Circumpubertal maxillomandibular growth in untreated subjects with skeletal Class II relationship: A controlled longitudinal study according to the third finger middle phalanx maturation

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Introduction: Despite the substantial prevalence of skeletal Class II Division 1 malocclusion, only a few studies analyzed the maxillomandibular growth changes in these subjects with contrasting results. This study compared the longitudinal maxillomandibular growth changes in growing subjects with Class I and II skeletal relationships, specifically during the circumpubertal growth phase assessed by the modified third finger middle phalanx maturation (MPM) method. An attempt to uncover any maxillomandibular growth peak in subjects with Class II relationship has been followed. **Methods:** From the files of the Burlington Growth Study, a total of 32 subjects (13 males, 19 females) with at least 7 annual lateral cephalograms taken at 9 and 16 years old were included and equally distributed between Class II and Class I groups matched for sex. Overall changes in 12 cephalometric parameters were calculated, and maxillomandibular growth peak was also identified individually and used to register subjects according to the year of growth peak ± 2 years. According to this procedure, annualized changes (trends) were analyzed along with the corresponding prepubertal, pubertal, and postpubertal MPM stages. **Results:** No significant differences were seen between subjects with Class I and II skeletal relationships at 9 and 16 years, except for the parameters of the sagittal maxillomandibular relationship, such as ANB angle. Overall, changes for all the cephalometric parameters were similar between the groups, except for the CoGn distance increment that was significantly lower in the subjects with a Class II relationship. In both groups, the annual changes in CoA, CoGn, and CoGo distances showed a clear peak at the time point corresponding to a median MPM stage 3. **Conclusions:** In subjects with a skeletal Class II relationship, mandibular deficiency appears to be mostly established during the prepubertal growth stage and further aggravated during puberty. However, the maxillomandibular growth trend in subjects with Class II relationship is generally similar to that of subjects with a Class I relationship, including the existence of a pubertal peak.

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Despite the substantial prevalence of skeletal Class II Division 1 malocclusion, only a few studies[1-9] aimed to assess the maxillomandibular growth changes in these subjects, reporting contrasting results. For instance, circumpubertal mandibular growth has been reported to be either significantly lower[5,7] or similar[2,9] in subjects with a Class II relationship than matched subjects with a Class I relationship. In contrast, mandibular deficiency has been claimed to be stable during growth,[9] whereas a reduced[2] or increased[4,5,7,10] tendency was reported. The absence of a mandibular growth peak in subjects with a Class II relationship has been evidenced only in a few studies,[5,7] whereas other investigations followed methodological designs not allowing for reliable conclusions.[2,4,9]

The lack of evidence regarding facial growth in subjects with a skeletal Class II relationship is mainly related to the several limitations of previous studies, in which either close circumpubertal stages of skeletal maturation were not considered,[1-6,9,11] only prepubertal subjects were included,[1] a control group was lacking,[3,11,12] a mixed-longitudinal design was followed,[10] and development stages were based on dentition phases[1,2,8] or on indicators of skeletal maturation[7] recently shown to be poorly reliable.[13,14] Among all these investigations, only 2 controlled longitudinal studies[5,7] have been performed reporting detailed annual changes of facial growth through puberty, allowing a comparative analysis of growth trends in subjects with Class I and II skeletal relationships. Limitations of these studies[5,7] are detailed below. Because the exact knowledge of the mandibular growth trend in subjects with a Class II relationship may have relevant clinical implications, especially when referring to orthopedic treatment, we aimed to compare the longitudinal maxillomandibular growth changes in subjects with Class I and II skeletal relationships from a prepubertal stage to a postpubertal stage of development, and specifically during the circumpubertal growth phase assessed by the modified third finger middle phalanx maturation (MPM) method.[15] An approach to uncover any growth peak on annual recordings from the Burlington Growth Study has also been followed.

