SHORT COMMUNICATION

The effect of Herbst appliance treatment on the mandibular plane angle: A cephalometric roentgenographic study

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The purpose of this investigation was to assess the individual reaction pattern and the long-term effect of Herbst appliance treatment on the vertical jaw base relationship, as expressed by the mandibular plane angle (ML/NSL). In the evaluation special reference was given to the pretreatment vertical jaw base relationship (hypodivergent, normodivergent or hyperdivergent). Lateral head films of 80 patients (47 males and 33 females) from before, at start (when the appliance was placed) and at the end of Herbst treatment (when the appliance was removed) as well as 6 months and 4.5 to 5 years posttreatment were analyzed. The ML/NSL angle was on the average unaffected by Herbst therapy. Posttreatment, a continuous decrease in the ML/NSL took place. Male subjects showed a larger angular decrease than female subjects. However, a large interindividual variation existed. No statistically significant differences were found between hypodivergent, normodivergent, and hyperdivergent subjects. (Am J Orthod Dentofac Orthop 1996;110:225-29.)

The influence of removable (activator, bionator, Fränkel) and fixed (Herbst) functional appliances on the vertical jaw base relationship is controversial.[1-6] In cases with a hyperdivergent vertical jaw base relationship, removable functional appliances are not recommended,[7,8] because these appliances may cause a backward rotation of the mandible[4] that, consequently, would deteriorate facial esthetics. In patients with a normodivergent vertical jaw base relationship, the mandibular plane angle seems, on the average, unaffected by Herbst therapy.[9] However, individual treatment changes, especially with respect to the pretreatment mandibular plane angle, as well as the long-term treatment effects on the mandibular plane angle (ML/NSL), have to date received no attention.

The aim of the current cephalometric roentgenographic study was to assess the individual reaction and the long-term effect of the Herbst appliance on the vertical jaw base relationship as expressed by the ML/NSL angle, with special emphasis on the pretreatment vertical jaw base relationship.

MATERIAL

The material was comprised of longitudinal data, derived from lateral head films of 80 patients (47 males and 33 females) with Class II malocclusion and treated with the Herbst appliance. The subjects were treated for an average period of 7 months and followed 4.5 to 5 years after therapy. All subjects were treated to a Class I molar relationship. The age of the subjects at start of treatment varied between 10 and 14 years. The appliance design used has been described previously.[10]

The radiographs were taken before, at start and at the end of treatment as well as 6 months and 4.5 to 5 years after treatment. The time interval between the radiographs from before and at start of treatment varied between 0 and 21 days.

METHOD

The radiographic data were collected at the following times:

- T1 Before treatment
- T2 Start of treatment (insertion of the Herbst appliance)
- T3 After treatment (removal of the Herbst appliance)
- T4 Six months after removal of the Herbst appliance (at the time the occlusion had settled)
- T5 Follow-up (4.5 to 5 years after removal of the Herbst appliance)

On the before treatment head film, the nasion-sella line (NSL) was defined by the anatomic points nasion and sella. The NSL was transferred to all following head films by superimposition of the radiographs on the stable bony structures of the anterior cranial base.[11] The mandibular plane (ML) was assessed by using gonion-gnathion as reference points. The measurements of the ML/NSL were made to the nearest 0.5°.

The subjects were divided into three groups according to their pretreatment vertical jaw base relationship (ML/NSL):

Hypodivergent	ML/NSL ≤ 25°	11 subjects
Normodivergent	25.5° ≤ ML/NSL ≤ 38°	61 subjects
Hyperdivergent	ML/NSL ≤ 38.5°	8 subjects

