Incisor stability in patients with anterior rotational mandibular growth

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The three-dimensional position of the mandibular incisors dictates sagittal and vertical occlusion and intra-arch space conditions and influences facial esthetics. As such, incisor position constitutes an important feature upon which orthodontic diagnosis and treatment planning is based. Treatment-induced protrusion of the mandibular incisors, often together with generalized arch enlargement, will create space, reduce overjet, and in some cases, enhance lip profile. However, the question of incisor stability following protrusion must be considered.

Edward Angle's[1] hypothesis that a full complement of teeth should always be maintained was later challenged by Tweed[2] based on experiences with orthodontic failures. Little et al.[3] reported in a study of 65 cases that crowding in the mandibular incisor area was still common after retention, even when four premolars had been extracted. Relating relapse in mandibular incisor crowding to the direction of active incisor movement (labial or lingual), Schulhof[4] concluded that no significant intergroup difference could be demonstrated.

Studies[3-6] of the posttreatment stability of mandibular incisors show that no treatment-induced position or inclination of the mandibular incisors can guarantee a stable treatment result. Cases that remain stable have been studied[5-6] with the aim of defining clinical parameters that could be used in prediction of long-term stability, but no such parameters have been found.

In general, the majority of studies have attempted to define optimal incisor position in relation to static morphological structures or

Abstract

The aim of this study was to investigate stability and patterns of relapse tendency in 42 children in whom mandibular incisors had been proclined as part of orthodontic treatment. All patients were selected on the basis of their predicted anterior rotational mandibular growth pattern. Results were based on study casts and standardized cephalometric profile radiographs, registered before and after active treatment as well as after a postretention period.

Results demonstrate the clinical acceptability of the treatment principle employed in that the majority of the treatment changes were maintained well after the cessation of retention. There was, however, a general tendency to slight crowding in the mandibular incisor region in connection with bite deepening and reduction in intercanine distance. The reliability of prediction of mandibular rotation using the morphological criteria method is discussed.

Key Words

Stability • Incisor proclination • Mandibular rotation

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Figure 1
Linear and angular cephalometric variables.
Var. 1: The distance from ii to APg-line, measured in mm
Var. 2: Lower incisor inclination (ILi/ML)
Var. 3: Mandibular prognathism S-N-Pg
Var. 4: Mandibular prognathism S-N-B
Var. 5: Vertical jaw relationship NL/ML
Var 6: Sagittal jaw relationship.

cephalometric planes. The concept of the ideal incisor position in relation to basal bone was first proposed by Tweed[2] and later developed in the FMIA angle.[7] Ricketts,[8] using the material from 1000 cases, recommended the mandibular incisors be placed from 2 mm posterior to 3 mm anterior to the A-Pg line.

Björk and Skieller[9] demonstrated that inclination of the mandibular incisors changed during growth, depending on the rotational pattern of growth. In anterior mandibular growth-rotation (counterclockwise), the incisors become more proclined in relation to a reference line representing the stable structures in the mandible, on average 2.3°, s.d. 4.7°, depending on the degree of anterior rotation. The prediction of anterior mandibular rotation is based on an evaluation of the morphology of the mandible, in particular vertical/anterior inclination of the condylar head; curvature of the mandibular canal; shape of the lower border of the mandible; a posterior inclination of the symphysis; large interincisal, interpremolar, and intermolar angles; and low anterior facial height.[10] These findings form the rationale behind the working hypothesis for the present study, namely that treatment-induced proclination of the mandibular incisors might be expected to be stable if performed in growing patients in whom the mandible is anticipated to develop in an anterior rotational pattern. The treatment would, in effect, take advantage of the normal pattern of growth.

The aim of the present study was to investigate mandibular incisor position and stability in a group of patients with an expected anterior mandibular rotational growth pattern. In each case proclination/anterior translation of the mandibular incisors was performed as part of active treatment. The study evaluates the clinical applicability of the treatment principle and elucidates factors concerned with relapse in incisal position and crowding.

Material and methods

The material for the present retrospective study consisted of study casts and standardized cephalograms (taken on the same cephalostat) of 42 patients (23 male, 19 female) treated by one of the authors (C.E.A.).

All patients were selected on the basis of assumed anterior rotational growth pattern, using the morphological criteria described by Björk.[10] The cases investigated exhibited either Angle Class I or Class II malocclusion. None had digit-sucking habits, although 11 had dysfunction of the lower lip in connection with a retroclination

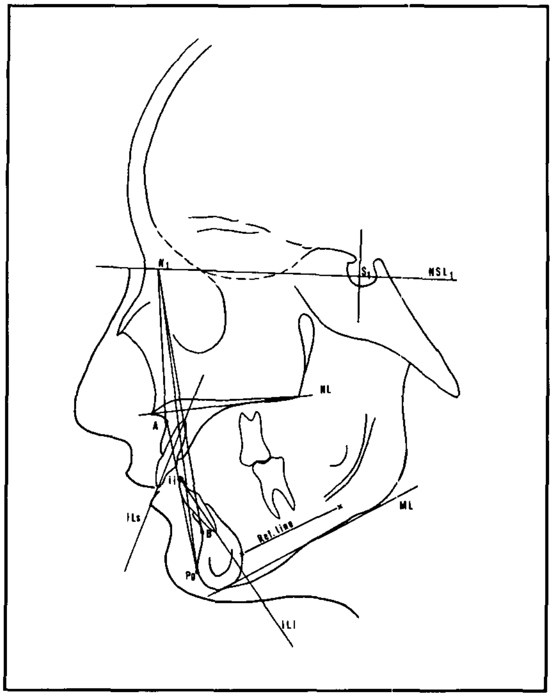

Figure 1

of the mandibular incisors.

All patients were treated with full edgewise mechanics. Maxillary first premolars were extracted in 15 patients, and all but two were treated without extractions in the mandibular arch. The one factor that all patients had in common was that their treatment included proclination or bodily anterior movement of the mandibular incisors. The patients were chosen consecutively before treatment, based on the fulfillment of the named criteria.