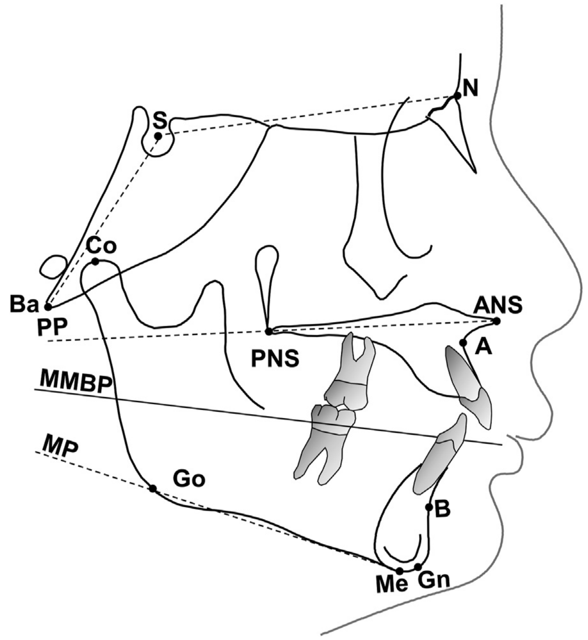

Fig 1. Landmarks and planes used in the cephalometric analysis. *Ba*, Basion; *Co*, Condylion; *N*, Nasion; *PNS*, posterior nasal spine; *ANS*, anterior nasal spine; *Me*, Menton; *Gn*, Gnathion; *Go*, Gonion; *PP*, palatal plane; *MP*, mandibular plane; *MMBP*, maxillary-mandibular bisected plane.

MATERIAL AND METHODS

Subjects were selected from the files of the Burlington Growth Study, extracted from the American Association of Orthodontists Foundation Craniofacial Growth Legacy Collection (www.aaoflegacycollection.org). Only subjects with an uninterrupted series of recordings of both lateral cephalograms and corresponding hand-and-wrist films from 9 to 16 years (not considering the 15 years recording, missing in most of the patients) were included.

Subjects with Class I and II skeletal relationships were identified as those having an ANB angle of 1°-4° and ≥5°,[7,16,17] respectively, in at least 3 out of the 4 first recordings. When a noteworthy maxillary retrusion/protrusion was seen with SNA angle ≤75°/≥85°, 1° was subtracted/added to the abovementioned thresholds.[16] Other parameters were evaluated for a more accurate classification as molar Class,[7] and Wits appraisal.[18] Exclusion criteria were: (1) doubtful Class II skeletal relationship as having an ANB angle of 4°-5° in more than 1 out of the 4 first recordings, (2) incomplete records, (3) radiographs of poor diagnostic quality, (4) subjects with recognizable craniofacial (or other) conditions or syndromes, and (5) in case of evident orthodontic treatment (with the exception for minimal treatment, such as space maintainers).

From an original sample of 100 patients available on the American Association of Orthodontists Foundation Craniofacial Legacy Collection, after selection, 32 subjects (13 males, 19 females) were equally distributed between Class II and Class I groups with a nonsignificant different sex distribution ($P = 0.280$), were included in the study. The 15 years recording was used whenever present, whereas annualized values were derived between 14 and 16 years, as previously reported for the rest of the patients.[15] Patients with a Class I relationship were already included in a previous longitudinal investigation.[15]

A customized digitization protocol and analysis were performed using cephalometric software (version 4.0, Viewbox; dHAL Software, Kifissia, Greece). The cephalometric analysis comprised the digitization of 11 landmarks. The customized cephalometric analysis included measurements as previously reported[19,20] generating 7 angles and 5 linear distances (see below) for each tracing

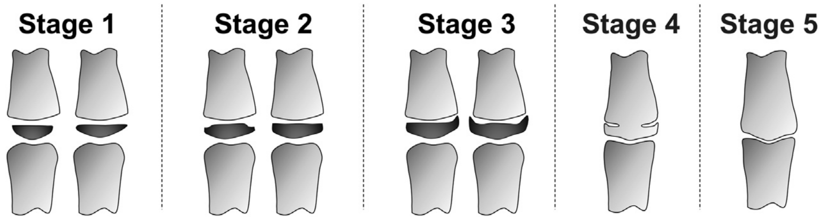

Fig 2. The stages of the third finger MPM method. *Stage 1,* Epiphysis is narrower than the metaphysis, or epiphysis as wide as metaphysis but with both tapered and rounded lateral borders. In the case of asymmetry, the most mature side is used to assign the stage. Attained before the onset of the mandibular growth peak. *Stage 2,* Epiphysis at least as wide as the metaphysis with sides increasing thickness and showing a clear line of demarcation at a right angle. In the case of asymmetry, the most mature side is used to assign the stage. Attained at coincidence with the onset of the mandibular growth peak. *Stage 3,* Epiphysis is either as wide or wider than the metaphysis, with lateral sides showing an initial capping toward the metaphysis. In the case of asymmetry, the most mature side is used to assign the stage. Epiphysis and metaphysis are not fused. Attained at the coincidence of the maximum mandibular growth peak. *Stage 4,* Epiphysis begins to fuse with the metaphysis, although the contour of the former is still clearly recognizable. Attained after the mandibular growth peak. *Stage 5,* Epiphysis fused with the metaphysis. Modified from Perinetti and Contardo.[21]

(Fig 1). A Wits appraisal on the maxillary-mandibular bisected plane (MMBP-Wits)[19] was preferred over the Wits on the occlusal plane[18] because of the different dentition stages across all ages. The maxillary-mandibular difference (Max-mand diff) was calculated as CoGn distance – CoA distance.[7] A magnification factor of 10% has been adopted.[15] An experienced orthodontist (V.B), blinded to the MPM stage, performed the cephalometric tracings. A second blinded investigator (V.S) checked tracings for accuracy.

