Class II division 1 malocclusion treatment with extraction of maxillary first permanent molars: cephalometric evaluation of treatment and post-treatment changes

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Objective: To investigate the cephalometric outcome and post-treatment changes following the orthodontic treatment involving the extraction of maxillary first molars in patients presenting with a Class II division 1 malocclusion.
Methods: A retrospective longitudinal study was conducted involving 83 patients treated by fixed appliances and the extraction of 16 and 26. The mean age at commencement was 13.2 ± 1.5 years. Lateral cephalograms were available pre-treatment (T1), immediately post-treatment (T2), and at 2.6 years post-treatment (T3). The sample was divided into hypodivergent (*n* = 18), normodivergent (*n* = 17), and hyperdivergent (*n* = 48) facial types. Mean increments, standard deviations, and 95% confidence intervals were calculated for T2–T1 and T3–T2. Increments were tested using paired-samples *t*-tests, and variables between groups by applying ANOVA followed by Tukey's post hoc test. Linear regression was used to examine the effect of facial type, age, and gender.
Results: Significant changes occurred during treatment for most cephalometric variables. Post-treatment, the growth pattern showed a tendency to return to the original form. Facial type had only a minor influence on cephalometric increments during and after treatment.
Conclusions: Post-treatment skeletal, soft tissue, and dentoalveolar changes were limited. Facial type had only a minor influence during and after treatment and care must be taken to control lower incisor inclination.
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Introduction

A Class II division 1 malocclusion is a common indication for orthodontic treatment. The orthodontist faces many challenges when deciding between early or late treatment, one- or two-phase treatment, extraction or non-extraction therapy, dentoalveolar compensation or possibly jaw orthopaedics, and orthognathic surgery. Treatment options also are based on patient age at referral, malocclusion severity, the maxillofacial growth pattern, patient expectations, and the current state of the art in orthodontics. Most patients prefer a fast non-extraction treatment with minimal discomfort and aesthetically pleasing appliances with minimal compliance required.[1,2]

For the dentoalveolar correction of a Class II division 1 malocclusion, two different treatment approaches may be considered: maxillary molar/premolar distalisation or extractions in the upper arch. Extraction therapy, however, may affect the soft tissue facial profile, and further development of the nose and chin in a growing patient must be considered. A systematic review of soft tissue changes in patients with a Class II malocclusion treated with extractions showed an increased nasolabial angle from 2.4° to 5.4° in a 2-premolar extraction protocol and from 1° to 6.84° in a 4-premolar extraction protocol.[3] A recent systematic review,[4] and meta-analysis on soft tissue changes following extraction versus non-extraction treatment found comparable results. Nevertheless, it was concluded that the present state of the art in orthodontics fails to precisely forecast the profile response to different orthodontic treatments because existing studies are too heterogeneous.[4]

Expected low co-operation, failed non-extraction treatment, large restorations or endodontic treatment, a bite-closing effect in patients with a hyperdivergent facial type, and facilitating normal eruption of the third molar could be reasons to consider the extraction of maxillary first molars instead of premolars for dentoalveolar Class II malocclusion treatment.[5–7] In a large group of Class II division 1 patients treated by this option, a satisfactory outcome was reported, and treatment effects on the facial soft tissue profile were limited.[8] However, little is known about post-treatment changes following dentoalveolar compensation. Bondemark et al.[9] published a systematic literature review on stability up to 5 years post-retention, but evidence was limited for predictions about stability at the individual level. More recently, Maniewicz Wins et al.[10] published a systematic review on sagittal stability after extraction or non-extraction treatment, using functional or fixed appliances, in Class II malocclusions with a minimum follow-up period of 2 years. Neither systematic review reported long-term results of orthodontic treatment including the consequences of maxillary first permanent molar extractions.

Published reports of orthodontic treatment involving upper first molar extractions are rare. According to current knowledge, no other studies have addressed the post-treatment skeletal, soft tissue, and dentoalveolar changes of Class II treatment as a result of maxillary first molar extraction. Therefore, the aim of this explorative study was to evaluate the cephalometric changes in a large group of consecutively treated patients who had maxillary first molar extractions after a mean follow-up period of 2.6 years.

Subjects and methods

Subjects

The cohort consisted of consecutively treated patients (36 girls, 47 boys) treated by one orthodontist (J.W.B.). The following inclusion criteria were applied: Caucasian, Class II division 1, molar relationship between ½ to 1 unit Class II, a sagittal overjet of ≥4 mm, the extraction of maxillary first permanent molars, no missing or extracted teeth except maxillary first molars, no agenesis, maxillary third molars present, and 1-stage full fixed appliance treatment. Patients with a cleft lip and palate or with craniofacial deformities were excluded.

This retrospective study involved a longitudinal, one-group outcome analysis in a private practice, with outcome evaluation by an independent academic hospital. The research was conducted in accordance with the Helsinki Declaration with regard to research in human participants and in accordance with the applicable legislation provided by the Medical Research involving Human Subjects Act and the Medical Treatment Contracts Act. Ethical approval was not required as this was an observational study using routinely collected anonymous health data. All patients gave written permission and signed informed consent for their anonymised records to be used.

Treatment method

Treatment using fixed appliances started 2 weeks after the extraction of the maxillary first molars. In the case of a deep bite, the extractions were delayed, and treatment was started with an upper bite plate and fixed appliances in the lower arch. Second maxillary molars were fully erupted before the extractions were carried out. All patients were treated using fixed appliances without additional anchorage control appliances according to the principles of the light-wire technique. The method has been described in detail earlier.[6] To summarise, the treatment method can be divided into three phases: Class II correction, torque and space closure, and finishing and detailing. At the beginning of treatment, during the Class II correction phase, Class I elastics (Light 5/16, T.P., Westville, IN, USA) were attached from a high-hat lock pin in the upper canine bracket to a hook on the upper second molar band. The patient was told to replace the elastics every week. Class II elastics (Medium 5/16, T.P., Westville, IN, USA) were similarly attached from the high-hat lock pin in the upper canine bracket to a ball-end hook on the bonded tube on the lower first molar. The Class II elastics were replaced daily, and as soon as a solid Class I premolar occlusion was achieved, the elastic wearing time was reduced. After debonding, fixed canine-to-canine retainers were bonded to the lower and upper anterior teeth (0.195-inch Wildcat, GAC, Central Islip, NY, USA). In cases in which the occlusion of the mandibular second molars was absent, a buccal retention wire (0.195-inch Wildcat, GAC, Central Islip, NY, USA) was bonded between the first and second molars to prevent continuing eruption. After complete eruption of the maxillary third molars, the buccal retention wires were removed.

Cephalometric outcome

Cephalograms of all patients were obtained at the following stages: T1 (pre-treatment), T2 (post-treatment), and T3 (follow-up). To study the effect of treatment for different facial types, the participants were allocated into three groups based on pre-treatment cephalometric values: hypodivergent (ANS-Me/N-Me ≤ 56%; n = 18), normodivergent (56% <ANS-Me/N-Me <58%; n = 17), and hyperdivergent (ANS-Me/N-Me ≥58%; n = 48).[11] The cephalometric measurements were conducted by one experienced observer who was not involved in the orthodontic treatment of the patients. The cephalometric analysis was performed using Viewbox3 (dHAL software, Athens, Greece). A life size correction was done for all tracings. The soft tissue, skeletal, and dental cephalometric landmarks and reference lines are illustrated in Figure 1. To test intra-observer reliability, the same observer repeated the measurements in 35 patients after one month.

