

ORIGINAL ARTICLE

Treatment timing for Twin-block therapy

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This cephalometric study evaluated skeletal and dentoalveolar changes induced by the Twin-block appliance in 2 groups of subjects with Class II malocclusion treated at different skeletal maturation stages in order to define the optimal timing for this type of therapy. Skeletal maturity in individual patients was assessed on the basis of the stages of cervical vertebrae maturation. The early-treated group was composed of 21 subjects (11 females and 10 males). Mean age of these subjects at time 1 (immediately before treatment) was 9 years \pm 11 months, and at time 2 (immediately after discontinuation of the Twin-block appliance) was 10 years 2 months \pm 11 months. According to the cervical vertebrae maturation staging at times 1 and 2, the peak in growth velocity was not included in the treatment period for any of the subjects in the early group. The late-treated group consisted of 15 subjects (6 females and 9 males). Mean age of this group was 12 years 11 months \pm 1 year 2 months at time 1 and 14 years 4 months \pm 1 year 3 months at time 2. In the late group, treatment was performed during or slightly after the onset of the pubertal growth spurt. Both treated samples were compared with control samples consisting of subjects with untreated Class II malocclusions also selected on the basis of the stage in cervical vertebrae maturation. A modification of Pancherz's cephalometric analysis was applied to the lateral cephalograms of all examined groups at both time periods. Linear and angular measurements for mandibular dimensions, cranial base angulation, and vertical relationships were added to the original analysis. Annualized differences for all the variables from time 1 to time 2 were calculated for both treated groups and contrasted to the annualized differences in the corresponding untreated groups by means of nonparametric statistics. The findings of this short-term cephalometric study indicate that optimal timing for Twin-block therapy of Class II disharmony is during or slightly after the onset of the pubertal peak in growth velocity. When compared with treatment performed before the peak, late Twin-block treatment produces more favorable effects that include: (1) greater skeletal contribution to molar correction, (2) larger increments in total mandibular length and in ramus height, and (3) more posterior direction of condylar growth, leading to enhanced mandibular lengthening and to reduced forward displacement of the condyle in favor of effective skeletal changes. The importance of the biological evaluation of skeletal maturity in individual patients with Class II disharmony to be treated with functional appliances is emphasized. (*Am J Orthod Dentofacial Orthop* 2000;118:159-70)

A wide range of functional/orthopedic appliances is available for the correction of Class II skeletal and occlusal disharmonies (eg, Bionator,¹⁻³ FR-2 of Fränkel,⁴⁻⁷ fixed and removable Herbst appliances⁸⁻¹³). Among these, the Twin-block originally developed by William J. Clark of Fife, Scotland, has gained increasing popularity during the last decade. The appliance consists of maxillary and mandibular acrylic plates with bite blocks that posture the mandible forward on closure, and it is indicated for the correction of Class II

malocclusions characterized in part by mandibular skeletal retrusion.¹⁴⁻¹⁹

The main objective of therapy with functional appliances such as the Twin-block is to induce supplementary lengthening of the mandible by stimulating increased growth at the condylar cartilage. It has been demonstrated that the effectiveness of functional treatment of mandibular growth deficiencies strongly depends on the biological responsiveness of the condylar cartilage, which in turn depends on the growth rate of the mandible. The rate of mandibular growth, however, is not constant throughout the juvenile and adolescent periods, with the existence of a pubertal peak in mandibular growth described previously in classical cephalometric studies.²⁰⁻²⁵ The onset, duration, and intensity of the pubertal spurt in mandibular growth vary on an individual basis.

Evidence has been gathered that shows the greatest effects of functional appliances occur when the peak in mandibular growth is included in the treatment period. In particular, investigations by Petrovic et al²⁶⁻²⁸ revealed

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that the therapeutic effectiveness of the Louisiana State University activator, Fränkel appliance, and Bionator is most favorable when these appliances are used during the ascending portion of the individual pubertal growth spurt. Malmgren et al²⁹ demonstrated significantly greater skeletal effects induced by the Bass appliance in boys treated during the peak period than in those treated in the prepeak period. Hägg and Panerz³⁰ found that sagittal condylar growth in patients treated with the Herbst appliance at the peak in pubertal growth was twice that observed in patients treated 3 years before or 3 years after the peak. In a study that did not take into account any specific appraisal of skeletal maturation in different groups, McNamara et al⁷ described less dramatic changes in mandibular length in subjects who started treatment with the FR-2 appliance of Fränkel during the early to mid-mixed dentition (average chronologic age, 8.8 years) than in those starting treatment during the late mixed to early permanent dentitions (average age, 11.6 years).

Different rates of mandibular growth at puberty, as well as the peak in mandibular growth velocity, can be detected on the basis of several methods for the assessment of skeletal maturity. These biological indicators include increase in body height,^{20,22} skeletal maturation of the hand and wrist,³¹ dental development and eruption,^{32,33} menarche, breast and voice changes,³⁴ and cervical vertebrae maturation.^{35,36} With regard to this last method, stages in the maturation of the cervical vertebrae show significant correlations with pubertal changes in mandibular growth, as demonstrated by O'Reilly and Yanniello.³⁶ In a previous work on the effects of bonded Herbst therapy,³⁷ the stages of cervical vertebrae maturation have been used to match the treated group and the untreated control groups according to pretreatment mandibular skeletal maturity.