The individual MPM stage was recorded at the beginning of each annual (or 14-16 years biannual) age interval. The previously reported[15] 5-stage MPM method has been used. A diagram of the MPM stages is shown in Figure 2. The MPM stages 2 and 3 have been reported to be associated with the onset and maximum mandibular growth peak, respectively.[15] An experienced orthodontist (G.P), blinded to the cephalometric data, assessed the MPM stages.

Method error was calculated through the moments variance estimator[21] and by both unweighted and linear weighted kappa coefficients, for the continuous and ordinal data sets, respectively. Data were derived from a repletion of 25 randomly chosen patients and expressed as mean (95% confidence interval [CI]).

Parametric or nonparametric tests were used according to the required assumptions.[22] Mean scores of each cephalometric parameter were calculated at 9 and 16 years for either group. A paired and an independent sample *t* test was used to assess the significance of the differences between the 9 and 16 years (within each group) and between the groups (within each 9 and 16 years), respectively. Overall changes (ie, score at 16 years – score at 9 years) were calculated for each group with the independent sample *t* test assessing the significance of the difference. The only exception was for the MMBP-Wits, in which a Wilcoxon rank sum test and a Mann-Whitney U test were used instead of the paired and independent sample *t* tests, respectively.

In either group, annualized changes of the cephalometric parameters were calculated for each subject according to each annual age interval from 9-10 years interval to the last biannual 14-16 years (or again to the annual 14-15 years and 15-16 years, when possible) interval. Finally, the annual age interval of maximum individual increment of the mean values of CoA, CoGn, and CoGo distances was identified as displaying the greatest increment of the whole series.[23] Subsequently, this maximum individual increment interval was used to register subjects according to the year of the maxillo-mandibular growth peak ± 2 years,[14,15] accounting for a 4-year interval (5-time points). For each time point of this interval, actual age and median MPM stage were also calculated. Within each time point and between the groups, the Mann-Whitney U test was used to assess the significance of the difference in the annual changes of the different cephalometric parameters. A P value <0.05 was considered statistically significant for all the comparisons.

A posteriori power analysis was carried out assuming a P value of 0.05, a power of 80%, and a sample size of 16 patients. According to this procedure, the minimum detectable mean differences for cross-sectional and longitudinal comparisons were those associated with effect

Table I. Actual age and MPM stage at 9 and 16 years for each group

Age	*Group* Class II	*Class I*
Actual age (y)		
9	9.0 ± 0.1	9.0 ± 0.1
16	16.1 ± 0.1	16.0 ± 0.1
MPM stage		
9	1 (1, 1)	1 (1, 1)
16	5 (4, 5)	5 (4, 5)

Note. Actual age and MPM stage are presented as mean ± standard deviation and median (25th, 75th percentile).

size (ES) coefficients[24] of 0.75 and 1.05, respectively. The ES coefficient is the ratio of the mean difference between the data sets being compared divided by the corresponding average standard deviation, and it was calculated as previously reported.[24]

RESULTS

For the cephalometric parameters, the greatest method error of 1.40° (1.09-1.94) was measured for the CoGoMe angle, corresponding to an error of 1.1% (0.9-1.6). For the MPM stage assessment, weighted and unweighted kappa values were 0.897 (0.803-0.991) and 0.796 (0.615-0.976), respectively. The overall percentage of agreement for the MPM stages was 84% (21 out of 25 patients). In all 4 instances in which staging was not exactly repeated, only 1 stage apart was scored. The actual age and MPM stage at 9 and 16 years for each group are summarized in Table I. In particular, the MPM stages (as median [25th, 75th percentile]) were 1(1, 1) and 5 (4, 5) at 9 and 16 years, respectively, in each group.

