Class II Division 2 malocclusion: A heritable pattern of small teeth in well-developed jaws

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In 1899, Edward Hartley Angle published his classification system of human dental malocclusion, based largely on the anteroposterior relationship between maxillary and mandibular permanent first molars.[1] In the ensuing century, Angle's classification has withstood occasional criticism and alternative proposals.[2-11] Today, it remains the most popular method used worldwide to abbreviate systematically the description of a malocclusion.

Angle divided human dental malocclusion into three Classes—I, II, and III—with divisions and subdivisions, all assuming that the relative position of the first molars was the key for the simplest description of discrepancies in dental occlusion and jaw relationship. In the process of formulating this simplification, Angle's designation of the Class II Division 2 malocclusion (herein abbreviated as II/2) may have been one of his greatest contributions. He was prescient to recognize that a triad of signs—deep overbite, retroclined maxillary incisors, and a posteriorly positioned mandibular dental arch—described a unique category of malocclusion, the II/2 pattern.

For many years, European specialists have

Abstract

Angle's designation of the Class II Division 2 (II/2) malocclusion recognizes a unique combination of overbite, incisor retroclination, and sagittal discrepancy. A very severe II/2 phenotype, characterized by concealment of the mandibular incisors in occlusion, has been called *Deckbiss* in German, or cover-bite. In this report, the cover-bite malocclusion is studied to identify morphological factors associated with Angle's II/2 occlusal discrepancy. Selected X-ray cephalometric and odontometric measurements were recorded for 23 subjects (M14; F9) with II/2 cover-bite malocclusion. Data were compared with those from a control-reference sample of 537 individuals. Cephalometrically, the II/2 cover-bite sample showed a pattern of strong vertical posterior development of the mandible with forward-rotation and skeletofacial hypodivergence ($p<0.0001$). Anteroposteriorly, the maxillomandibular dentoalveolar relationship was relatively normal, and the basal bone region of the mandibular corpus appeared significantly well developed anteriorly, accounting for excessive bony chin projection ($p<0.0001$). Dentally, mesiodistal tooth diameters for the maxillary and mandibular incisors of the II/2 cover-bite sample were significantly smaller than those of the reference sample ($p<0.002$), pointing to systematically reduced tooth-size as a trait associated with II/2 malocclusion. These findings of a characteristic pattern of heritable skeletal and tooth-size features in II/2 cover-bite malocclusion indicate the presence of strong genetic influences in the formation of Angle's II/2 deep-bite discrepancy.

Key Words

Malocclusion • Angle Class II • Cover-bite • Overbite • Cephalometry • Odontometry • Genetics, clinical

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Figure 1A

Figure 1B

Figure 1C

Figure 1A-E
Intraoral photographs of an 11.3-year-old boy with Class II Division 2 (II/2) cover-bite (*Deckbiss*) malocclusion. To qualify as one of the subjects in the cover-bite study sample, at least one maxillary central incisor had to exhibit complete vertical coverage of the corresponding mandibular incisor's clinical crown in centric occlusion.

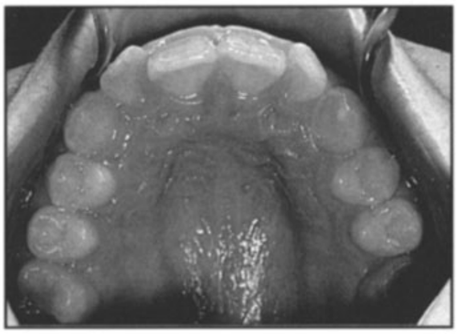

Figure 1D

Figure 1E

distinguished a pattern of malocclusion that closely corresponds to Angle's II/2 type. German-speaking dentists call it *Deckbiss*, which translates to "cover-bite." When the term was first introduced in 1912 by Bernhard Mayrhofer,[12] it was used to name a condition of total buccal crossbite, or vertical coverage of all mandibular teeth by all maxillary teeth (i.e., Brodie bite or scissor bite). In current usage, however, cover-bite and *Deckbiss* refer to complete vertical coverage of only the incisors. Thus, cover-bite may be defined as a severe expression of Angle's II/2 malocclusion characterized by concealment or complete covering of the mandibular incisor crowns due to excessive overbite and retroclination of the maxillary incisors. As an extreme II/2 phenotype, cover-bite would seem to be a potentially useful model for objective study of the anatomic and biologic bases of Angle's II/2 malocclusion.