A few clinical investigations have studied skeletal and dentoalveolar changes induced by the Twin-block appliance in patients with Class II malocclusions.³⁸⁻⁴⁰ Data from these studies indicate the effectiveness of the appliance in enhancing mandibular growth and in correcting Class II occlusal relationship. None of these contributions, however, deals with the issue of treatment timing for Twin-block therapy, as an analysis of treatment effects in groups of Class II patients at different ages and/or skeletal developmental stages has not been performed.

The aim of the present study, therefore, is to evaluate skeletal and dentoalveolar modifications produced by the Twin-block appliance in 2 samples of subjects with Class II disharmony treated at different stages of mandibular skeletal maturity (before and during the pubertal peak in mandibular growth), as determined on the basis of cervical vertebrae maturation, in order to define optimal treatment timing for this type of therapy.

SUBJECTS AND METHODS

Subjects

The cephalometric records of 79 patients treated with the Twin-block appliance were collected from 7 private orthodontic practices as well as from the Graduate Orthodontic Clinic at the University of Michigan.⁴⁰ Practitioners were asked to send pretreatment and posttreatment records of all patients treated with the Twin-block appliance regardless of treatment results or patient compliance.

Forty-three of the patients were eliminated from the study according to exclusionary criteria (absence of full Class II molar relationship, poor film quality, additional orthodontic treatment, or extractions of permanent teeth during the period of Twin-block therapy). The remaining 36 sets of cephalograms were analyzed in the present study. The treated sample was divided into 2 groups according to skeletal maturity at the start of treatment evaluated by means of the cervical vertebrae maturation method.^{35,36}

The early-treated group (ETG) consisted of 21 subjects (11 females and 10 males) presenting with either stage 1 or stage 2 in cervical vertebrae maturation (ie, before the onset of the pubertal growth spurt). Mean age of ETG at time 1 (T1, immediately before treatment) was 9 years \pm 11 months and at time 2 (T2, immediately after discontinuation of the Twin-block appliance) was 10 years 2 months \pm 11 months. Mean T1 to T2 period for ETG was 1 year 2 months \pm 4 months. Stages in cervical vertebrae maturation at T2 ranged from stage 1 to stage 3. Therefore, the peak in growth velocity was not included in the treatment period for any of the subjects in the early group.

The late-treated group (LTG) consisted of 15 subjects (6 females and 9 males) presenting with stages in cervical vertebrae maturation ranging from stage 3 to stage 5. Mean age of LTG was 12 years 11 months \pm 1 year 2 months at T1 and 14 years 4 months \pm 1 year 3 months at T2. Mean T1 to T2 period for LTG was 1 year 5 months \pm 5 months. Stages in cervical vertebrae maturation at T2 ranged from stage 4 to stage 6. In LTG, therefore, treatment was performed during or slightly after the onset of the pubertal growth spurt.

The treated sample was compared with a sample of 30 subjects with untreated Class II malocclusions (control sample) selected from the University of Michigan Elementary and Secondary School Growth Study.⁴¹ The control sample also was divided into 2 groups according to the stage in cervical vertebrae maturation.

The early-control group (ECG) was 16 subjects (7 females and 9 males) presenting with either stage 1 or stage 2 in cervical vertebrae maturation. Mean age of

ECG was 9 years 1 month \pm 10 months at T1 and 10 years 5 months \pm 9 months at T2. Mean observation period (T1 to T2) for ECG was 1 year 4 months \pm 7 months. As in ETG, stages in cervical vertebrae maturation at T2 in ECG ranged from stage 1 to stage 3.

The late-control group (LCG) consisted of 14 subjects (7 females and 7 males) presenting with stages in cervical vertebrae maturation ranging from stage 3 to stage 5. Mean age of LCG was 13 years 7 months \pm 1 year 2 months at T1 and 14 years 10 months \pm 1 year 4 months at T2. Mean observation period (T1 to T2) for LCG was 1 year 3 months \pm 5 months. As in LTG, stages in cervical vertebrae maturation at T2 in LCG ranged from stage 4 to stage 6, thus including the pubertal growth spurt in the observation period.

Assessment of Skeletal Maturation

Six stages corresponding to 6 different maturation phases in the cervical vertebrae can be identified during the pubertal period according to the evaluation method by Lamparski.³⁵ The 6 stages are characterized by definite morphologic and dimensional changes of the bodies of the second through the sixth cervical vertebra (Fig 1). This procedure has proven to be effective and clinically reliable for the appraisal of skeletal maturation in growing subjects. The stages of cervical vertebral maturation are related to the mandibular growth changes that take place during puberty.³⁶ The 6 stages include observations before the peak, ie, during the accelerative growth phase (vertebral stages 1 to 3) and observations after the peak, ie, during the decelerative phase of growth (vertebral stages 4 to 6). Pubertal growth peak occurs on average between vertebral stage 3 and 4.³⁶

Treatment Protocol

Most of the Twin-block appliances used in this study were of the design originally developed by Clark. The appliance is composed of maxillary and mandibular appliances that fit tightly against the teeth, alveolus, and adjacent supporting structures (Fig 2). Delta clasps¹⁸ were used bilaterally to anchor the maxillary appliance to the first permanent molars, and 0.030 inch ball clasps (or arrow clasps) were placed in the interproximal areas anteriorly. The precise clasp configuration depended on the type (deciduous or permanent) and number of teeth present at the time of appliance construction. In the lower arch, Clark has recommended using a series of ball clasps that lie in the interproximal areas between the canines and lower incisors (Fig 2B). For a few of the appliances used in the study, the design was modified by placing a labial bow anterior to the lower incisors that has labial acrylic similar to that of a lower spring retainer as designed by Barrer.⁴² In contrast to the fab-

