CONTINUING EDUCATION ARTICLE

Johnston analysis evaluation of Class II correction in patients belonging to Petrovic growth categories 3 and 5

Alexandre Moro, DDS, MS,[a] Marco A. Scanavini, DDS, PHD,[b] and Julio W. Vigorito, DDS, PHD,[c]
Curitiba, Paraná and São Bernardo do Campo, São Paulo, Brazil

Petrovic and Lavergne have proposed a classification of facial growth, consisting of 6 growth categories, according to which patients belonging to growth category 5 at the beginning are supposed to have greater mandibular growth during treatment than patients belonging to growth category 3. We tested this hypothesis with 2 groups of Class II patients: 25 from growth category 3 and 25 from category 5. Both groups consisted of males and females and had starting ages that ranged from 10 to 15 years. Treatment was carried out with a nonangulated edgewise appliance in conjunction with the extraction of four first premolars. The Johnston "Pitchfork" analysis was used to assess treatment changes. It showed that the molar correction was almost identical in amount in growth categories 3 and 5. Its source, however, was not. Differential jaw growth (ABCH) accounted for 75% of molar correction in category 3, but 107.5% in category 5. On average, there was 1.9 mm of extra mandibular advancement relative to cranial base in category 5 as compared with that of category 3. Mandibular advancement was the most important single factor for the molar and overjet corrections in both groups. Treatment success, evaluated according to Lavergne's treatment objectives, showed that edgewise extraction therapy with headgear is more suitable to patients in category 3 than to the ones in category 5. Further research should explore the treatment methods and goals appropriate to these two growth categories. (Am J Orthod Dentofacial Orthop 2000;117:86-97)

Since Angle's definition of Class II malocclusion,[1] there has been relatively little disagreement concerning the associated dental characteristics[2]; however, numerous concepts have been proposed concerning cause, development, and treatment. The growth potential of individuals with Class II malocclusion is of interest to practicing orthodontists because this type of malocclusion represents a significant percentage of the cases they treat.[3] Success of treatment depends both on the clinician's ability and on the patient's growth pattern. A poor growth pattern during treatment will make it difficult to achieve a skeletal correction and to improve the facial profile. One of the recurrent themes in the orthodontic literature, therefore, is a desire to predict the course of craniofacial development and to know in advance a given patient's growth potential and response to orthodontic treatment.

Petrovic and Lavergne have developed a cephalometric analysis that also generates a growth prediction. In 1977, Lavergne and Gasson[4] introduced the concept of morphogenetic and positional rotations. They[5] also found it useful to classify growth rotations as posterior, neutral, and anterior. In an effort to account for the individuality of the facial type, including sagittal and vertical discrepancies, Lavergne and Gasson[6] worked out a classification in the form of a 2-tier arborization. The first tier corresponds to the basic growth difference between the 2 jaws; the second tier corresponds to the mandibular and maxillary rotations. Taking into account the cybernetic type of regulation of mandibular growth,[7] Lavergne and Petrovic[8] added a third tier to the arborization (Fig 1). By investigating the mandibular tissue level growth potential, ie, the alveolar bone turn-over rate (specimens were removed during premolar extraction before and during orthodontic treatment) and ramus subperiosteal ossification rate (the index of tritiated thymidine-labeled cells, in organ culture, from bone specimens removed during surgery for trauma) and responsiveness to orthodontic, orthopedic, and functional appliances, Petrovic and Stutzmann[9] described 6 biologic growth potential categories. Petrovic et al[10] ranked all of their cases from
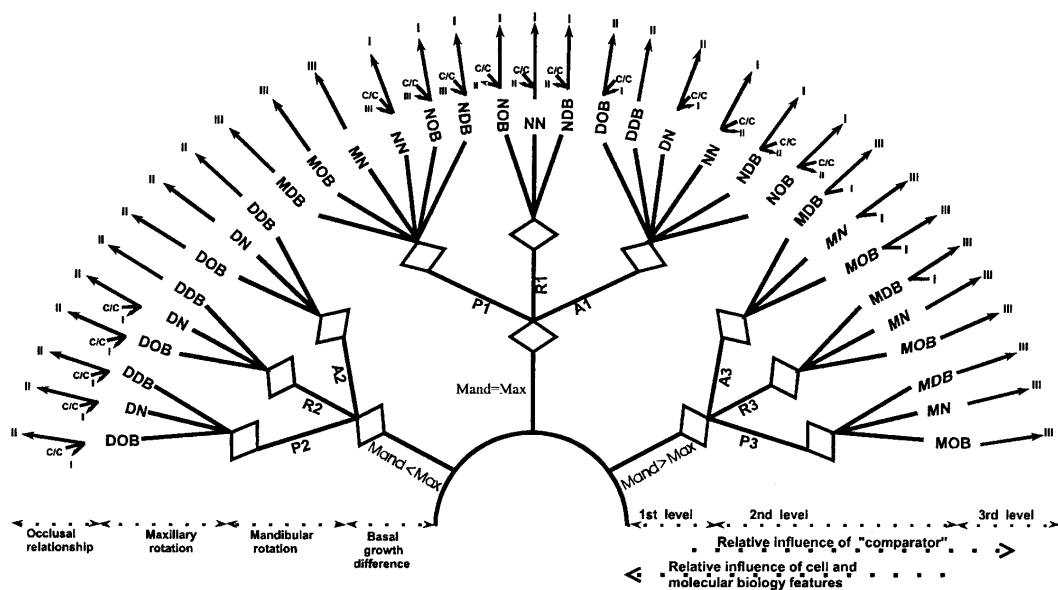
Fig 1. Three-tier arborization according to Petrovic et al.[10] Mandibular rotational type: A, anterior; R, neutral; P, posterior. Basal growth inequality: 1, mandible = maxilla; 2, mandible < maxilla; 3, mandible > maxilla. Sagittal interjaw relationship: N, normal; D, distal; M, mesial. Vertical state: OB, open bite; N, normal bite; DB, deep bite. I, II, III: occlusal first molar relationship (stable); C/C, cusp-to-cusp (unstable). larger main outcome. smaller less frequent outcome. – unachieved outcome.
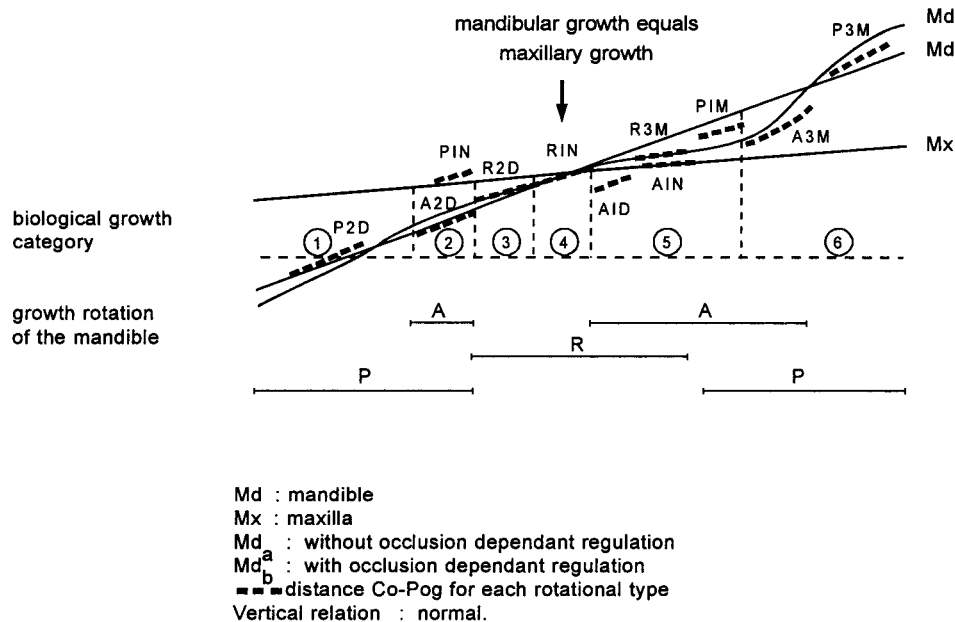

