Original Article

Investigation of the Changes in the Positions of Upper and Lower Incisors, Overjet, Overbite, and Irregularity Index in Subjects with Different Depths of Curve of Spee

Bülent Baydaş, DDS, PhD[a]; İbrahim Yavuz, DDS, PhD[a]; Nesrin Atasaral, DDS[b]; İsmail Ceylan, DDS, PhD[c]; İlhan Metin Dağsuyu, DDS[b]

Abstract: The aim of this study was to investigate the relationship between the depth of the curve of Spee and positions of upper and lower incisors, overjet, overbite, and anterior lower crowding. The material consisted of lateral head films and dental casts of 137 untreated adolescent subjects, 76 girls and 61 boys, aged 13 to 16 years. The subjects were divided into three groups with normal Spee, flat Spee, and deep Spee and were compared with one another. Differences between the Spee groups and between sexes were assessed by means of analysis of variance and a post hoc multiple comparison test. In addition, correlation coefficients between the depth of curve of Spee and other variables were calculated. Finally, cephalometric measurements for all subjects were subjected to a multiple regression analysis, with the depth of curve of Spee as the dependent variable. The results showed that there were no statistically significant differences in the positions of upper and lower incisors and anterior lower crowding among the Spee groups. However, overjet and overbite demonstrated significant differences among the groups. Statistically significant correlations were found between the depth of curve of Spee and overjet and overbite. Multiple linear regression analysis revealed that chronological age and all other variables used in the study could account for only 28.7% of the total variance of the curve of Spee. The overbite alone explained 17.3% of the total variance of the curvature. (*Angle Orthod* 2004;74:349–355.)

Key Words: Curve of Spee; Incisor positions; Overjet; Overbite; Anterior lower crowding

INTRODUCTION

F Graf von Spee, who used skulls with abraded teeth to define a line of occlusion, first described the curve of Spee in 1890. That line lies on a cylinder that is tangent to the anterior border of the condyle, the occlusal surface of the second molar, and the incisal edges of the mandibular incisors. Spee located the center of this cylinder in the midorbital plane so that it had a radius of 6.5 to 7.0 cm.[1] However, clinically the distal marginal ridges of the posterior teeth in the arch and the incisal edges of the central incisors determine the curve of Spee.[2]

The functional significance of the curvature has not been completely understood.[3] However, it has been suggested that the curve of Spee has a biomechanical function during food processing by increasing the crush-shear ratio between the posterior teeth and the efficiency of occlusal forces during mastication.[4,5]

Recently, the curve of Spee and/or leveling of this curve has been related to incisor overbite,[6–9] lower arch circumference,[7,10–13] lower incisor proclination,[10,13–17] and craniofacial morphology.[3,8,18,19] A deep curve of Spee is usually associated with an increased overbite. Orthodontic correction of the overbite often involves leveling the curve of Spee by anterior intrusion, posterior extrusion, or a combination of these actions. The process of proclining the lower incisor has been used in some cases to decrease the relative vertical overlap of the lower incisors by the upper incisors.[16]

Leveling of the curve of Spee represents a routine procedure in orthodontic practice. Clinicians have been concerned for some time with the degree of reduction in arch circumference that accompanies leveling of the curve of Spee because they believe that this leads to incisor protrusion.[20]

[a] Associate Professor, Department of Orthodontics, Faculty of Dentistry, Atatürk University, Erzurum, Turkey.

[b] Research Assistant, Department of Orthodontics, Faculty of Dentistry, Atatürk University, Erzurum, Turkey.

[c] Professor, Department of Orthodontics, Faculty of Dentistry, Atatürk University, Erzurum, Turkey.

Corresponding author: İsmail Ceylan, DDS, PhD, Atatürk Üniversitesi, Diş Hekimliği Fakültesi, Ortodonti Anabilim Dalı, 25240 Erzurum, Turkey
(e-mail: iceylan@atauni.edu.tr).

Accepted: April 2003. Submitted: March 2003.

On the other hand, Andrews[21] stated that there is a natural tendency for the curve of Spee to deepen with time because the lower jaw's growth downward and forward sometimes is faster and continues longer than that of the upper jaw. This causes the lower anterior teeth, which are confined by the upper anterior teeth and lips, to be forced back and up, resulting in crowded lower anterior teeth and/or a deeper overbite and deeper curve of Spee.