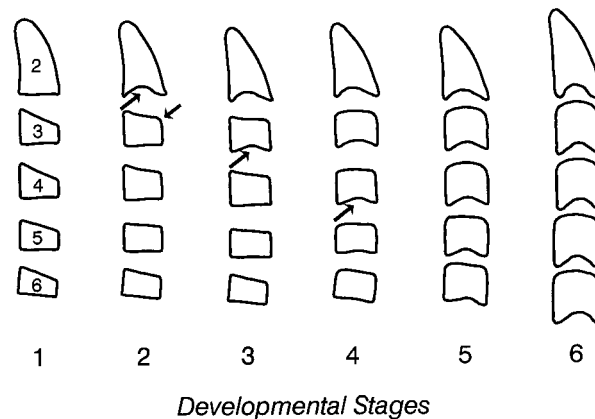


Fig 1. Developmental stages of cervical vertebrae. *Stage 1*, the inferior borders of the bodies of all cervical vertebrae are flat. The superior borders are tapered from posterior to anterior. *Stage 2*, a concavity develops in the inferior border of the second vertebra. The anterior vertical height of the bodies increases. *Stage 3*, a concavity develops in the inferior border of the third vertebra. *Stage 4*, a concavity develops in the inferior border of the fourth vertebra. Concavities in the lower borders of the fifth and of the sixth vertebrae are beginning to form. The bodies of all cervical vertebrae are rectangular in shape. *Stage 5*, concavities are well defined in the lower borders of the bodies of all 6 cervical vertebrae. The bodies are nearly square in shape and the spaces between the bodies are reduced. *Stage 6*, all concavities have deepened. The bodies are now higher than they are wide. (Modified from O'Reilly and Yanniello.³⁶)

rication of a spring retainer, however, the positions of the lower incisors were not altered in the work model before appliance construction.

For those patients beginning Twin-block treatment with mild-to-moderate overjets, the appliances were constructed from bite registrations taken with the incisors in an end-to-end position. In instances in which the pretreatment overjet exceeded 6 to 7 mm, the bite registration protocol varied. In about half of the large overjet patients, the bite registration was obtained with the mandible initially postured forward 4 to 6 mm, with the appliance reactivated after a few months so that the incisors ultimately were in an end-to-end position. In the remaining patients with large overjets, the Twin-block appliance was constructed with the incisors in an end-to-end position initially.

Typically the bite registration was taken to allow 5 to 7 mm of vertical opening in the region of the posterior bite blocks. A proposed benefit of the Twin-block appliance is the ability to control vertical development of the molars and premolars through selective removal

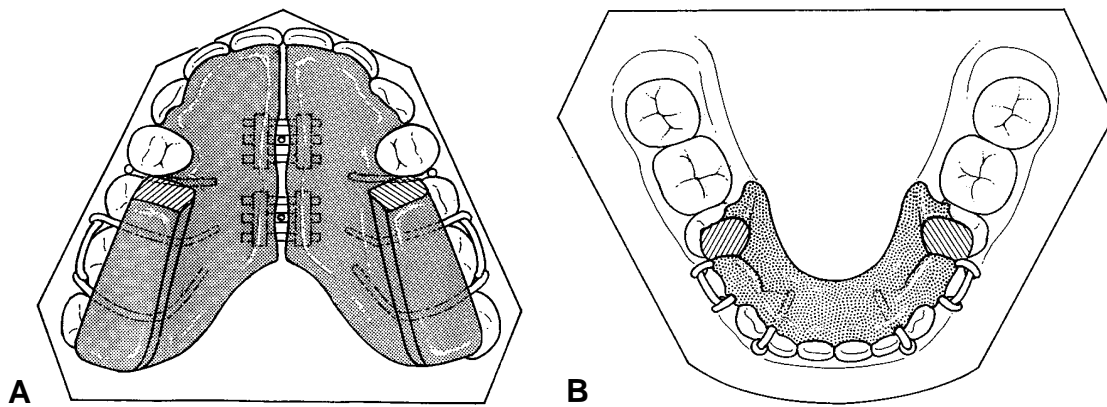


Fig 2. Twin-block appliance. A, Maxillary view; B, mandibular view.

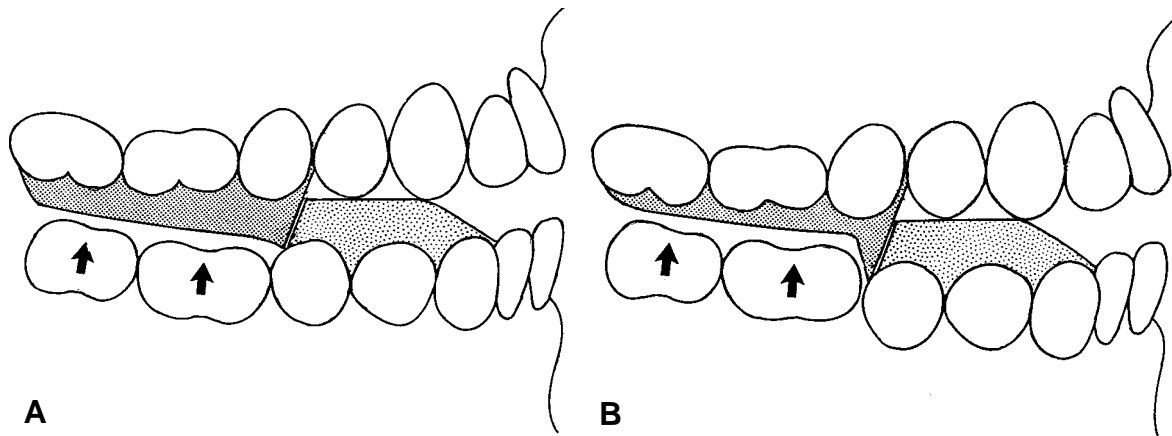


Fig 3. Contouring of the posterior bite blocks. A, Acrylic is removed from the undersurface of the posterior bite blocks to allow for the eruption of the mandibular first molars, which helps level the curve of Spee; B, further removal of acrylic facilitates further molar eruption.