In the early 1930s, Korkhaus[13,14] documented families with cover-bite malocclusion and concluded that there was a considerable hereditary component in the formation of this occlusal abnormality. Furthermore, Korkhaus found that almost half his cover-bite cases showed Class I, not Class II, molar relationships, often with retroclined and crowded mandibular incisors in addition to retruded and confining maxillary incisors. In the 1950s, Schwarz[15,16] confirmed Korkhaus' observations that a Class II (distoclusion) occlusal pattern was not an essential feature of the cover-bite malocclusion. Even Angle may have sensed that the pathognomonic anterior appearance of II/2 was not really limited to Class II molar malocclusions, since 70% of the II/2 cases in Angle's own survey[1] of malocclusion showed unilateral expression (subdivision), meaning that the first molars on only one side could be considered in Class II relation, while those on the other side were closer to Class I.

In some of the early cephalometric studies of the condition, Schwarz[15,16] concluded that subjects with *Deckbiss* or cover-bite malocclusion displayed only dentoalveolar discrepancies (such as deep overbite and incisor retroclination) without any distinctive skeletofacial pattern. Some of Schwarz's contemporaries questioned his views, hypothesizing that skeletal factors, such as overgrowth of the maxilla, might also contribute to the development of cover-bite malocclusion.[17-21]

More recent cephalometric studies[22-27] of Class II Division 2 malocclusion (including all II/2 phenotypes, not just cover-bite) seem to agree with Schwarz's findings of an unremarkable and highly variable skeletofacial pattern associated with the malocclusion. They generally indicate the absence of a clearly defined skeletal component in the character of the II/2 discrepancy, although at least two studies have suggested that the II/2 malocclusion is associated with a hypodivergent skeletofacial pattern.[28,29]

So questions persist: Which dental and skel-

Table 1
Distribution, frequency of molar relationships in Class II Division 2 cover-bite malocclusion according to location and sex

Class II molar relationship	Male	Female	
Bilateral	7	7	= 14 (61%)
Right side only	3	2	= 5 (22%)
Left side only	4	0	= 4 (17%)
	14 (61%)	9 (39%)	

etal factors actually make Angle's Class II Division 2 type such a distinctive and recurrent morphogenetic pattern of malocclusion? What underlying biologic characteristics may be responsible for the prevalence of II/2 malocclusion? The intent of this article is to highlight a new combination of findings that may help answer these old questions. Specifically, we searched for significant, measurable tooth-size and skeletal differences that set II/2 malocclusion apart from the normal range of occlusal patterns. This study examines Class II Division 2 occlusal discrepancy in its most severe phenotype, the cover-bite malocclusion.

Materials and methods

A sample was formed of adolescents and adults with Class II Division 2 (II/2) malocclusion of such overbite severity that they also qualified as cases of *Deckbiss* or cover-bite. (Figure 1.) The following direct-visual anatomic criteria were established to define and select the II/2 cover-bite malocclusions for this sample:

1. 100%-or-greater overbite of at least one central incisor (i.e., complete vertical coverage by a maxillary central incisor of the corresponding mandibular incisor's clinical crown, when in centric occlusion)

2. Retroclination of two or more maxillary incisors

3. Tendency to Class II molar relationship (distoclusion) on at least one side (i.e., either II/2 subdivision type or bilateral II/2 type).

The study sample collected by this visual inspection method consisted of 23 persons with II/2 cover-bite occlusal appearance. Table 1 shows that 61% of the II/2 cover-bite sample displayed bilateral Class II molar relationships and 39% exhibited unilateral Angle Class II molar relationships (i.e., II/2 subdivision type) with the contralateral side nearer to Class I. Fourteen of the subjects were male (61%), nine were female (39%) and all were white orthodontic patients living in the northeastern United States. The range of ages for the 23 II/2 cover-bite subjects was from 9 to 35 years with a mean age of 14.8 years and a median age of 12 years. Nine (M5; F4) of the 23 subjects were part of a pretreatment survey of 537 orthodontic patients (M228; F309) further described in an earlier report.[30] This survey sample (N=537) was also used as a control-reference group and as a source of data to determine the prevalences for II/2 malocclusion and the cover-bite phenotype in an orthodontic population. Additional cover-bite subjects were sought to improve the value of the study sample for statistical testing, so another 14 II/2 cover-bite cases were located by screening pretreatment intraoral photographs and plaster dental casts of later patients (outside the survey sample) within the same orthodontic practice population to ensure sampling homogeneity.