Orthodontic records were gathered at three stages: stage 1 was prior to active orthodontic treatment (mean age 12 years 5 months, range 8 year 6 months to 15 years 11 months); stage 2 was after active treatment and prior to retention (mean age 14 years 4 months, range 12 years 7 months to 17 years 8 months); and stage 3 was after retention and a postretention period of not less than 12 months (mean age 22 years 1 month, range 18 years 7 months to 26 years 6 months).

The period between stage 1 and stage 2—active treatment—is termed time 1; the retention and postretention phases, between stage 2 and stage 3, constitute time 2. Time 2 lasted, on average 7 years 4 months, with a range of 2 years 9 months to 12 years 11 months. During this period, standard retention was performed (upper plate and lower canine-to-canine retainer) and discontinued at the cessation of growth (hand-wrist radiographs). Final registration (stage 3) was performed on average 4 years 0 months (range 1 year 1 month to 9 years 3 months) later.

Table 1
Reproducibility of cephalometric parameters.

Variable	First reading mean	First reading s.d.	Second reading mean	Second reading s.d.	d	t-test	sig.	r	sig
1 ii-APg	3.1	1.75	2.6	1.72	0.44	2.37	*	0.91	***
2 ILi/ML	103.1	8.45	102.8	6.90	0.21	0.22	n.s.	0.90	***
3 S-N-Pg	81.1	6.94	81.2	6.04	0.11	0.71	n.s.	0.996	***
4 S-N-B	78.2	4.89	78.3	4.71	0.16	1.12	n.s.	0.99	***
5 NL/ML	25.5	8.84	25.4	8.41	0.06	0.24	n.s.	0.99	***
6 ANB	4.6	1.82	4.4	1.71	0.20	1.32	n.s.	0.95	***

*=P<0.05; **=P<0.01; ***=P<0.001

Time 3 represents the entire observation period (stage 1 to stage 3).

Cephalometric reference points were recorded on acetate paper by one author (C.E.A). All tracings were digitized and measured using a Cherry (R) digitizer and a standard cephalometric program ("Cephaloplot," Megasoft, Randers, Denmark).

The variables used in the cephalometric analysis are shown in Figure 1 and Table 1. The majority of the parameters used are standard cephalometric parameters, although the method of radiographic superimposition should be mentioned. Due to remodeling of structures in the cranial base and of the mandibular contour, points sella (S_1) and nasion (N_1) were transferred from the first radiograph in each series to the subsequent two using the stable structure method, as described by Björk and Skieller.[11] In the mandible, two points placed arbitrarily on the first radiograph were used to create a reference line that was transferred to the subsequent radiographs using the stable structures.[11] Mandibular rotation was expressed as change in the inclination of the constructed reference line to the stable N_1-S_1 line. Changes in incisal inclination were expressed by the angle between the mandibular incisor and the mandibular reference line. Because the mandibular reference line was arbitrary, it was necessary to express the absolute values for mandibular incisor inclination at each of the three registration stages in relation to the mandibular line (ML).

Study casts at each stage were measured by one of the authors (C.E.A.) using a Vernier caliper measuring to 0.1 mm and using parameters describing arch length, arch width (canine, premolar, and molar), and irregularity index, as shown in Figure 2A-B (Little[12]).

Further computation of the results of both the cephalometric and study cast analyses was performed by means of a computer statistical program (Epistat, public domain program, T. Gustafson, Tex).

The value of each cephalometric and linear parameter for the various stages was described using group means and standard deviations. Changes in values observed in the three registration stages were tested for statistical significance using a paired Students t-test, after confirming normal distribution and homogeneity of variance. Correlation between changes observed in time 1 and time 2 were evaluated using Pearson's correlation analysis, again assuming normal distribution.

Reproducibility study

A study of intraobserver reproducibility for both the cephalometric and the study cast analyses was performed by one of the authors (C.E.A.), repeating the measurements after an interval of at least 1 week. Differences between first and second readings were tested using a paired Students t-test, and correlation coefficients were calculated. The results are shown in Tables 1 and 2.

Figure 2A
Linear variables in study cast analysis.
a: intercanine width
b: interpremolar width
c: intermolar width
d+e: arch length.

Figure 2B
Irregularity index (sum u+v+x+y+z).

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Figure 3A
Incisal position relative to A-Pg line at stage 1 and stage 2.

Figure 3B
Incisal position relative to A-Pg line at stage 2 and stage 3.

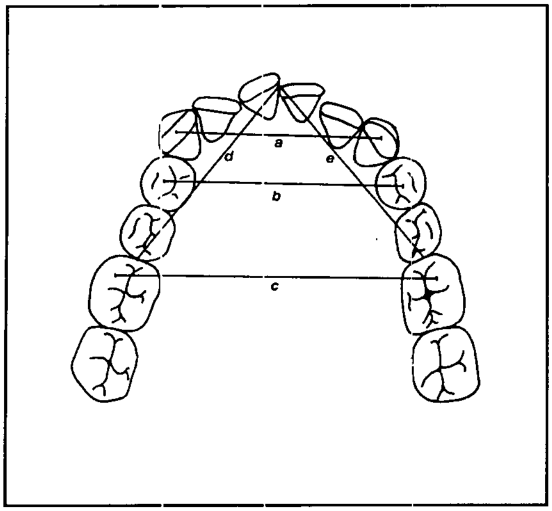

Figure 2A

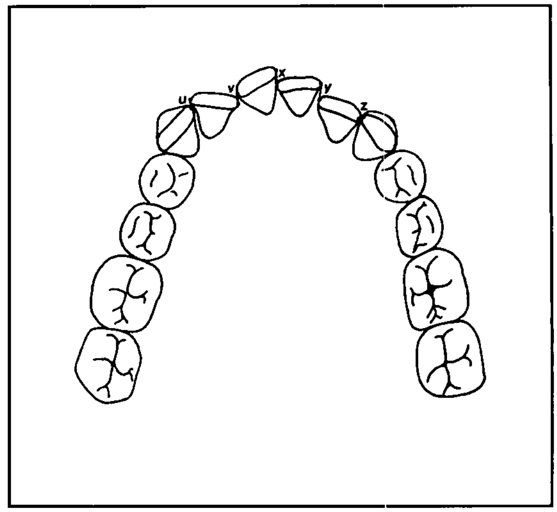

Figure 2B

Table 2
Reproducibility of linear study cast parameters.