of acrylic during treatment (Fig 3). In patients with a short lower anterior facial height and/or an accentuated curve of Spee, the acrylic on the posterior portion of the maxillary bite block was trimmed according to the recommendations of Clark¹⁸ in order to promote eruption of the posterior dentition. All patients involved in the study were asked to wear the appliance 24 hours a day (with the exception of eating and playing certain sports) until the end of treatment. The compliance to these instructions, however, varied among patients.

Cephalometric Analysis

Lateral cephalograms of both treated groups and of both control groups at T1 and at T2 were standardized as to magnification factor and analyzed by means of a digitizing tablet (Numonics, Lansdale, Pa) and of a digitizing software (Viewbox, ver. 2.0).⁴³

Pancherz's cephalometric analysis with a modified reference system for the superimposition procedure was applied. The definitions for the landmarks used in the analysis have been provided previously.³⁷

The following variables were measured using the superimposed tracings at T1 and T2 (Fig 4):

- is/OLp minus ii/OLp: overjet
- ms/OLp minus mi/OLp: molar relation (a positive value indicates a distal relation; a negative value indicates a mesial relation)
- A point/OLp: sagittal position of the maxillary base
- pg/OLp: sagittal position of the mandibular base
- co/OLp: sagittal position of the condylar head
- pg/OLp + co/OLp: composite mandibular length
- is/OLp minus A point/OLp: sagittal position of the maxillary central incisor within the maxilla

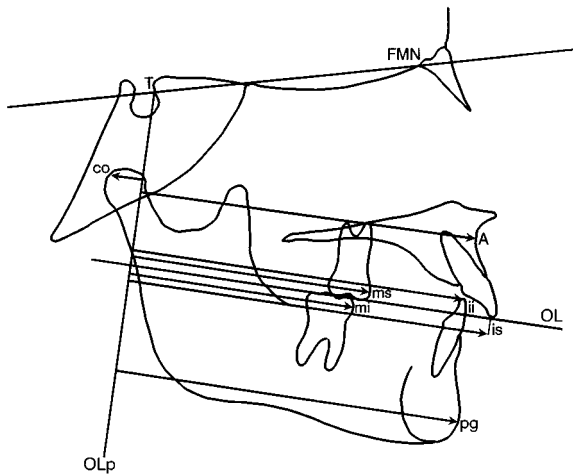


Fig 4. Modified Pancherz's analysis.

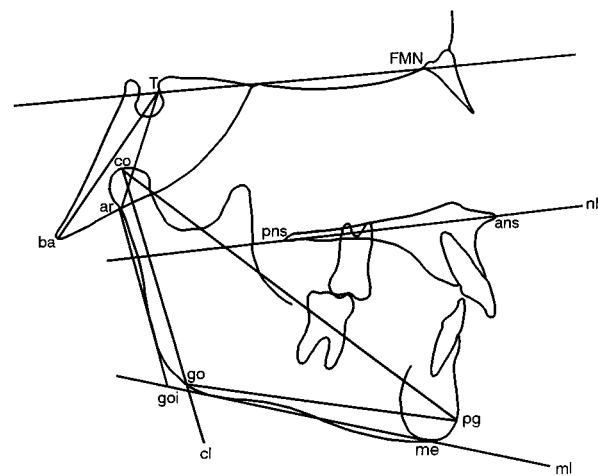


Fig 5. Additional cephalometric measurements

- ii/OLp minus pg/OLp : sagittal position of the mandibular central incisor within the mandible
- ms/OLp minus A point/ OLp : sagittal position of the maxillary permanent first molar within the maxilla
- mi/OLp minus pg/OLp : sagittal position of the mandibular permanent first molar within the mandible

Additional measurements for cranial base angulation, mandibular dimensions, and skeletal vertical relationships were obtained on all cephalograms at T1 and T2, independently from the superimposition reference system (Fig 5): linear measurements, $co-pg$, $co-go$, $go-pg$; and angular measurements, $FMN-T-ba$, $FMN-T-ar$, $cl-ml$, $ar-goi-me$, $nl/T-FMN$ line, $ml/T-FMN$ line, $nl-ml$.

Thirty randomly selected cephalograms were retraced to calculate method errors for all the variables. Systematic error was determined by calculating the coefficients of reliability for all the variables. Method errors ranged from 0.10 to 0.68 mm, corresponding to coefficients of reliability from 0.981 to 0.997.

Statistical Analysis

The starting forms of ETG and LTG were compared with those in ECG and LCG, respectively. The T2 to T1 changes for all cephalometric variables in both treated and control groups were annualized. The annualized changes in the ETG were contrasted with those in the ECG. Similarly, the annualized changes in the LTG were compared with those in the LCG. All statistical comparisons were performed by means of a nonparametric test (Mann-Whitney *U* Test) for independent samples ($P < .05$) that was carried out with the aid of a commercial statistical package (SPSS for Windows, release 8.0.0, SPSS, Inc).