Cephalometric parameters at 9 and 16 years for each group are summarized in Table II. The cross-sectional analyses showed no significant differences between the Class I and II groups for none of the cephalometric parameters. The only exceptions were the ANB angle and MMBP-Wits, which were significantly greater, and Max-mand diff, which was significantly smaller in subjects with a Class II relationship than a Class I relationship, both at 9 and 16 years ($P < 0.001$ and $P = 0.031$, respectively). At the longitudinal analyses within each group, and for both groups, the CoA distance, SNB angle, CoGn and CoGo distances, and Max-mand diff underwent significant increases between 9 and 16 years ($P < 0.05$, at least); whereas the MMBP-Wits, SN-MP angle, and CoGoMe angle significantly decreased between 9 and 16 years ($P < 0.05$, at least). The SNA angle increased in both groups over time, although only for subjects with a Class I relationship; this increase reached a statistically significant level. The SNA, ANB, and SN-PP angles did not show any significant change between 9 and 16 years. Finally, overall changes for all the cephalometric parameters were similar between the groups with no significant differences, except for the CoGn distance increment that was significantly lower ($P = 0.033$) in subjects with a Class II relationship (13.6 mm) than a Class I relationship (16.1 mm).

Circumpubertal annualized changes of each cephalometric parameter according to MPM stage and group are summarized in Figure 3. In both groups, the changes in CoA, CoGn, and CoGo distances had a clear peak at the time point with a median MPM stage of 3.1. Similarly, such a clear peak was present also for the SNA angle, but only for subjects with a Class I relationship, whereas it was less evident for subjects with a Class II relationship. Other cephalometric parameters did not show a clear peak behavior or showed peaks of a minor entity. Generally, no significant difference between the groups was seen for any cephalometric parameter at any time point, with few exceptions. At the time point before the growth peak (median MPM stage, 2.1), the CoA distance showed an annualized change that was slight, although significantly greater, in subjects with a Class II relationship than a Class I relationship ($P < 0.05$). Moreover, at the time point after the growth peak (median MPM stage, 3.7), the SNA angle showed an annualized increase that was significantly lower in the subjects with a Class II relationship than a Class I relationship ($P < 0.05$).

DISCUSSION

This longitudinal investigation compared maxillomandibular growth changes in subjects with a skeletal Class I and Class II relationship from a prepubertal to a postpubertal stage (determined with a skeletal maturation indicator) using annual recordings. To the best of our knowledge, the present study is the first to report a clear mandibular growth peak in subjects with a skeletal Class II relationship, which was generally concomitant with the passage from an MPM stage 2 to 3.

Facial growth is deeply influenced by the stages of skeletal maturation,[23,25,26] which are best identified through specific growth indicators.[27] Existence of maxillary and mandibular growth peak in subjects with a Class II relationship may be of clinical relevance in terms of timing of intervention for orthopedic treatment, as it may be expected that during this stage, condylar growth may be more responsive to mechanical stimuli.[28] A previous longitudinal study[7] evaluated facial growth in

