Gn/SN	70	33.2	20.0	5.4	34.0
E-L	70	67.3	57.9	8.3	67.0
Se-N	70	69.7	17.2	3.5	69.5
Go-vpUK	70	77.8	15.5	6.6	79.0
Snp-vpOK	70	49.3	11.7	6.6	4.0

Table 7
Results of Correlations Between
the Morphological Variables Considered (N=70)

Association between variables tested		Correlation coefficient	Significance
Go-vpUK (mm)	CVT/EVT (degree)	-.342	P=.004*
Go-vpUK (mm)	E-L (mm)	.423	P=.000*
E-L (mm)	CVT/EVT (degree)	-.013	P=.916 NS
Snp-vpOK (mm)	SeN (mm)	.243	P=.035**

Sample coefficients: Spearman rank correlation
NS: No statistical significance
*p<0.01
**p<0.05

Other studies examined the linear relationship between selected cervicovertebral and craniofacial dimensions in different aged-groups.

Hellsing[15] found that cervical lordosis decreased with increasing age. Based on these conclusions, our study was comprised of only of women 25-35 years of age.

The population was comprised of women in skeletal class II, with normal inclination of the mandible, because Hellsing[15] showed a correlation between decreased lordosis and increased inclination of the mandible (SN/GoGn). In order to eliminate the effect of mandibular inclination in the cervical lordosis angle, only normal angle tracings were chosen.

Finally, the sample was comprised of women who had not received orthodontic treatment or undergone orthognathic surgery. Previous studies suggested important influences on the cervical spine angulation in children using removable orthodontic appliances to increase vertical occlusal dimension.[36] In order to eliminate the existence of this type of influence on the results of this study, women who had never been treated with orthodontic appliances were chosen.

Results

The results showed a significant negative correlation between mandibular length (with normal mandibular inclination) and cervical lordosis angle, measured from second to sixth vertebra (CVT/EVT), as shown in **Figure 3** ($p<0.01$). This means that straighter cervical lordosis correlates with a long mandible. However, one must remember that correlation is calculated on the basis of topographically related variables. One of the possible hypotheses could be the influence of mandibular inclination on head posture. For example, Hellsing[15] showed a correlation between decreased lordosis and increased inclination of the mandible (SN/GoGn). However, the sample in this study was comprised only of patients with a normal value of mandibular inclination. So we cannot correlate mandibular inclination with the cervical lordosis angle.

A further hypothesis could take into consideration the position of a long mandible in skeletal class II, where the class II occlusion seems to close the mandible in a posterior position, possibly creating compression of the retromandibular area. It is noted that skeletal class II is correlated to a short or retrognathic mandible. However, in the case where the mandible is retrognathic, its body at the same time could be longer than the ideal values listed

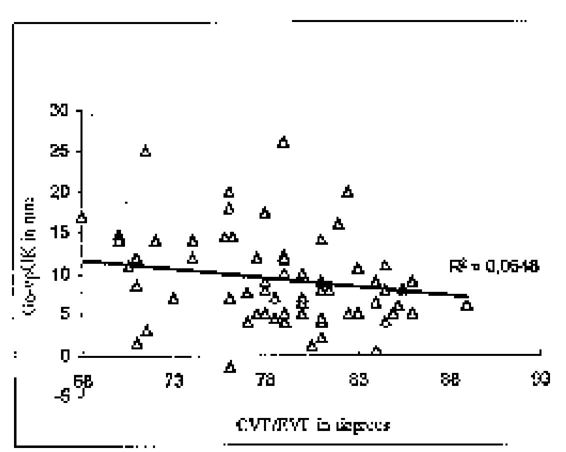

Figure 3
Shows the correlation between the cervical lordosis angle (CVT/EVT) and mandibular length, according to Schwarz.[1] $P<0.01$

by Schwarz (**Table 4**) but closed to a posterior position (retropositioned) due, i.e., to the presence of a deep bite. In the case where the mandible is short, skeletal class II is due to mandibular shortness, but in the case of a mandibular retrognathic position, its length could be short as well as long, although the skeletal class is always II.