Statistical analysis

Statistical analysis was performed using SPSS version 22 for Windows (IBM, Armonk, NY, USA). The reliability coefficients between two measurements were calculated as Pearson's Correlation Coefficients. Paired-samples t-tests were applied to identify systematic differences between the first and second measurements. The duplicate measurement error was calculated as the standard deviation (SD) of the difference between two observations divided by $\sqrt{2}$. Additionally, Bland–Altman plots were generated for each variable.

Means, SDs, and 95% confidence intervals (CIs) were calculated for all cephalometric variables at T1, T2, and T3. Mean increments, SDs, and 95% CIs also were calculated for T2–T1, and T3–T2. The increments were tested using paired-samples t-tests. The cephalometric variables were compared between the groups (hypodivergent, normodivergent, and hyperdivergent) by applying ANOVA followed by Tukey's post hoc test. Linear regression was used to examine the effect of facial type (reference is normodivergent facial type), age, and gender (independent variables) on the dependent cephalometric variable. The amount of variance explained by the independent variables was estimated by the R^2 values. The level of significance was set at $p \leq 0.05$.

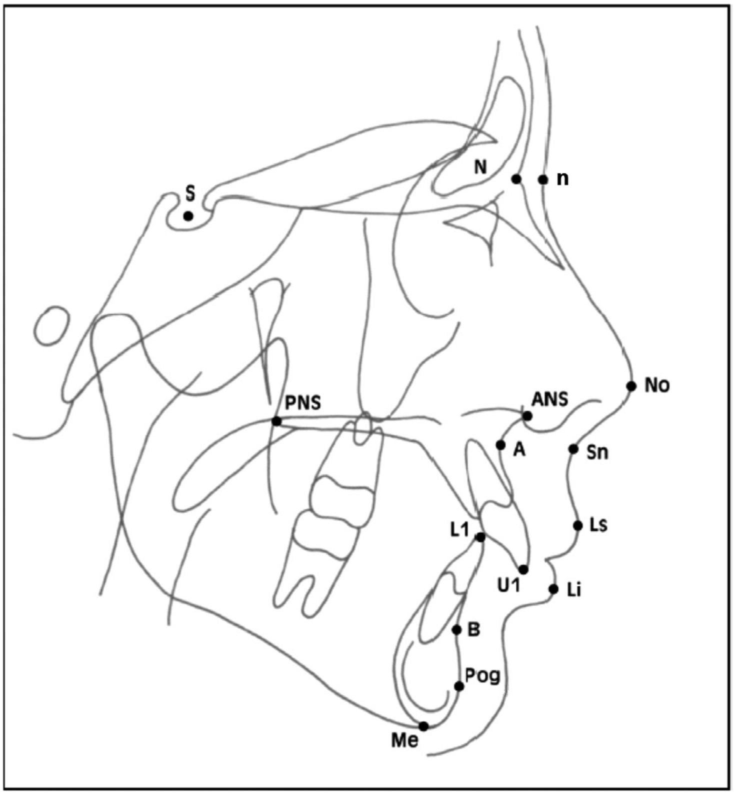
Results

Participants

The distribution of the sample is shown in Table I. The average age at T1 was 13.2 ± 1.5 years, and the average age at T2 was 15.6 ± 1.6 years, with a mean treatment duration of 2.46 years (SD 0.56). The mean age at T3 was 18.2 ± 1.9 years, and the mean post-treatment period was 2.63 years (SD 1.12).

Error of the method

The intra-observer reliability and measurement error for the cephalometric variables are provided in Table II. For the following seven cephalometric variables, a statistically significant difference between the two measurements was found: SNB(°), SN/ANS-PNS (°), ANS-PNS/ML (°), L1L/ML (°), L1 to A-Pog (mm), Ls-U1 (mm), and Li-L1 (mm). However, in all cases, the differences, although clearly present from a statistical perspective, were too small to have a relevant influence. All duplicate measurement errors were small compared to the SDs of the variables and not clinically meaningful (Table III). Bland–Altman plots for all outcomes are shown in Supplementary Figure 1.



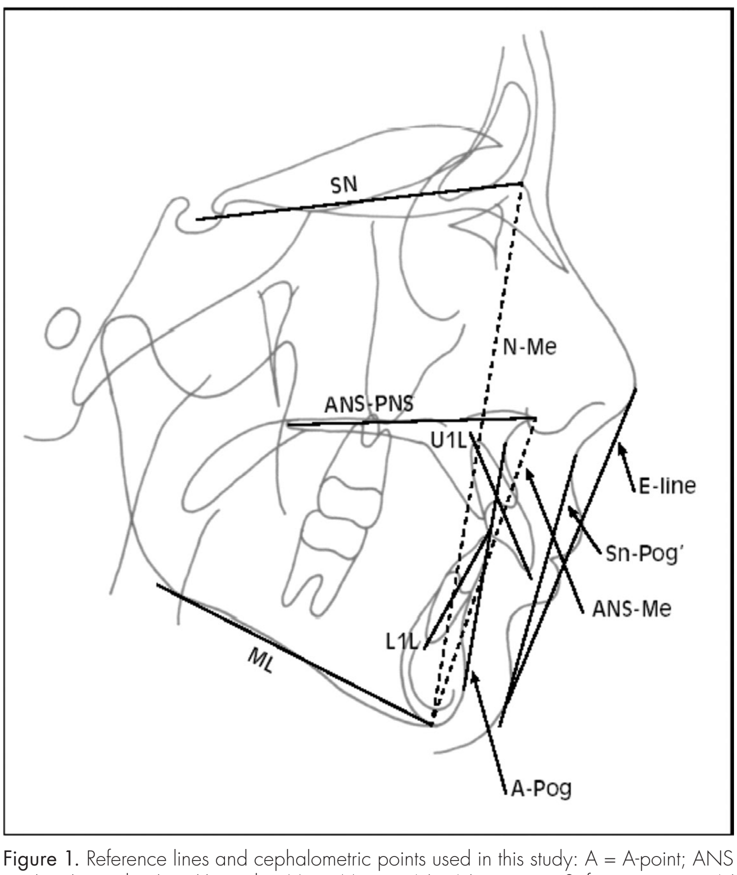


Figure 1. Reference lines and cephalometric points used in this study: A = A-point; ANS = Anterior nasal spine; B = B – point; L1 = Lower incisor edge tip; Li = Lower lip; Ls = Upper lip: Me = Menton; N = Nasion; n = Soft tissue nasion; No = Pronasale; PNS = Posterior nasal spine; Pog = Pogonion; S = Sella; Sn = Subnasale; U1 = Upper incisor edge tip (figure adapted from Stalpers et al.[8]).