Measurements were obtained for selected skeletal and dental variables. The following 16 pretreatment measurements were recorded for the II/2 subjects (N=23) and for the control-sample participants (N=537):

A. Cephalometric measurements (all are angles, except *IFL*), traced manually from sagittal cephalograms taken at the time of orthodontic diagnosis and recorded to the nearest degree or millimeter (Figure 2):

1. Skeletal variables

a. *M-Occ*, degrees = Margolis' mandibular plane — occiput relation,[31] an angle originating at menton and whose sides are the mandibular plane extended posteriorly and a line

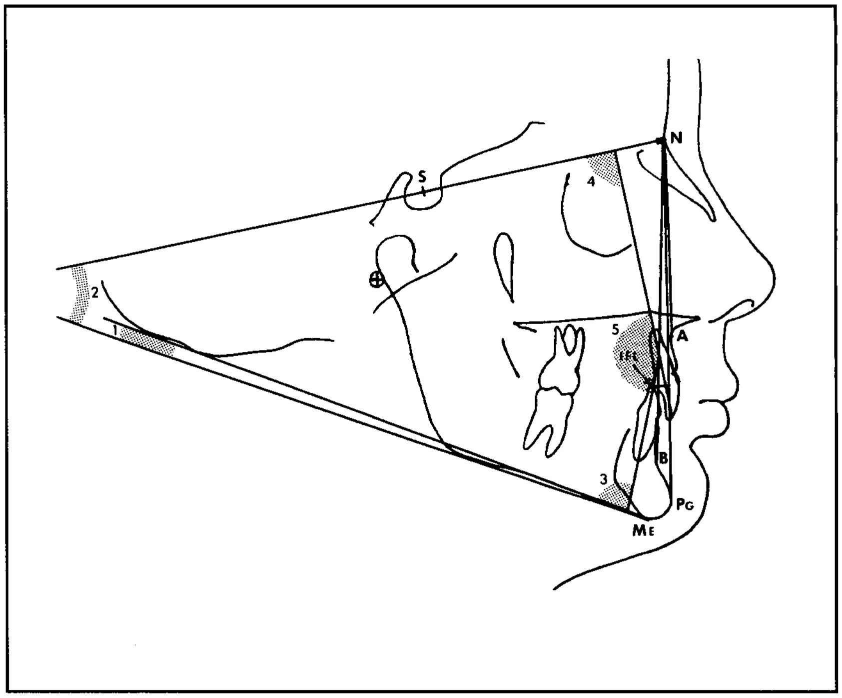

Figure 2

Figure 2
Tracing constructed from the sagittal cephalogram of boy with II/2 cover-bite shown in Figure 1, illustrating anatomical landmarks and 10 cephalometric measurements employed in this study. Numbers 1 to 5 represent the following cephalometric angles: (1) Margolis' M-Occ (signed positively here); (2) SN-MP; (3) IMPA; (4) 21[ISO/FDI tooth designation]-to-SN; (5) 21-to-31, interincisal angle. Four other angles measured, all formed at N, are SNA, SNB, SN-Pg and ANB. A linear measurement, IFL (signed negatively here), is a perpendicular to the facial line (N-Pg) constructed from the incisal edge of the most anterior mandibular central incisor.

