Incisal changes and orthodontic stability

Gavin J. Lenz, BDSc (Qld), MDSc (Melb), FRACDS;
Michael G. Woods, MDSc, FRACDS, FRACDS (Orth), DOrthRCS

Abstract: Lateral cephalograms and study casts of 55 patients were evaluated to determine if any relationships exist among incisal positions and angulations, changes in positions and angulations, and long-term occlusal stability. No significant relationships could be found between long-term changes occurring in a number of commonly used incisal measurements and end-of-treatment incisal positions, changes in incisal positions during treatment, or long-term changes in the facial axis angle, ANB angle, or weighted PAR score. Long-term incisal changes occurring in individual patients were not necessarily associated with negative occlusal changes. Since incisal positions usually change in the long-term, it is suggested that the use of published norms or recommended absolute goals for end-of-treatment incisal positions be used more as general functional and esthetic clinical guides, rather than as predictors of stability.

Key Words: Incisal positions, Incisal angulations, Stability, PAR scores

Since posttreatment occlusal change is a cause of considerable frustration for orthodontists,[1] many researchers have attempted to identify dental and skeletal factors that might be predictive of long-term stability.[2] Unfortunately, these workers have met with limited success and the use of permanent or semipermanent retention has become popular.[3] Factors that have been investigated include the severity of the presenting malocclusion,[4] the amount of overbite,[5] the future growth pattern of the individual,[6,7] whether or not teeth have been extracted,[8,9] the anterior component of bite force,[10] the presence of third molars,[11] various soft tissue relationships,[12] co-existing skeletal malrelationships,[6] treatment mechanics,[7] changes in dental arch form during treatment,[13] changes in intercanine widths,[4,14] the type and duration of retention,[15] and incisal positions and angulations following treatment.[16-21]

Some authors have stated that the angulation of the incisors to the underlying basal bone is most important.[20,21] Others have stated that occlusal stability depends more on the anteroposterior relationship of the incisors to the surrounding hard and soft tissues.[16,17,19,22] Nanda and Burstone[23] listed three concepts regarding ideal positions and angulations of the incisors for stability that differ from those traditionally accepted. These three concepts are: the so-called cephalometric normal values for the incisors are the most stable, and yet stability can and does exist outside these norms; the original positions of the mandibular incisors before treatment are the most stable positions and correcting any malocclusion may move the incisors into unstable positions; and there is only one stable position for the mandibular incisors.

Ricketts et al.[16] suggested that the preferred incisal positions and angulations vary depending on the underlying vertical facial type of the patient, with so-called low-angle, brachyfacial types tolerating somewhat more protrusive and proclined incisors than high-angle, dolichofacial types. The results of other studies, however, have not shown that specific positions of the lower incisors in relation to either the APo plane, the NB plane, or the mandibular plane, are related to occlusal stability.[24] Instead, the collective experience of orthodontists has shown that there seem to be many stable positions for the incisors, none of which necessarily relate to traditionally accepted

Author address
Associate Professor Michael Woods
Orthodontic Unit
School of Dental Science
The University of Melbourne
711 Elizabeth Street
Melbourne, Victoria 3000
Australia

Gavin J. Lenz, private practice of orthodontics, Melbourne, Victoria, Australia.
Michael G. Woods, associate professor and head of orthodontics, School of Dental Science, The University of Melbourne, Victoria, Australia.

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cephalometric goals for correcting malocclusions.[25] Normal age-related changes further complicate the matter. Behrents,[26] for instance, showed that in untreated subjects, the interincisal angles in males increased after adolescence, while in females, little change occurred. He did not, however, relate these changes in angulation to any changes in the occlusion.

With all this in mind, the only really consistent feature described throughout the literature appears to be the unpredictable continued movement of teeth, irrespective of whether they have been subjected to the effects of orthodontic treatment.[27-33] Despite the many studies that have tried to determine useful predictors of posttreatment orthodontic stability,[7,11,15,20,22,34-39] there remains little evidence in the literature regarding relationships between such stability and the actual positions and angulations of the incisors before and after treatment, and any changes occurring in these positions and angulations during or after active treatment. The present study was therefore designed to investigate these relationships.