RESULTS

Comparison of Starting Forms

Initial average craniofacial configurations at T1 in ETG and LTG did not show significant differences when compared with ECG and LCG, respectively, with the exception of a few variables. The ETG presented with a more accentuated downward inclination of the nasal line in relation to the cranial base, a slightly less protrusive maxilla, and a more mesial position of first maxillary molars. The LTG exhibited larger overjets, due to slightly more protrusive upper incisors, and more accentuated distal molar relationships.

Treatment Effects in the ETG (Table I and Fig 6)

Treatment with the Twin-block appliance before the pubertal peak produced an overjet correction of 4.6 mm and a correction in molar relation of 4.7 mm when compared with growth changes in the early-control group. The skeletal contribution to overjet correction was predominant (55%) due exclusively to mandibular changes. Mandibular base measurement showed significantly greater increments in ETG when compared with ECG. The dentoalveolar component of overjet correction was due mainly to mandibular changes. The mandibular incisors were proclined significantly by treatment, whereas the position of the maxillary incisors was not affected significantly.

Skeletal and dentoalveolar contributions to molar correction were almost equivalent. Increments in mandibular base measurement completely accounted for the skeletal changes, whereas dental changes primarily were due to distal movement of the maxillary molars. The changes in the position of both maxillary and mandibular molars, however, were significant when compared with ECG.

Table I. Changes T2-T1 in the early groups

Variable	Early-treated group (ETG) (n = 21)		Early-control group (ECG) (n = 16)		Mann-Whitney U test	Group difference ETG/ECG ("treatment effect")
	Mean	SD	Mean	SD		
Modified Pancherz's analysis (mm)						
Overjet is/OL _p minus ii/OL _p	-3.73	3.33	+0.83	0.92	S	-4.56
Molar relation mis/OL _p minus mi/OL _p	-4.53	1.74	+0.20	0.91	S	-4.73
Maxillary base A point/OL _p	+1.00	1.65	+1.04	1.16	NS	-0.04
Mandibular base og/OL _p	+3.92	3.73	+1.45	2.30	S	+2.47
Condylar head co/OL _p	+0.10	1.23	-1.29	1.32	S	+1.39
Composite mandibular length pg/OL _p + co/OL _p	+3.81	3.49	+2.74	2.13	NS	+1.07
Maxillary incisor is/OL _p minus A point/OL _p	+0.04	1.88	+0.72	1.35	NS	-0.68
Mandibular incisor ii/OL _p minus pg/OL _p	+0.86	2.03	-0.52	1.24	S	+1.38
Maxillary molar ms/OL _p minus ss/OL _p	-0.83	1.30	+0.43	1.47	S	-1.26
Mandibular molar mi/OL _p minus pg/OL _p	+0.78	1.50	-0.17	1.11	S	+0.95
Other variables						
FMN-T point-ba (°)	-0.11	1.82	+0.22	1.42	NS	-0.33
FMN-T point-ar (°)	-0.67	2.38	+0.71	2.21	NS	-1.38
co-pg (mm)	+4.95	2.43	+3.07	1.09	S	+1.88
co-go (mm)	+1.98	1.50	+1.70	1.47	NS	+0.28
go-pg (mm)	+2.98	2.26	+1.94	1.00	NS	+1.04
cl-ml (°)	+0.67	0.38	-0.29	1.28	NS	+0.96
ar-goi-me (°)	+0.53	2.09	-1.32	2.08	S	+1.85
nl/FMN-T line (°)	-0.02	1.61	-0.37	1.84	NS	+0.35
ml/FMN-T line (°)	+0.13	1.72	-0.66	1.41	NS	+0.79
nl-ml (°)	+0.15	2.03	-0.29	1.13	NS	+0.44

S, Significant comparison ($P < .05$); NS, not significant comparison.

Early treatment produced a significant forward displacement of the condylar head in relation to the reference system (co/OL_p) when compared with early controls.

Total mandibular length (co-pg) showed significantly greater increments in ETG, whereas the height of the mandibular ramus (co-go) and the length of the mandibular body (go-pg) did not exhibit significant differences. The gonial angle (ar-goi-me) demonstrated significantly greater increments in ETG when compared with ECG, whereas the increments in the inclination of the condylar line in relation to the mandibular line (cl-ml) were not significant. No significant differences between ETG and ECG were found as to cranial base angulation and vertical skeletal relationships.

Treatment Effects in the LTG (Table II and Fig 7)

Treatment with the Twin-block appliance during or slightly after the pubertal peak induced an overjet

correction of 5.8 mm and a correction in molar relation of 4.8 mm when compared with growth changes in the LCG. The skeletal contribution to overjet correction was predominant (54%). Both skeletal and dentoalveolar components of overjet correction were due mainly to mandibular changes. Mandibular base measurement showed significantly greater increments in LTG when compared with LCG. Mandibular incisors were proclined significantly by treatment, whereas the position of the maxillary incisors was not affected significantly.

Skeletal contribution to molar correction also was predominant (67%), and it was due mainly to significantly greater increments in mandibular base. Dentoalveolar changes were due primarily to mesial movement of the mandibular molars. The changes in the position of both maxillary and mandibular molars, however, were significant when compared with LCG.