Table 2
Error analysis with 30 double-determinations

Measurement	Unit	Mean absolute difference	Mean signed difference	SD of the signed difference	Error of the method
SN-MP	degrees	0.53	0.33	0.80	0.57
21-to-SN	degrees	0.60	-0.067	0.87	0.61
MD31	mm	0.057	0.003	0.085	0.060

drawn tangent to the inferior border of the occiput posterior to the foramen magnum. The angle is signed positively when the mandibular plane extended posteriorly falls below the base of the occiput, and negatively in the reverse circumstances.

b. *SN-MP*, degrees

c. *SNA*, degrees

d. *SNB*, degrees

e. *SNPg*, degrees

f. *ANB*, degrees

2. Dentoalveolar variables

a. *IFL*, mm = a line from the most anterior mandibular-incisor's incisal edge drawn perpendicular to the facial line (N-Pg), signed postively if the incisal edge is anterior to the facial line, and negatively if it is not.[32]

b. *IMPA*, degrees

c. *21-to-SN*, degrees

d. *21-to-31*, degrees = the interincisal angle

B. Measurements taken directly from the patient's mouth at the time of orthodontic diagnosis:

1. *OJ*, mm. = overjet, the horizontal distance between the facial surface of the maxillary left central incisor at its mesioincisal corner and the facial surface of its opposing mandibular tooth, in centric occlusion, measured directly on the subject to the nearest 0.5 mm.

2. *OB*, mm. = overbite, the vertical overlap from the mesioincisal corner of the maxillary left central incisor to its opposing mandibular tooth, in centric occlusion, measured directly on the subject to the nearest 0.5 mm.

3. Incisor mesiodistal (MD) crown diameters to the nearest 0.1mm, using an odontometric dial caliper. Measurements were recorded for the four incisors on one side only (left), by reason of strong right-left metrical concordance between homologous human teeth.[33,34]

a. *MD21* = maximum MD crown diameter, maxillary left central incisor.

b. *MD22* = maximum MD crown diameter, maxillary left lateral incisor.

c. *MD31* = maximum MD crown diameter, mandibular left central incisor

d. *MD32* = maximum MD crown diameter, mandibular left lateral incisor

The II/2 cover-bite sample was studied using the case-control method of comparative analysis. Measurement data from the II/2 cover-bite sample were compared with equivalent data from the survey sample of 537 orthodontic patients. Student's *t*-test was employed to test differences between the mean values found for the II/2 cover-bite sample of 23 subjects and for the control-reference survey of 537 orthodontic patients. Moreover, the sign test (binomial test) was used statistically to discriminate trends in II/2 MD tooth-size. The null hypothesis was that the skeletodental pattern in Angle's II/2 cover-bite subjects does not differ from that of a typical orthodontic population. Statistical significance was set at the 0.05 probability level.

Estimates of measurement error were calculated for three representative variables using a double-determination method.[35] One MD tooth diameter was remeasured and two cephalometric angles were retraced and remeasured on 30 subjects by the same observer. Calculations were performed for the mean absolute difference between determinations, the mean signed difference (determination 1 minus determination 2), the standard deviation of the signed difference, and the error of the method for each of the three variables tested. Table 2 shows the results of this error analysis, which were reasonably consistent with expectations.

Results

Table 3 displays the means and standard deviations of measurements from the study group of 23 subjects with II/2 cover-bite malocclusion compared with the values derived from a control-reference group of 537 orthodontic patients. Nine of the 16 comparisons showed differences between the means that were statistically significant. Thus, the null hypothesis was rejected for these nine variables.

In the control-reference group, 13 of 537 subjects (M7; F6) had II/2 malocclusions, equaling a prevalence rate of 2.4%. When this study's criteria for cover-bite was applied, 9 (M5; F4) of these 13 II/2 subjects qualified, yielding a prevalence rate of 1.7% (9/537) in an orthodontic population. Since 9 subjects with cover-bite were identified among the 13 II/2 malocclusions in the control-reference sample, the cover-bite phenomenon was observed to occur in 69%

Table 3
Cephalometric and odontometric analyses of Angle's Class II Division 2 malocclusion: II/2 cover-bite sample compared with control-reference sample