Md : mandible
Mx : maxilla
Md$_a$: without occlusion dependant regulation
Md$_b$: with occlusion dependant regulation
∎ ∎ ∎ distance Co-Pog for each rotational type
Vertical relation : normal.

Fig 2. Six tissue level growth categories of the mandible with rotational types and corresponding condylion-pogonion (Co-Pog) distances. On the left side, the growth potential of the mandible is below the growth potential of the maxilla, and there is a tendency toward Class II; on the right side, the situation is reverse. The growth potential of the mandible is superior to that of the maxilla and there is a tendency toward Class III. With respect to the neutral growth rotation of the mandible (R), a posterior growth rotation (P) increases the condylion-pogonion distance by opening the angle between the corpus and ramus, whereas an anterior growth rotation (A) decreases this distance by closing the angle. The rotational type P1N should be named P2N.[15]
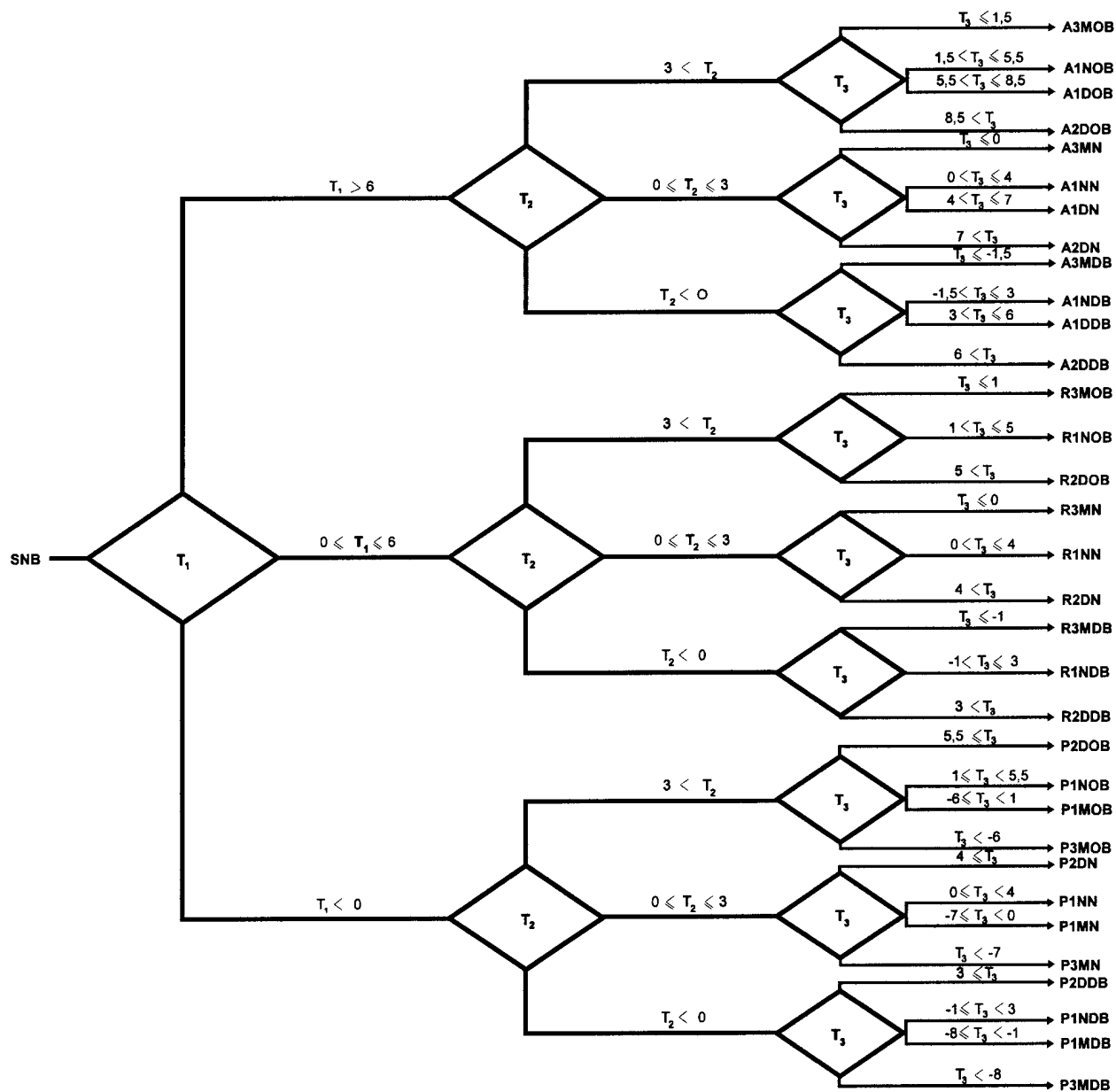
Fig 3. Identification of positional growth group. ML, mandibular line, the line tangent to the lower border of the mandible through gnathion; NSL, nasion-sella-line, the line through N and S; NL, nasal line, the line through ANS and PNS (ANS, anterior nasal spine; PNS, posterior nasal spine); ML/NSL, angle between mandibular line and nasion-sella-line; NL/NSL: angle between nasal line and nasion-sella-line; T_1= expected ML/NSL − measured ML/NSL; T_2 = expected NL/NSL − measured NL/NSL; T_3 = measured ANB; expected ML/NSL = 192 − 2 (measured SNB); expected NL/NSL = (measured ML/NSL)/2−7. This cephalometrically based flow diagram allows for the indirect identification of the rotational group, ie, for an indirect recognition of the growth category.[15]