These findings suggested that the curve of Spee might be related to the position and inclination of the upper and lower incisors, lower arch crowding, overjet and overbite. Thus, the determination of this relationship may be useful to assess the feasibility of leveling the curve of Spee by orthodontic treatment. Therefore, this study aimed to:

- Examine differences in the position and inclination of the upper and lower incisors, overjet, overbite, and lower arch crowding in subjects with different depths of curve of Spee.
- Determine the relationships between the depth of curve of Spee and these variables.

MATERIALS AND METHODS

The material comprised pretreatment lateral cephalometric head films and dental casts from a sample of 137 adolescent subjects, 61 boys and 76 girls, aged 13 to 16 years. All the subjects were healthy with complete dentition, with no history of orthodontic treatment, with no severe craniofacial disorders, such as cleft palate, with no absent maxillary and mandibular permanent teeth, except for the third molars. The sample investigated consisted of a group with skeletal and dental Class I and slight Class II or Class III malocclusions (ANB angle between 1 and 5 degrees). Severe Class II and Class III malocclusions were not included.

The subjects were divided into three groups according to the depth of curve of Spee. The three Spee groups were classified as follows:

- Normal Spee group: the depth of curve of Spee was >2 mm but ≤ 4 mm;
- Flat Spee group: the depth of curve of Spee was ≤ 2 mm;
- Deep Spee group: the depth of the curve of Spee was >4 mm.

In this classification, the results of a preliminary study regarding the amount of curve of Spee in subjects with normal occlusion and acceptable facial profile were used.

The normal Spee group consisted of 20 boys and 33 girls, the flat Spee group 20 boys and 23 girls, and the deep Spee group 21 boys and 23 girls. The depth of curve of Spee was measured as the perpendicular distance between the deepest cusp tip and a flat plane that was laid on top of the mandibular dental cast, touching the incisal edges of the central incisors and the distal cusp tips of the most posterior teeth in the lower arch[16] (Figure 1). The measurement was made on the right and left side of the dental arch, and the mean value of these two measurements was used as the depth of curve of Spee.

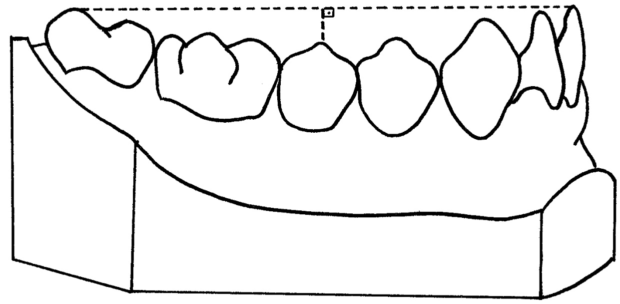


FIGURE 1. The measurement of the depth of curve of Spee.

The cephalometric radiographs were exposed using standard methods. A single investigator performed the cephalometric tracings on tracing paper. The cephalometric and dental cast measurements used in the study are described in Figures 2 and 3, respectively. Nine angular and six linear measurements were performed on lateral cephalometric head films. The measurements of the depth of curve of Spee, overjet, overbite, and anterior lower crowding were made on dental casts.

Error study

To evaluate tracing and measurement error, the records of 20 patients (20 dental casts and 20 lateral cephalograms) were selected at random and the experimental procedure was repeated. Testing for systematic errors was performed by using a paired *t*-test, whereas testing for method errors was done by using Dahlberg's formula[22] (method error $= \sqrt{\Sigma d^2/2n}$, where d is the difference between two measurements of a pair and n is the number of subjects). The *t*-test at the .05 level was not significant. The method errors did not exceed 0.7 degrees (range 0.3° to 0.7°) for angular measurements or 0.5 mm (range 0.1 to 0.5 mm) for linear measurements.

Statistical analysis

Data were analyzed, using Statistical Package program SPSS Version 10.0 (SPSS Inc., Chicago, Ill). Descriptive statistics, including the mean and standard deviation (SD) values, were calculated for all variables in each Spee group.

Analysis of variance was used to determine if significant differences were present in the measurements used in the study between the groups with different depths of curve of Spee and between sexes. If significant differences were present, the least significant difference (LSD) post hoc multiple comparison test was used to determine which of the means were significantly different from one another.