Variable	First reading mean	First reading s.d.	Second reading mean	Second reading s.d.	d	t-test	sig.	r	sig.
Arch length	61.9	3.02	62.0	2.70	0.07	0.28	n.s.	0.95	***
Intermolar width	45.1	2.37	44.8	2.10	0.24	2.00	n.s.	0.99	***
Interpremolar width	35.0	1.48	34.99	1.49	0.01	0.04	n.s.	0.92	***
Intercanine width	26.9	1.82	27.1	1.81	0.18	1.90	n.s.	0.98	***
Irregularity index	3.5	2.45	3.6	2.33	0.09	0.47	n.s.	0.95	***

*=P<0.05; **=P<0.01; ***=P<0.001

Results

The results of the reproducibility study indicate that all variables in both cephalometric and linear study cast measurements were highly reproducible at the intraobserver level. The only exception was in the cephalometric variables where the position of the incisal edges to the A-Pg line showed a slightly significant difference between first and second readings (P<0.05). A very high correlation existed between all first and second readings. With regard to the linear measurements performed on the study casts (Table 2), no statistical difference between first and second readings was found, and all correlation coefficients were high and significant.

The results of the cephalometric analysis are shown in Table 3. Prior to orthodontic treatment the average position of incision inferius was 2.1 mm (s.d. 1.95 mm) posterior to the A-Pg line, the incisors being inclined at 94.5° (s.d. 7.56°) to the mandibular plane. The inclination of the maxillary incisors to the nasal plane was 110.1° (s.d. 9.86°). Mandibular prognathism to pogonion was 77.7° (s.d. 4.23°) and to point B, 75.5° (s.d. 3.73°). The ANB angle was 4.8° (s.d. 2.20°) and the mandibular inclination, SN/ML, was 28.9° (s.d. 5.71°). The average overjet was 10.5 mm (s.d. 4.16) and the overbite 6.5 mm (s.d. 1.79).

After active treatment (stage 2) the mandibular incisors had been proclined to an average position of 1.1 mm (s.d. 2.27 mm) anterior to the A-Pg line and at an inclination of 104.3° (s.d. 8.41°) to the mandibular plane. Both changes were statistically significant (P<0.001). At the same time the inclination of the maxillary incisors was statistically unchanged. Mandibular prognathism, measured to both pogonion (78.8°) and B point (76.6°), had increased significantly (P<0.001), while ANB decreased to 3.6° (P<0.001). The change in the mandibular inclination to 29.1° was not statistically significant. As a result of these changes, mean overjet re-

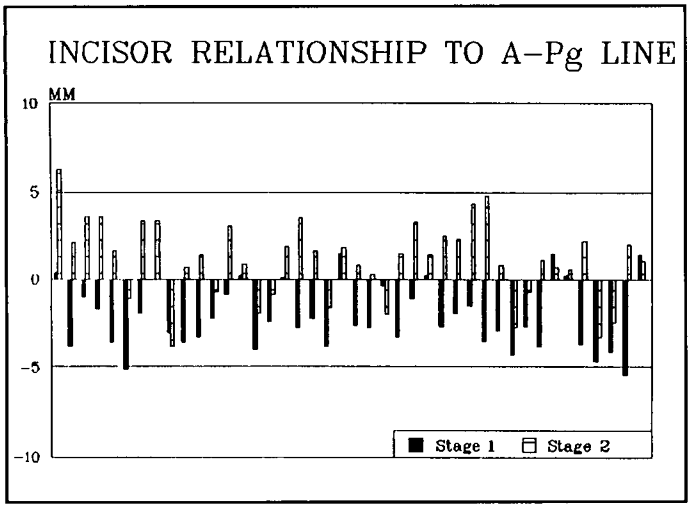

Figure 3A

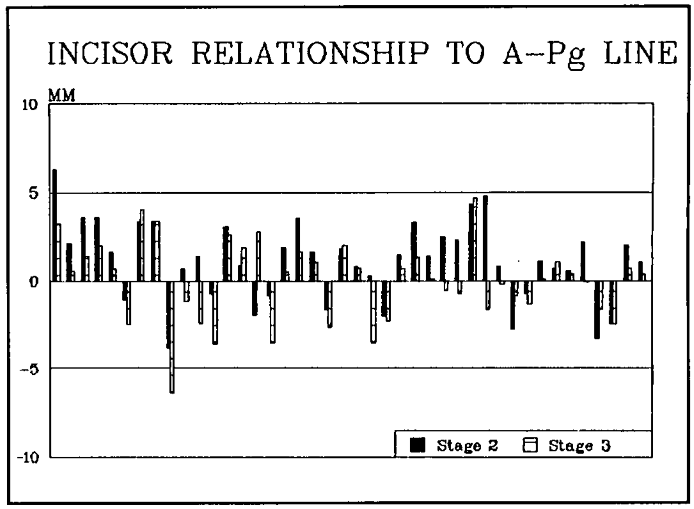

Figure 3B

duced from 10.5 mm (s.d. 4.16) at stage 1 to 3.5 mm (s.d. 1.02) at stage 2. Good incisor contact was achieved.