Table II. Cephalometric parameters at 9 and 16 years for each group

Age	*Group* Class II	Class I	Difference	Significance
Cranial base				
MPM stage				
9 years	129.4 ± 4.0	130.1 ± 3.4	−0.7 (1.3)	0.598; NS
16 years	129.7 ± 5.2	130.8 ± 4.6	−1.2 (1.7)	0.504; NS
Overall change	0.3 (0.5)	0.7 (0.6)	–	0.569; NS
Maxillary				
SNA angle (°)				
9 years	81.5 ± 4.1	79.2 ± 3.1	2.2 (1.3)	0.096; NS
16 years	82.0 ± 4.0	80.4 ± 2.9*	1.5 (1.2)	0.227; NS
Overall change	0.5 (0.5)	1.2 (0.4)	–	0.305; NS
CoA distance (mm)				
9 years	74.7 ± 4.0	73.3 ± 2.6	1.4 (1.2)	0.262; NS
16 years	82.9 ± 4.0***	82.7 ± 3.9***	0.2 (1.4)	0.906; NS
Overall change	8.2 (0.5)	9.4 (0.4)	–	0.068; NS
Mandibular				
SNB angle (°)				
9 years	75.4 ± 3.9	76.4 ± 2.9	−0.9 (1.2)	0.440; NS
16 years	76.6 ± 4.2*	77.9 ± 2.6*	−1.4 (1.2)	0.279; NS
Overall change	1.1 (0.5)	1.6 (0.5)	–	0.569; NS
CoGn distance (mm)				
9 years	92.2 ± 4.1	93.6 ± 3.0	−1.4 (1.3)	0.266; NS
16 years	105.7 ± 6.4***	109.7 ± 4.9***	−3.9 (2.0)	0.061; NS
Overall change	13.6 (0.8)	16.1 (0.8)	–	0.033; S
CoGo distance (mm)				
9 years	43.2 ± 3.2	44.0 ± 3.5	−0.8 (1.2)	0.487; NS
16 years	52.0 ± 4.5***	53.1 ± 5.4***	−1.0 (1.8)	0.562; NS
Overall change	8.8 (0.9)	9.0 (0.8)	–	0.868; NS
Maxillary-mandibular				
ANB angle (°)				
9 years	6.0 ± 1.0	2.9 ± 0.9	3.2 (0.0)	0.000; S
16 years	5.4 ± 1.3	2.5 ± 1.1	2.9 (0.4)	0.000; S
Overall change	0.6 (0.3)	−0.3 (0.3)	–	0.473; NS
Max-mand diff (mm)				
9 years	17.5 ± 2.4	20.3 ± 2.0	−2.8 (0.8)	0.001; S
16 years	23.6 ± 4.5***	26.7 ± 3.1***	−3.1 (1.4)	0.031; S
Overall change	6.1 (0.9)	6.4 (0.6)	–	0.798; NS
MMBP-Wits (mm)				
9 years	0.5 ± 1.9	−1.9 ± 1.5	2.5 (0.6)	0.000; S
16 years	−0.7 ± 2.4*	−3.0 ± 2.0*	2.4 (0.8)	0.005; S
Overall change	−1.2 (0.4)	−1.1 (0.5)	–	0.877; NS
Vertical				
SN-PP angle (°)				
9 years	6.9 ± 2.7	8.2 ± 3.0	−1.3 (1.0)	0.187; NS
16 years	8.0 ± 3.7	8.3 ± 3.1	−0.3 (1.2)	0.802; NS
Overall change	1.1 (0.5)	0.1 (0.6)	–	0.183; NS
SN-MP angle (°)				
9 years	35.3 ± 4.5	32.9 ± 4.7	2.4 (1.6)	0.138 NS
16 years	34.0 ± 4.9*	30.9 ± 5.8**	3.1 (1.9)	0.120; NS
Overall change	−1.3 (0.6)	−2.0 (0.6)	–	0.458; NS
CoGoMe angle (°)				
9 years	126.0 ± 3.3	124.2 ± 4.5	1.8 (1.4)	0.205; NS
16 years	124.3 ± 4.2**	121.6 ± 5.9**	2.7 (1.8)	0.151; NS
Overall change	−1.7 (0.5)	−2.6 (0.9)	–	0.397; NS

Note. Data are presented as mean ± standard deviation or mean (standard error). Significance of the difference as compared with the corresponding 9 years score.
S, difference statistically significant; *NS*, difference not statistically significant.
*P <0.05; **P <0.01; ***P <0.001.