Table I. Sample distribution.

Treatment stage and facial type		N	Male	Female	Mean age (SD)	Min	Max
T1	Start of treatment	83	47	36	13.2 (1.5)	10.5	17.1
	Hypodivergent	18	14	4			
	Normodivergent	17	9	8			
	Hyperdivergent	48	24	24			
T2	End of treatment	83	47	36	15.6 (1.6)	12.4	19.3
T3	Two years posttreatment	83	47	36	18.2 (1.9)	14.4	23.9

Table II. Intra-observer reliability and measurement error for the cephalometric values.

Variable	Reliability	DME	Mean diff	95% CI for diff.	*p* value
SNA (º)	0.981	0.42	–0.07	–0.27... 0.14	0.502
SNB (º)	0.994	0.25	–0.15	–0.27... –0.03	*0.018*
ANB (º)	0.971	0.38	0.07	–0.11... 0.26	0.421
SN/ANS-PNS (º)	0.979	0.46	0.36	0.14... 0.59	*0.002*
SN/ML (º)	0.998	0.30	–0.14	–0.28... 0.01	0.065
ANS-PNS/ML (º)	0.992	0.51	–0.49	–0.74... –0.24	*<0.001*
ANS-Me by N-Me (ratio)	0.961	0.53	–0.01	–0.26... 0.25	0.968
U1L/ANS-PNS (º)	0.989	0.64	0.16	–0.15... 0.47	0.295
U1 to A-Pog (mm)	0.892	0.72	0.03	–0.33... 0.38	0.883
L1L/ML (º)	0.975	1.17	0.75	0.18... 1.32	*0.012*
L1 to A-Pog (mm)	0.979	0.26	0.27	0.14... 0.39	*<0.001*
Nasolabial angle (º)	0.849	3.60	0.70	–1.05... 2.45	0.423
Ls to E-line (mm)	0.941	0.56	–0.19	–0.46... 0.08	0.164
Li to E-line (mm)	0.953	0.45	–0.15	–0.37... 0.06	0.159
n-No (mm)	0.972	0.75	–0.14	–0.50... 0.23	0.451
Ls-U1 (mm)	0.912	0.67	0.40	0.08... 0.73	*0.017*
Li-L1 (mm)	0.840	0.64	–0.67	–0.98... –0.36	*<0.001*

Reliability expressed by Pearson's correlation coefficient. Results of paired *t*-test for the mean diff (*p* values). DME, duplicate measurement error (in mm or degree); Mean diff, mean difference between first and second measurement (in mm or degree); and 95% CI for diff, 95% confidence interval.

Cephalometric analysis/descriptive data

Descriptive statistics for the cephalometric variables at T1, T2, and T3 are summarised in Table III. At T1, the patient group had typical Class II division 1 characteristics, of an increased ANB angle (mean 5.5˚ ± 1.8˚) and a protruded position of the maxillary incisors in relation to the A-Pog line. During treatment, SNA decreased (Table III) from 79.48˚(SD, 3.66) to 77.25˚(SD, 3.71) but increased after treatment to 80.07˚(SD, 3.79). The ANB angle also decreased between T1–T2 from 5.48˚(SD, 1.77) to 3.6˚(SD, 2.19) but increased to 4.22˚(SD, 2.2) from T2–T3. During treatment, the lower incisors were proclined from 97.77˚(SD, 6.28) to 103.2˚(SD, 6.44), and post-treatment (T3), the lower incisor inclination remained the same at 103.87˚(SD, 6.99). At T1, the nasolabial angle was 115.1˚(SD, 9.12), which increased to 117.05˚(SD, 9.78) at T2 and remained unchanged at T3 (117.09˚; SD, 8.71).

Outcome analysis

Table IV shows the mean increments and 95% CIs for T2–T1, T3–T2, and the *p* values for the paired-

Table III. Descriptive statistics for cephalometric variables (mean and SD) at the start of treatment (T1), posttreatment (T2) and 2 years posttreatment (T3).

Variable	T1	T2	T3
Skeletal sagittal			
SNA (⁰)	79.48 (3.66)	77.25 (3.71)	80.07 (3.79)
SNB (⁰)	74.00 (3.51)	73.65 (3.54)	75.86 (3.74)
ANB (⁰)	5.48 (1.77)	3.60 (2.19)	4.22 (2.20)
Skeletal vertical			
SN/ANS-PNS (⁰)	7.58 (3.21)	7.63 (3.18)	5.65 (3.18)
SN/ML (⁰)	35.35 (5.48)	35.68 (6.04)	34.15 (6.59)
ANS-PNS/ML (⁰)	27.77 (5.22)	28.05 (5.64)	28.61 (6.23)
ANS-Me by N-Me (ratio)	57.98 (2.39)	58.33 (2.38)	59.47 (2.15)
Dentoalveolar			
U1L/ANS-PNS (⁰)	110.23 (5.63)	108.13 (5.52)	108.04 (6.16)
U1 to A-Pog (mm)	9.00 (2.42)	6.36 (1.89)	5.88 (1.96)
L1L to ML (⁰)	97.77 (6.28)	103.20 (6.44)	103.87 (6.99)
L1 to A-Pog (mm)	1.61 (2.02)	3.94 (1.86)	2.90 (2.04)
Soft tissue			
Nasolabial angle (⁰)	115.10 (9.12)	117.05 (9.78)	117.09 (8.71)
Ls to E-line (mm)	–0.73 (2.57)	–3.30 (2.25)	–3.97 (2.52)
Li to E-line (mm)	0.08 (2.44)	–1.58 (2.37)	–1.67 (2.76)
n-No (mm)	48.82 (3.79)	51.8 (3.96)	52.77 (4.15)
Ls-U1 (mm)	11.08 (2.18)	13.52 (1.98)	13.66 (2.00)
Li-L1 (mm)	14.61 (1.53)	13.05 (1.42)	13.22 (1.55)

samples *t*-tests. All skeletal sagittal dimensions decreased significantly during treatment but increased significantly between T2 and T3. The ratio of ANS-Me by N-Me was the only vertical dimension that changed significantly during treatment, but in the post-treatment period (T3–T2), all vertical dimensions showed significant change. The inclination of the upper incisor to the palatal plane (U1L/ANS-PNS) decreased significantly during treatment (–2.10˚; 95% CI –3.51 to –0.68; p = 0.004) and remained stable after treatment (T2–T3). The lower incisors (L1L/ML) were proclined (5.43˚; 95% CI 4.29–6.56; p < 0.001) and remained stable afterwards. All soft tissue variables showed significant changes during treatment, and remained stable in the post-treatment period except for the distance of the upper lip to the E-line (Ls to E-line) which slightly further decreased (T3–T2) (–0.67 mm; 95% CI, –0.99 to –0.36; p < 0.001). The same effect was true for the length of the nose (n-No).