In addition, Pearson's correlation analysis was used to determine correlation coefficients between the depth of the curve of Spee and other variables used in the study. Fur-

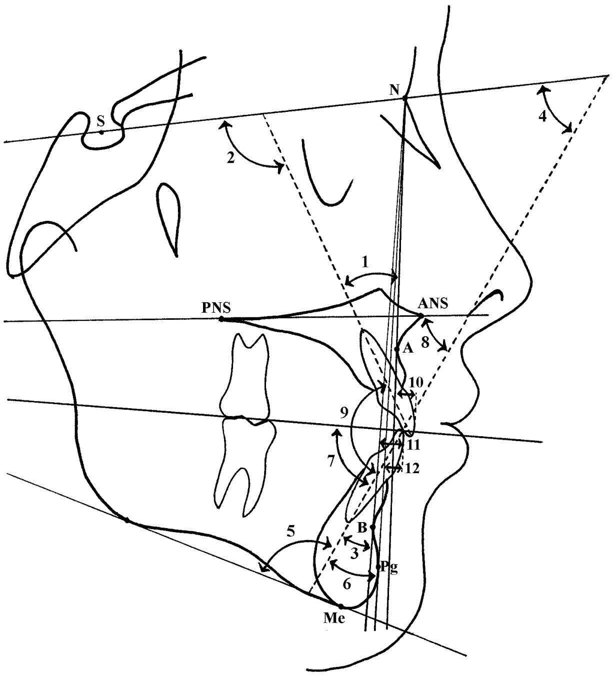
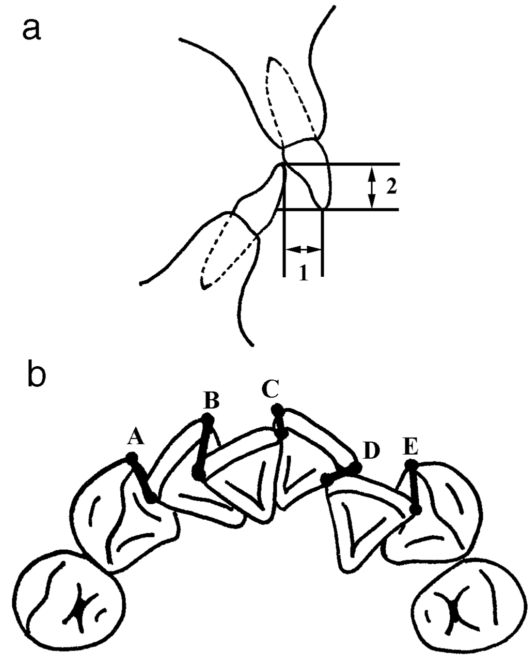


FIGURE 2. The cephalometric landmarks and measurements used in the study are as follows. (1) Upper incisor–NA (°): the angle between the long axis of the maxillary central incisor and N-A line. (2) Upper incisor–SN (°): the angle between the long axis of the maxillary central incisor and S-N line. (3) Lower incisor–NB (°): the angle between the long axis of the mandibular central incisor and N-B line. (4) Lower incisor–SN (°): the angle between the long axis of the mandibular central incisor and S-N line. (5) Lower incisor–MP (°): the angle between the long axis of the mandibular central incisor and mandibular plane. (6) Lower incisor–NPg (°): the angle between the long axis of the mandibular central incisor and N-Pg line. (7) Lower incisor–OP (°): the angle between the long axis of the mandibular central incisor and occlusal plane. (8) Lower incisor–PP (°): the angle between the long axis of the mandibular central incisor and palatal plane. (9) Interincisal angle (°): the angle between the long axes of the maxillary and mandibular central incisors. (10) Upper incisor–NA (mm): the horizontal distance between the buccal surface of the maxillary central incisor and N-A line. (11) Lower incisor–NB (mm): the horizontal distance between the buccal surface of the mandibular central incisor and N-B line. (12) Lower incisor–NPg (mm): the horizontal distance between the buccal surface of the mandibular central incisor and N-Pg line.