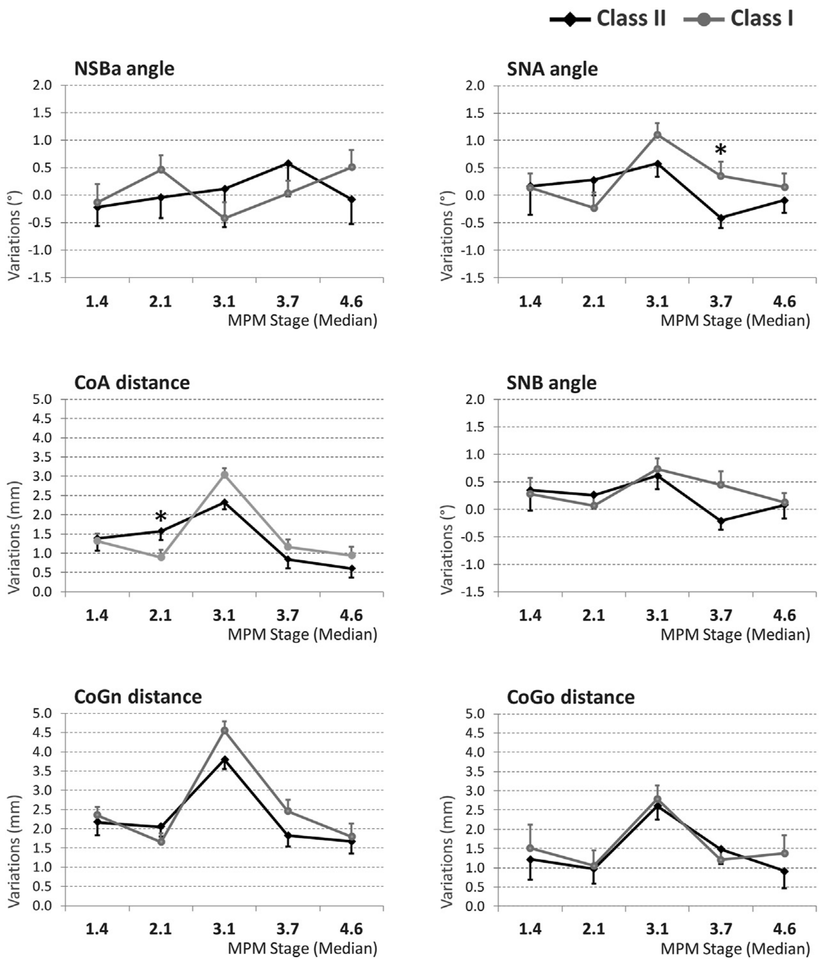

Fig 3. Circumpubertal annual changes of each cephalometric parameter according to each group and MPM stage. Data are presented as mean ± standard error with n = 16 in each group. Actual mean ages at each consecutive time point were 11.2, 12.0, 12.9, 13.9, and 14.8 years, respectively. Significance of the difference between the groups: *$P < 0.05$. Extreme time points <10 years and >15 years omitted.

untreated subjects with a Class II malocclusion according to the different skeletal maturation stages, reporting a lack of a clear mandibular growth peak (as total mandibular length) for subjects with a Class II relationship. However, this investigation was based on the cervical vertebral maturation method, the reliability of which in the identification of the mandibular growth peak has been highly debated over the last few years.[14,23,29] Therefore, evidence of any maxillary and mandibular growth peak in subjects with a Class II relationship is still scarce.

The MPM method was used herein as it has been shown previously to be a good diagnostic indicator of the mandibular growth peak with an overall accuracy of 0.91.[15] Nevertheless, a slightly different approach was used compared with previous investigations.[2,7] More in detail, this study first individually identified the year of the maxillomandibular growth peak (as the one with the highest mean value of CoA, CoGn, and CoGo distances as the main outcome). Consecutive annual age intervals and the corresponding MPM stage were arranged accordingly. This approach, already used to evaluate facial growth in subjects with a Class I relationship,[23] would thus uncover the existence of a growth peak irrespective of the reliability of the growth indicator being used. In contrast, when data on facial growth is arranged according to chronological age[2,4,5,9] any peak may be missed.[15,27]

This study included limited sample size, resulting in the application of strict inclusion/exclusion criteria.

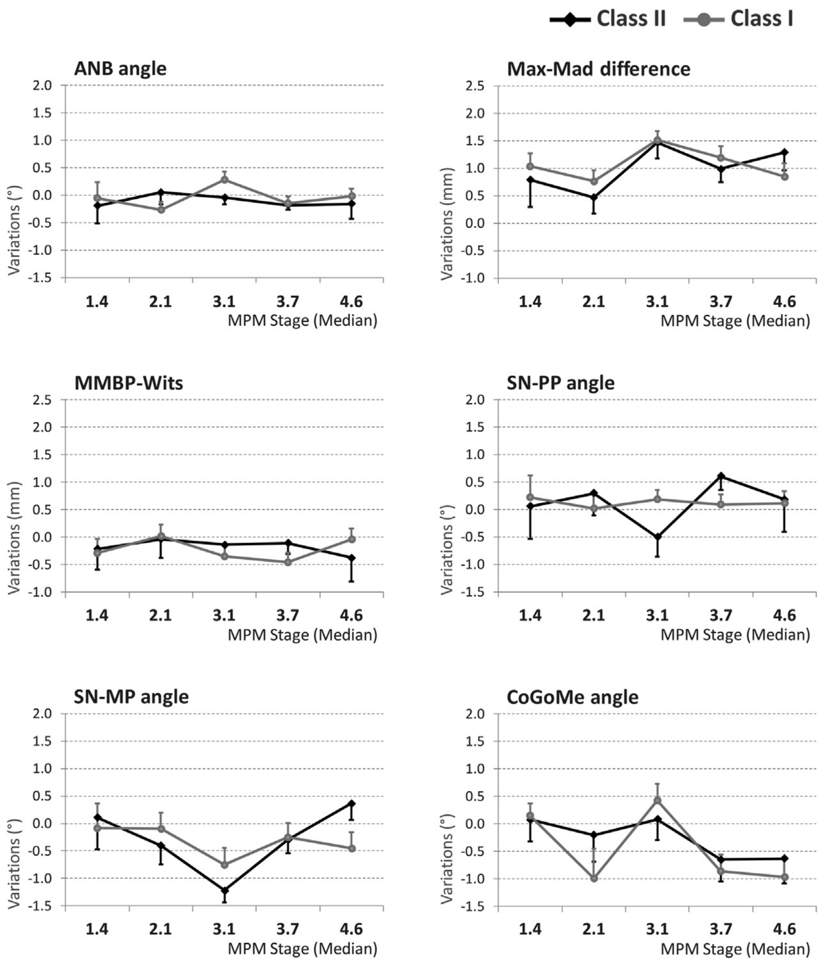

Fig 3. Coninued.