We plan further future studies of samples that will include skeletal class I and III. In all the tracings, mandibular length resulted in longer than proportional value to maxillary length, according to Schwarz's ideal proportion table (**Table 4**).[30] A very long jaw could be the cause of a decreasing lordosis angle. Previous studies about peak isometric strength of cervical muscles showed that cervical isometric strength is affected by bite position and vertical dimension of occlusion suggesting a craniomandibular-cervical masticatory system.[37] Based on these conclusions, cervical muscular activity and occlusion could influence cervical lordosis angle. However, cervical region was shown to influence mandibular growth, perhaps through the soft-tissue stretching hypothesized by Solow and Kreiborg[20] and Rocabado[38,39] They considered cervical column curvature alterations to be the cause of the aggravating factors in some craniomandibular dysfunctions.[40] For example, a correlation was shown between forward head posture (FHP) and craniomandibular dysfunction (CMD): an increase of the distance between the first thoracic vertebra and middle cervical zone (normal value: 6-8 cm) was associated with a posterior rotation of the cranium, and consequently, a compression of the suboccipital zone aggravated some types of vascular headache through vascular compression.[40]

Other studies showed that head posture could influence vertical dimension in the rest position,[41,42] initial occlusal contact (influenced by forward head posture),[43] and muscle contact position, predominantly after the age of 30 (the sliding cranium theory).[44,45] It was also shown that head posture could play a role in snoring and obstructive sleep apnea.[46] Conclusions about the mechanism of influence and about *what influences what* at this time are not possible. Cross sectional studies are unable to clarify this point, because the situational data is not known before the time of the study. Longitudinal controlled studies are required.

Another hypothesis refers to neurological contact between the jaw and cervical area.[47] In small laboratory marsupials, the upper cervical spine was examined by serial section; large numbers of free nerve endings supplied by A-delta and C-fibers were found in longitudinal ligaments and facet joint capsules. Using an electronic microscope, the authors observed areas of direct contact between axon and collagen fibers which suggests mechanoreceptive or polymodal nociceptive functions. Lamellated corpuscles were seen in the lower intervertebral disks. These are known to rapidly adapt mechanoreceptors supplementing information supplied by the muscle spindles to the CNS regarding movements of the cervical spine.[47]

Based upon this conclusion, occlusal position could influence through CNS, the position and the movement of the cervical spine, and a retrusion of the mandible, and as in this study, could determine a straighter cervical spine.

Other results showed no correlation between the cervical lordosis angle and mandibular length.[31] However, a significant positive correlation resulted between Schwarz[30] and Steiner[31] values of mandibular length ($r=.423$; $p<0.05$), as shown in **Figure 4**. This result could be explained by the change of millimeter distance between two points when they are projected on an inclined line (SN) (for the construction of the tracing, consult **Table 1**, **Table 2**, **Table 3** and **Figure 2**). Remember that E Point is the projection of the posterior point of the condylar head on SN and L Point is the projection of pogonion on SN. The variation of SN/GoGn angle could change the distance between the two projections. So EL distance does not describe very well the mandibular length because of the possible influence of mandibular inclination on this value. This is why we used the Schwarz[30] measurements to describe morphological correlation between mandibular and cervical dimensions.

Finally, **Figure 5** shows the correlation between anterior cranial base length (SeN) and maxillary length (snp-vpOK). This could be explained by Enlow's theory and by a phylogenetic *package* according to which the orientation of the brain seems to influence the spatial relation of the face.[48] This result confirms the concept that anterior cranial base length seems to be influenced by mandibular and maxillary length.[49]

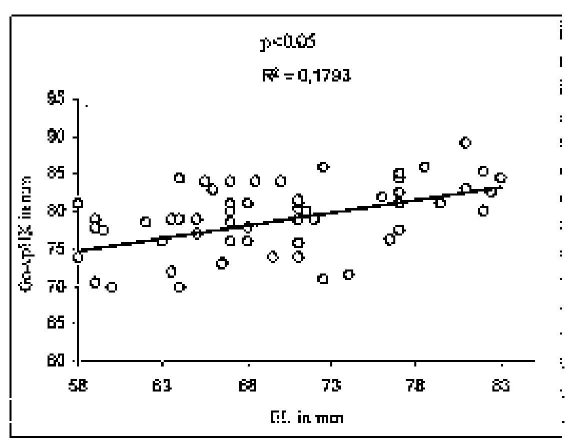

Figure 4
Shows the correlation between Schwarz's[1] analysis results (Go-vpUK) and Steiner's[31] analysis results (EL) of mandibular length, P<0.05.