the lowest to the highest value of turnover rate, and they tested various methods of categorization. The best fitting method was observed when all of the children were categorized according to the Lavergne and Gasson classification of growth rotations.[5,6,11] Petrovic et al[10,12] detected specific connections between the 6 growth potential categories identified biologically, and the 11 rotational types described cephalo-
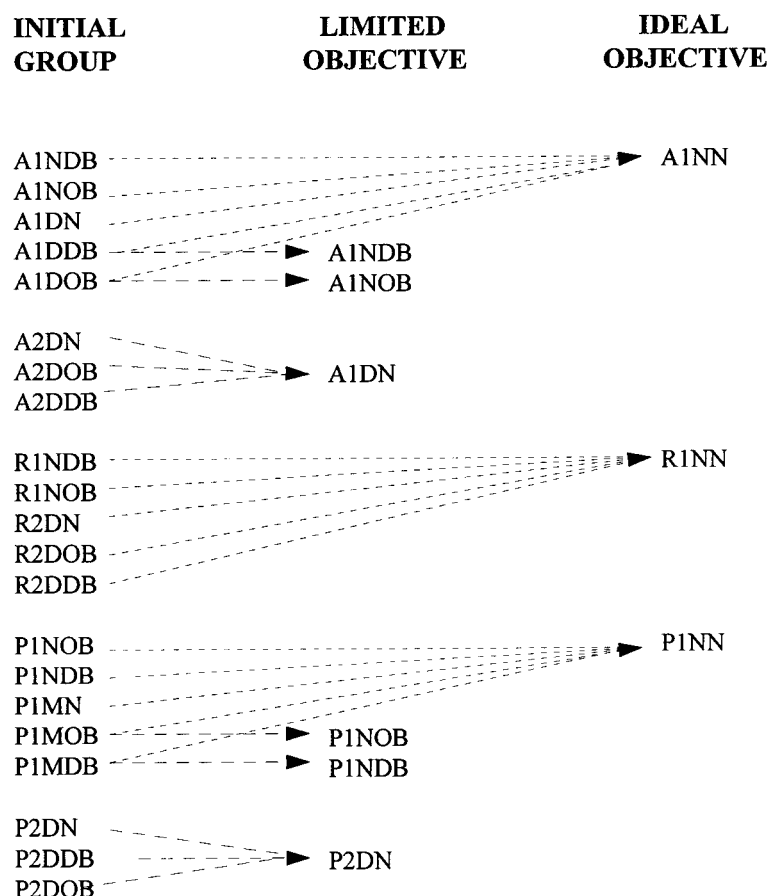
INITIAL GROUP	LIMITED OBJECTIVE	IDEAL OBJECTIVE

A1NDB
A1NOB
A1DN
A1DDB ▶ A1NDB
A1DOB ▶ A1NOB
→ A1NN

A2DN
A2DOB ▶ A1DN
A2DDB

R1NDB
R1NOB
R2DN
R2DOB
R2DDB
→ R1NN

P1NOB
P1NDB
P1MN
P1MOB ▶ P1NOB
P1MDB ▶ P1NDB
→ P1NN

P2DN
P2DDB ▶ P2DN
P2DOB

Fig 4. Mode of action of treatment objectives over facial type.[18] The ideal objective is to move the patient facial type to the closest "normal" group. But for a certain number of cases this change is not possible, and treatment is not a complete correction but just an improvement of facial type.

metrically. This categorization perhaps provides a basis for the biologic heterogeneity of the human growing mandible.[13] The identification of a rotational type through cephalometric analysis is, in fact, an indirect identification of the growth potential and of the responsiveness of a growing child to orthodontic and functional appliances. According to the authors,[9] the existence of facial growth categories is a fortunate situation because it becomes possible to group children who are morphologically alike, who grow alike, and who are more likely to respond in a similar way to a given type of treatment.

The 11 rotational types can be distinguished and designated by a trinomial label.[10] In each label, the 3 successive symbols represent:

1. Mandibular growth rotation (mandibular inclination might be more appropriate because it is dealing with a feature of an individual estimated at a given moment), posterior (P), neutral (R), and anterior (A);

2. A numeric estimate of the difference in growth poten-

tial between the mandible and maxilla: 1, mandible = maxilla; 2, mandible < maxilla; 3, mandible > maxilla;

3. The sagittal interjaw relationship: distal (D), normal (N), and mesial (M).

In addition, each rotational type is subdivided according to the vertical dimension into open bite (OB), normal bite (N), or deep bite (DB).[1] Accordingly, 33 rotational groups were described.

In this study, patients belonging to the rotational type R2D were used. And what do these letters mean? The letter R means that these patients have a neutral mandibular growth rotation. The number 2 means that maxillary growth potential is greater than mandibular growth potential. And the letter D means that these patients have a distal sagittal interjaw relationship. We also used A1N and A1D patients. These patients have an anterior mandibular growth rotation represented by letter A. In spite of having an N in their trinomial label A1N patients have a Class II malocclusion. And in both rotational types A1D and

A1N, the growth potential of the mandible is greater than maxillary growth potential.

Lavergne and Petrovic[8] observed that a given growth potential may give rise in 2 or more rotational types. In other words, a given morphologic pattern (distal, normal, or mesial interjaw relationship) may originate in several ways. As can be seen in Fig 2, the rotational type P2D belongs to growth category 1. The rotational types P1N and A2D belong to the same category (category 2) of the tissue level turnover rate. The rotational type R2D belongs to category 3. The rotational types R3M, A1N, A1D, and P1M belong to the same tissue level category, category 5. Rotational types A3M, and P3M belong to category 6. A clear-cut correlation appears between the alveolar bone turnover rate level and the 6 categories. So far, it is not obvious why some biologic categories split into 2 or even more rotational types.[9]

In categories 1, 2, and 3, the tissue level growth potential of the mandible is inferior to that of the maxilla. Accordingly, there is a tendency toward Class II malocclusion. In category 4 mandibular growth equals maxillary growth. In categories 5 and 6, the tissue level growth potential of the mandible is superior to that of the maxilla, and there is a tendency toward Class III, especially in category 6. Globally, there is a satisfactory correspondence between the cephalometric nomenclature and the growth categorization. However, the rotational type P1N should be named P2N, because the growth potential of the mandible is inferior to that of the maxilla[14] (Fig 2).