Materials and methods

Sample

The records of 55 patients, treated by one experienced orthodontist, were obtained for this study. The sample included all the patients who could be contacted and who, regardless of age at the start of treatment or duration of active treatment, satisfied the following criteria:

1. Complete course of treatment with full upper and lower preangulated edgewise appliances (slot size 0.018 × 0.025 inches)

2. Maxillary removable and mandibular fixed or removable retainers worn for approximately 3 years, with no retention in the remaining years before the taking of follow-up records

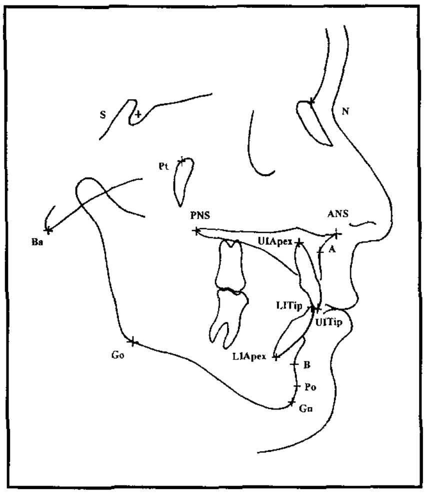

Figure 1
Cephalometric landmarks

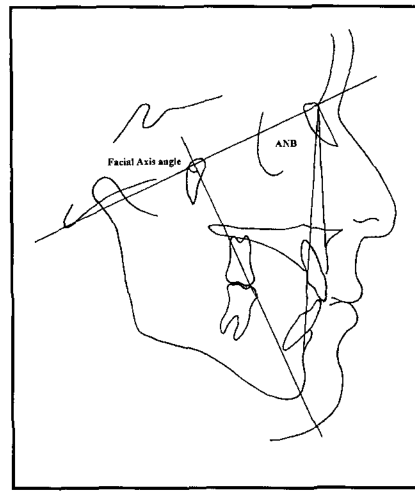

Figure 2
Facial axis and ANB angles

3. Pretreatment (T1), posttreatment (T2), and follow-up (T3) models and lateral cephalograms available at the time of the study. The follow-up records were taken at least 6.5 years following the removal of all retention appliances.

Of the 55 patients, 41 were female and 14 were male. Sixteen patients had been treated with premolar extractions, 38 without. The mean age at start of treatment was 14 years 9 months, with the distribution heavily weighted around a median age of 13 years 5 months. The mean duration of active treatment was 2 years 6 months, and the average follow-up period was 11 years. There was considerable individual variation within the sample.

The aims of treatment for all patients in the sample included: an ideal interdigitating occlusion as described by Andrews;[40] overcorrection of rotations, overbite, and overjet; control of vertical growth and treatment effects using directional headgear as necessary; careful use of intermaxillary elastics; avoidance of further proclination of the lower incisors where possible; and maintenance of lower arch form and intercanine width (except in very deepbite locked-in malocclusions). Excessive overbite was reduced using continuous archwires with reverse and/or exaggerated curves of Spee. Accessible mandibular second molars were generally banded or bonded. Any necessary anterior retraction was carried out en masse, and residual spaces were closed using sliding mechanics and continuous archwires.

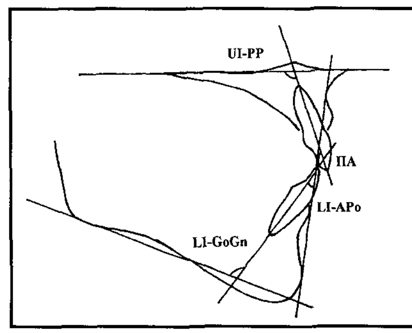

Figure 3
Incisal position and angulation measurements

Lateral cephalometric measurements

All lateral cephalograms had been taken using the same calibrated cephalostat with a consistent magnification factor of 8%. The pretreatment (T1), posttreatment (T2), and follow-up (T3) cephalograms were assigned numbers and arranged in random order by an independent observer before being traced and digitized by one examiner (GJL). In a previous pilot study[41] using 30 randomly selected radiographs, three methods of data collection were compared. These methods were (a) hand-traced then hand-measured, (b) hand-traced then digitized using Dentofacial Planner, version 7.01, and (c) directly digitized using Dentofacial Planner version 7.01. The hand-traced and digitized cephalometric assessment was found to be the most reproducible method and was therefore used for all further cephalometric analysis in this study. Cephalometric landmarks were located (Figure 1) and specific measurements were made (Figures 2 and 3). These measurements are listed in Table 1. Changes in incisal positions and angulations during active treatment (T1 to T2) and during the follow-up period (T2 to T3) were calculated.