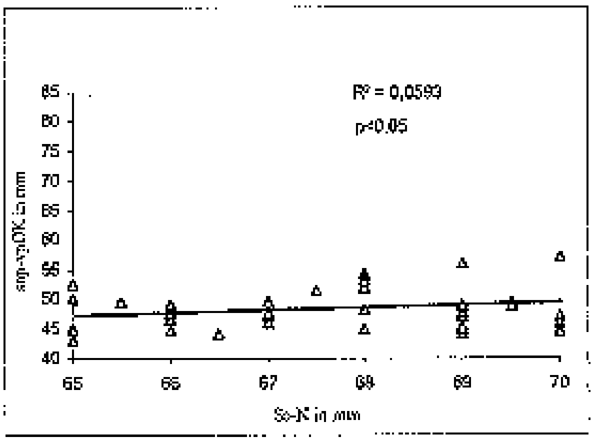

Figure 5
Shows the correlation between the anterior cranial base length (SeN) and maxillary length (snp-vpOK), according to Schwarz.[1] P<0.05

An interesting point arising from this study is the question of whether the mandibular length responds to cervical postural differences or whether morphogenetics determine what influences jaw length, head posture, and consequently, craniofacial morphology. Several studies provided a hypothetical model based on the growing mechanism relationship among craniocervical angulation and mandibular growth.[13,14,16,19,21] However, in interpreting this correlation one must proceed with considerable caution. In cross-sectional studies, we can only indirectly understand the growth mechanism.

The current study is limited to a description of relations between cervical lordosis and morphological variables in Caucasian adult women with skeletal class II. Because of the cross-sectional structure of the study, no conclusions were possible concerning the growth mechanism. There are possible conclusions concerning the absolute importance of studying the variation of cervical lordosis angle in a homogeneous population based upon gender, race, age, morphological craniofacial pattern, and clinical history, because there are numerous factors which can influence cervical lordosis angle.

Future cross-sectional studies of a different population (samples that include men, skeletal class III, etc.), and future longitudinal studies are required to analyze the detailed nature of the mechanism at work. The studies should be directed to investigate the extent of environmental and genotype influences on cervical vertebral growth. A clearer appreciation of these determinants will clarify the complex interrelationship between form and function in craniofacial and cervical vertebrae morphogenesis.

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Dr. Simona Tecco *received her D.D.S. degree in 1999 from the Faculty of Dentistry, University of Chieti, Italy. Since 1999, she has been an assistant at the Department of Ortoghatodontics at the same university. Currently, she is has a fellowship position at the Faculty of Dentistry, University of Chieti.*

Dr. Marco Dolci *received his M.D. degree in 1989 at the University of Rome and his maxillofacial specialization in 1994 at the University of Verona. Since 1996, he has been a researcher at the same university. He is an associate professor at the University of Chieti and a member of the Italian Association of Maxillofacial Sugery. Dr. Dolci has written many clinical and research articles.*

Dr. Fabio Ciuffolo *received his D.D.S. degree in 2001 from the Faculty of Dentistry, University of Chieti, Italy. Since 1999, he has been a staff member in the Department of Orthodontics and Gnathology, School of Dentistry.*

Dr. Silvio Di Meo *received his D.D.S. degree in 2001 from the Faculty of Dentistry, University of Chieti, Italy. Since 1999, he has been a staff member in the Department of Orthodontics and Gnathology, School of Dentistry, University of Chieti.*

Dr. Maria R. Filippi *received her D.D.S. degree in 1992 from the Faculty of Dentistry, University of L' Aquila, Italy. She is currently a staff member in the Department of Orthodontics and Gnathology, School of Dentistry, University of Chieti.*

Dr. Anna L. Ferritto *received her D.D.S. degree in 1998 from the Faculty of Dentistry, University of L'Aquila, Italy. She is currently a staff member in the Department of Orthodontics and Gnathology, School of Dentistry, University of Chieti.*

Dr. Michele D'Attillio *received his D.D.S. degree in 1987 from the Faculty of Dentistry, University of Chieti, Italy. Since 2000, he has been a researcher in the Department of Orthodontics, University of Chieti. Also since 2000 he has been the Head Chair in Orthodontics I. He is a member of the Italian Association of Maxillofacial Surgery and has written many clinical and research articles.*