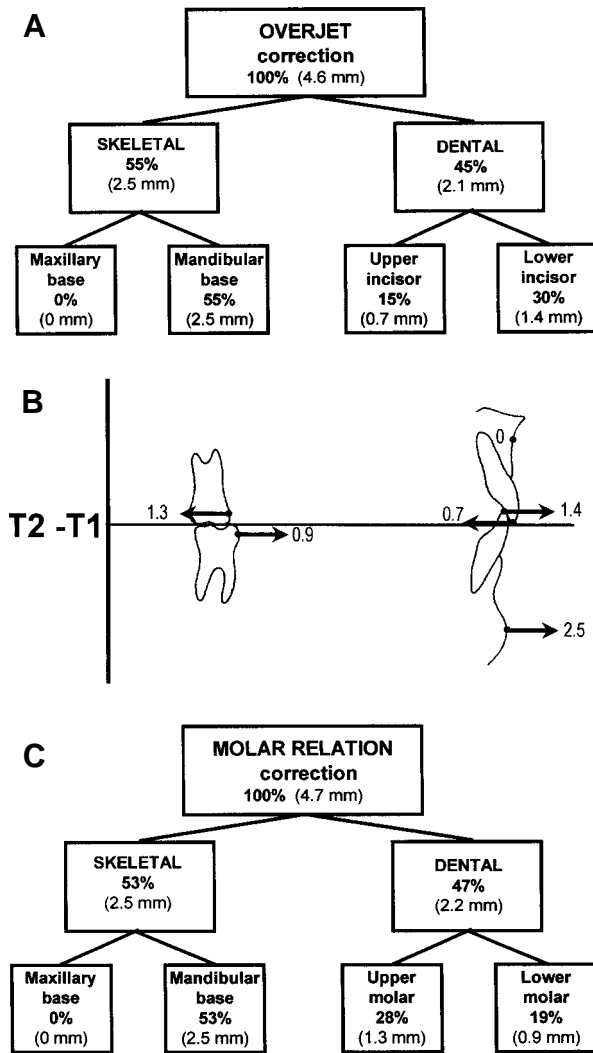


Fig 6. Diagram of maxillary and mandibular skeletal and dentoalveolar changes contributing to sagittal overjet correction and molar correction in the early-treated group (see the column "Treatment effect" in Table I).

Late treatment induced a significant backward displacement of the condylar head in relation to the reference system (co/OLp) when compared with late controls.

Treatment during or slightly after the pubertal peak also induced significantly greater increments in total mandibular length (co-pg), in the height of the mandibular ramus (co-go), and in the length of the mandibular body (go-pg). The increments in the inclination of the condylar line in relation to the mandibular line (cl-ml) and in the gonial angle (ar-goi-me) were significantly greater when compared with the corresponding control subjects. No significant differences between LTG and LCG were

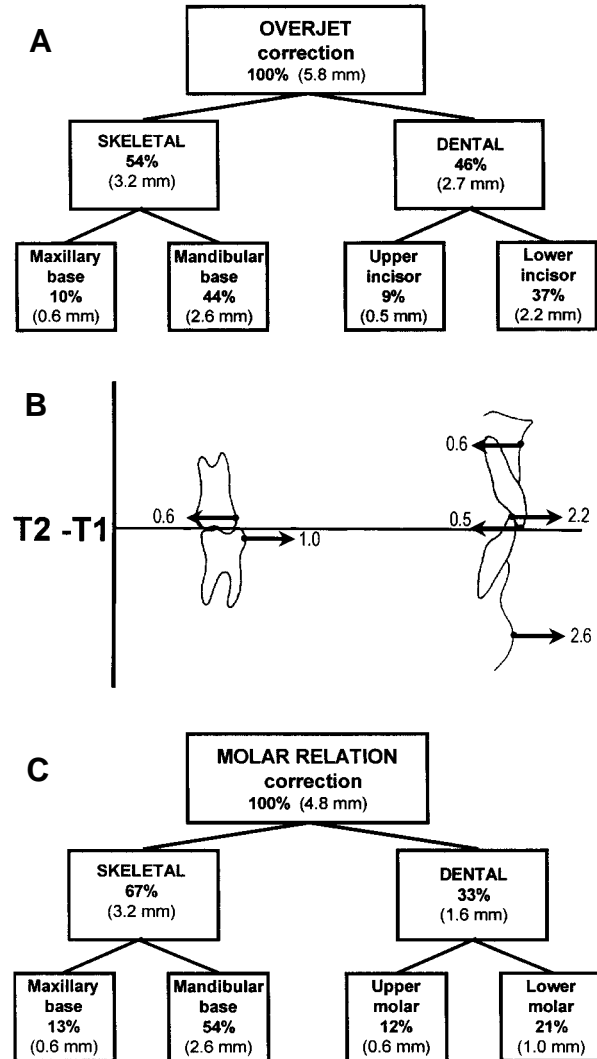


Fig 7. Diagram of maxillary and mandibular skeletal and dentoalveolar changes contributing to sagittal overjet correction and molar correction in the late-treated group (see the column "Treatment effect" in Table II).

found as to cranial base angulation and vertical skeletal relationships.

DISCUSSION

Despite a few cephalometric studies on treatment effects of the Twin-block appliance in growing subjects,³⁸⁻⁴⁰ no previous investigation has dealt with the issue of optimal treatment timing for this type of functional therapy of Class II disharmony. In order to provide this missing information, the present study analyzed the skeletal and dentoalveolar changes produced by the Twin-block in 2 different groups of individuals at different stages of skeletal maturation.