Table 1
Lateral cephalometric measurements

Measurement	Description
IIA	Interincisal angle
LI-APo (mm)	Distance from lower incisal tip to APo plane in millimeters
LI-APo (°)	Angulation of lower incisor to APo plane
LI-GoGn	Angulation of lower incisor to mandibular plane
UI-PP	Angulation of the upper incisor to palatal plane (ANS - PNS)
Facial axis angle	Posteroinferior angle defined by planes basion-nasion and facial axis (Pt-Gn), giving an indication of the underlying vertical facial pattern and likely direction of future mandibular growth
ANB	Relating maxillary and mandibular dentoalveoli in the anteroposterior dimension

Error measurement

To determine tracing and measurement error, 30 lateral cephalograms were chosen at random. These radiographs were retraced and redigitized under the same conditions by the same investigator (GJL) 6 weeks after the original measurements had been made. The differences between the two sets of measurements were assessed and subjected to the Student's *t*-test. Low mean differences were found for all the cephalometric measurements used in this study.

Occlusal assessment using the PAR index

Pretreatment (T1), posttreatment (T2), and follow-up models (T3) were assessed by one examiner[41] using the PAR index exactly as described by Richmond et al.[42] Richmond himself had first assessed the examiner's ability to assess occlusions using the official PAR index calibration models. Once the examiner's method had been calibrated, the models for all patients were arranged randomly so that the models for any patient were not scored in sequence (T1, T2, T3). In order to determine intraexaminer reliability, 30 randomly-selected sets of models were scored twice, 4 weeks apart. With a correlation coefficient of 0.96 the scores were considered highly consistent, matching the findings of Richmond et al.[43] and Lee,[44] who reported correlation coefficients for intraexaminer reliability of 0.94 and 0.97, respectively.

Treatment of the data

Following tabulation of the individual cephalometric and PAR score measurements at T1, T2, and T3, means were calculated for all the measurements for the total sample. Mean changes occurring in the cephalometric measurements and the PAR scores during active treatment (T1 to T2) and following active treatment (T2 to T3) were also calculated. Pearson's product moment correlation coefficients were calculated to determine if any relationships existed between the long-term change (T2 to T3) in each of the incisal measurements and (1) that particular incisal measurement at the end of active treatment (T2), (2) the change that had occurred during active treatment (T1 to T2) in that particular incisal measurement, (3) the facial axis angle change during the follow-up period (T2 to T3), or (4) the ANB angle change during the follow-up period (T2 to T3).

Correlations between long-term incisal changes and long-term ANB and facial axis angle changes were calculated to assess whether any incisal changes were more likely to accompany specific anteroposterior and vertical dentoalveolar or skeletal changes. Those correlations with $p<0.05$ were deemed statistically significant.

Results

Incisal positions and angulations at T1, T2, and T3

The mean values for the various incisal measurements for the total sample at T1, T2, and T3 are listed in Table 2. The means for all incisal measurements, at all stages, are similar to previously published norms for untreated subjects.[45] In fact, all the means in this sample fell well within one standard deviation of the previously published norms.

Changes in incisal positions and angulations during and after treatment

The mean changes in incisal measurements for the total sample occurring during active treatment (T1 to T2) and during the long-term follow-up period (T2 to T3) are pre-

Table 2
Mean incisal positions and angulations at T1, T2 and T3

Measurement	T1	T2	T3	*Norms - male	*Norms - female
IIA	132.1±13.57	130.73±8.37	131.59±7.51	129.20±10.10	131.90±10.30
LI-APo (mm)	1.02±2.84	1.94±1.94	1.50±2.14	1.90±2.60	1.20±2.50
LI-APo (°)	21.09±5.91	25.27±5.11	24.89±4.88	23.80±5.40	22.10±4.90
LI-GoGn	90.77±7.67	92.77±7.81	92.98±6.70	94.80±6.80	92.30±6.50
UI-PP	111.82±9.21	111.20±7.31	111.67±8.13	109.90±5.80	111.50±6.70

* Riolo ML, Moyers RE, McNamara JA, Hunter WS. An atlas of craniofacial growth: Cephalometric standards from the University School Growth Study, The University of Michigan, Ann Arbor 1974.

sented in Table 3. Distributions for each of these incisal measurements from T2 to T3 are further illustrated in Figures 4 to 8. In general, the changes occurring during active treatment were greater than those occurring during the follow-up period. There was considerable individual variation in the amount of change for all measurements during the follow-up period. Individual changes for this follow-up period were, however, grouped largely around small mean values.