Variable	II/2 cover-bite sample N	II/2 cover-bite sample Mean	S.D.	*t*-test		Control-reference sample N	Control-reference sample Mean	S.D.
Cephalometrics (in degrees, except IFL)								
M-Occ	23	4.4	3.1	-5.49	$p<0.0001$	534	-0.6	4.3
SN-MP	23	28.3	4.4	5.06	$p<0.0001$	533	34.5	5.8
SNA	23	80.6	4.1	-0.06	NS	534	80.6	3.8
SNB	23	76.7	3.8	-0.58	NS	534	76.3	3.6
SN-Pg	23	78.6	4.0	-1.85	NS	531	77.2	3.6
ANB	23	3.9	1.5	0.75	NS	534	4.3	2.4
IFL (mm)	23	-1.3	2.6	6.87	$p<0.0001$	533	3.3	3.2
IMPA	23	92.1	8.8	1.12	NS	534	94.0	7.8
21-to-SN	23	92.0	6.1	7.17	$p<0.0001$	533	103.4	7.5
21-to-31	23	148.9	9.8	-8.40	$p<0.0001$	532	128.6	11.4
Odontometrics (in millimeters)								
OJ	23	3.4	1.1	3.10	$p<0.01$	537	5.1	2.6
OB	23	6.7	1.0	-6.37	$p<0.0001$	537	4.0	2.0
MD21	23	8.5	0.6	2.91	$p<0.01$	531	8.8	0.6
MD22	22	6.6	0.6	1.30	NS	521	6.8	0.7
MD31	23	5.4	0.3	1.58	NS	533	5.5	0.4
MD32	23	5.8	0.3	2.40	$p<0.05$	535	6.0	0.4

NS = not significant

of the II/2 malocclusions.

Cephalometrically, the M-Occ angle of Margolis, a measure of vertical posterior development of the mandible, and the SN-MP angle both indicated strong mandibular vertical development and hypodivergent, forward-rotating mandibular growth as characteristics of the II/2 cover-bite skeletal pattern. The mandible and maxilla each appeared to be well-developed, although some discrepancies existed in their sagittal interrelationship.

Not surprisingly, the two chief dentoalveolar features in II/2 cover-bite were: (1) statistically significant retroclination of the upper incisors relative to the SN intracranial reference line (21-to-SN angle) and (2) deep overbite (OB), both of which represent selection criteria for the study sample. Furthermore, the interincisal angle (21-to-31) demonstrated a statistically significant increase in II/2 cover-bite, reflecting an obtuseness caused by upper incisor retroversion. However, the mean axial inclination for the lower incisors (IMPA) in II/2 cover-bite statistically was not significantly different than that of the reference group.

The IFL measurement—the perpendicular distance in millimeters from the N-Pg "facial line" to the incisal edge of the most anterior lower incisor—showed a dramatic, statistically significant difference. The II/2 study sample and the reference group differed in mean IFL values by 4.6mm with the mean lower-incisor edge in the II/2 sample positioned slightly lingual to the facial line and the mean lower-incisor edge in the reference group located several millimeters anterior to the N-Pg facial line, the usual finding in cephalometric norm studies.[32,36] This finding indicates relative prominence anteriorly of the chin in II/2 cover-bite malocclusion, causing the mandibular dentition and its dentoalveolar process to appear retruded relative to the well-developed basal

Table 4
Comparisons of mesiodistal incisor diameters (left-side only) in Angle's II/2 cover-bite sample vs. control-reference sample, segregated into eight categories according to tooth type and sex, with results of sign test (Binomial test) for significant direction among the eight data comparisons

	II/2 study sample			Control-reference sample		
Variable	N	Mean	S.D.	N	Mean	S.D.
Males						
MD21	14	8.70	0.54	223	9.00	0.56
MD22	13	6.75	0.46	222	6.91	0.62
MD31	14	5.46	0.33	226	5.57	0.32
MD32	14	5.94	0.34	226	6.08	0.37
Females						
MD21	9	8.16	0.40	308	8.72	0.56
MD22	9	6.37	0.62	299	6.69	0.67
MD31	9	5.26	0.26	307	5.45	0.37
MD32	9	5.63	0.24	309	5.97	0.40

Sign test (Binomial test)= 8:0, $p<0.002$, indicating a statistically significant difference in incisor mesiodistal dimensions between the Angle II/2 cover-bite sample and the control-reference group.

segment of mandibular bone.

The mean overjet recorded for the II/2 cover-bite subjects (3.4 mm) was significantly smaller statistically compared with the mean overjet of the orthodontic control-reference group (5.1 mm).