ANOVA was used to analyse the differences in increments of the cephalometric variables for the three facial types and two time periods (T2–T1 and T3–T2). The results showed significant differences between facial types for five variables between T1 and T2 (Table V). No significant differences (not shown in table) between the facial types were found in increments for any of the variables during the post-treatment period (T3–T2). Tukey's range test showed no significant difference in the increments between the hyperdivergent and normodivergent facial types. For four variables out of 17, increments differed significantly between normo- versus hypo-divergent biotypes and/or between hypo- versus hyper-divergent facial types.

The linear regression analysis (Supplementary Table I) showed several significant age and gender effects, mainly concerning the soft tissue cephalometric variables during treatment (T1 to T2), but the explained

Table IV. Mean increments of the cephalometric variables and 95% confidence intervals (95% CI) for the two different time periods (T2–T1 and T3–T2).

	T2–T1			T3–T2		
	Mean diff	95% CI	*p* value	Mean diff	95% CI	*p* value
Skeletal sagittal						
SNA (º)	–2.23	–2.66… –1.80	<0.001	2.82	2.19…3.45	<0.001
SNB (º)	–0.35	–0.64… –0.07	0.016	2.21	1.75…2.67	<0.001
ANB (º)	–1.88	–2.22… –1.54	<0.001	0.61	0.18…1.04	0.006
Skeletal vertical						
SN/ANS-PNS (º)	0.04	–0.28…0.37	0.797	–1.98	–2.46… –1.49	<0.001
SN/ML (º)	0.33	–0.04…0.70	0.08	–1.53	–2.06… –0.99	<0.001
ANS-PNS/ML (º)	0.28	–0.09…0.66	0.137	0.56	0.06… 1.06	0.029
ANS-Me by N-Me (ratio)	0.35	0.07…0.63	0.015	1.14	0.81… 1.48	<0.001
Dentoalveolar						
U1L/ANS-PNS (º)	–2.10	–3.51… –0.68	0.004	–0.09	–0.96… 0.77	0.828
U1 to A-Pog (mm)	–2.64	–3.05… –2.22	<0.001	–0.48	–0.74… –0.22	<0.001
L1L/ML (º)	5.43	4.29… 6.56	<0.001	0.67	–0.11… 1.45	0.092
L1 to A-Pog (mm)	2.33	1.97… 2.68	<0.001	–1.03	–1.30… –0.77	<0.001
Soft tissue						
Nasolabial angle (º)	1.95	0.49… 3.41	0.009	0.04	–1.56… 1.64	0.961
Ls to E-line (mm)	–2.57	–2.93… –2.20	<0.001	–0.67	–0.99… –0.36	<0.001
Li to E-line (mm)	–1.67	–2.02… –1.31	<0.001	–0.09	–0.36… 0.18	0.519
n-No (mm)	2.98	2.50… 3.46	<0.001	0.97	0.51… 1.42	<0.001
Ls-U1 (mm)	2.44	2.11… 2.78	<0.001	0.13	–0.23… 0.50	0.469
Li-L1 (mm)	–1.56	–1.90… –1.22	<0.001	0.18	–0.11… 0.46	0.223

P values for the paired samples *t*-test.

variance was low, except for n-No (R^2 = 0.419). In addition, after treatment (T2 to T3), there were only a few significant age and gender effects. The highest explained variance was found for the angle ANS-PNS/ML (R^2 = 0.211). Facial type had only a minor influence on the cephalometric increments during and after treatment.

Discussion

According to current knowledge, the present study is the first to record the cephalometric outcomes including post-treatment changes of orthodontic treatment following the extraction of maxillary first permanent molars in patients presenting with a Class II division 1 malocclusion. Significant changes were found during treatment for most cephalometric variables. In the post-treatment period, the patient's growth pattern showed a tendency to return to the original form, but the dentoalveolar and soft tissue changes were small.

Sagittal and vertical skeletal changes

Most skeletal changes were highly significant, likely because of normal growth as the mean age at the end of treatment (T2) was 15.6 years. Both the SNA angle and SNB angle decreased during treatment (T1–T2) but increased after treatment (T2–T3), which is a change towards the original growth pattern. In a systematic review on the changes seen in the apical base sagittal relationship in Class II malocclusion management, a mean decrease of the ANB angle of 1.88 degrees (SD 2.06) was found following treatment involving two maxillary premolar extractions, which supports the current findings (Table IV).[12]

Table V. ANOVA followed by Tukey's post hoc test for the differences in the increments of the cephalometric variables for the three facial types.

Cephalometric variable	Facial type	N	Mean	SD	95% CI for Mean Lower bound	95% CI for Mean Upper bound	ANOVA *p* value	Tukey Normo vs hypo	Tukey Normo vs hyper	Tukey Hypo vs hyper
T2–T1										
ANB (°)	Hypo	18	–2.64	1.24	–3.26	–2.03	0.034	x		
	Normo	17	–1.35	1.27	–2.00	–0.70				
	Hyper	48	–1.78	1.64	–2.26	–1.30				
SN/ANS-PNS (°)	Hypo	18	–0.86	1.43	–1.57	–0.15	0.005			x
	Normo	17	–0.10	1.15	–0.69	0.49				
	Hyper	48	0.43	1.48	0.00	0.86				
ANS-Me by N-Me (ratio)	Hypo	18	0.91	1.19	0.31	1.50	0.027			
	Normo	17	0.64	0.91	0.17	1.11				
	Hyper	48	0.04	1.36	–0.36	0.43				
U1L/ANS-PNS (°)	Hypo	18	2.30	6.34	–0.85	5.45	0.004	x		x
	Normo	17	–3.24	6.87	–6.77	0.29				
	Hyper	48	–3.34	5.77	–5.02	–1.67				
U1 to A-pog (mm)	Hypo	18	–1.41	2.01	–2.41	–0.41	0.004			x
	Normo	17	–2.56	1.94	–3.56	–1.57				
	Hyper	48	–3.12	1.69	–3.61	–2.63				

Only variables that showed significant differences for the three facial types are given. X indicates between which facial types Tukey's post hoc test found a significant difference. For ANS-ME by N-Me (ratio), despite the overall significance by ANOVA, Tukey did not reveal any pair of groups to show statistically significant differences. Facial type: hypo, hypodivergent, normo, normodivergent, hyper, hyperdivergent.

The vertical jaw relationship was slightly increased during both observational periods as the skeletal vertical increment ANS-Me by N-Me (ratio) showed a statistically significant change of 0.35% during the treatment period (T2–T1) and 1.14% throughout the follow up (T3–T2). However, the palatal plane-mandibular plane angle (ANS-PNS/ML) showed a statistically non-significant increase during treatment. The clinical significance of this finding is minor due to the limited amount of change. A systematic review reported a comparable result on the vertical dimensions of the face in a comparison of four premolar extraction treatment with non-extraction treatment.[13]

In an earlier study, Class II division 1 extraction treatment was compared with two-phase treatment consisting of a Herbst appliance followed by fixed appliances.[14] At the end of active treatment, larger dental effects were found for the extraction group, whereas in the case of Herbst treatment, the skeletal effects prevailed. Interestingly, a meta-analysis including 12 Herbst appliance studies with data on the ANB-angle and a post-treatment follow-up period of at least one year found a mean ANB reduction during treatment of 1.5°, while the mean change after treatment was 0.2°.[15] Therefore, the net treatment reduction by the Herbst appliance of –1.3° at follow-up is the same as found in the present study.