Relationships between long-term changes for each incisal measurement and other cephalometric measurements

Coefficients of correlation between long-term changes (T2 to T3) occurring in each of the incisal measurements and other cephalometric measurements are presented in Table 4. No significant correlations were found between long-term incisal changes and changes in facial axis angle and ANB angle. However, there were significant correlations between the long-term incisal changes and some of the incisal measurements at the end of active treatment (T2) and changes that occurred in some of the incisal measurements during treatment (T1 to T2).

PAR scores and PAR score changes

Mean weighted PAR scores for the total sample at T1, T2, and T3 and mean changes occurring in those scores during treatment (T1 to T2) and during the long-term follow-up period (T2 to T3) are presented in Table 5. It can be seen that there was a mean reduction in the PAR score of 23.84 during active treatment. This was followed by a small mean increase in PAR score during the long-term follow-up period. Obviously, there was a great deal of individual variation in the pretreatment PAR scores. This variation had, however, reduced considerably by the end of active treatment (T2). Once again, there was significant variation in the long-term PAR scores (T3), although this variation was not as large as that seen in the pretreatment scores.

Relationships between long-term incisal and PAR score changes (T2 to T3)

Coefficients of correlation between long-term PAR score changes (T2 to T3) and changes occurring in the various incisal measurements are presented in Table 6. No obvious correlation could be found between any of the changes for the incisal measurements and posttreatment PAR score changes.

Individual variation

Because of the considerable individual variation found for both incisal and occlusal changes occurring during the long-term follow-up period, stylized superimpositions from 12 individual cases are presented. In each case, bony superimpositions have been made on the sella-nasion line at nasion. The

Table 3
Mean changes in incisal positions and angulations during and after treatment

Measurement	T1 to T2	T2 to T3
IIA	-1.37±15.19	0.86±8.95
LI-APo (mm)	0.92±2.43	-0.45±1.39
LI-APo (°)	4.18±7.78	-0.38±4.91
LI-GoGn	2.20±7.12	0.01±5.02
UI-PP	-0.62±10.85	0.47±6.63

incisors have simply been moved forward parallel to the sella-nasion line to more clearly illustrate the changes in incisal angulation. Changes in PAR score, interincisal angle, facial axis angle, and ANB angle for all these cases are presented in Table 7. Changes in the facial axis angle and ANB angle were themselves quite variable during the follow-up period.

Three cases showing the greatest (T2 to T3) changes in interincisal angle and three showing the smallest, and three cases showing the greatest PAR score changes and three showing the least are presented in Figures 9, 10, 11, and 12, respectively. These individual cases show that long-term changes occurring in either interincisal angle or PAR score, whether large or small, were not necessarily associated with similar changes in other measurements. For example, the interincisal angle in case 9 increased 10 degrees during the T2 to T3 period, a somewhat similar change to that occurring in the PAR score. In cases 7 and 8, however, the interincisal angle changes were much smaller, despite the fact that the PAR score changes were similar to that seen in case 9. It is also interesting to note that, despite the fact that no changes at all were noted in the PAR scores in cases 10, 11, and 12, the long-term changes in interincisal angulation were quite variable, ranging from –5.1 to +3.4 degrees.