Table II. Changes T2-T1 in the late groups

Variable	Late-treated group (LTG) (n = 15)		Late-control group (LCG) (n = 14)		Mann-Whitney U test	Group difference LTG/LCG ("treatment effect")
	Mean	SD	Mean	SD		
Modified Pancherz's analysis (mm)						
Overjet	-5.96	2.63	-0.12	1.39	S	-5.84
is/OL _p minus ii/OL _p						
Molar relation	-4.92	2.36	-0.13	0.56	S	-4.79
ms/OL _p minus mi/OL _p						
Maxillary base	-0.06	1.31	+0.56	0.86	NS	-0.62
A point/OL _p						
Mandibular base	+3.47	2.11	+0.90	2.14	S	+2.57
pg/OL _p						
Condylar head	-1.21	1.25	-0.20	1.30	S	-1.01
co/OL _p						
Composite mandibular length	+4.68	1.95	+1.11	2.25	S	+3.57
pg/OL _p + co/OL _p						
Maxillary incisor	-0.92	1.72	-0.45	1.73	NS	-0.47
is/OL _p minus A point/OL _p						
Mandibular incisor	+1.52	0.87	-0.68	1.41	S	+2.20
ii/OL _p minus pg/OL _p						
Maxillary molar	-0.55	1.22	+0.03	1.38	S	-0.58
ms/OL _p minus ss/OL _p						
Mandibular molar	+0.84	0.78	-0.18	1.51	S	+1.02
mi/OL _p minus pg/OL _p						
Other variables						
FMN-T point-ba (°)	+0.94	1.70	+0.24	1.48	NS	+0.70
FMN-T point-ar (°)	+0.09	1.86	+0.39	2.20	NS	-0.30
co-pg (mm)	+7.29	2.39	+2.54	1.01	S	+4.75
co-go (mm)	+3.98	2.24	+1.25	1.45	S	+2.73
go-pg (mm)	+3.23	1.24	+1.57	1.14	S	+1.66
cl-ml (°)	+1.53	1.33	-1.27	2.05	S	+2.80
ar-go-me (°)	+0.82	1.71	-1.03	2.02	S	+1.85
nl/FMN-T line (°)	+0.83	1.42	+0.52	1.38	NS	+0.31
ml/FMN-T line (°)	+0.68	1.26	-0.30	1.59	NS	+0.98
nl-ml (°)	-0.15	1.50	-0.82	0.89	NS	+0.67

S, Significant comparison ($P < .05$); NS, not significant comparison.

The assessment of skeletal age in both treated and untreated Class II samples was performed by means of the evaluation of maturational stages in the cervical vertebrae, according to the method originally developed by Lamparski³⁵ and successively implemented by O'Reilly and Yanniello³⁶ and by Hassel and Farman.⁴⁴ The same method has been used in a previous article³⁷ to match a sample of subjects treated with the acrylic splint Herbst appliance to 2 control groups of untreated subjects as to stage of skeletal development. In the present investigation, the evaluation of cervical vertebrae maturation was adopted to discriminate between a group of subjects treated before the onset of the pubertal spurt in mandibular growth (early-treated group) and a group of subjects who started treatment during or slightly after the spurt (late-treated group).

As general consideration, Twin-block therapy produces an efficient reduction in the overjet (ranging from

about 4.5 mm/year in an early-treated group up to about 6 mm/year in a late-treated group) and a remarkable correction in the molar relation (about 4.8 mm/year in both groups). Both favorable occlusal changes are due mainly to skeletal modifications occurring almost exclusively in the mandible. The chin point at pogonion shows an increased advancement of about 2.5 mm/year in all treated groups when compared with controls. As for dentoalveolar changes, major contribution to overjet correction is represented by proclination of the lower incisors (increased by 1.4 mm/year in the early-treated group and by 2.2 mm/year in the late-treated group when compared with corresponding controls). Both the distal movement of upper molars and the mesial movement of lower molars contributed to the correction in molar relation in both treated groups. Significant changes in mandibular dimensions consisting of greater increments in total mandibular length (co-pg) associ-

ated with an opening of the gonial angle (ar-goi-me) also were found in both treated groups. Functional treatment of Class II skeletal disharmony with the Twin-block did not produce any significant change in sagittal growth of the maxilla, vertical facial relationships, and cranial base angulation.

Late treatment with the Twin-block starting during or slightly after the onset of the peak in mandibular growth appears to be more effective than early treatment, as it induces more favorable mandibular skeletal modifications. The amount of supplementary elongation of the mandible in the late-treated group (4.75 mm/year) was more than twice that of the early-treated group (1.88 mm/year). The greater increase in total mandibular length (co-pg) was associated with significant increases in the height of the mandibular ramus (co-go, 2.73 mm/year) and in the length of the mandibular body (go-pg, 1.66 mm/year) in the group treated at the peak when compared with the corresponding control group, whereas the changes in these 2 last measurements were not significant in the early-treated group.

The greater additional growth of the mandible in the late-treated group was concomitant with significant changes in the direction of condylar growth. Late-treated individuals showed significantly more backward direction of growth in the mandibular condyle, as revealed by the significant opening of the angle formed by the condylar line in relation to the mandibular line (cl-ml, 2.8°/year). This growth modification has been described previously as "posterior mandibular morphogenetic rotation,"⁴⁵ a biological mechanism leading to greater increments in total mandibular length and, thus, efficiently improving the skeletal sagittal relationships in Class II malocclusion.