Dentoalveolar changes

The upper incisor inclination (U1L/ANS-PNS) decreased by 2.10° during treatment (95% CI –3.51 to –0.68; p = 0.004), while the upper incisor moved 2.64 mm distally (U1 to A-Pog). The latter was a decisive movement that resulted in a distal displacement of Point A. The partial loss of distal root displacement, due to the 2.10° of incisor tipping, is considered to be too small to counteract the distal displacement of Point A. The distal displacement of Point A as a result of treatment has also been shown in two previous studies using the same material and the Sagittal Occlusal analysis (SO) according to Pancherz.[14,16]

The lower incisor inclination (L1L/ML) increased significantly during treatment by 5.43° (95% CI 4.29–6.56; $p < 0.001$) and remained stable in the post-treatment period, probably because of the fixed retainers. This rather large proclination likely resulted from levelling of the curve of Spee and the use of Class II elastics. A change in lower incisor inclination is a common finding in Class II treatment and particularly reported in studies involving upper premolar extractions.[17,18]

Proclined lower incisors are assumed to be a risk factor for gingival recession; however, clinical examination of the study patients did not support this. In a systematic review of orthodontic therapy and gingival recession, weak evidence was found that orthodontically proclined lower incisors created a risk for gingival recession.[19] A later systematic review in 2018 concluded that there was no evidence for such a relationship.[20] A 5-year follow-up study comparing proclined and non-proclined lower incisors found no association between the proclination of mandibular incisors and the prevalence of gingival recession[21] and two recent studies in which orthodontically treated patients 10 to 15 years post-treatment were compared with an untreated control group found comparable labial/buccal and lingual/palatal recession between the groups.[22,23] In the absence of evidence, great care must be taken to control the position of the lower incisors during treatment, for example, by reducing the use of Class II elastics or by interproximal stripping of the teeth in the lower arch. In addition, extractions in the lower arch should be considered more often. However, extractions in both arches will be expected to have a greater effect on the soft tissues.[4]

The extraction of the maxillary first molars may also affect the inclination of the second and third molars. The findings of Livas et al.[24] showed that the extraction of the upper first molars resulted in an improvement in the inclination of the second and third molars. In a recent study on dental outcome, it was found that, in 83.3% of the patients, the third molars had erupted by the end of the post-treatment follow-up of 2.5 years.[25] In 8 out of 96 patients, one of the molars had erupted at that time, and in another 8 patients, the molars had yet to erupt. When radiographically checked, only one third molar had a doubtful prognosis, supporting the assumption that normal eruption of the M3s after the extraction of the first molars may be expected.

Soft tissue changes

The patients in the present study showed an increase in the nasolabial angle and a flattening of the profile accompanying a reduction in the overjet. As is known, orthodontic treatment may influence a patient's profile, especially following extractions and extensive retraction of the upper incisors.[26] However, the pattern of soft tissue response after tooth extractions and incisor retraction is unpredictable.[27] To interpret the soft tissue profile changes over the treatment- and post-treatment periods, physiological growth changes first must be taken into consideration. The nasolabial angle does not change significantly with normal growth.[28,29] The Burlington Growth Study showed that nasal projection, chin projection, and upper and lower lip thickness increased with growth between the ages of 6 and 18 years.[30] The midsagittal facial tissue thickness of children and adolescents showed significant gender differences at all ages.[31] Bisharaet al.[32] and Nanda et al.[33] reported that the upper and lower lips become significantly more retruded to the E-line during growth. Gender differences were reported: in females, the lower lip was positioned 2.0 mm posterior to the E-line, which was slightly more retruded than in males.[34] Bishara et al.[32] found that, lower lip position was an average of 1.7 mm posterior to the E-line for adolescent females and males at age 15 years which compares favourably with the present findings.

A systematic review on soft tissue changes in Class II malocclusion patients treated by extractions concluded that the debate regarding extraction effects on soft tissue changes is still far from certain.[3] Factors such as soft tissue thickness, gender differences, pre-treatment labial tension, the type of malocclusion, crowding, and face height influence the effect that extractions have on the soft tissues.[35–41] In one systematic review that included seven articles on upper premolar extractions, it was reported that a mean increase in the nasolabial angle from 2.4° to 11.6° occurred during treatment. Furthermore, the distance from the upper and lower lips to the E-line (Ricketts Esthetic line) changed during treatment, between –0.75 mm and –5.03 mm for Ls to E-line and between –1.00 mm and –4.19 mm for Li to E-line.[3]

In the present case sample, an increase in the nasolabial angle of 1.99° was found over the total observation period, which favours the extraction of more posterior teeth. However, individual variation (SD) was large. Ls to E-line changed in the present cases by –2.57 mm (95% CI –2.93 to –2.20; $p < 0.001$) during treatment, which is comparable with the findings of Janson et al.[3] This change in Ls to E-line continued after treatment and was related to growth of the nose and chin.[42] The Li to E-line changed by –1.67 mm (95% CI –2.93 to –2.20; $p < 0.001$) during treatment, which was again comparable with the findings of the systematic review by Janson et al.[3] This effect remained unchanged during the post-treatment period. A recent systematic review[4] on the soft tissue changes following extraction versus non-extraction fixed appliance treatment reported a considerably heterogeneous soft tissue post-treatment response after Class II extraction therapy, which precluded a consistent prediction of the soft tissue response.

No significant differences can be highlighted, when comparing the outcomes of soft tissue change during Class II treatment involving upper first molar extractions and other extraction modalities, as reported in the systematic reviews.[3,4] The present study further showed that facial type had minimal effect on treatment outcome or post-treatment stability which suggests that, for all facial types, Class II treatment with the extraction of the maxillary first permanent molars might be considered. A study on the dental outcome of this patient group using the Peer Assessment Rating showed that the PAR index was reduced from 28.26 (SD 7.10) at the start of the treatment to 1.22 (SD 2.36), and rose slightly to 2.86 (SD 3.57) during the follow-up period (T2–T3).[25] Furthermore, the literature reports that the mean treatment duration for maxillary first molar extraction cases is comparable to first premolar extraction cases and of the order of 29 versus 28 months, respectively.[12]

When a decision to extract in the upper arch to treat a Class II malocclusion is made, the treatment method described in the present paper could be considered, in particular, when the prognosis of the first maxillary molars is poor compared with the first or second premolars. The result will be an "eight premolar smile," and comparable with non-extraction treatment. The presence of the upper third molars is a mandatory prerequisite. Although the extraction of first molars is a heavier burden for the patient and dentist than extraction of premolars, the advantage is an improved prognosis for the upper third molars, which prevents future surgical removal.[7]

Limitations

This retrospective study was a longitudinal, one-group outcome analysis, which had design limitations. All observed changes were a combination of growth, treatment effects, and aging and it was not possible to differentiate between the three. A selection bias cannot be overlooked. In the selected sample, hyper-divergent patients were over-represented, which might not reflect the Dutch population. Furthermore, compared to a multi-centre, multi-operator trial, a single-centre, one-operator study design is less favourable for generalisability. However, because this is the first study of post-treatment changes of Class II division 1 treatment following upper first permanent molar extractions, it is believed that the design was a solid beginning to the accumulation of additional knowledge regarding the scope and limitations of this treatment option.