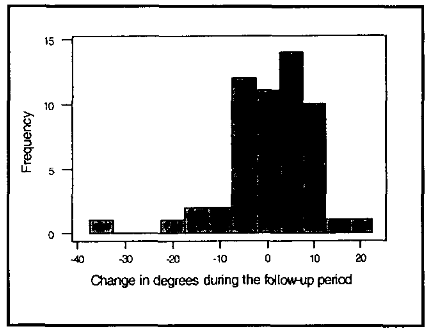

Figure 4
Interincisal angle: individual changes T2 to T3

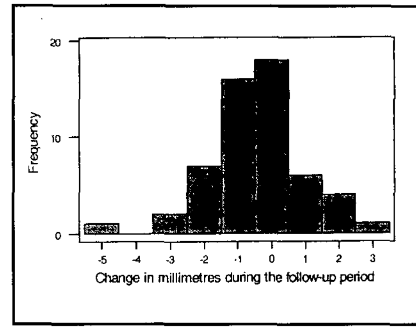

Figure 5
Lower incisor to APo (mm): individual changes T2 to T3

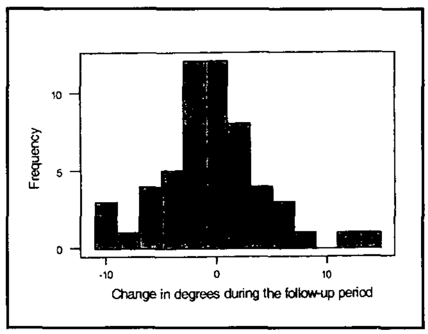

Figure 6
Lower incisor to APo (°): individual changes T2 to T3

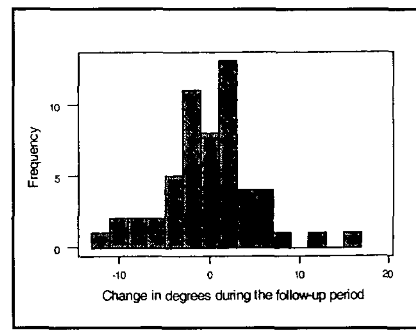

Figure 7
Lower incisor to mandibular plane: individual changes T2 to T3

Discussion

Limitations of the study

This is a retrospective study of a nonhomogenous sample of patients in terms of sex, malocclusion, and age. The patients were, however, all treated by the same clinician who applied the same treatment philosophy and occlusal aims, followed a similar retention regime, and kept accurate and consistent records. It would therefore seem to be an acceptable sample for identifying the range of likely changes occurring in incisal positions and angulations after treatment, and especially for relating those changes to any occlusal changes that may also have taken place at the same time. Considerable effort was made to reduce the potential for error within the chosen cephalometric technique. The cephalometric landmarks used in this study have been shown to be reasonably predictable[46,47] and the use of a computer for all calculations has reduced measurement error. While the incisal irregularity index has been used in many previous studies to assess relapse,[9,33,38,55] it deals only with change in the alignment of the mandibular incisors and does not take into account other positive or negative changes in the occlusion. The PAR index was therefore chosen for this study because it does provide such an overall assessment of the occlusion. Possible limitations with the use of the PAR index for assessing the quality of treatment results have previously been noted.[41] Weighted PAR scores, however, have been and are being used by a number of researchers around the world[48-51] and have been accepted as providing reliable, objective, and quantitative measures of the occlusion.

Incisal positions and angulations at T2

While the means for incisor positions and angulations at T2 were similar to those at T3, these means actually concealed the substantial individual variation that occurred. This variation is demonstrated by the large standard deviations for all measurements. This variation is consistent with the fact that means presented for untreated subjects by Riolo et al.[45] and widely accepted for use as treatment goals in clinical practice also have large standard deviations.

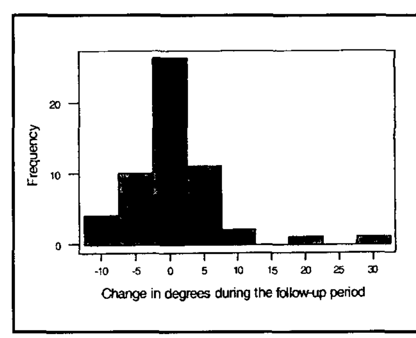

Figure 8
Upper incisor to palatal plane: individual changes T2 to T3

Changes in incisal positions and angulations after treatment (T2 to T3)

Over the years, various authors[19,21,22,52] have recommended particular end-of-treatment incisal positions and angulations as treatment goals; they believed that, by achieving such incisal goals, they might limit the amount of incisal change following active treatment. In this study, however, it has been

Table 4
Correlations among changes in each incisal measurement following treatment (T2 to T3) and other cephalometric measurements

Incisal measurement	Incisal measurement at T2	Change in incisal measurement (T1 to T2)	Facial axis change (T2 to T3)	ANB change (T2 to T3)
IIA	-0.626 (*p*=0.000)*	-0.396 (*p*=0.003)*	0.069 (*p*=0.618)	0.092 (*p*=0.504)
LI-APo (mm)	-0.205 (*p*=0.134)	-0.553 (*p*=0.000)*	-0.097 (*p*=0.482)	-0.334 (*p*=0. 013)*
LI-APo (°)	-0.527 (*p*=0.000)*	-0.583 (*p*=0.000)*	-0.088 (*p*=0.524)	-0.208 (*p*=0.127)
LI-GoGn	-0.528 (*p*=0.000)*	-0.571 (*p*=0.000)*	-0.132 (*p*=0.337)	0.021 (*p*=0.881)
UI-PP	-0.323 (*p*=0.016)*	-0.259 (*p*=0.056)	0.144 (*p*=0.295)	-0.204 (*p*=0.135)

* significant correlation at $p<0.05$ level.