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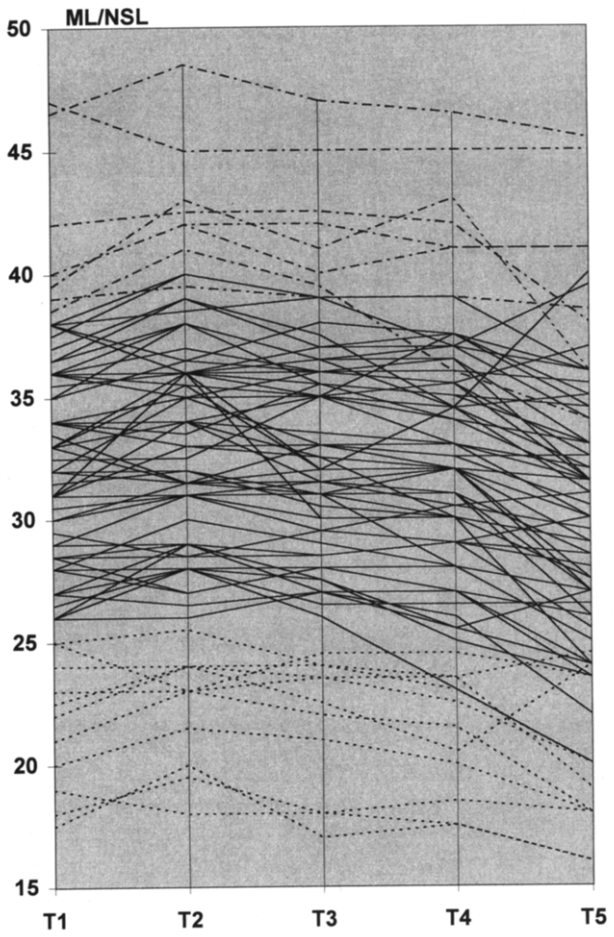

Fig. 1. Individual changes (in degrees) of ML/NSL at different observation intervals (see Method) in 80 subjects treated with Herbst appliance. Differentiation of subjects with hypodivergent (•••••), normodivergent (————), and hyperdivergent (—•—•—) vertical jaw base relationship.

Statistical Methods

For the different variables, the arithmetic mean (M), the standard deviation (SD), the maximum (Max), and minimum (Min) were assessed.

Student's t tests were performed to evaluate the difference in the changes of the ML/NSL when comparing the various observation intervals, the three vertical jaw base relationship groups, and the gender groups. Pearson's correlation coefficients (r) were calculated to assess the interrelations between the pretreatment ML/NSL and its changes during Herbst treatment. The following levels of significance were used: $p < 0.001$ (***), $p < 0.01$ (**), $p < 0.05$ (*). A value of $p \geq 0.05$ was considered as not significant (ns).

Error of the Method

For the assessment of the method error in the measurement of the mandibular plane angle, the lateral head films from 10 randomly selected subjects were analyzed twice. The following formula was used for the method error (ME) calculation: $ME = \sqrt{\sum d^2/2n}$. Where d is the difference between two measurements of. a pair and n is the number of subjects. The combined method error in defining and transferring the NSL from the first head film to the following films, as well as assessing and measuring the mandibular plane angle varied between 0.22° and 0.48° for the different times of examination.

RESULTS

The changes in ML/NSL angle for each subject and each observation interval are shown in Fig. 1. A great interindividual variation was present.

At start of treatment when the appliance was placed (T1-T2), the ML/NSL angle increased an average of 0.8° ($p < 0.001$) (Table I). During the following observation intervals, the ML/NSL angle decreased continuously. In comparison to before treatment, the angle was, on the average, 0.2° smaller (ns) 6 months after treatment and 1.8° smaller ($p < 0.001$) at the time of follow-up.

Considering the whole observation period (T1-T5), male subjects (Mean 2.5°) showed a larger reduction ($p < 0.05$) in the ML/NSL angle than female subjects (Mean 1.4°). This was due to a larger decrease of the ML/NSL angle during the follow-up period in the male subjects (Mean 2.1°) than in the female subjects (Mean 1.2°).