Subsequent to the retention and postretention periods (stage 3), the mean position of incision inferius was exactly on the A-Pg line (0.0 mm, s.d. 2.29 mm), and incisor inclination to the mandibular line diminished to 100.9° (s.d. 7.78°). Both changes were significant (P<0.001). Individual values for the distance from incision inferius to the A-Pg line at all three stages are shown in Figure 3A-B. Figure 3A demonstrates how, in the majority of cases, the incisors were proclined from a position behind the A-Pg line to a point in front of the line. For a number of patients, the result of proclination was an incisor position anterior to that (3.0 mm) recommended by Ricketts.[8] In the majority of cases the incisors uprighted subsequent to time 2, although they tended to remain in a position anterior to the A-Pg line (Figure 3B). In some cases, even though active treatment left the incisors anterior to the A-Pg line, the teeth tipped even farther anteriorly during time 2.

The average inclination of the maxillary incisors at stage 3 (Table 3) diminished to 109.2° (s.d. 7.02°, P<0.001). Mandibular prognathism continued to increase, both to Pg (80.9° s.d. 4.72°) and to B point (78.3° s.d. 4.26°), both cases P<0.001. The ANB angle remained practically unchanged at 3.8° (s.d. 2.14°, n.s). Mandibular inclination was reduced to 26.0° (s.d. 6.06° P<0.001).

The sum of the changes mentioned above was an increase in overjet to 4.1 mm (s.d. 1.13, P< 0.05) and vertical overbite to 4.1 mm (s.d. 1.72, P<0.001).

Compared with the values seen at stage 1, the results of the treatment, retention and postretention phases, as described at stage 3,

Table 3
Comparison of cephalometric values at the three registration stages.

	Stage 1 mean	Stage 1 s.d.	Stage 2 mean	Stage 2 s.d.	Stage 3 mean	Stage 3 s.d.
ii/A-Pg	-2.1	1.95	1.1	2.27	0.0	2.29
		t=8.77***			t=3.89***	
			t=5.75***			
ILi/ML	94.5°	7.56	104.3°	8.41	100.9°	7.78
		t=8.96***			t=4.30***	
			t=7.66***			
ILs/NL	110.1°	9.86	111.2°	7.49	109.2°	7.02
		t=0.84 n.s			t=3.59***	
			t=0.63 n.s			
S-N-Pg	77.7°	4.23	78.8°	4.71	80.9°	4.72
		t=4.45***			t=***	
			t=8.95***			
S-N-B	75.5°	3.73	76.6°	4.21	78.3°	4.26
		t=4.80***			t=4.79***	
			t=7.44***			
SN/ML	28.9°	5.71	29.1°	5.60	26.0°	6.06
		t=0.67 n.s.			t=7.07***	
			t=6.82***			
ANB	4.8°	2.20	3.6°	2.30	3.8°	2.14
		t=6.19***			t=1.01 n.s.	
			t=.79***			
Overjet	10.5 mm	4.16	3.5 mm	1.02	4.1 mm	1.13
		t=10.96***			t=2.65*	
			t=10.58***			
Overbite	6.5 mm	1.79	2.4 mm	1.40	4.1 mm	1.72
		t=11.62 ***			t=5.15***	
			t=8.18***			

*=P<0.05; **=P<0.01; ***=P<0.001

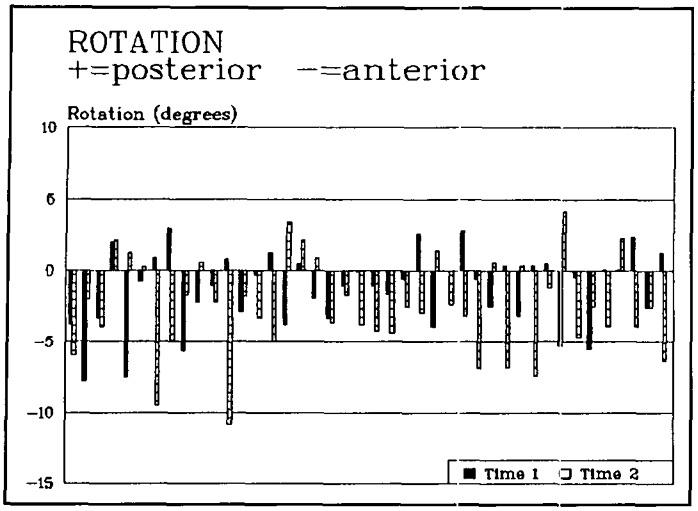

Figure 4A

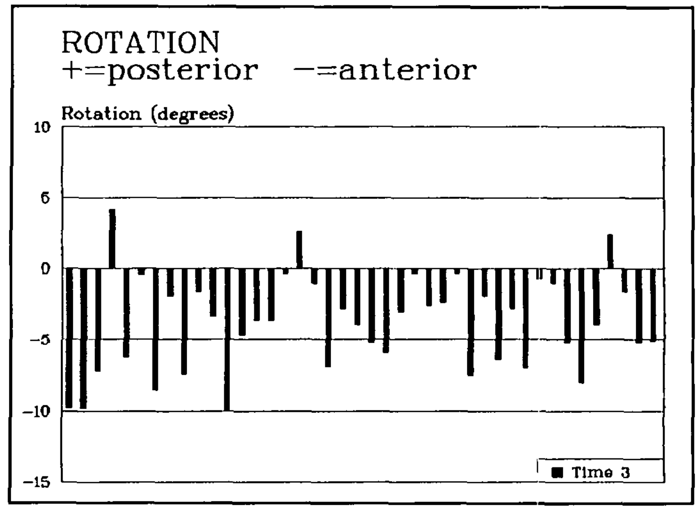

Figure 4B

Table 4
Analysis of correlation for cephalometric changes observed in time 1 and time 2.

	Time 1 mean	Time 1 s.d.	Time 2 mean	Time 2 s.d.	r	sig.
ii/A-Pg	2.7 mm	3.00 mm	-1.2 mm	1.78 mm	-0.35	**
ILi/ML	8.9°	8.49°	-3.4°	5.38°	-0.51	***
ILs/NL	1.4°	10.05°	-1.9°	4.52°	-0.06	n.s.
S-N-Pg	1.1°	1.49°	2.1°	2.16°	-0.40	**
S-N-B	1.1°	1.39°	1.6°	2.12°	-0.27	n.s.
Mand. rotation	-1.3°	2.70°	-2.7°	3.28°	-0.31	*
ANB	-1.3°	1.32°	0.2°	1.24°	-0.37	**

*=P<0.05; **=P<0.01; ***=P<0.001

Figure 4A
Mandibular rotation in time 1 (active treatment) and time 2 (retention and postretention).