Thus, selection bias was limited, whereas uncovering small growth effects may have been missed. However, the power analysis detected mean differences associated with ES coefficients as small as 0.75 and 1.05 in the cross-sectional and longitudinal comparisons, respectively. As such, the minimum detectable mean difference in any parameter for each comparison had to be at least equal to 0.75 of the corresponding average standard deviation. As a ratio, the ES coefficients are independent of the parameter under consideration, making it suited when multiple equally relevant parameters with different absolute magnitudes are considered. The ES coefficients above 0.80 have been associated with a large effect,[24] and this threshold may be reasonably considered consistent with a clinically relevant growth effect. Although the present sample size may have caused failure to detect some statistically significant differences between subjects with Class I and II relationships (especially in the circumpubertal annualized changes that showed more heterogeneity), these differences may thus have been of limited clinical relevance. Nevertheless, future investigations with larger sample sizes are warranted to detect any significant growth change, even in a minor clinical entity.

Herein, growth of the cranial base, as recorded through the NSBa angle, was similar between the groups at 9 and 16 years, with no significant difference in the overall changes (Table I and Fig 3). This evidence is in line with previous reports.[2,7] The SN-PP angle values were very similar between the groups, whereas the SN-MP angle and CoGoMe angle parameters, although slightly greater in subjects with a Class II relationship, did not reach a significant level at the cross-sectional comparisons (absolute values or overall changes, Table II). In addition, the corresponding annualized changes did not show any significant difference between the groups at any time point (Fig 3). Although some previous evidence was in favor of greater facial divergence in subjects with a skeletal Class II relationship,[5] the present results, along with those from several investigations,[2,4,7] demonstrate that growth in subjects with skeletal Class I and II relationships are similar in terms of facial vertical dimensions. However, such evidence applies to samples with an average vertical growth, which must be confirmed by further studies, including subjects with more extreme vertical growth patterns.

According to the CoA distance data, a clear peak in the maxillary growth was seen in both groups. Although this peak (coincident to the median MPM stage 3.1 and with the mandibular growth peak) appears to be lower for subjects with a Class II relationship compared with a Class I relationship, the difference was not significant at each time point with 1 exception before the growth peak (coincident with a median MPM stage 2.1), in which a significantly greater annual increment has been seen for subjects with a Class II relationship. However, the absolute difference between the groups was <1 mm, thus with poor clinical meaning. Previously, a pubertal peak in the maxillary growth (as CoA distance) in subjects with a Class II relationship has also been reported.[7] Moreover, the SNA angle showed a peak in coincidence with a median MPM stage 3.1, although this was more evident for subjects with a Class I relationship. Generally, annual changes were lower for the subjects with a Class II relationship, with a statistically significant difference at a later time point coincident with a median MPM stage 4 (Fig 3). This evidence, along with the overall changes (Table II), would show that subjects with a Class II relationship likely express a slightly lower sagittal growth of the maxilla that would have minor clinical implications.

From 9 to 16 years, the overall mandibular length (as CoGn distance) deficiency in subjects with a Class II relationship was 2.5 mm. This evidence is in line with results from comparable age range samples from Sthal et al[7] (CoGn distance, 2.9 mm) and Kerr and Hirsh[4] (ArPog distance, 2.5 mm). In contrast, Bishara et al[2] and Jacob and Buschang[10] reported no significant mandibular growth deficiency (as ArPog distance and CoGn distance, respectively) in growing subjects with a Class II relationship. Of note, the former study[2] evaluated a sample up to 12 years of age, possibly missing puberty in some of the subjects, and both investigations[2,10] did not use an indicator of skeletal maturity. Another possible explanation resides in the entity of the skeletal Class II malocclusion under evaluation. Indeed, in the study by Jacob and Buschang,[10] the mean ANB angle for the subjects with a Class II relationship was 4.9°, whereas, in this study, it was 6.0°.