The outcome was assessed from the orthodontic perspective. The importance of cephalometrics as a valid outcome measure is currently being questioned. Nevertheless, standard cephalometrics were performed because lateral head films were routinely available, while 3D tools such as stereophotogrammetry and cone beam computerised tomography were unavailable. At the time of these procedures and follow-up, patient-reported outcome and experience measures were not yet widely available, and data that represented the patient's perspective were not collected. In addition, the opinion of the referring general dentists regarding the extraction of the first permanent molars would likely have been of interest.

Conclusion

The results of the present study of Class II division 1 fixed appliance treatment incorporating the extraction of the maxillary first permanent molars suggests that post-treatment skeletal, soft tissue, and dentoalveolar changes are limited. Facial type had only a minor influence on the cephalometric changes during and after treatment. It is advised that care must be taken to control lower incisor inclination during treatment.

Conflict of interest

The authors report no conflict of interest.

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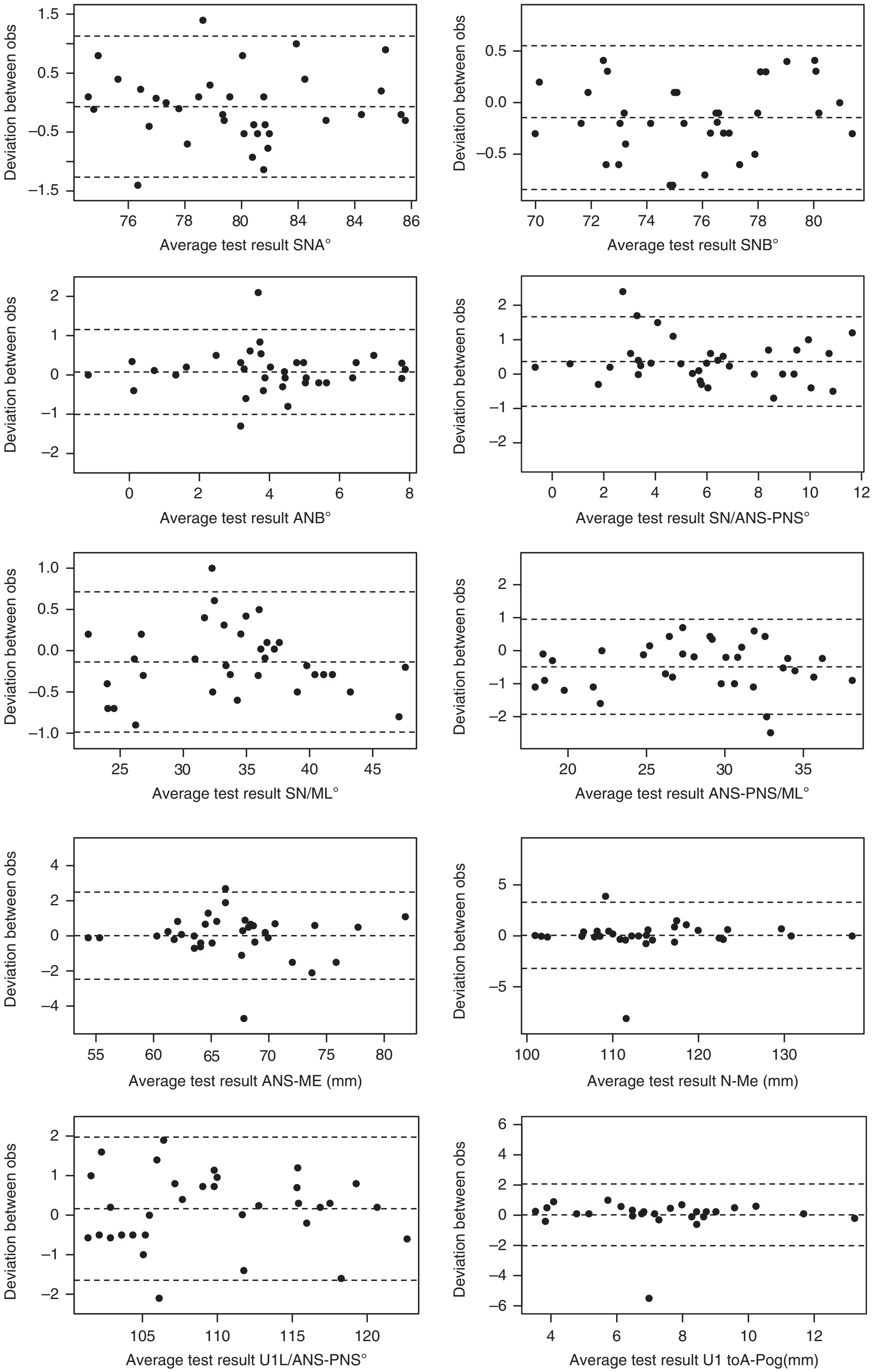
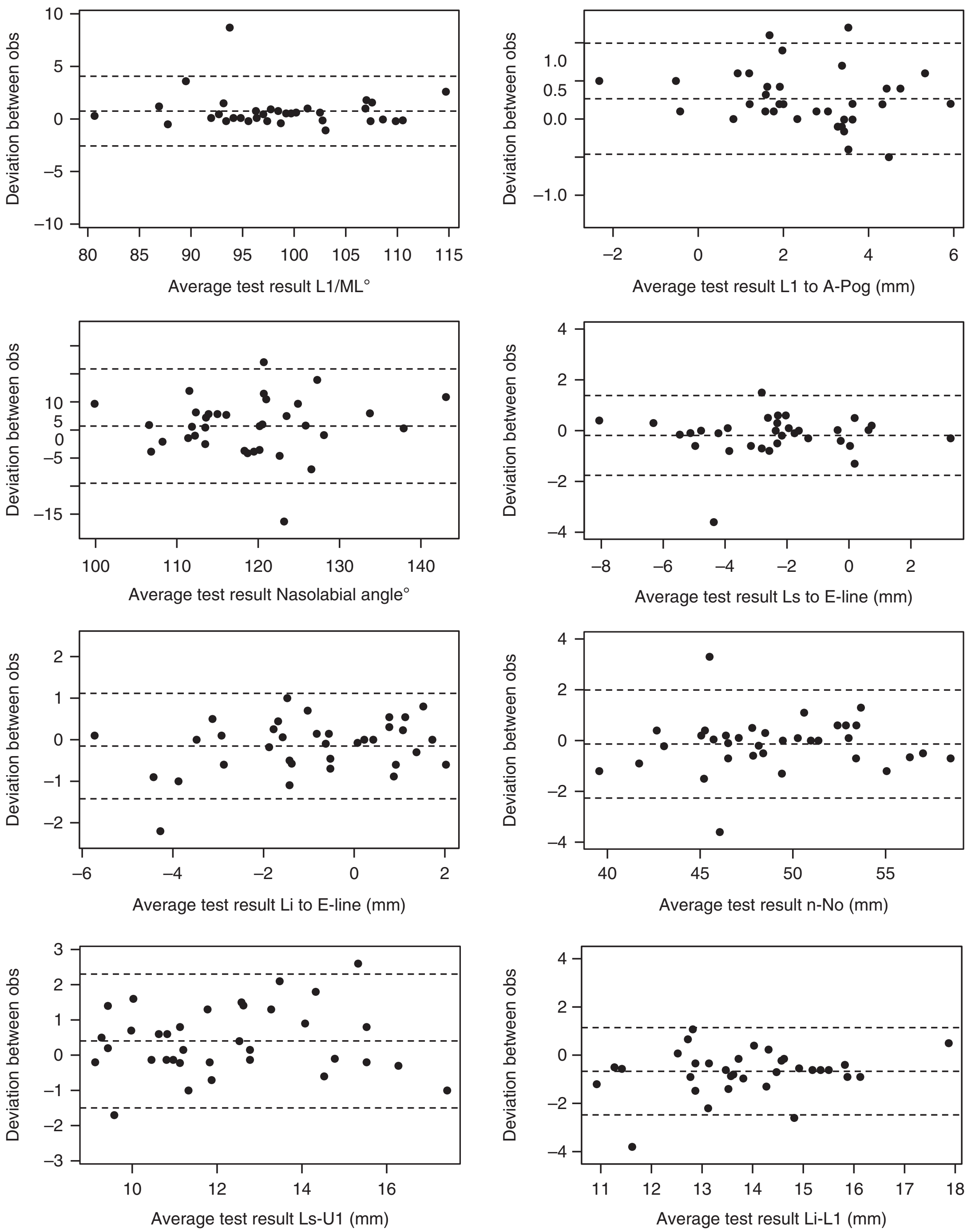
Supplementary Figure 1. Bland Altman plots for the cephalometric variables.