In identifying rotational groups cephalometrically, the recognition of the phenomena named by "letters" is easy.[15,16] The difficulty concerns the assessment of the so-called "cephalometric growth potential" designated by the number 2, 1, or 3, which corresponds respectively to mandibular growth potential that is inferior, equal, or superior to the maxillary growth potential. The cephalometric growth potential 2 corresponds to the auxologic (growth) potential 1, 2, or 3; the cephalometric growth potential 1 corresponds to auxologic potential 4 or 5; cephalometric growth potential 3 corresponds approximately to auxologic potential 5 and 6. This correspondence only is valid, however, when the cephalometric categorization is made before initiation of treatment, in view of the observation that no appliance can appear to increase the basic mandibular growth potential, according to research done at tissue and cell level.[13]

To detect the growth category directly in patients where extraction of mandibular premolars is clinically indicated, the alveolar bone specimens are collected, put in organ culture for 3 days, and analyzed according to Stutzmann and Petrovic.[17] The indirect approach for the identification of growth rotational groups[13,15] uses the pretreatment lateral cephalogram,

Table I. Distribution of patients by category at start and end of treatment

| | *End of treatment by category* | | | | |
	3	*4*	*5*	*6*	*Total*
Start of treatment					
3	15 (60%)	10 (40%)	0	0	25 (100%)
5	1 (4%)	1 (4%)	22 (88%)	1 (4%)	25 (100%)
Total	16 (32%)	11 (22%)	22 (44%)	1 (2%)	50 (100%)

from where we measure SNA, SNB, ANB, ML/NSL (angle between mandibular line and nasion-sella-line), and NL/NSL (angle between nasal line and nasion-sella-line). We used two formulae to find 2 expected angles, and through a flow diagram, we reach the rotational group types (Fig 3).

In 1992, Lavergne[18] proposed therapeutic objectives for the facial types (Fig 4). Accordingly, the ideal objective is to change the patient's facial type to the closest "normal" group through growth rotations. There are 3 groups that have normal, vertical, and saggital relationships. In group RlNN, mandibular growth equals maxillary growth. In group A1NN, the tissue level growth potential of the mandible is superior to that of the maxilla, but the anterior mandibular rotation will diminish its length. In group P1NN, the growth potential of the mandible is inferior to that of the maxilla, but the posterior rotation of the mandible will increase the overall mandibular length. However, for some patients who have a very severe malocclusion, it is impossible to achieve optimal results (the displacement to a normal group). In these cases, palliative therapeutics, like the extraction or even orthognathic surgery, are chosen to establish a correct interdental relationship.

What happens when, during treatment, the rotational group changes cephalometrically into another group? One possibility is that even with no change in the physiologic basic growth potential, the cephalometric denomination of the rotational group, after treatment, simply may reflect the new appliance-induced anatomic relationship between the maxilla and the mandible.[16]

The purpose of this investigation was to evaluate Class II correction in patients belonging to Petrovic growth categories 3 and 5, treated with the standard edgewise appliance. The so-called "Johnston analysis" was used to analyze treatment changes.[19]

MATERIAL AND METHODS
Sample

The present investigation consisted of 2 groups of Class II patients: 25 patients from category 3 and 25 patients from category 5. The selection was done con-

Table II. Distribution of patients by rotational group in the beginning and in the end of treatment for category 3

	End of treatment						
Rotational Group	*R1NDB*	*R1NN*	*R1NOB*	*R2DDB*	*R2DN*	*R2DOB*	*Total*
Start of treatment							
R2DDB	3 (75%)	0	1 (25%)	5 (83.3%)	0	0	9 (36%)
R2DN	1 (25%)	2 (100%)	0	1 (16.7%)	3 (60%)	0	7 (28%)
R2DOB	0	0	3 (75%)	0	2 (40%)	4 (100%)	9 (36%)
Total	4 (100%)	2 (100%)	4 (100%)	6 (100%)	5 (100%)	4 (100%)	25 (100%)

Table III. Distribution of patients by rotational group in the beginning and in the end of treatment for category 5

	End of treatment									
Rotational group	*A1DDB*	*A1DN*	*A1NDB*	*A1NN*	*A1NOB*	*A3MOB*	*R1NDB*	*R2DN*	*R3MOB*	*Total*
Start of treatment										
A1DDB	1 (33.3%)	0	3 (33.3%)	0	0	0	0	0	0	4 (16.0%)
A1DN	2 (66.7%)	1 (100%)	0	2 (33.3%)	0	0	1 (100%)	0	0	6 (24.0%)
A1DOB	0	0	0	1 (16.7%)	0	0	0	1 (100%)	0	2 (8.0%)
A1NDB	0	0	5 (55.6%)	0	0	0	0	0	0	5 (20.0%)
A1NN	0	0	1 (11.1%)	2 (33.3%)	0	0	0	0	0	3 (12.0%)
A1NOB	0	0	0	1 (16.7%)	2 (100%)	1 (100%)	0	0	1 (100%)	5 (20.0%)
Total	3 (100%)	1 (100%)	9 (100%)	6 (100%)	2 (100%)	1 (100%)	1 (100%)	1 (100%)	1 (100%)	25 (100%)

secutively, ie, the first 50 patients, male or female, who were encountered from a sample consisting of 800 subjects. The lateral radiographs of 192 Class II patients were traced until we found 25 patients for each category. The main criteria for inclusion in this study were the availability of adequate pretreatment and posttreatment cephalograms and an initial molar relationship that was end-to-end or worse. We did not have a sufficient number of patients in the other growth categories to include them in the study.

Both groups were treated by residents of Methodist University with a standard edgewise appliance, the extraction of 4 first premolars, and extraoral traction (Interlandi Headgear). Several adjuncts (lip bumper, lingual arch, angulated brackets, Class III elastics) were sometimes used for anchorage control in the lower arch. The starting age ranged from 10 to 15 years.

Cephalometric Analysis

The cephalometric tracings in the Petrovic/Lavergne and Johnston analyses were done by hand. No digitization was used. All linear measurements were executed to the nearest 0.1 mm. Angles were obtained to the nearest 0.5°.

The variables for the Petrovic/Lavergne analysis were: SNA, SNB, ANB, ML/NSL, and NL/NSL. To facilitate the classification of the rotational groups and growth categories, a computer program[20] developed at our university was used. The regional superimposition used in the Johnston analysis is described in detail elsewhere.[19]

Treatment Objectives

The determination of the treatment success was carried out according to Lavergne's treatment objectives[18] (Fig 4), based on the rotational group and growth category to which the patient belonged at the beginning of treatment. Treatment improvement was considered to have occurred when a patient changed from category 3 to category 4, and when they changed from deep bite (DB) or open bite (OB) to a normal vertical dental relationship (N) after treatment. The treatment was considered to have failed when a patient changed from category 5 to some other category or when there was a change from a normal vertical incisal relationship to a deep bite or to an open bite.

Error Study

With the aid of a table of random numbers, 15 two-film series for the Johnston and Petrovic/Lavergne analyses were selected and reanalyzed. Dahlberg's formula[21] was used to calculate the error standard deviations for each variable in the 2 analyses.