The CoGo distance was similar between the groups of both ages; no significant differences were seen in overall changes (Table II). No significant differences in the overall changes of ramus length have also been reported earlier by several investigations.[2,7,10] Herein, a clear growth peak was detected for both the total mandibular length (CoGn distance) and ramus length (CoGo distance) in both groups (Fig 3). This last evidence is partially in line with the study by Stahl et al[7] in that subjects with a Class II relationship reported a growth peak for the mandibular ramus length but not for the total mandibular length. The remaining investigations performed to date did not report this data[5] or followed designs unable to uncover a growth peak.[2-4,9,10]

The present evidence regarding the annualized changes (ie, trends of most of the cephalometric parameters) shows that both subjects with Class I and II relationships may have a similar behavior of facial growth, including the mandible. In particular, the maxillomandibular skeletal difference (as ANB angle, Max-mand diff, and MMBP-Wits) was significantly different between subjects with Class I and II relationships at 9 years, and it did not improve or worsen through puberty (Table II), as also previously reported by some investigations.[5,7,10] In contrast, Bishara et al[2] did not find a significant maxillomandibular growth difference between subjects with Class I and Class II relationships at the early development of the malocclusion (ie, prepubertal). However, the inclusion criteria used in the different studies may explain this discrepancy. For instance, in this study, doubtful subjects with a Class II relationship were excluded, and a wider age range was considered. Although an overall circumpubertal mandibular growth deficiency is in accordance with previous studies,[4,7] this was not because of a lack of a growth peak (Table II and Fig 3). Moreover, the "catch up" in mandibular growth in subjects with a Class II relationship reported by Bishara et al[2] was not seen, consistent with a not self-correction with growth.[4,7] The present results thus reinforce the concept that longitudinal studies are necessary to uncover any growth difference between subjects with skeletal Class I and II relationships, as cross-sectional comparisons do not appear to be sufficient.[2,7]

As reported for Class I subjects,[15] the present investigation showed that maxillomandibular growth peak generally appears between the MPM stages 2 and 3, even in subjects with a Class II relationship (Fig 3). Previous investigations (mainly in Class I subjects, see below) focused on the possibility of predicting mandibular growth peak on the basis of skeletal maturation and reported apparent constating results. However, great differences in the procedures followed and hypotheses tested have to be taken into account. For instance, according to Greulich and Pyle,[30] or according to a stage-based indicator, skeletal maturity was defined by bone age.[7,14,15,23,26] Most investigations were based on repeated recordings of skeletal maturation and the increment in mandibular length over time.[7,14,15,23,26,29] In contrast, 2 investigations used a single (or few) skeletal maturation recording at a prepubertal phase of growth to predict the future total amount[12] or timing[30] of mandibular growth peak. Using samples from the Burlington Growth Study, the latter investigation[30] reported failure of the bone age determination at 9-11 years in predicting the timing of future mandibular growth peak. Although this study[30] included only males and did not give information regarding types of malocclusions (if present), the results reported herein may be considered in line with that evidence. Indeed, as the duration of stages of any radiographic growth indicator is unpredictable,[15,27,31] it would not be possible to predict the exact timing of mandibular growth peak in individual subjects years before it occurs. Taken together all of this evidence, the only reliable procedure to identify the onset of the mandibular growth peak would be based on a repeated evaluation of the skeletal maturation over time to follow the ossification events,[31] and such a prediction would become reliable only for imminent mandibular growth peak. Future investigations are thus warranted to elucidate the role of the MPM method in predicting mandibular growth peak in early, average, or late maturing subjects and in relation to different vertical growth patterns.

The present data shows that skeletal Class II malocclusion, although with similar maxillomandibular growth trends to subjects with a Class I relationship, has a mandibular deficiency established at prepuberty. Skeletal Class II malocclusion does not self-correct, requiring specific treatment. The first uncovering of a mandibular growth peak in subjects with Class II malocclusion would support previous data[27,32] on the greatest efficiency of functional treatment when performed during puberty.

CONCLUSIONS

- In subjects with a skeletal Class II relationship, mandibular deficiency appears to be mostly established during the prepubertal growth stage and further aggravated during puberty.
- The maxillomandibular growth trend for subjects with a Class II relationship is generally similar to that of Class I subjects, including the existence of a pubertal peak.

AUTHOR CREDIT STATEMENT

Giuseppe Perinetti contributed to conceptualization, formal analysis, and original draft preparation; Valentina Sbardella contributed to investigation; Valentina Bertolami contributed to investigation; Luca Contardo contributed to methodology; and Jasmina Primozic contributed to original draft preparation.

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