Figure 4B
Mandibular rotation in time 3 (total observation time).

demonstrate the following effects: proclination of the mandibular incisors, both to the A-Pg line and the mandibular plane; an increase in mandibular prognathism (to Pg and B point); and a reduction in sagittal and vertical jaw relationships. These changes were all statistically significant (P<0.001). Inclination of the maxillary incisors to the NL plane was unchanged. The reductions in overjet and overbite were likewise significant at the P<0.001 level.

Differences in cephalometric values were calculated for the two periods of observation, namely, time 1, the period of active treatment, and time 2, the retention and postretention period. Correlation between changes observed during the above-named periods was tested using a Pearson's correlation analysis. Values and correlation coefficients can be seen in Table 4. With regard to the position (ii/A-Pg) and inclination (ILi/ML) of the mandibular incisors, a negative correlation existed between the changes in the two periods (r= -0.35 P<0.01 and r=-0.51 P<0.001, respectively). The same applied to the sagittal position of the mandible, measured to pogonion (r= -0.40 P<0.01) and to the rotation of the mandible as judged by the difference in the inclination of the arbitrary reference line to the "stable" (transferred) N_1-S_1 line (r= -0.31 P<0.05).

With regard to the study cast analyses, average values and standard deviations for the parameters measured at the three registration stages can be seen in Table 5, as can the statistical evaluation of interstage differences, tested by means of a paired Students t-test. During treatment, arch length and width at the molars and premolars increased significantly (P<0.001) and the irregularity index decreased (P<0.001), although the intercanine distance remained practically unchanged. In the retention and postretention period (time 2) all parameters describing arch width and length were significantly decreased and the irregularity index increased.

Comparing stage 3 with stage 1, arch length was unchanged, although an increase in arch width had been maintained at the molars (P<0.05) and premolars (P<0.01). No change in intercanine width was seen and the irregularity index had decreased (P<0.01).

Average differences for changes occurring in time 1 and time 2 are shown in Table 6. Correlation coefficients between changes observed in the two periods were calculated and, as shown, a negative correlation existed for all parameters, although at various levels of significance.

With regard to changes in the irregularity index, it was decided to evaluate possible correlations with a number of factors that could be of etiological relevance. The variables chosen and their correlation to the change in the irregularity index in time 2 can be seen in Table 7. The results illustrate that change in irregularity of the mandibular incisor region during time 2 is correlated to loss of intercanine width (r= -0.46 P<0.01) and overbite (r=-0.39 P<0.05). No correlation was found between the irregularity index and arch length, incisor inclination, changes in mandibular prognathism, sagittal jaw relationship (ANB), or mandibular rotation.

The present study was based on a series of patients chosen on the pretext of an anterior rotational mandibular growth pattern. The average mandibular rotations for the two periods, time 1 and time 2, are shown in Table 4. The individual values for these two periods, as well as the total observation time, are illustrated in Figure 4A-B. During the period of active treatment, Figure 4A, the majority of patients exhibited an anterior rotational pattern (negative value), although 15 patients rotated in a posterior direction. During time 2 (retention and postretention), 30 patients rotated in an anterior direction, and 12 patients rotated in a posterior direction. Over the total observation period, Figure 4B (time 3), most patients exhibited an anterior rotational growth pattern, although three demonstrated an overall posterior rotational pattern.

Discussion

Mandibular incisors are often proclined, either as a means of creating space in the mandibular arch, to reduce an increased overjet, or to improve the facial profile. While proclination can be achieved easily, the stability of the results has been the subject of much discussion. In an attempt to approach the subject in a physiological manner, the present study related active mandibular incisor proclination to anterior mandibular growth rotation. The evaluation of incisor proclination and mandibular rotation raises two questions: how reliable is the prediction method, and how stable are the orthodontic results?

The patients comprising the study material were chosen consecutively, and diagnostic records were gathered at three stages. The final registration was made at least 1 year subsequent to retention so that the natural development after retention was included. Reproducibility of the cephalometric and linear parameters was tested and found to be acceptable; reproducibility of the method of superimposition has been reported previously by Baumrind et al.[13] and Cook and Gravely.[14] All measurements were made by one investigator to avoid possible interobserver variation. Patient selection was based on a morphological appraisal of the growth pattern as

Table 5
Comparison of linear study cast variables at three registration stages

	Stage 1 mean	Stage 1 s.d.	Stage 2 mean	Stage 2 s.d.	Stage 3 mean	Stage 3 s.d.
Arch length	59.9	4.72	62.5	3.95	58.9	3.75
		t=4.86***			t=15.06***	
			t=1.56 n.s.			
Intermolar width	44.1	2.53	45.5	2.33	44.8	2.45
		t=4.34***			t=3.07**	
			t=2.67*			
Interpremolar width	33.5	2.34	35.1	1.84	34.5	2.31
		t=4.83***				t=3.04***
			t=3.49**			
Intercanine width	26.5	2.23	27.0	1.45	26.2	1.66
		t=1.95 n.s.			t=5.61***	
			t=0.85 n.s.			
Irreg. index	4.5	3.61	1.7	0.73	2.8	1.68
		t=5.06***			t=4.55***	
			t=3.03**			

*=P<0.05; **=P<0.01; ***=P<0.001

Table 6
Analysis of correlation for changes in linear study cast measurements in time 1 and time 2

	Time 1 mean	Time 1 s.d.	Time 2 mean	Time 2 s.d.	r	sig.
Arch length	2.6	3.89	-3.6	1.45	-0.36	**
Intermolar width	1.4	2.18	-0.7	1.46	-0.53	***
Interpremolar width	1.8	2.62	-0.6	1.15	-0.34	*
Intercanine width	0.5	2.00	-0.8	0.92	-0.37	**
Irregularity index	-2.9	3.59	1.1	1.60	-0.19	n.s.