The changes of the ML/NSL angle in the hypodivergent group during and after Herbst treatment were similar to those of the normodivergent group (Table I and Fig. 2). In the hyperdivergent group, the increase in the ML/NSL angle at insertion of the Herbst appliance (start) was almost twice as large (Mean 1.4°) as in the other two groups. Furthermore, in these subjects, the ML/NSL angle was still increased 6 months after removal of the appliance, in comparison to the ML/NSL angle before treatment (Mean 0.1°). During the follow-up period, ML/NSL decreased by a similar amount in the hyperdivergent (Mean 1.8°), hypodivergent (Mean 1.4°), and normodivergent (Mean 1.8°) groups.

At follow-up, there were still eight subjects (two hypodivergent, four normodivergent, and two hyperdivergent) with increased ML/NSL angles when compared with the pretreatment values. On closer examination of these subjects, different unspecific patterns in ML/NSL development during the various examination periods were seen (Fig. 1).

Even though slight differences in the changes of the ML/NSL angle during the various examination periods existed in the three examination groups, none of the group differences were statistically significant.

Correlation analyses were performed to detect possible interrelations between the ML/NSL angles before treatment as well as the angular changes at start (T1-T2) and the changes during and after Herbst treatment.

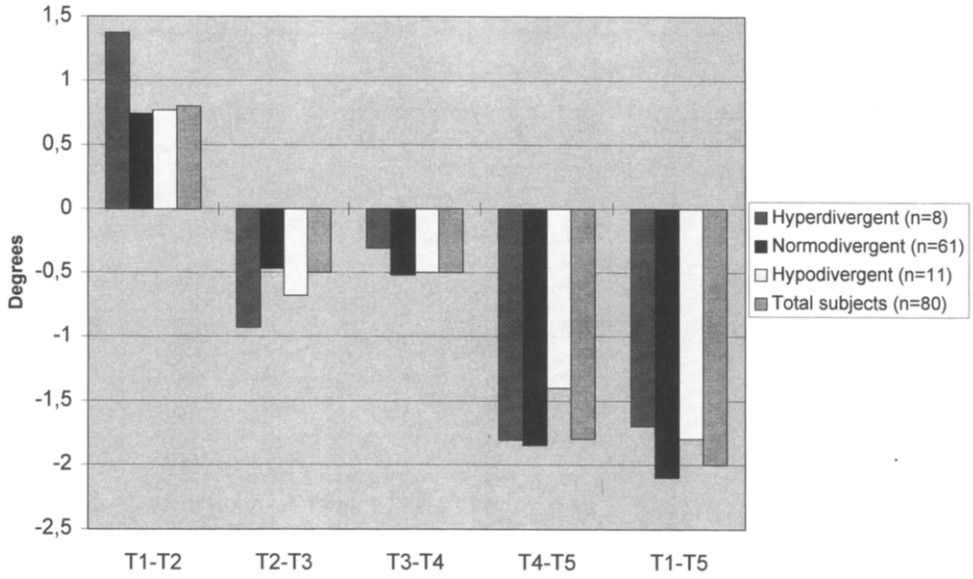

Fig. 2. Average changes in ML/NSL angle (in degrees) during different observation intervals (see Method). Analysis of 80 subjects treated with Herbst appliance grouped according to their vertical jaw base relationship before treatment.

Moderate correlations were detectable both in the hypodivergent and hyperdivergent groups, which showed a tendency toward a smaller opening of ML/NSL at start of treatment with a larger ML/NSL angle before treatment (r = -0.51 and -0.58, respectively). In addition, the total treatment changes (T1-T3) in the hyperdivergent group were smaller in cases with a larger pretreatment ML/NSL (r = -0.61). However, none of these correlations were statistically significant.

The degree of initial ML/NSL opening (T1-T2) showed weak to high correlations with the total treatment changes (T1-T3) meaning that an increased vertical opening at start was associated with an increased vertical closure during treatment. The correlations were significant for the normodivergent (r = 0.30*) and hyperdivergent (r = 0.85**) groups as well as for the total subject material (r = 0.39***).

DISCUSSION

In evaluating the results, it should be taken into account that the hyperdivergent and hypodivergent groups were relatively small.