Statistical Analysis

The distribution of the patients according to category and rotational group at the beginning and at the end of treatment is summarized in Table I. A univariate repeated measures analysis of variance was used to assess whether variables SNA, SNB, ANB, ML/NSL, and NL/NSL differed among categories and at the

Table IV. Means (initial and final of treatment) and standard deviations for the variables of Petrovic/Lavergne analysis

Variables	Initial		Final	
	Mean	SD	Mean	SD
SNA (SD$_e$ = 0.6)				
Category 3	83.76	2.76	81.52	2.76
Category 5	78.32	3.83	76.72	3.88
SNB (SD$_e$ = 0.4)				
Category 3	77.28	2.74	77.08	3.26
Category 5	74.12	3.43	74.80	3.61
ANB (SD$_e$ = 0.5)				
Category 3	6.48	1.69	4.44	1.79
Category 5	4.20	2.04	1.92	1.86
ML/NSL (SD$_e$ = 0.6)				
Category 3	34.68	4.73	34.06	5.91
Category 5	33.40	6.06	31.80	6.20
NL/NSL (SD$_e$ = 0.7)				
Category 3	8.40	3.54	9.34	3.27
Category 5	8.94	3.30	9.28	3.17

Table V. F-ratios for univariate repeated measures analysis of variance

Measures	F		
	Category	Time	Time × Category
SNA	29.40**	92.58**	2.57
SNB	8.92**	2.01	6.74*
ANB	24.73**	113.68**	0.35
NL/NSL	1.21	18.88**	3.68
NL/NSL	0.07	5.24*	1.15

*$P < .05$; **$P < .01$.

beginning and at the end of treatment. To assess differences among proportions of patients in both categories who improved or got worse after treatment in relation to their initial rotational group and growth category, 95% confidence intervals were constructed.

Because the present study covered both sexes and a wide range of starting ages and treatment times, Schulhof and Bagha's[22] sex-specific growth curves were integrated over each subject's period of treatment observation. The resulting area was then expressed as a multiple of the area under the curve for the minimum prepubertal year: the average of 9 or 10 for females and 11 or 12 for males. The resulting expected growth units (EGU)[23,24] constitute individualized estimates of the relative intensity of growth and the attendant change in form that an untreated subject of the same age and sex would be expected to experience during the specified interval.

For the Johnston analysis measurements of treatment change, analysis of covariance, in which EGU served as the covariate, was used to assess differences between categories and to examine the relationship between the number of anchorage devices used by patients and the movement of lower molars.

Correlation coefficients for the relationship between treatment change and EGU were calculated under the assumption that growth potential as estimated by EGU may bear a significant linear relationship to individual components of the molar correction.

RESULTS

Patient distribution by growth category at the beginning and at the end of treatment is shown in Table I. Table II and III show the patient distribution by rotational group at the beginning and at the end of treatment. The number of patients is small when the categories are broken down to the rotational groups, but no comparison was made between these rotational groups. These tables permit the visualization of the individualized change in facial type after treatment, for example, 2 patients that were initially R2DOB (open bite) had their facial type improved to R2DN (normal vertical dimension) after treatment.

The proportions of the sample that were improved in relation to Lavergne's treatment objectives were 12 of 25 and 7 of 25 for categories 3 and 5, respectively. Thus, 12 patients from category 3 and 7 from category 5 had their initial facial type improved after treatment. According to the 95% confidence interval, differences between the proportions of improvement for the 2 categories were not statistically significant.

The proportions of patients who got worse were 1 of 25 and 7 of 25 for the categories 3 and 5, respectively. According to the 95% confidence interval, differences between the proportions of worsening for the two categories were statistically significant.

Descriptive statistics for the measurements of the Petrovic/Lavergne analysis are summarized in Table IV. Table V shows the results for the univariate repeated measures analysis of variance. It may be seen that SNA, SNB, and ANB were significantly different, both at the beginning and at the end of treatment when category 3 is compared to category 5. The variables ML/NSL and NL/NSL were not significantly different between patients of categories 3 and 5. All variables showed no significant interaction (Time × Category) with the exception of SNB. Students' *t* tests confirmed that SNB was not significantly different ($P = .4404$) between initial and final for category 3 patients and that it was significantly different for category 5 ($P = .0056$). This difference (0.68°) for category 5 patients was not clinically significant, however.

Descriptive statistics (means and standard deviations) for the variables of Johnston analysis are shown in Fig 5 and in Table VI, together with F-ratios from the analyses
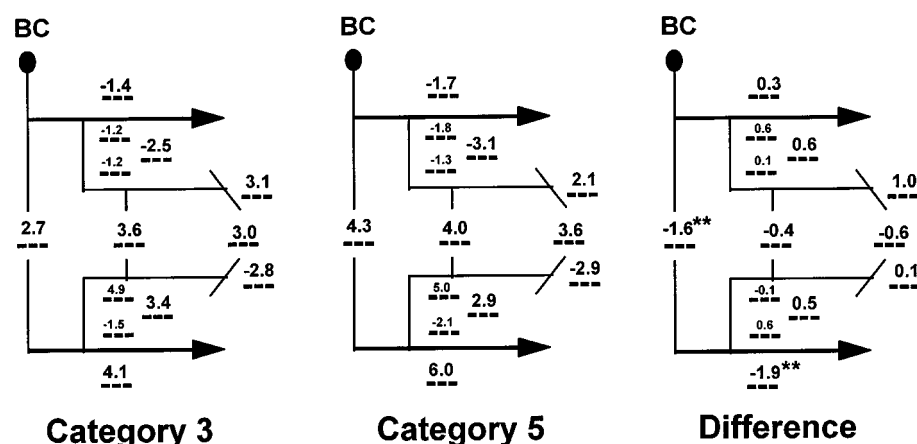
Fig 5. Comparison between category 3 and 5 subjects.