All four incisor mesiodistal (MD) crown diameters on average measured smaller in the II/2 cover-bite sample than the control-reference sample. Two of these comparisons showed statistical significance according to tooth type (maxillary central incisor and mandibular lateral incisor). However, effects of sexual dimorphism in human tooth size (i.e., men have larger teeth than women)[37] tended to reduce the odontometric differences between the two samples, because the majority of II/2 cover-bite subjects were male (61%) and most of the control-reference group consisted of females (58%).

Therefore, as a more specific test of the statistical significance of differences between incisor MD tooth-size in II/2 cover-bite malocclusion and that of an orthodontic reference population, a statistical analysis known as the sign test (binomial test) was employed. If there were no statistically significant differences (null hypothesis) between II/2 incisor size and that of the reference group, the II/2 sample, segregated into eight categories according to sex and tooth type, would show an equal number of mean values above and below similarly segregated control-group means. Table 4 indicates that for all eight comparisons the mean values for the MD crown diameter in the II/2 sample were below the comparable means for the reference group, thus rejecting the null hypothesis and supporting a finding of statistically significant reductions in incisor tooth-size associated with II/2 cover-bite malocclusion ($p< 0.002$).

Discussion

The present study of Class II Division 2 malocclusion focused on II/2 *Deckbiss* or cover-bite, a phenotype exhibiting exaggerated, deep overbite. Our roentgenocephalometric and odontometric analyses of this extreme type of II/2 malocclusion indicated the presence of a characteristic pattern of skeletal and tooth-size features associated with II/2 cover-bite.

The finding of a low prevalence rate (2.4%) for II/2 malocclusion is consistent with data from most of the rare, previous prevalence studies of this condition. Angle's original survey[1] of malocclusion showed an exceptionally high II/2 prevalence rate of 14%, which may be an indicator of a greater concentration of severe malocclusions in the practices of very early orthodontists, compared with the present. A 1935 clinical survey concluded that only "3 to 4%" of 3670 orthodontic patients in the eastern USA presented with II/2 malocclusion.[38] Massler and Frankel[39] found II/2 discrepancies among American high school students in 2.7% of all subjects and in 3.4% of those with malocclusion. Björk[40] calculated that II/2 malocclusion comprised 4.5% of an untreated sample of Danish boys in either the mixed dentition or the permanent dentition. A survey of Finnish children recorded II/2 prevalence rates for those in the mixed dentition at 2.4% and children in the permanent dentition at 4.8%.[41]

No published prevalence data could be found for the cover-bite subgroup of Angle's II/2 malocclusion, which in our study was recorded at a prevalence rate of 1.7% in an orthodontic population. However, a recent, large-scale survey[42] of dental occlusion in the United States determined that 8% of the population exhibited deep overbites of 6 mm or greater, an intensity similar to that found in cover-bites. Only a fraction of this small group would be expected to have the additional anatomic features (e.g., retroclined maxillary incisors and Class II molar relation) necessary to qualify as II/2 cover-bite, confirming that the calculated occurrence rate of 1.7% for cover-bite or *Deckbiss* malocclusion is a reasonable value for its prevalence in the population.

The statistically significant reductions noted in the maxillary and mandibular incisors' MD crown size for the II/2 cover-bite subjects indicate a pattern of smaller-than-average teeth as a characteristic of this malocclusion. Earlier work by Beresford[43] examined each of Angle's classes in terms of maxillary central incisor MD tooth width and found statistically significant tooth-size reductions only in the Class II Division 2 category. Robertson and Hilton[44] measured the faciolingual dimension of maxillary central incisors on plaster casts of II/2 malocclusions and found these teeth to be significantly "thinner" than the same teeth from other orthodontic subjects. Given the positive interrelationships known to exist between anterior tooth size and size of the remaining teeth, reduced incisor tooth widths would be associated with generalized reductions in tooth size throughout the dentition.[45-47] Therefore, the odontometric findings in this II/2 cover-bite study point to systematic tooth-size reduction in individuals with II/2 malocclusion. Furthermore, the presence of smaller-than-average teeth supports the likelihood of dentoalveolar arch-space adequacy or slight dental spacing, not crowding, associated with the II/2 malocclusion (after anterior alignment decompensation).