A+B+C+D+E = ANTERIOR LOWER CROWDING

FIGURE 3. (a) The measurements of the overjet and overbite. (1) Overjet (mm): the horizontal distance between the buccal surface of the mandibular central incisor and the incisal tips of the maxillary central incisor. (2) Overbite (mm): the vertical distance between the incisal tips of the maxillary and mandibular central incisor. (b) The measurement of the anterior lower crowding. The linear displacement of the anatomic contact points of each mandibular incisor from the adjacent tooth anatomic contact point, the sum of these five displacements representing the anterior lower crowding.

thermore, a multiple linear regression analysis with stepwise elimination and enter methods was performed to determine the relationship between the curve of Spee as the dependent variable and chronological age and other variables used in the study as the independent variables. *P* values of .05 or less were considered statistically significant.

RESULTS

The means and SDs of the chronological ages and the depth of curve of Spee for each group and the *F* values are presented in Table 1. No statistically significant differences between the chronological age among the Spee groups were found, whereas there were statistically significant differences in Spee measurements among the groups ($P < .001$).

Descriptive statistics, including the mean and SD values, were determined for each Spee group and are shown in Table 2. The mean and SD values of the upper incisor–NA

TABLE 1. Sample Description and *F* Values Found By Analysis of Variance

	Normal Spee, Group I	Flat Spee, Group II	Deep Spee, Group III	*F*
Number of subjects	53	43	41	
Sex				
Male	20	20	21	
Female	33	23	20	
Age, y				
Mean	14.6	15.3	14.2	2.4[a]
SD	3	2.3	2.1	
The depth of curve of Spee, mm				
Mean	3.1	1.5	4.4	330.0*
SD	0.5	0.5	0.5	

[a] NS indicates not significant.

* $P < .001$.

TABLE 2. The Mean and Standard Deviation Values for Each Spee Groups and Sex[a]

Measurements		Normal Spee, Group I		Flat Spee, Group II		Deep Spee, Group III	
		Mean	SD	Mean	SD	Mean	SD
Angular cephalometric							
Upper incisor–NA		23.7	7.5	23.9	6.6	21	7.2
Upper incisor–SN		101.6	8.2	101.4	7.5	99.3	7.1
Lower incisor–NB		23.5	5.3	25	4.2	22.9	5.3
Lower incisor–SN		51.3	6.7	50.6	6.5	52.5	6.9
Lower incisor–MP		93	5.9	92.3	5	94.2	6.6
Lower incisor–NPg		25	5.4	26.1	4.3	24.6	4.9
Lower incisor–OP		66.6	5.5	67.8	5.2	67.7	6
Lower incisor–PP		59.3	7.7	60	6.1	61.1	6.8
Interincisal angle		128.9	9.9	129.7	9.4	132.8	9.4
Linear cephalometric							
Upper incisor–NA	F	6.4	2.8	6.5	2	5.7	2.3
	M	6.5	2	7.7	2.9	7.4	3
Lower incisor–NB		5.8	2.7	6	2.4	5.1	2
Lower incisor–NPg		4.2	3.6	4.5	3	3.2	3.2
Linear dental cast							
Overjet		4.2	3	3	2.2	4.3	2.4
Overbite		2.2	2.7	1.3	2.2	3.3	2.3
Anterior lower crowding		4.3	3.4	5.2	4.1	4.8	3.7

[a] F indicates female; M, male.

TABLE 3. The Results of Analysis of Variance

Measurements	*F* Spee Groups	Sex	Spee × Sex
Angular cephalometric			
Upper incisor–NA	2.2	0.5	1.1
Upper incisor–SN	1.4	1.3	1.5
Lower incisor–NB	1.9	0.5	1.4
Lower incisor–SN	0.8	0	0.4
Lower incisor–MP	1.1	0.3	0.3
Lower incisor–NPg	1	0.4	1.3
Lower incisor–OP	0.9	1.2	0.4
Lower incisor–PP	0.9	2	0.3
Interincisal angle	2.3	0.3	1.2
Linear cephalometric			
Upper incisor–NA	0.9	5.3*	1.1
Lower incisor–NB	1.6	0.1	0.2
Lower incisor–NPg	1.9	0.2	0.3
Linear dental cast			
Overjet	2.9*	0.9	0.7
Overbite	6.7**	0.8	5.4**
Anterior lower crowding	0.9	0	0.5

* $P < .05$; ** $P < .01$.