Table VI. Treatment change: skeletal and dental components of the molar and overjet corrections for categories 3 and 5

| Measures | SD_e (n=15) | Category 3 (n = 25) | | Category 5 (n = 25) | | F | |
		Mean	SD	Mean	SD	Category	EGU
Skeleton							
Maxilla	0.5	−1.4	1.1	−1.7	1.2	1.56	14.37**
Mandible	1.0	4.1	2.4	6.0	2.5	13.18**	25.70**
Apical base change	0.6	2.7	1.7	4.3	1.5	17.95**	17.01**
Dentition							
U6 relation to maxilla							
Total	0.6	−2.5	1.7	−3.1	1.6	2.86	10.35**
Bodily	0.5	−1.2	1.3	−1.8	1.9	2.08	6.40*
Tipping	0.7	−1.2	1.4	−1.3	1.2	0.08	0.63
L6 relation to mandible							
Total	0.5	3.4	1.4	2.9	1.4	1.39	0.28
Bodily	0.7	4.9	1.7	5.0	1.7	0.04	1.76
Tipping	0.7	−1.5	1.1	−2.1	1.2	2.57	1.64
U1 relation to maxilla	0.6	3.1	2.5	2.1	3.2	1.65	1.23
L1 relation to mandible	0.4	−2.8	2.5	−2.9	2.2	0.01	3.90
Total Correction							
Molar (6/6)	0.6	3.6	1.4	4.0	0.8	1.43	2.43
Overjet (1/1)	0.7	3.0	2.9	3.6	2.7	0.33	0.52

*$P < .05$; **$P < .01$.

of covariance. The difference (1.9 mm) in mandibular advancement relative to cranial base between category 3 (4.1 mm) and category 5 (6.0 mm) was statistically significant ($P < .01$). This extra mandibular advancement resulted in a greater differential jaw displacement (ABCH) in category 5 (4.3 mm) than in category 3 (2.7 mm); the difference (1.6 mm) was statistically significant ($P < .01$). The relationship between the individual components of the molar correction and EGU can be seen in Figs 6 to 10, for those with a significant relationship.

There was no statistically significant difference in net molar correction. Even the bodily and tipping movements were essentially the same in categories 3 and 5. There was a mesial movement of the maxillary molars (–2.5 mm in category 3 and –3.1 mm in category 5) and of the lower molars (3.4 mm in category 3 and 2.9 mm in category 5) in both categories. Even when the movement of the lower molar was studied with respect to EGU and the number of devices used for anchorage, there was no significant difference between the two growth categories.

Skeletal and dental variables showed a significant correlation with EGU. Mandibular advancement $r =$ 0.6) relative to cranial base and ABCH $r =$ 0.6) bore a positive relationship to expected growth in categories 3 and 5. We also found that maxillary displacement $r =$
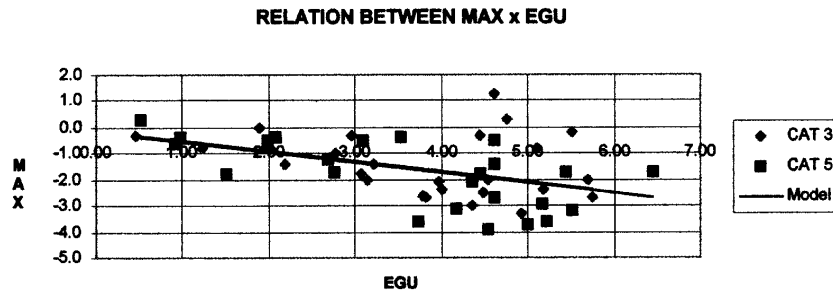
RELATION BETWEEN MAX x EGU

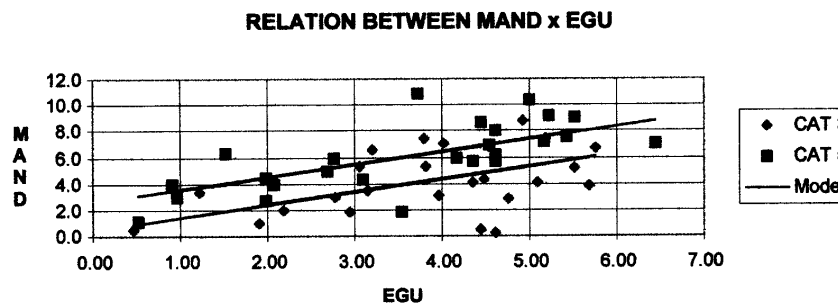**Fig 6.** Relationship between maxillary growth and EGU.

RELATION BETWEEN MAND x EGU

Fig 7. Relationship between mandibular advancement and EGU.
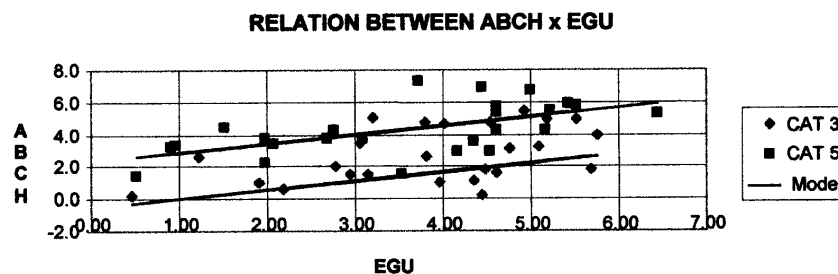
RELATION BETWEEN ABCH x EGU

Fig 8. Relationship between apical base change and EGU.

–0.4) and upper molar movement (total: $r = -0.4$; bodily: $r = -0.3$) have a negative relationship with EGU: the greater the expected growth, the more the maxilla and upper molars come forward.

DISCUSSION

Skeletal and dental changes that accompany edgewise extraction therapy differ when executed in growth categories 3 and 5. Mandibular advancement (*the word advancement is used rather than growth because the present method of regional superimposition cannot distinguish between mandibular growth and bodily functional shifts*) was greater in category 5, a finding that corroborate studies done by Petrovic et al,[13-15] who showed that physiologically determined mandibular lengthening, as seen in untreated patients, increases from growth category 1 to growth category 5. By these

results, we can conclude that the analysis made a successful growth prediction, and this prediction says just who is going to have a good growth potential, instead of trying to calculate how many millimeters the mandible will grow in the near future, a type of prediction that still seems impossible.[25-29] The analysis also seems to be useful in explaining why not all patients respond well to functional appliance treatment: ie, only category 5 patients will show a significant increase in the overall mandibular length.[13-15,30]

Considering that mandibular displacement was greater in category 5, we expected that the loss of anchorage would be smaller in this category, given that less mesial movement would be required to correct the Class II molar relationship. There was, however, no statistically significant difference in the movement of the lower molar between categories 3 and 5.
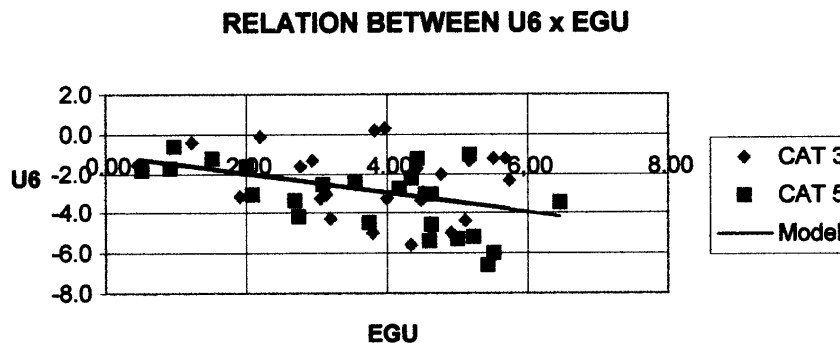
RELATION BETWEEN U6 x EGU