Table 5
Means, standard deviations, and ranges for weighted PAR scores at T1, T2, and T3 and changes occurring during and after active treatment

Par score	Mean	Standard deviation	Range
T_1	27.24	9.21	7 - 42
T_2	3.4	2.7	0 - 13
T_3	7.51	5.26	0 - 21
T_1 to T_2	23.84	9.28	1 - 40
T_2 to T_3	4.11	4.64	-3 - 16

Table 6
Correlations between changes in each incisal measurement and changes in PAR score following treatment (T2 to T3)

Incisal measurement	PAR score change T2 to T3
IIA	0.105 (*p*=0.45)
LI-APo (mm)	-0.237 (*p*=0.08)
LI-APo (°)	-0.19 (*p*=0.17)
LI-GoGn	-0.075 (*p*=0.58)
UI-PP	-0.141 (*p*=0.30)

* significant correlation at $p<0.05$ level.

Table 7
Individual variation in T2 to T3 changes

Case	IIA	PAR score	Facial axis	ANB
1	**-15.5**	-2	0.7	-4.2
2	**-19.5**	7	-1.3	1.0
3	**19.1**	1	2.7	-4.2
4	**0.8**	4	-0.7	-2.4
5	**0.2**	7	5.8	-1.5
6	**-1.6**	0	1.8	0.3
7	1.7	**15**	0.7	1.0
8	-3.0	**13**	3.9	-1.2
9	10.3	**16**	-3.5	0.3
10	-5.1	**0**	-1.0	-2.4
11	-1.6	**0**	1.8	0.3
12	3.4	**0**	1.5	-0.8

found that changes occurred in incisal positions and angulations during the follow-up period, regardless of how close the final treatment positions and angulations were to those recommended goals.

Although some association was found between the end-of-treatment incisal positions and angulations and a tendency for the teeth to move toward their untreated norm values[45] (Table 2), this was certainly not always the case. Similarly, there was a tendency for the incisal positions and angulations of the teeth to move back in the direction of the pretreatment (T1) values (Table 2). While this finding is supported by previous studies,[53-55] again, that was not always the case in this study. These results would, therefore, not support the use of a particular predictable ratio for likely posttreatment incisal change, as has previously been suggested.[53] Whereas the changes are likely to be quite small, one still needs to be aware of the possibility that large posttreatment incisal changes can occur in individual patients. Given all this, the incisal angulations in this study were found to change considerably in some cases, yet the occlusions did not necessarily collapse. In fact, in some cases, posttreatment incisal changes were found to accompany occlusal improvement.

It is interesting that, in this study, no relationship could be found between any of the long-term incisal changes and long-term changes in the PAR score. This finding supports the results of a previous study[44] in which no relationship could be found between the standard of occlusal finish at the end of

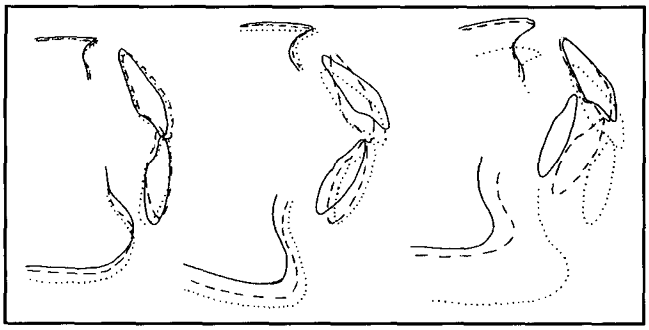

Figure 9
Cases 1, 2, and 3. Greatest interincisal angulation change, T2 to T3. Solid line: pretreatment (T1); broken line: end of active treatment (T2); dotted line: long-term follow-up (T3)