In the II/2 cover-bite sample, the maxillary and mandibular dentoalveolar segments were reasonably well related to each other anteroposteriorly (as recorded in the ANB angle). Moreover, judging from the statistically significant anteroposterior discrepancy between the positions of the lower incisor and pogonion (as recorded in the IFL measurement) and the relatively normal axial inclination of the mandibular incisor (IMPA), the basal bone region of the mandibular body appeared significantly well developed, thus contributing to the appearance of excessive anterior development of the chin. These conclusions are consistent with the findings of Demisch, Ingervall and Ther,[48] discrediting the long-held belief that a posteriorly displaced mandible is one of the underlying features of II/2 malocclusion.

Chin prominence is primarily a rotational byproduct of the generous amount of vertical and forward growth of the mandibular base found in II/2 cover-bite subjects. Variations in mandibular jaw growth rotation were identified and explained in a series of classic studies, principally by Björk and Skieller,[49,50] Schudy,[51,52] and Isaacson et al.[53] Björk and Skieller[50] hypothesized that the rotational growth of the mandible resulted from the condylar growth pattern and that this would be under genetic controls in most individuals. In Angle's II/2 malocclusion, forwardly rotating mandibular development appears largely responsible for many of the discrepancy's distinctive traits, such as strong chin, hypodivergent angular relationship of the mandible with the cranial base and deep, restrictive overbite.

The present II/2 cover-bite sample of orthodontic patients consisted predominantly of males (M14:F9), contradicting the usual ratio of girls exceeding boys, 3 to 2, in orthodontic populations.[30,54] Isaacson et al.[53] and Maj and Lucchese[55] also showed male dominance in samples of deep-overbite cases with patterns of strong vertical facial growth. Elevated male expression of II/2 cover-bite may be indicative of a sex-linked genetic pattern of strong mandibular development, a mechanism possibly like that responsible for the higher male prevalence[56,57] reported for Class III malocclusion.

The control-reference group means and standard deviations for the studied cephalometric and odontometric variables compared favorably with normative data reported for the same parameters in standard reference atlases,[32,58] thereby validating the reference group as an unbiased sample. Thus, significant differences noted in this study between the cover-bite and the reference groups can be confidently attributed to factors associated with the II/2 cover-bite sample.

By integrating the results of this study with anthropologic viewpoints of occlusal variation, we may speculate on the genesis of II/2 deep-overbite malocclusion. Overbite is a characteristic rarely found in the dental occlusion of extinct hominids and existing primitive peoples.[59,60] Instead, deep anterior overbite is an element of malocclusion uniquely associated with modern "civilized" populations, those demonstrating relatively little tooth wear. Deep-bite malocclusion is a condition that usually develops in the mixed dentition. The eruption of the maxillary incisors approximately at age seven to eight years is probably the first event leading to the expression of the phenomena of overbite and incisor retroclination associated with the II/2 discrepancy.[61-63] In a child with a vertically well-developing mandible (i.e., a forward, bite-closing rotator), further exaggeration of overbite would develop with growth. Moreover, the generalized tooth-size reductions identified in this study as an associated feature of the II/2 would permit easy retroclination of the maxillary incisors. As strong, posterior-vertical mandibular growth of II/2 continues, the anterior growth of the dentoalveolar segment of the mandible would be restrained by the deep overbite, but mandibular basal growth at the bony symphysis, or chin, would persist unabated, since it appears to be under independent genetic control[64]. Thus, this sequence of formative occlusal events could be one pathway leading to the ontogenetic expression of the II/2 deep-bite phenomenon.

Within the skeletal and dental pattern identified in this study as characteristic for II/2 cover-bite are at least three hard-tissue anatomic features with generally accepted hereditary bases: small tooth size,[35] abundant mandibular basal growth,[64] and strong chin.[64] Familial occurrence of II/2 cover-bite has been documented in several published reports, including twin and triplet studies by Kloeppel,[65] Markovic,[66] and others[67] and family pedigrees from Korkhaus,[13,14] Rubbrecht,[68] and Trauner.[69] Our examination of these published family pedigrees of II/2 cover-bite points to incontestable genetic influence, probably of an autosomal dominant type with incomplete penetrance, as a significant factor in the formation and expression of Angle's II/2 deep-bite or cover-bite malocclusion. Inheritance of a complex occlusal variation such as II/2 deep-bite malocclusion may actually be polygenic and additive in nature, through combined expression of genetically determined anatomical components, rather than being the effect of a single controlling gene for the entire occlusal malformation.