*=P<0.05; **=P<0.01; ***=P<0.001

Table 7
Analysis of correlation between changes in irregularity index (dependant variable) and changes in other selected parameters in time 2

Arch length	r= 0.08	n.s.
Intercanine width	r= -0.46	**
ILi/ML	r= -0.08	n.s.
S-N-Pg	r= o.12	n.s.
Mand. rot.	r= 0.17	n.s.
Overbite	r= 0.39	*
ANB	r= -0.08	n.s.

*=P<0.05; **=P<0.01; ***=P<0.001

Figure 5A
Changes during active treatment (time 1).

Figure 5B
Changes in the retention/postretention period (time 2).

Figure 5C
Intramandibular and rotational changes in time 1.

Figure 5D
Intramandibular and rotational changes in time 2.

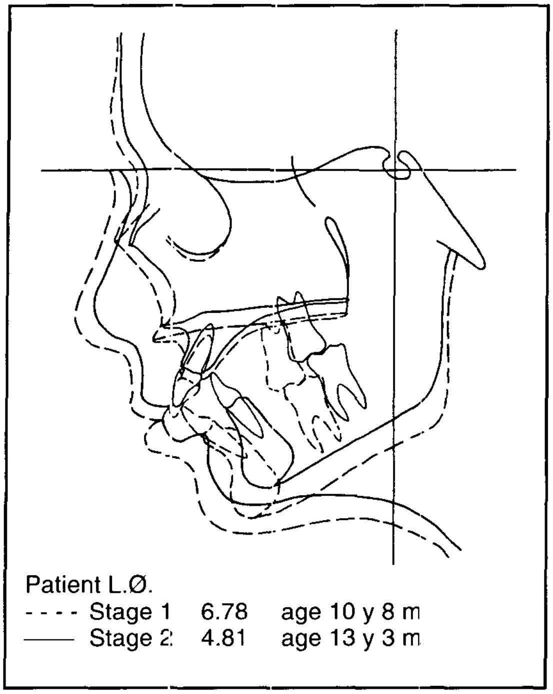

Figure 5A

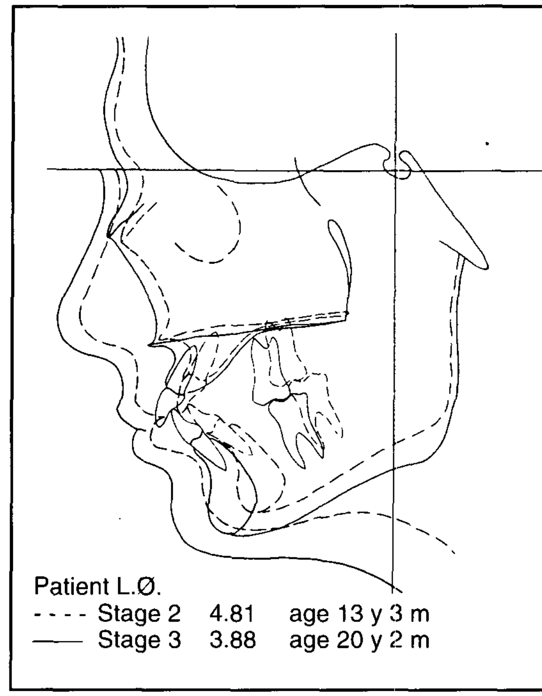

Figure 5B

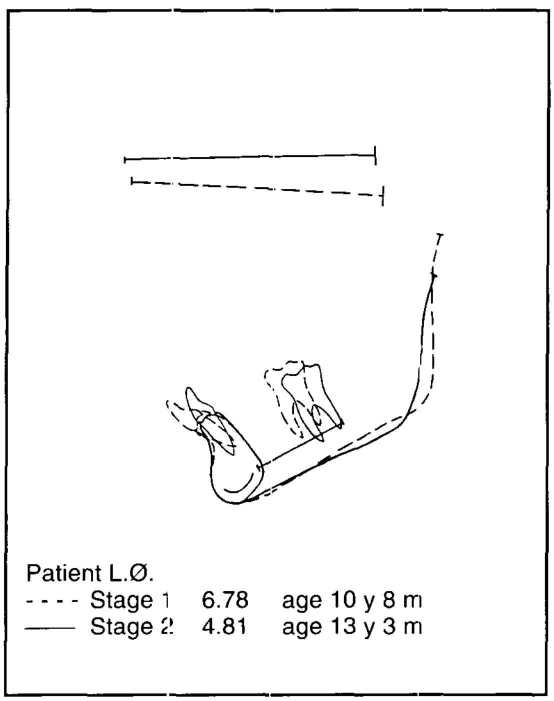

Figure 5C

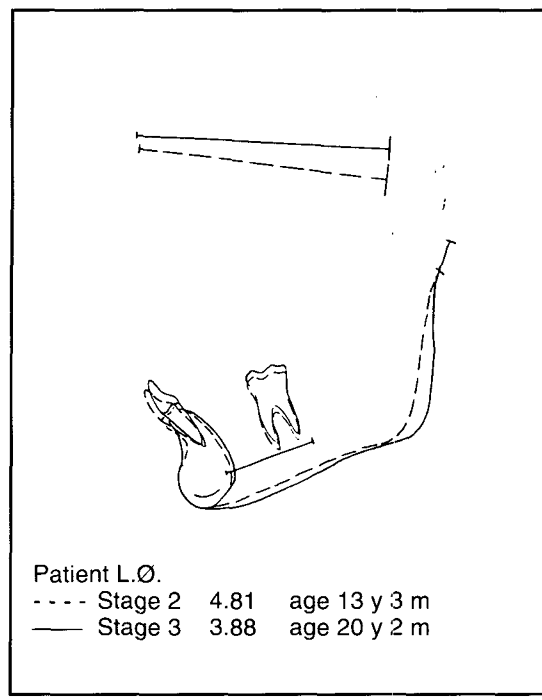

Figure 5D

described by Björk.[10] While the applicability of the method has been criticized by Baumrind et al.,[16] the simplicity of the morphological evaluation makes it the most realistic for general clinical use. In the present study, a posterior mandibular rotation was often observed during treatment, presumably as a result of treatment-induced tooth extrusion (Figure 4A). In the posttreatment phase it could be hypothesized that patients who underwent posterior rotation during the active treatment (time 1) would demonstrate anterior "catch up" in time 2. Unexpectedly, this was not always the case, as can be seen in Figure 4A. Equally unexpectedly, a number of patients exhibited a posterior rotation in time 2 after an anterior rotation in time 1. A predictable relationship between the rotational patterns in time 1 and time 2 could therefore not be determined. As shown in Figure 4B, a majority of the patients dem-

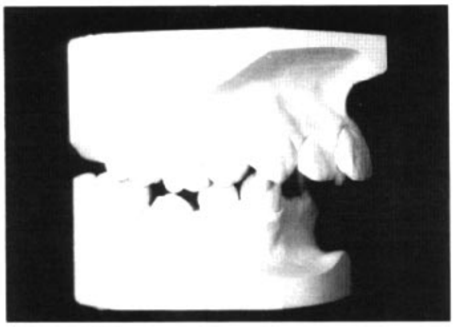

Figure 5E

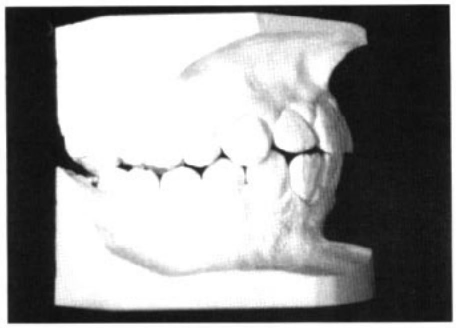

Figure 5G

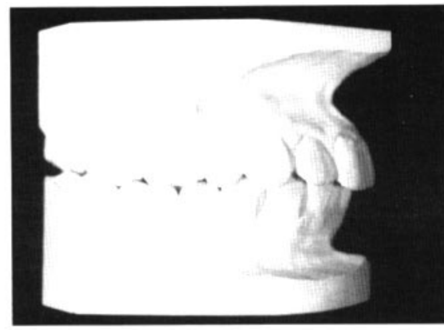

Figure 5I

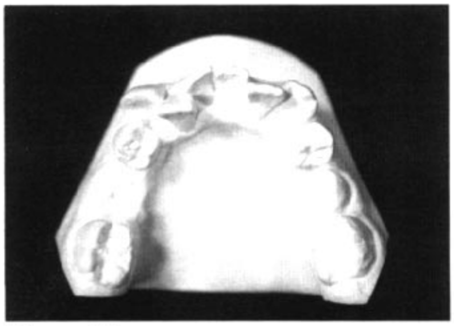

Figure 5F

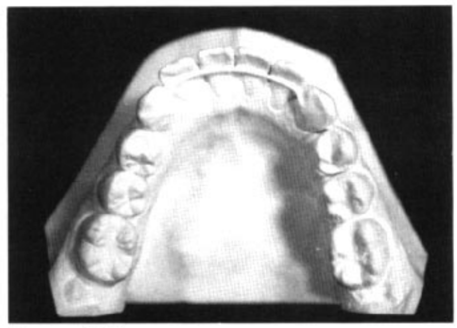

Figure 5H

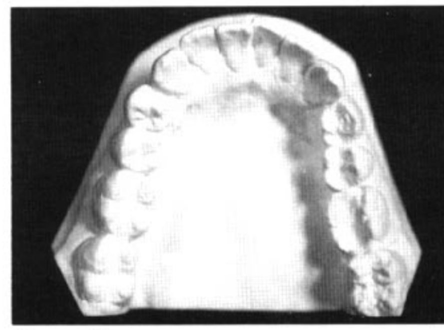

Figure 5J

Figure 5E-J
Occlusion (lateral) and mandibular arch condition for patient L.O.
E,F: Stage 1, 10 years 8 months
G,H: Stage 2, 13 years 3 months
I, J: Stage 3, 20 years, 2 months