The average changes in the ML/NSL angle for the total subject material showed a characteristic pattern. The increase of ML/NSL at start (T1-T2) was a result of the incisal edge-to-edge construction bite, which leads to a backward autorotation of the mandible. The decrease in ML/NSL from start to after treatment (T2-T3) can be attributed to a forward autorotation of the lower jaw due to the headgear effect of the appliance[9,12] intruding the maxillary molars. Furthermore, proclination and intrusion of the lower incisors[9] may also facilitate a closing rotation of the mandible.

In contrast to the results of Valant and Sinclair,[13] Herbst appliance therapy did not have a significant effect on the ML/NSL angle, as the initial opening was compensated for both during the active treatment and the settling period after treatment. Even though ML/NSL was, on the average, unaffected by Herbst therapy there was a wide range in the individual response. Of the subjects, 31% had an increased ML/NSL angle 6 months after treatment (T4), when compared with pretreatment values. However, continuous ML/NSL decrease took place during the follow-up period in almost all subjects, which could be interpreted as a result of a normalized function[14] that permitted normal growth and development. In examining the records of the cases, which showed an increased ML/NSL at follow-up no, uniform pattern of ML/NSL development was detectable, neither within nor between the vertical jaw base relationship groups.

The relation between the vertical growth of the anterior (AFH) and the posterior (PFH) face determines the direction of mandibular growth rotation.[15,16] Vertical ramus development has been shown to increase during activator[3] and Herbst[17] treatment. Thus the increased PFH growth might also have contributed to the decrease in ML/NSL. This seems especially plausible as the increase in AFH during Herbst is due to a geometric effect of anterior mandibular repositioning and increased mandibular length.

After removal of the Herbst appliance, a settling

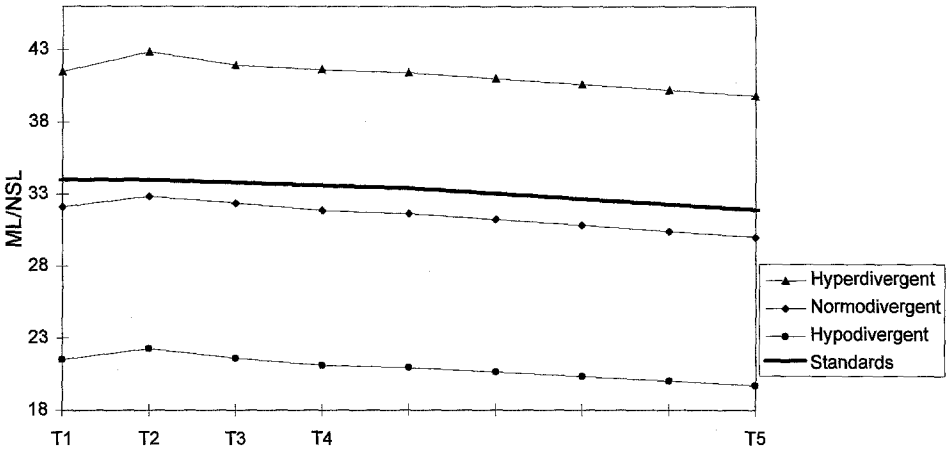

Fig. 3. Average changes in ML/NSL angle (in degrees) during different observation intervals (see Method). Graph shows 80 subjects treated with Herbst appliance grouped according to their vertical jaw base relationship before treatment (hypo-, normo-, and hyperdivergent) and growth standards of normal untreated subjects.[19]

Table I. Changes in the ML/NSL angle (in degrees) during the different observation intervals (see Method). Analysis of 80 subjects treated with the Herbst appliance