Deviation between obs
Average test result L1/ML°
Deviation between obs
Average test result L1 to A-Pog (mm)
Deviation between obs
Average test result Nasolabial angle°
Deviation between obs
Average test result Ls to E-line (mm)
Deviation between obs
Average test result Li to E-line (mm)
Deviation between obs
Average test result n-No (mm)
Deviation between obs
Average test result Ls-U1 (mm)
Deviation between obs
Average test result Li-L1 (mm)

Supplementary Table I. Linear regression analysis to analyze the effects of sex, age, hypodivergent facial type, and hyperdivergent facial type (reference is normodivergent) on cephalometric outcome variables.

		Analysis T1 to T2 (during treatment)					Analysis T2 to T3 (after treatment)				
		Intercept	Gender (M = 0; F = 1)	Age	Hypo	Hyper	Intercept	Gender (M = 0; F = 1)	Age	Hypo	Hyper
Skeletal sagittal		Outcome (degrees): SNA (R^2 = 0.032)					Outcome (degrees): SNA (R^2 = 0.13)				
	Effect	−3.66	0.47	0.13	−0.52	−0.55	7.35	0.89	−0.43	2.12	0.37
	95%CI	[−8.11...0.8]	[−0.46...1.4]	[−0.19...0.44]	[−1.88...0.84]	[−1.68...0.59]	[1.19...13.52]	[−0.4...2.17]	[−0.86...0.01]	[0.23...4.01]	[−1.19...1.94]
	p	0.106	0.316	0.431	0.449	0.34	0.02	0.172	0.056	0.028	0.635
		Outcome (degrees): SNB (R^2 = 0.07)					Outcome (degrees): SNB (R^2 = 0.085)				
	Effect	−0.28	−0.14	0	0.64	−0.17	5.24	0.13	−0.29	1.34	0.73
	95%CI	[−3.16...2.61]	[−0.74...0.46]	[−0.21...0.2]	[−0.24...1.53]	[−0.9...0.56]	[0.66...9.81]	[−0.82...1.09]	[−0.61...0.04]	[−0.06...2.74]	[−0.43...1.89]
	p	0.85	0.637	0.967	0.151	0.648	0.026	0.787	0.081	0.061	0.216
		Outcome (degrees): ANB (R^2 = 0.123)					Outcome (degrees): ANB (R^2 = 0.084)				
	Effect	−3.4	0.61	0.13	−1.15	−0.39	2.14	0.75	−0.14	0.77	−0.36
	95%CI	[−6.7... −0.1]	[−0.08...1.3]	[−0.1...0.37]	[−2.16... −0.14]	[−1.23...0.45]	[−2.15...6.43]	[−0.14...1.65]	[−0.44...0.17]	[−0.55...2.08]	[−1.45...0.73]
	p	0.044	0.081	0.265	0.026	0.355	0.323	0.097	0.368	0.248	0.516
Skeletal vertical		Outcome (degrees): SN/ANS-PNS (R^2 = 0.153)					Outcome (degrees): SN/ANS-PNS (R^2 = 0.079)				
	Effect	1.49	0.29	−0.13	−0.68	0.46	−0.91	−1.26	−0.02	−0.29	−0.3
	95%CI	[−1.64...4.63]	[−0.36...0.95]	[−0.35...0.09]	[−1.64...0.28]	[−0.33...1.26]	[−5.81...3.99]	[−2.28... −0.23]	[−0.37...0.33]	[−1.79...1.21]	[−1.54...0.94]
	p	0.345	0.372	0.25	0.162	0.25	0.713	0.017	0.901	0.7	0.633
		Outcome (degrees): SN/ML (R^2 = 0.029)					Outcome (degrees): SN/ML (R^2 = 0.105)				
	Effect	2.33	−0.1	−0.12	−0.73	−0.37	−6.02	0.74	0.38	−1.41	−0.97
	95%CI	[−1.47...6.13]	[−0.89...0.69]	[−0.39...0.15]	[−1.89...0.44]	[−1.33...0.6]	[−11.31... −0.73]	[−0.36...1.84]	[0.01...0.76]	[−3.03...0.21]	[−2.31...0.37]
	p	0.226	0.799	0.374	0.217	0.449	0.026	0.185	0.045	0.087	0.154
		Outcome (degrees): ANS-PNS/ML (R^2 = 0.079)					Outcome (degrees): ANS-PNS/ML (R^2=0.211)				
	Effect	0.94	−0.41	0	−0.05	−0.85	−5.34	1.85	0.43	−0.87	−0.57
	95%CI	[−2.84...4.72]	[−1.2...0.38]	[−0.27...0.27]	[−1.21...1.11]	[−1.81...0.11]	[−10.01... −0.67]	[0.88...2.82]	[0.1...0.76]	[−2.3...0.56]	[−1.75...0.62]
	p	0.623	0.307	0.989	0.932	0.083	0.026	<0.001	0.012	0.227	0.345
		Outcome (ratio): ANS-Me by N-Me (R^2 = 0.096)					Outcome (ratio): ANS-Me by N-Me (R^2 = 0.104)				
	Effect	−0.52	−0.03	0.09	0.25	−0.56	3.21	0.29	−0.18	0.98	−0.11
	95%CI	[−3.32...2.28]	[−0.62...0.55]	[−0.11...0.29]	[−0.61...1.11]	[−1.28...0.15]	[−0.12...6.53]	[−0.4...0.99]	[−0.41...0.06]	[−0.04...2]	[−0.95...0.74]
	p	0.713	0.916	0.381	0.56	0.118	0.058	0.402	0.136	0.059	0.801