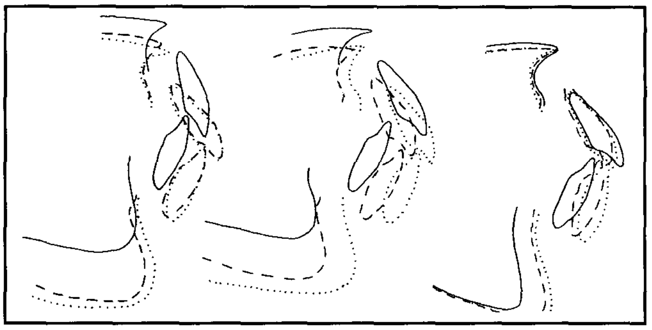

Figure 10
Cases 4, 5, and 6. Smallest interincisal angulation change, T2 to T3. Solid line: pretreatment (T1); broken line: end of active treatment (T2); dotted line: long-term follow-up (T3)

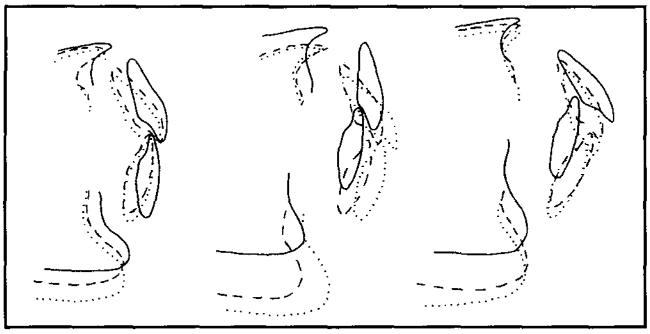

Figure 11
Cases 7, 8, and 9. Greatest PAR score change, T2 to T3. Solid line: pretreatment (T1); broken line: end of active treatment (T2); dotted line: long-term follow-up (T3)

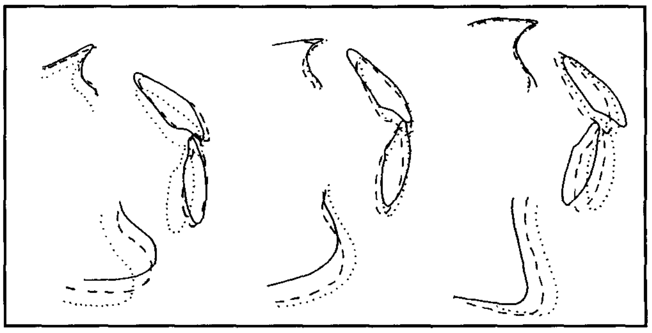

Figure 12
Cases 10, 11, and 12. Smallest PAR score change, T2 to T3. Solid line: pretreatment (T1); broken line: end of active treatment (T2); dotted line: long-term follow-up (T3)

active treatment and long-term occlusal changes taking place after treatment. It would not, however, support the views of others[40,56,57] that, by providing an ideal, well-interdigitating occlusion, chances of long-term stability are increased. The incisal changes found in this study were not, however, necessarily associated with negative occlusal changes in individual cases. On the contrary, significant incisal changes occurred in some cases where the occlusions seemed to remain absolutely stable. It is obvious, then, that the so-called dentoalveolar compensatory mechanism[56] has the potential to continue to work in the long-term. Unfortunately, this does not always seem to be the case, and the findings of the study would lend some support to the suggestion of Solow[56] that "norms for cephalometric dimensions should not be applied in the individual case." Instead, these norms should be used more as esthetic and functional guides.

Conclusions

Keeping in mind its limitations, the results of this study support the following conclusions:

1. Incisal positions and angulations will tend to change in the long-term following routine, comprehensive orthodontic treatment. On average, these changes are small, although individual variations may be large.
2. These changes do not seem to be directly related to the positions and angulations of the incisors at the end of active treatment or, in fact, to changes that have occurred in these positions and angulations during treatment.
3. Long-term incisal changes do not appear to be directly related to long-term changes in the facial axis or ANB angles.
4. Long-term posttreatment incisal changes and long-term changes occurring in the occlusion are not directly related, at least as reflected in the weighted PAR score.
5. Published norms or recommended absolute goals for end-of-treatment incisal positions and angulations should be used as general clinical guides, primarily for esthetic and functional reasons, and not as a basis for predicting stability. Furthermore, some changes in incisal measurements should be expected in the long-term. These changes will not neces-

sarily be associated with detrimental occlusal changes.

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