	T1-T2	*T1-T3*	*T1-T4*	*T1-T5*	*T2-T3*	*T2-T4*	*T2-T5*	*T3-T4*	*T4-T5*
Hypodivergent group (n = 11)									
Mean	0.8	0.1	-0.4	-1.8	-0.7	-1.2	-2.6	-0.5	-1.4
SD	1.3	0.8	0.9	1.9	1.1	1.3	2.1	0.7	2.1
Max	2.5	1.5	1.0	2.0	1.5	1.5	0.5	0.5	3.5
Min	-2.0	-1.0	-2.0	-5.0	-3.0	-3.5	-5.5	-2.0	-4.5
p value	ns	ns	ns	*	ns	*	**	*	ns
Normodivergent group (n = 61)									
Mean	0.7	0.3	-0.2	-2.1	-0.5	-1.0	-2.8	-0.5	-1.8
SD	1.4	1.0	1.2	2.0	1.5	1.8	2.4	1.1	2.0
Max	5.0	2.5	2.0	3.0	2.5	2.0	1.0	2.5	5.5
Min	-2.0	-2.0	-3.0	-7.0	-6.0	-6.0	-12.0	-3.0	-6.0
p value	***	*	ns	***	*	***	***	***	***
Hyperdivergent group (n = 8)									
Mean	1.4	0.4	0.1	-1.7	-0.9	-1.2	-3.1	-0.3	-1.8
SD	1.6	1.1	1.7	2.0	0.8	1.5	2.6	1.5	2.3
Max	3.5	2.0	3.5	1.0	0.0	0.0	0.0	2.0	0.0
Min	-2.0	-2.0	-2.5	-4.5	-2.0	-5.0	-7.0	-3.5	-7.0
p value	ns	ns	ns	ns	*	ns	*	ns	ns
Total subject material (n = 80)									
Mean	0.8	0.3	-0.2	-2.0	-0.5	-1.0	-2.8	-0.5	-1.8
SD	1.4	1.0	1.2	2.0	1.4	1.7	2.4	1.1	2.0
Max	5.0	2.5	3.5	3.0	2.5	2.0	1.0	2.5	5.5
Min	-2.0	-2.0	-3.0	-7.0	-6.0	-6.0	-12.0	-3.5	-7.0
p value	***	*	ns	***	***	***	***	***	***

Mean,= The arithmetical mean; *SD*, the standard deviation; *Max*, the maximum; *Min*, the minimum.
* Implies $p < 0.05$; ** implies $p < 0.01$; *** implies $p < 0.001$; *ns* implies not significant.

of the occlusion takes place[18] during which the incisor edge-to-edge position changes to a normal overjet and overbite. As a consequence, the ML/NSL decreases by autorotation. The decrease of the ML/NSL during the follow-up period can be considered to be the result of a normal growth process.[19] The gender differences in the changes of ML/NSL may be explained by the fact that, on the average, boys were treated at earlier skeletal maturity stages and therefore had more residual growth after treatment. These findings are in concordance with other studies that show the mandibular growth direction can be changed with the Herbst appliance but returns to its original pattern after treatment.[17,20,21]

When comparing the current Herbst sample to the normal growth standards of Bhathia and Leighton,[19] the interindividual differences in the changes of ML/NSL in the Herbst sample seem to be the result

of a normal variance than an effect of treatment. The only difference between the growth standards of Bhathia and Leighton[19] and the three vertical jaw base relationship groups of Herbst patients was the absolute value of the ML/NSL angle (Fig. 3). The posttreatment developmental pattern of ML/NSL was identical.

Weak to moderate correlations existed between the before treatment ML/NSL and the observed angular changes during treatment. The tendency in both the hypodivergent and hyperdivergent groups toward a smaller backward rotation of the mandible at start (T1-T2), with a larger ML/NSL before treatment, can be explained by a smaller pretreatment overbite in these subjects. Furthermore, an increased vertical bite opening at start (T1-T2) was associated with a larger compensatory decrease during treatment (T2-T3). This was possibly a consequence of increased vertical forces excerted by the appliance in cases with a large pretreatment overbite.

CONCLUSION

A considerable interindividual variation in the short-term and long-term effects of Herbst appliance treatment on the mandibular plane angle exists. However, Herbst treatment seems not to result in an undesired backward rotation of the mandible.

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