Dento-alveolar		Outcome (degrees): U1L/ANS-PNS (R^2 = 0.137)						Outcome (degrees): U1L/ANS-PNS (R^2 = 0.087)			
	Effect	−3.42	−1.15	0.05	5.25	−0.04	3.23	−1.89	−0.27	0.46	1.74
	95%CI	[−17.19…10.36]	[−4.02…1.72]	[−0.92…1.03]	[1.03…9.47]	[−3.54…3.46]	[−5.41…11.87]	[−3.69… −0.09]	[−0.89…0.34]	[−2.18…3.11]	[−0.45…3.93]
	p	0.623	0.427	0.913	0.015	0.981	0.459	0.04	0.375	0.729	0.118
		Outcome (mm): U1 to A-Pog (R^2 = 0.13)						Outcome (mm): UI to A-Pog (R^2 = 0.055)			
	Effect	−2.19	−0.18	−0.02	1.11	−0.56	−1.54	−0.01	0.08	−0.53	0.14
	95%CI	[−6.27…1.9]	[−1.03…0.67]	[−0.31…0.27]	[−0.14…2.36]	[−1.6…0.48]	[−4.18…1.09]	[−0.56…0.54]	[−0.1…0.27]	[−1.34…0.27]	[−0.53…0.8]
	p	0.29	0.672	0.881	0.081	0.285	0.247	0.961	0.373	0.191	0.688
		Outcome (degrees): L1L to ML (R^2 = 0.05)						Outcome (degrees): L1L to ML (R^2 = 0.013)			
	Effect	15.47	−1.35	−0.67	−0.01	−1.19	0.01	0.21	0.03	−0.52	0.42
	95%CI	[3.87…27.07]	[−3.77…1.07]	[−1.49…0.15]	[−3.56…3.54]	[−4.13…1.76]	[−8.13…8.16]	[−1.48…1.91]	[−0.54…0.61]	[−3.01…1.97]	[−1.64…2.49]
	p	0.01	0.271	0.11	0.994	0.425	0.997	0.802	0.91	0.679	0.684
		Outcome (mm): L1 to A-Pog (R^2 = 0.127)						Outcome (mm): L1 to A-Pog (R^2 = 0.034)			
	Effect	6.62	−0.62	−0.31	0.7	−0.09	−2.01	0	0.07	−0.34	0.2
	95%CI	[3.11…10.13]	[−1.35…0.11]	[−0.56… −0.07]	[−0.38…1.77]	[−0.98…0.8]	[−4.77…0.75]	[−0.57…0.58]	[−0.12…0.27]	[−1.19…0.5]	[−0.5…0.9]
	p	<0.001	0.097	0.014	0.2	0.847	0.152	0.994	0.474	0.42	0.569
Soft tissue		Outcome (degrees): Nasolabial angle (R^2 = 0.066)						Outcome (degrees): Nasolabial angle (R^2 = 0.02)			
	Effect	12.83	−3.2	−0.68	−2	−0.14	−5.68	−0.29	0.42	1.68	−0.05
	95%CI	[−1.94…27.6]	[−6.28… −0.12]	[−1.73…0.36]	[−6.52…2.52]	[−3.89…3.61]	[−22.3…10.93]	[−3.75…3.18]	[−0.76…1.59]	[−3.41…6.76]	[−4.27…4.17]
	p	0.088	0.042	0.198	0.381	0.942	0.498	0.87	0.48	0.514	0.981
		Outcome (mm): Ls to E-line (R^2 = 0.104)						Outcome (mm): Ls to E-line (R^2 = 0.068)			
	Effect	−6.44	0.65	0.3	−0.43	−0.53	−3.04	0.74	0.14	0.24	0.18
	95%CI	[−10.07… −2.81]	[−0.1…1.41]	[0.05…0.56]	[−1.55…0.68]	[−1.45…0.39]	[−6.21…0.13]	[0.08…1.4]	[−0.08…0.37]	[−0.73…1.21]	[−0.63…0.98]
	p	<0.001	0.089	0.021	0.439	0.254	0.06	0.029	0.205	0.624	0.658
		Outcome (mm): Li to E-line (R^2 = 0.02)						Outcome (mm): Li to E-line (R^2 = 0.048)			
	Effect	−2.73	0.32	0.07	0.32	−0.14	−2.27	0.33	0.13	0.6	0.41
	95%CI	[−6.44…0.98]	[−0.45…1.09]	[−0.19…0.33]	[−0.82…1.45]	[−1.08…0.8]	[−5.07…0.53]	[−0.26…0.91]	[−0.07…0.32]	[−0.26…1.45]	[−0.3…1.12]
	p	0.147	0.412	0.59	0.581	0.77	0.111	0.269	0.205	0.169	0.254
		Outcome (mm): n-No (R^2 = 0.419)						Outcome (mm): n-No (R^2 = 0.121)			
	Effect	13.45	−2.58	−0.71	−0.31	0.18	6.67	−1.2	−0.37	−0.81	−0.15
	95%CI	[9.59…17.3]	[−3.38… −1.78]	[−0.99… −0.44]	[−1.49…0.87]	[−0.8…1.16]	[2.19…11.14]	[−2.13… −0.27]	[−0.69… −0.06]	[−2.18…0.56]	[−1.29…0.98]
	p	<0.001	<0.001	<0.001	0.602	0.721	0.004	0.012	0.021	0.243	0.787

	Outcome (mm): Ls-U1 (R^2 = 0.023)						Outcome (mm): Ls-U1 (R^2 = 0.099)			
Effect	1.68	−0.07	0.06	−0.35	0.22	2.16	0.5	−0.2	0.24	0.59
95%CI	[−1.78…5.13]	[−0.8…0.65]	[−0.19…0.3]	[−1.41…0.71]	[−0.65…1.1]	[−1.48…5.79]	[−0.26…1.26]	[−0.46…0.06]	[−0.87…1.35]	[−0.33…1.52]
p	0.337	0.837	0.646	0.513	0.613	0.241	0.195	0.125	0.669	0.204
	Outcome (mm): Li-L1 (R^2 = 0.042)						Outcome (mm): Li-L1 (R^2 = 0.031)			
Effect	−2.84	−0.44	0.11	0.21	0.05	1.37	0.06	−0.11	0.31	0.34
95%CI	[−6.33…0.65]	[−1.17…0.29]	[−0.14…0.35]	[−0.86…1.28]	[−0.83…0.94]	[−1.57…4.31]	[−0.55…0.67]	[−0.32…0.1]	[−0.59…1.21]	[−0.41…1.08]
p	0.11	0.236	0.398	0.698	0.905	0.357	0.846	0.285	0.494	0.373