(mm) measurement were calculated separately for each sex because this measurement demonstrated significant sex differences.

The results of the analysis of variance are shown in Table 3. These results indicated that the overjet and overbite measurements were significantly different among the Spee groups. Upper incisor–NA distances demonstrated a significant sex difference. In addition, overbite showed significant interaction effects between sex and Spee groups.

The results of the LSD post hoc test are shown in Table 4. According to these results, overjet showed significant differences between the normal and flat Spee groups and between the flat and deep Spee groups. However, overbite demonstrated significant differences between the normal and deep Spee groups and between the flat and deep Spee groups.

Pearson's correlation coefficients were calculated between the depth of curve of Spee and other variables (Table 5). The largest correlation coefficient was present between the depth of curve of Spee and overbite (mm, + .42). In addition, statistically significant correlations were found between the depth of curve of Spee and overjet (mm, + .30), lower incisor–NPg (mm, − .23), lower incisor–NB (mm, − .20), and lower incisor–NB (angle, −0.17) measurements.

The results of the multiple linear regression analysis are presented in Table 6. After the stepwise elimination, the overbite (mm) alone explained 17.3% of the total variance of the depth of curve of Spee. Age and all other variables showed no significant correlation with the amount of the curvature in the stepwise model. Therefore, these variables were excluded from the regression model. In the enter method, age and all other variables used in the study were included into the regression model. All of them explained only 28.7% of the total variance of the curve of Spee. Among the parameters tested in the enter method, only overbite (mm), lower incisor–NB (°), lower incisor–NPg

TABLE 4. The Results of the Least Significant Difference Test[a]

	Group Means			Mean Differences		
	Normal Spee, Group I	Flat Spee, Group II	Deep Spee, Group III	I-II	I-III	II-III
Measurements						
Overjet	4.2	3	4.3	1.1*	NS	1.2*
Overbite	2.2	1.3	3.3	NS	1.2*	1.9***

[a] NS indicates not significant.
* $P < .05$; *** $P < .001$.

TABLE 5. Correlation Coefficients Between the Depth of Curve of Spee and Other Variables

Measurements	R
Angular cephalometric	
Upper incisor–NA	−0.12
Upper incisor–SN	−0.09
Lower incisor–NB	−0.17*
Lower incisor–SN	0.12
Lower incisor–MP	0.15
Lower incisor–NPg	−0.12
Lower incisor–OP	−0.04
Lower incisor–PP	0.06
Interincisal angle	−0.12
Linear cephalometric	
Upper incisor–NA	−0.09
Lower incisor–NB	−0.20*
Lower incisor–NPg	−0.23**
Linear dental cast	
Overjet	0.30***
Overbite	0.42***
Anterior lower crowding	−0.06

* $P < .05$; ** $P < .01$; *** $P < .001$.

(°), and lower incisor–NB (mm) correlated significantly with the depth of curve of Spee. These four variables explained only 22.6% of the total variance of the depth of curve of Spee. The depth of curve Spee was not significantly influenced by the age of the subjects investigated.

DISCUSSION

Although leveling the curve of Spee is an everyday occurrence in orthodontic practices, little research has been dedicated to the examination of the relationship between the depth of the curve of Spee and dentofacial structures. In the present study, therefore, the relationships between the depth of the curve of Spee and the positions of upper and lower incisors, overjet, overbite, and anterior lower crowding were investigated.

The data obtained in this study indicated that there were no significant differences in the positions and inclinations of the lower and upper incisors and anterior lower crowding among the subjects with different depths of curve of Spee. However, statistically significant differences in the overbite and overjet were found between different Spee groups. The statistically significant correlation coefficients between the depth of curve of Spee and overbite (+ .42) and overjet (+ .30) confirmed this result. The overjet and overbite measurements in the deep Spee group were significantly larger than in the normal and flat Spee groups. The most pronounced differences for overjet and overbite were found between the flat and deep Spee groups.

The results of multiple regression analysis suggested that overbite explained the variation of the depth of curve of Spee to the largest extent. The amount of overbite alone explained 17.3% of the total variance of the curve of Spee in the stepwise regression model. The position of the lower incisor (ie, lower incisor–NB and lower incisor–NPg angles and lower incisor–NB distance) also influenced the curve of Spee. However, the variance explained by these measurements was very limited, amounting for only about 5% of the total variance. In the enter regression model, overbite and these three measurements explained only 22.6% of the total variance of the curvature.