onstrated an overall anterior rotational growth pattern when judged from stage 1 to stage 3. Three patients, however, rotated posteriorly, confirming the doubts raised by Baumrind et al.[15] as to the reliability of the prediction method. Skieller et al.[16] introduced a refined prediction method based on a multivariate regression analysis of the independent variables determining rotation. They concluded that rotational pattern in a mild form was difficult to predict, although they could predict anterior rotation in all cases if the mathematical model was employed. Skieller's method was later appraised and criticized by Lee et al.,[17] using a sample that included patients who had possibly not passed the pubertal growth spurt, a period in which the growth pattern is probably most pronounced. The morphological prediction of mandibular rotation, even with its limitations, is still widely used.

In the present study the result of mandibular incisor proclination was clinically acceptable, with good incisal relationships and facial balance being achieved. Even though the recommendations by Ricketts[8] had been exceeded in many cases, a large degree of the original incisal proclination and decrease in overjet was maintained. Considering the relationship between the mandibular incisors and the A-Pg line, a large and unpredictable variation in effect was observed. Figure 3A-B demonstrates that much of the change brought about in the active treatment was maintained after the retention and postretention period, although in several cases proclination of the incisors continued to increase after active treatment. A possible explanation of this phenomenon is the continued anterior rotation of the mandible (reference line) away from the incisors, which remain stable in relation to their antagonists. In 11 cases the final incisal position was posterior to the generally accepted optimal minimum of -2.0 mm to the A-Pg line. Pogonion, the most anterior point on the bony chin, will become more prominent in connection with anterior growth rotation, thus influencing the spatial position of the A-Pg line. This phenomenon also affected the value of the parameter ii-APg, giving the impression that, in a few cases, the incisors were not proclined. Proclination of the incisors in the active treatment phase was, on average, 10° (Table 3) and was accompanied by a significant lengthening of the arch and a reduction in the irregularity index (Table 5). In Figure 3A, it appears that in a small number of cases, the mandibular incisors were not proclined.