Fig 9. Relationship between maxillary molar movement (total) and EGU.
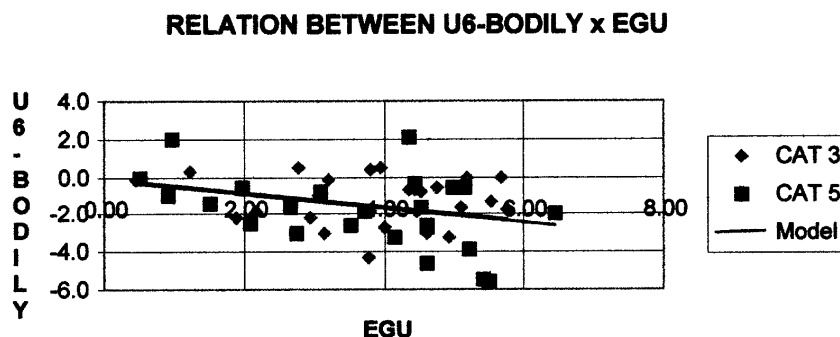
RELATION BETWEEN U6-BODILY x EGU

Fig 10. Relationship between maxillary molar movement (bodily) and EGU.

In this study, we observed that loss of anchorage seems be one of the greatest problems during Class II extraction treatment. Besides a good growth potential, we thus should try to minimize this loss, especially in the upper arch. Johnston[23] reported 1.8 mm of maxillary anchorage loss and 3.2 mm of mandibular anchorage loss in premolar extraction patients. Harris et al[31] reported similar findings in adolescent girls: 2.5 mm in the maxilla; 3.7 mm in the mandible. Baumrind,[32] in two stratified random samples of Class II patients, recently found about 6.0 mm for upper anchorage loss in extraction subjects. In the present study, upper molar mesial movement consumed almost 50% (2.5 mm in 3 category and 3.1 mm in 5 category) of the extraction space during treatment.

When the contributions of dental and skeletal changes to the molar correction are compared between categories, we can see that, in category 3, dental change contributed 25%, whereas skeletal change contributed 75% of the molar correction. In category 5, however, dental correction was –0.2 mm (–5%), which was compensated for by differential jaw displacement (ABCH = 4.3 mm), representing 107.5% of the molar correction. Johnston[23] reported that apical base change accounted for 60% of the molar correction in his study, whereas Harris et al[31] found that advancement accounted for 70%

of the molar correction in adolescents. The importance of mandibular advancement for Class II correction has already been highlighted,[2,33,34] although Hixon and Klein[35] have stated that growth is not related to Class II correction. Obviously, in the absence of appliances, dentoalveolar compensation[36] will tend to preserve the occlusal status quo in the face. Given the usual pattern of growth, the skeleton will improve, but the occlusion will remain the same. If, however, the compensations were prevented, a favorable pattern would be able to contribute to the buccal segment correction.[23] Our results also agree with Rubin,[37] who stated that many of our failures in orthodontics are established the moment we plan treatment and before the first band is cemented. For example, in a Class II case with the extraction of 4 first premolars, if we plan to drive the maxillary molars distally a full cusp and the lower extraction site is consumed by the crowding; if the patient has a poor skeletal growth, we will certainly be disappointed because we will not be able to correct the Class II molar relationship.

There was no statistically significant difference in overjet correction and in the component movements of the upper and lower incisors. However, in category 3 dental movement accounted for 10% (0.3 mm) of the overjet correction; in category 5, the movement of incisors made the overjet correction worse by 22% (–0.8

mm). We can conclude that ABCH was responsible for 90% of the overjet correction in category 3 and for 119.4% in category 5. Thus, our data support the findings of Paquette et al,[38] who reported that mandibular advancement was the most important net contributor to the overjet correction. Considering that there were no statistically significant differences between the movement of the molars and of the incisors in categories 3 and 5, we cannot corroborate the argument[38] that the more the mandible outgrows the maxilla, the greater the probability that the upper molars and the incisors will tip forward, that the lower incisors will tip lingually, and that lower molar anchorage will be preserved.

Considering that treatment can lead to growth rotations[18] that can change a patient's rotational group, it was expected that the patients in categories 3 and 5 would have their rotational groups changed after treatment. Accordingly, it was shown that edgewise therapy with premolar extraction tended to produce better results (less worsening in facial type) for patients of growth category 3. These results corroborate Lavergne,[11,18] who stated that category 3 patients would benefit more from a headgear and fixed appliance treatment, whereas category 5 patients are suited to functional appliance treatment (or both). Actually, further studies should be done in which each category is treated in a different way so that ultimately each category can have its appropriate treatment goals and therapy. In addition, more research is needed on the growth and treatment effects on the TMJ fossa.

Finally, considering the existence of well-defined different facial types[15,16] for the Class II malocclusion, we can conclude that one approach of treatment may not be effective for all Class II patients. As a result, to study and also to treat Class II malocclusion, it is necessary first to divide patients according to their facial type. When these patients are treated, the clinician should try to improve the patient facial type. If this is not possible, he or she should at least not make it worse.

CONCLUSIONS

1. Molar correction was almost identical in growth categories 3 and 5; however, its source was not. Differential jaw growth (ABCH) accounted for 75% of molar correction in category 3 and 107.5% in category 5. Molar movement accounted for 25% of the molar correction in category 3, but worsened it 4% in category 5. There was no significant difference, either for incisors movement or for overjet correction in both categories. Mandibular advancement was the most important single factor in the molar and overjet corrections.
2. Petrovic/Lavergne analysis made a successful growth prediction of mandibular advancement relative to cranial base.
3. Incisor movement produced little net contribution to the overjet correction.
4. There was no significant difference in anchorage loss between patients of categories 3 and 5.
5. Edgewise extraction therapy is more suitable for patients belonging to growth category 3 than to patients belonging to category 5.