TABLE 6. The Results of Multiple Regression Analysis[a]

Dependent Variable: Sp	Statistically Significant Independent Variables	B	SE	β	t	P Value	R^2 Change
Method 1 stepwise	Overbite, mm	0.212	0.04	0.416	5.321	.001	0.173
Method 2 enter	Overbite, mm	0.18	0.059	0.354	3.077	.003	
	Lower incisor–NB, °	−0.226	0.084	−0.884	−2.699	.008	
	Lower incisor–NPg, °	0.228	0.103	0.874	2.215	.029	0.226[b]
	Lower incisor–NB, mm	−0.313	0.158	−0.599	−1.983	.05	

[a] Sp indicates depth of the curve of Spee, mm; B, unstandardized regression coefficient; SE, standard error of B; and β, standardized regression coefficient.
[b] Total R^2 change for all these four variables.

Balridge[10] reported that decreasing the depth of curve of Spee leads to an increase in arch circumference and that often the lower incisors will be proclined in direct response to this increase. Braun and Hnat[23] found an association between lower incisor proclination and reduction in lower intercanine width. However, other clinicians have attributed this incisor proclination to the treatment mechanics used for orthodontic treatment.

Woods[15] showed that incisor flaring might be primarily related to the mechanics of leveling the curve of Spee and not necessarily because of the differential in arch circumference. Braun et al[7] confirmed this in a study with computer-supported technology. AlQabandi et al[16] reported that there is no significant correlation between reduction in the depth of curve of Spee and proclination of the lower incisor. However, they found lower incisor proclination significantly correlated with reduction in intercanine width and reduction of crowding. In the present study, the positions and inclinations of the upper and lower incisors and anterior lower crowding showed no statistically significant differences between Spee groups, whereas significant differences in the measurements of overjet and overbite were found between the groups. In addition, significant correlation coefficients were found between the depth of curve of Spee and overjet and overbite. Furthermore, some significant correlation coefficients were found between the depth of curve of Spee and position of lower incisors. However, the correlations were relatively low (Table 5).

It was interesting to observe the statistically significant changes in the overjet and overbite among the Spee groups without significant changes in the positions and axial inclinations of the upper and lower incisors. These findings support the results of Braun et al[7] and Woods,[17] who have shown that the reduction of the curve of Spee and overbite may be achieved without flaring of the incisors by using appropriate mechanics.

Trauten et al[6] and Orthlieb[8] reported that there was a negative curve of Spee in open-bite cases, whereas a deep curve of Spee in deep-bite cases was found. On the other hand, Farella et al[3] found that the curve of Spee is more marked in short-face subjects and less marked in long-face subjects. Similarly, we found that the overbite in the deep Spee group was significantly larger than in the normal and flat Spee groups.

Dusek[17] and Çelik[19] concluded that there were significant correlations between the curve of Spee and the positions and inclinations of lower incisors. Dusek[17] also found that the more protrusively the lower incisor is positioned, the less marked the depth of curve of Spee is. In our study, the positions and inclinations of lower and upper incisors showed no statistically significant differences among the Spee groups. However, there were some significant, but low, correlations between the depth of curve of Spee and the position of lower incisors.

CONCLUSIONS

Overall, the findings of the present study suggested that the positions and inclinations of the lower and upper incisors and anterior lower crowding were not affected by the variation of the depth of curve of Spee, whereas the amount of overjet and overbite was significantly influenced by the variation of the curve. The overjet and overbite in the deep Spee group were significantly larger than in the normal and flat Spee groups. The correlation coefficients obtained from the study confirmed these results. The largest correlation was found between the depth of curve of Spee and overbite. The overbite had a positive correlation with the depth of curve of Spee.

The multiple regression analysis showed that the curve of Spee was significantly influenced by the overbite. The overbite alone explained about 17% of the total variance of the curve of Spee in the stepwise regression model. The amount of the curvature was weakly influenced by the positions and inclinations of the lower and upper incisors and anterior lower crowding.