Angle's II/2 malocclusion, at least in its cover-bite phenotype, is one of a small but growing group of dentofacial abnormalities that show evidence of substantial genetic influence in their origin. Although recent heritability studies[70,71] have been unable to identify specific aspects of genetic influence in occlusal variability, we estimate that 10% to 15% of patients in orthodontic treatment possess genetically determined anomalies resulting in malocclusion. These gene-controlled abnormalities are sometimes found occurring in combinations (although such patients can usually be classified as nonsyndromic) and at present they include hypodontia, infraocclusion, ectopic mesial eruption of first molars, maxillary lateral incisor peg-shape anomaly, palatally displaced canine anomaly, certain canine tooth transpositions, and Class III skeletal discrepancy, in addition to II/2 deep-bite malocclusion.

Clinical implications

The combination of significantly smaller teeth and cephalometric signs of ample skeletofacial growth identified in this study of II/2 cover-bite malocclusion may help improve understanding and treatment of the II/2 bite discrepancy.

Orthodontic treatment of children with II/2 deep-overbite malocclusion involves initial appliances to decompensate the retroclined maxillary incisors and to "free up" or "unlock" certain attributes of the mandible's position caused by the confining overbite. Functional and fixed appliances may be applied to correct the overbite, tooth irregularity, and any sagittal imbalances.[72-74] Given a pattern of reduced tooth size and well-developed jaw size, it is easy to understand that a prevalent II/2 feature is adequate dental arch space and that adolescent II/2 orthodontic corrections usually do not demand permanent-tooth extractions.[75]

For adult II/2 treatment, conventional orthodontic treatment often suffices in the correction of mild expressions of the malocclusion. Adult cover-bite discrepancies, however, generally require a comprehensive approach combining orthodontic treatment and orthognathic surgery. The initial, decompensating orthodontic treatment is usually manageable on a nonextraction basis. Current surgical management of II/2 malocclusion with severe overbite favors a mandibular advancement osteotomy procedure to improve the relatively retruded dentoalveolar segment, with a concomitant anteroposterior reduction of either the chin eminence (viz., reduction genioplasty) or the entire strong basal segment of the mandible (viz., total subapical osteotomy).[76-79] These procedures are again easy to reconcile in light of the abundant basilar osseous development of the mandible and the reduced tooth-size pattern characterizing II/2 malocclusion in the present study.

In addition to the present findings indicating ample anteroposterior and vertical jaw size, we believe from clinical observations that II/2 patients generally have adequacy in transverse development of the maxilla and mandible. A controlled study would be necessary to properly test this hypothesis.

The collective evidence that Angle's II/2 *Deckbiss* or cover-bite malocclusion has genetic determinants underscores the increasing importance of observing and recording family histories of orofacial and occlusal variations as part of the orthodontic diagnostic process. At the early signs of a II/2 deep-overbite malocclusion developing in a child with a positive family history, maxillary anterior decompensation, bite-opening appliances or dentofacial orthopedics may well be initiated to mitigate or possibly intercept the condition.

Research into the nature of the cover-bite phenotype should help in refining effective treatment approaches for all degrees of II/2 malocclusion. However, some mild to moderate expressions of II/2 malocclusion may incorporate mixed clinical features, anatomically different than those found associated with the specific extreme of cover-bite. Van der Linden[80] believes that II/2 malocclusion should be segregated into at least three distinct anatomical types. Such large intraclass variability may account for some of the indeterminate findings published in many earlier, nonspecific II/2 studies.

In studies of dentofacial treatment and growth, investigators today often combine II/2 and II/1 malocclusions into a single, generic "Class II" category (see Tuncay and Tulloch[81] and Enlow[82] for examples). In contrast, Angle[1,83] in applying his classification system always specifically separated the first and second divisions of Class II malocclusion. The evidence in the present study supporting Class II Division 2 malocclusion as a distinct skeletodental entity would clearly discourage the practice of pooling II/2 and II/1 data. All reports of cases and samples of Angle's Class II malocclusion prudently should be identified and segregated at least according to divisions. Study samples lacking this important anatomical specificity may best be designated as "Class II *mixed*," signaling a potential drawback in the research design.

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