Subsequent to the period of active treatment, a certain degree of relapse was observed both in incisor inclination and irregularity index. In general it can be stated that the degree of relapse was related to the size of the change made during the active phase of treatment (Table 6), although even after the relapse period the majority of the change achieved in the active phase was maintained.

The lack of major change in the inclination of maxillary incisors is not surprising. Their relationship was normal before treatment, was slightly increased during treatment, and slightly decreased after retention.

Considering the irregularity index, it can be hypothesized that crowding in the mandibular incisor region is related to a number of factors, including arch length, intercanine width, and/or mandibular incisor inclination. Growth of the mandible could also lead to crowding of the mandibular incisors, where a reduction in the sagittal jaw relationship will result either in a compensatory retroclination of the incisors or in an anterior rotational pattern where the necessary proclination of incisors is inhibited by a deep bite (Björk and Skieller[9]). Each of these factors was expressed in either the cephalometric or study cast analysis and correlated to the observed changes in the irregularity index (Table 7). Only changes in the vertical overbite and intercanine distance were significantly correlated. Could a correlation between these two traits demonstrate a general pattern in bite-deepening? In a separate correlation analysis, change in intercanine distance was consequently correlated to a change in overbite; a coefficient of $r = 0.31$ ($P<0.05$) indicated a determination coefficient (r^2) of approximately 10%, supporting the findings of Shields et al.[5] of a relationship between intercanine distance and the development of incisal crowding. At the same time, however, this result reveals that less than 10% of the change observed in overbite can be related to intercanine distance. It might seem surprising that a reduction in arch length did not correlate to the change in irregularity index. Reported changes in the transverse dimension at the molars influence space conditions in the mandibular arch and affects the length of the arch anteroposteriorly when viewed on a cephalogram.

With regard to the clinical acceptability of the method of incisal proclination, all previous reports—including that of Little et al.[3]—showed a similar or greater relapse of crowding in the mandibular incisor region subsequent to orthodontic treatment, even when space had been gained by extraction. Interestingly, a similar increase in incisor irregularity was reported by Sinclair and Little[18] in a study of untreated normal occlusions. The relative stability reported in this study could imply that a certain degree of muscular adaptation can take place.

It is interesting to note that the irregularity index in the present study at stage 3 was 2.8 (s.d. 1.86), which compares very favorably with the untreated normal reported by Sinclair and Little[18] (2.7, s.d. 1.64). In a study reporting the effects of extraction/orthodontic therapy, Little et al.[3] reported a final "pooled" irregularity index of 4.63 (s.d. 1.91). The growth pattern was not reported and could have been different than in the present study. It must be remembered that the subjects presented here were chosen on the presumption of an anterior rotational growth pattern, so the findings support the original working hypothesis regarding incisor proclination and mandibular rotation.

As stated above, good incisor contact was achieved during active treatment and maintained during the retention/postretention phase, as illustrated in Figure 5A-J, one of the patients in whom the mandibular incisors were proclined to the greatest degree.

The patient was a 10-year-8-month-old girl who sought treatment for extreme overjet (19.0 mm) and overbite (6.9 mm). At the start of treatment the mandibular incisors were 2.0 mm posterior to the A-Pg line at an inclination of 98° to the mandibular plane. The lip profile demonstrated a pronounced mentolabial sulcus. After active treatment the mandibular incisors were 5.0 mm anterior to the A-Pg line and the angle ILi/ML was 114°. Mandibular rotation in this period was 3.8° anterior. In the retention and postretention phase (time 3), the mandibular incisors ended 3.2 mm anterior to the A-Pg line at an inclination of 108° to the mandibular plane, and mandibular development was in an anterior direction, 5.0°. The result of the active mandibular incisor proclination was therefore largely maintained in the posttreatment phase. The irregularity index was 10.2 at stage 1, 1.0 at stage 2, and showed virtually no increase at stage 3 (1.7). Despite the very large proclination, a large degree of stability is seen, possibly as a result of the correction of the deep mentolabial sulcus and the normalizing of lip function.

Björk[9] has stressed the importance of establishing and maintaining good incisal contact if an anterior rotational mandibular growth pattern is to develop in an optimal manner. Proclination of mandibular incisors, usually in conjunction with a nonextraction technique, facilitates establishment of this contact. In view of the mechanical advantages connected with a nonextraction technique and the findings reported in this study, it can be maintained that this method, when used in patients with an anterior rotational mandibular growth pattern, seems worthy of recommendation. Incisor proclination in patients exhibiting posterior rotation, while not the subject of this report, would not follow the physiological pattern as described by Björk[9,10] and stability would therefore be questionable. It must, however, be realized that even in the cases described, some slight relapse in mandibular incisor alignment is common and permanent retention must be considered.[6]

Conclusion

The aim of the present study was to evaluate the stability of proclination of mandibular incisors in growing patients with a predicted anterior rotational growth pattern. The conclusions are:

1. Proclination of mandibular incisors in selected cases leads to good results, although slight posttreatment relapse can be expected.
2. Relapse in the mandibular incisor region is related, slightly, to a deepening in the vertical incisor relationship and to a reduction in the intercanine width.
3. Changes in angular and linear values taking place in time 2 (relapse) are negatively correlated to the degree of change taking place in the active treatment phase (time 1), with a maximum determination coefficient of 25%. For the majority of parameters the determination coefficient is less than 10%
4. The predictability of an anterior rotational growth pattern using the morphological determination method alone is difficult when dealing with mild forms of rotation, but still applicable as a clinical diagnostic tool. If more reliable prediction is required, the index method should be considered.

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