Only a minor part of the variance of the curve of Spee could be explained by the cephalometric variables describing incisor positions and chronological age. Most of the variation of the curve of Spee remains unexplained by these variables and is probably explained better by other factors.

REFERENCES

1. Spee FG. The gliding path of the mandible along the skull. *J Am Dent Assoc.* 1980;100:670–675.
2. Hitchcock HP. The curve of Spee in Stone Age man. *Am J Orthod.* 1983;84:248–253.
3. Farella M, Michelotti A, van Eijden TMGJ, Martina R. The curve of Spee and craniofacial morphology: a multiple regression analysis. *Eur J Oral Sci.* 2002;110:277–281.
4. Osborn JW. Relationship between the mandibular condyle and the occlusal plane during hominid evolution: some of its effects on jaw mechanics. *Am J Phys Anthropol.* 1987;73:193–207.
5. Baragar FA, Osborn JW. Efficiency as a predictor of human jaw design in the sagittal plane. *J Biomech.* 1987;20:447–457.
6. Trouten JC, Enlow DH, Rabine M, Phelps AE, Swedlow D. Morphologic factors in open bite and deep bite. *Angle Orthod.* 1983;53:192–211.
7. Braun S, Hnat WP, Johnson BE. The curve of Spee revisited. *Am J Orthod Dentofacial Orthop.* 1996;110:206–210.
8. Orthlieb JD. The curve of Spee: understanding the sagittal organization of mandibular teeth. *Cranio.* 1997;15:333–340.
9. De Praeter J, Dermaut L, Martens G, Jagtman AMK. Long-term stability of the leveling of the curve of Spee. *Am J Orthod Dentofacial Orthop.* 2002;121:266–272.
10. Balridge DW. Leveling the curve of Spee: its effect on the mandibular arch length. *J Pract Orthod.* 1969;3:26–41.
11. Proffit WR, Ackerman J. Diagnosis and treatment planning in orthodontics. In: Graber TM, ed. *Orthodontics: Current Principals and Techniques.* St Louis, Mo: CV Mosby; 1986:62–67.
12. Germane N, Staggers JA, Rubenstein L, Revere JT. Arch length considerations due to the curve of Spee: a mathematical model. *Am J Orthod Dentofacial Orthop.* 1992;102:251–255.
13. Chung TS, Sadowsky PL, Wallace DS, McCutcheon MJ. A three-dimensional analysis of mandibular arch changes following curve

of Spee leveling in non-extraction orthodontic treatment. *Int J Adult Orthod Orthognath Surg.* 1997;12:109–121.
14. Mitchell DL, Stewart WL. Documented leveling of the lower arch using metallic implants for reference. *Am J Orthod.* 1973;63:526–532.
15. Woods M. A reassessment of space requirements for lower arch leveling. *J Clin Orthod.* 1986;20:770–778.
16. AlQabandi AK, Sadowsky C, BeGole EA. A comparison of the effects of rectangular and round arch wires in leveling the curve of Spee. *Am J Orthod Dentofacial Orthop.* 1999;116:522–529.
17. Dusek MW. *The Curve of Spee: A Search for Causation* [master's thesis]. Memphis, Tenn: University of Tennessee; 2000.
18. Ghezzi F, Drago E, De Thomatis P, Zallio F. Profondità della curva di Spee in rapporto a FMA, FH, ANB e classe dentale. *Mondo Orthodontico.* 1991;1:73–76.
19. Çelik M. *Ortodontik tedavi ile Spee eğrisinde görülen değişiklikler ve bu değişikliklerin dentofasiyal yapılar üzerine etkilerinin incelenmesi* [master's thesis]. Ankara, Turkey: University of Ankara; 2002.
20. Proffit WR, Epker BN. Treatment planning for dentofacial deformities. In: Bell W, Proffit R, eds. *Surgical Corrections of Dentofacial Deformities.* Philadelphia, Penn: WB Saunders; 1980: 167.
21. Andrews LF. The six keys to normal occlusion. *Am J Orthod.* 1972;62:296–309.
22. Dahlberg G. *Statistical Methods for Medical and Biological Students.* New York, NY: Interscience Publications; 1940.
23. Braun S, Hnat W. Dynamic relationship of the mandibular anterior segment. *Am J Orthod Dentofacial Orthop.* 1997;111:518–524.