REFERENCES

1. Angle EH. Malocclusion of the teeth, seventh ed. Philadelphia: S.S. White Dental Mfg Co; 1907.
2. Moore AW. Orthodontic treatment factors in Class II malocclusion. Am J Orthod 1959;45:323-52.
3. Bishara SE, Zaher AR, Cummins DM, Jakobsen JR. Effects of orthodontic treatment on the growth of individuals with Class II Division 1 malocclusion. Angle Orthod 1994;64:221-30.
4. Lavergne J, Gasson N. Operational definitions of mandibular morphogenetic and positional rotations. Scand J Dent Res 1977;85:185-92.
5. Lavergne J, Gasson N. Analysis and classification of the rotational growth pattern without implants. Br J Orthod 1982;9:51-6.
6. Lavergne J, Gasson N. The influence of jaw rotation on the morphogenesis of malocclusion. Am J Orthod 1978;73:658-66.
7. Petrovic A, Stutzmann J, Oudet J. Control processes in postnatal growth of condylar cartilage of the mandible. In: McNamara JA Jr, ed. Determinants of mandibular form and growth. V.4, Craniofacial Growth Series. Ann Arbor: Center for Human Growth and Development, The University of Michigan; 1975. p. 101-53.
8. Lavergne J, Petrovic A. Pathogenesis and treatment conceptualization of dentofacial malrelations as related to the pattern of occlusal relationship. In: Dixon AD, Sarnat BG. Normal and abnormal bone growth: basic and clinical research. New York: Liss; 1985. p. 393-402.
9. Petrovic A, Stutzmann J. The concept of the mandibular tissue-level growth potential and the responsiveness to a functional appliance. In: Graber LW, ed. Orthodontics. state of the art: essence of the science. St Louis: CV Mosby; 1986. p. 59-74.
10. Petrovic A, Lavergne J, Stutzmann J. Tissue-level growth and responsiveness potential, growth rotation and treatment decision. In: Vig PS, Ribbens KA, eds. Science and clinical judgment in orthodontics. Monograph 19, Craniofacial Growth Series. Ann Arbor: Center for Human Growth and Development, The University of Michigan; 1986. p. 181-223.
11. Lavergne J. Morphogenetic classification of malocclusion as a basis for growth prediction and treatment planning. Br J Orthod 1982;9:132-45.
12. Petrovic A, Lavergne J, Stutzmann J. Diagnostic et traitement en orthopédie dentofaciale principes et diagramme de décision. Orthod Fr 1987;58:517-42.
13. Petrovic A, Stutzmann J, Lavergne J. Mechanisms of craniofacial growth and modus operandi of functional appliances: a cell-level and cybernetic approach to orthodontic decision making. In: Carlson DS, ed. Craniofacial growth theory and orthodontic treatment. Monograph 23. Craniofacial Growth Series. Ann Arbor: Center for Human Growth and Development, The University of Michigan; 1990. p. 13-74.
14. Petrovic A, Stutzmann J, Lavergne J. Diferenças interindividuais no potencial de crescimento a nivel tecidual e na capacidade de resposta ao tratamento pelo bionator ou pela técnica de Begg: abordagem metodológica, fundamentação auxológica; resultado clinico. (Interindividual differences in tissue-level growth potential and responsiveness to bionator or Begg technique: methodological approach, auxilogical foundations, clinical outcome.) Ortodontia 1992;25:4-14.
15. Petrovic A. Heritage paper: auxologic categorization and chronobiologic specification for the choice of appropriate orthodontic treatment. Am J Orthod Dentofacial Orthop 1994;105:192-205.
16. Petrovic A, Stutzmann J, Orthopedically induced growth stimulation of the mandible. In: McNamara JA Jr, Trotman C, eds. Distraction osteogenesis and tissue engineering. Monograph 34. Craniofacial Growth Series. Ann Arbor: Center for Human Growth and Development, The University of Michigan; 1998. p. 153-70.
17. Stutzmann J, Petrovic A. Variations in the human mesial and distal alveolar bone turnover rate and orthodontically induced tooth movement. In: Davidovitch Z, ed. The biological mechanisms of tooth movement and craniofacial adaptation. Columbus, Ohio: The Ohio State University College of Dentistry; 1992; p. 241-55.
18. Lavergne J. Diagnostic orthodontique et informatique. Rev Orthop Dento Faciale 1992;26:295-307.
19. Johnston LE Jr. Balancing the books on orthodontic treatment: an integrated analysis of change. Br J Orthod 1996;23:93-102.

20. Toigo E, Moro A, Vigorito JW. Proposta de um programa computadorizado para a Análise de Petrovic/Lavergne (Proposal of a computerized program for Petrovic/Lavergne analysis). Ortodontia 1996;29:16-26.

21. Houston WJB. The analysis of errors in orthodontic measurements. Am J Orthod 1983;83:382-90.

22. Schulhof R J, Bagha L. A statistical evaluation of the Ricketts and Johnston growth-forecasting methods. Am J Orthod 1975;67:258-76.

23. Johnston LE Jr. A comparative analysis of Class II treatment. In: McNamara JA Jr, Carlson DS, Vig PS, Ribbens KA, eds. Science and clinical judgement in orthodontics. Monograph 18, Craniofacial Growth Series. Ann Arbor: Center for Human Growth and Development, The University of Michigan; 1986. p. 103-48.

24. Johnston LE Jr. Growth and the Class II patient: rendering unto Caesar. Seminars Orthod 1998;4:59-62.

25. Greenberg LZ, Johnston LE Jr. Computerized prediction: the accuracy, of a contemporary long-range forecast. Am J Orthod 1975;67:243-52.

26. Houston WJB. The current status of facial growth prediction: a review. Br J Orthod 1979;6:11-17.

27. Lee RS, Daniel F J, Swartz M, Baumrind S, Korn EL. Assessment of a method for prediction of mandibular rotation. Am J Orthod 1987;91:395-402.

28. Baumrind S. Prediction in the planning and conduct of orthodontic treatment. In: Melsen B, ed. Current controversies in orthodontics. Chicago: Quintessence; 1991. p. 25-43.

29. Cangialosi T J, Chung JM, Elliott DF, Meistrell ME Jr. Reliability of computer-generated prediction tracing. Angle Orthod 1995;65:277-84.

30. Rudzki-Janson I, Noachtar R. Functional appliance therapy with the bionator. Semin Orthod 1998;4:33-45.

31. Harris EF, Dyer GS, Vaden JL. Age effects on orthodontic treatment: skeletodental assessments from the Johnston analysis. Am J Orthod Dentofacial Orthop 1991;100:531-6.

32. Baumrind S. Unbiased quantitative testing of conventional orthodontic beliefs. Semin Orthod 1998;4:3-16.

33. Coben SE. Growth and Class II treatment. Am J Orthod 1966;52:5-26.

34. Herzberg R. A cephalometric study of Class II relapse. Angle Orthod 1973;43:112-8.

35. Hixon E, Klein P. Simplified mechanics: a means of treatment based on available scientific information. Am J Orthod 1972;62:113-41.

36. Solow B. The dentoalveolar compensatory mechanism: Background and clinical implications. Br J Orthod 1980;7:145-61.

37. Rubin RM. Treatment planning in Class II malocclusions. Angle Orthod 1969;39:152-61.

38. Paquette DE, Beattie JR, Johnston LE Jr. A long-term comparison of nonextraction and premolar extraction edgewise therapy in "borderline" Class II patients. Am J Orthod Dentofacial Orthop 1992;102:1-14.