Virtually all functional/orthopedic appliances for Class II correction (Twin-block included) are constructed from bite registrations taken with the mandible postured in a forward and downward position. The rationale for this clinical procedure is that favorable mandibular growth changes are expected after mandibular displacement. The modifications involve mainly the mandibular condyle, which shows additional growth in a superoposterior direction, with increased bone apposition at the posterior aspects of the condylar head and of the ramus. These findings have been documented extensively in experimental studies on monkeys and rats⁴⁶⁻⁵⁰ and in clinical and anatomic studies on human subjects as well.^{27,51,52}

Condylar modifications induced by functional appliances can be expressed cephalometrically by means of the changes in a series of measurements, whose combined information may provide adequate biological interpretation: (1) increases in total mandibular length

(co-pg); (2) increases in ramus height (co-go); (3) opening of the gonial angle (ar-goi-me); (4) posterior rotation of the condylar line in relation to the mandibular line (cl-ml); (5) absence of forward displacement of the condylar head in relation to the reference system (co-OLp). In the present study, all these cephalometric signs were detected in the group treated during the pubertal growth spurt, thus demonstrating the effectiveness of functional treatment of skeletal Class II disharmony at the peak in mandibular growth velocity. On the contrary, only a slight, although significant, increase in total mandibular length associated with an opening of the gonial angle was found in the group treated before the onset of the growth spurt. Moreover, in this group, the condylar head exhibited a significant displacement in a forward direction when compared with untreated controls. These data would suggest a component of forward repositioning of the mandible in the overall mandibular modifications in the early-treated group, whereas effective treatment-induced adaptations in the amount and direction of condylar growth occurred in the late-treated group.

Further investigation, however, is needed in order to clarify the role of glenoid fossa modifications after protrusive mandibular function in groups treated at different stages of skeletal maturation. Animal studies reported that the temporal bone of the glenoid fossa adapts to forward displacement of the mandible through a reversal of the normal growth pattern, ie, with bone formation along the posterior border and bone resorption on the anterior border.^{47,53,54} These changes take place with some delay with respect to the condylar response and, therefore, they should be evaluated during the immediate posttreatment period.⁵¹

As for the comparison of the results of the present study with those reported by previous investigations on Twin-block therapy,³⁸⁻⁴⁰ an agreement exists with regard to the predominant mandibular effect, the concomitance of dentoalveolar changes, and the lack of effects on the sagittal position of the maxilla and on the vertical facial relationships (with the exception of Toth and McNamara⁴⁰ who found a significant increase in the inclination of the mandibular plane in relation to the Frankfurt plane). The amount of additional mandibular lengthening notably differed, however, among various contributions. Lund and Sandler³⁸ reported an increase for Ar-Pog in relation to untreated Class II controls of 2.4 mm/year; Mills and McCulloch³⁹ described an increase in Co-Gn of 4.2 mm/14 months; Toth and McNamara⁴⁰ found an increase for the same measurement of about 3 mm/16 months. These increments are greater than those shown by the early-treated group in the present study (additional increase in Co-Pg = 1.88 mm/year), but they are definitely smaller than those

shown by the late-treated group (4.75 mm/year). The differences in results with regard to mandibular skeletal effects have to be ascribed to the different case selection in that previous investigations did not take into account the stage of skeletal maturation. Once again, major favorable effects were found in the group treated with the Twin-block at the pubertal spurt.

Because of the similarity in skeletal maturation at the start of treatment and in the nature of control groups, the results of the present study with regard to the late-treated group can be contrasted with the effects induced by the acrylic splint Herbst appliance as analyzed in a previous investigation.³⁷ Twin-block therapy is able to produce greater increments in mandibular length (4.8 mm/year vs 2.7 mm/year for the Herbst appliance) and in the height of the mandibular ramus (2.7 mm/year vs 1.2 mm/year). The amount of dentoalveolar contribution to molar correction in patients treated with the acrylic splint Herbst appliance is relatively larger because of greater distal movement of maxillary molars (-1.7 mm/year vs -0.6 mm/year for the Twin-block). The amount of extra growth of the mandible in another study on the bonded Herbst appliance⁵⁵ was 3.5 mm/year, associated with a remarkable contribution given by the increase in ramus height (about 3.0 mm/year).

In addition, of some interest is the comparison of the Twin-block treatment results with those produced by the Fränkel appliance. Petrovic et al²⁷ found an additional increase in Co-Pg ranging from 0.8 mm/year to 5.5 mm/year depending on different biological growth categories in subjects treated with the FR-2 at the pubertal peak. McNamara et al⁷ reported a supplementary biannualized increment in mandibular length (Co-Gn) of 3.6 mm and in ramus height (Co-Go) of 3.1 mm in patients treated in the late mixed and early permanent dentitions.

Although the significance of a direct comparison among different appliances in separated investigations is limited by a series of factors regarding the severity of the skeletal disharmony in different treated groups, adequate treatment duration in relation to the various appliances, composition of untreated control groups, etc, 2 major considerations still may be deduced.

1. The assessment of the growth potential and of the stage of skeletal maturation in individual patients definitely is important for treatment effectiveness, regardless of the functional/orthopedic appliance that is used to correct the skeletal disharmony.
2. Both the Twin-block and the FR-2 appear to be more effective in inducing supplementary mandibular lengthening than the acrylic splint Herbst appliance.

One of the most widely debated issues in contemporary orthodontics is the controversy regarding the more favorable therapeutic chances that presumably would be offered by early intervention with functional appliances in patients with Class II skeletal disharmony.⁵⁶ Undoubtedly, early correction of large overjets in severe skeletal Class II discrepancies may be indicated to reduce the risk of trauma to prominent incisors during adolescence. However, the findings of the present study on skeletal and dentoalveolar effects of Twin-block therapy, in association with the data derived from previous studies dealing with other devices such as the FR-2²⁷ and the Herbst appliance,^{30,57} strongly suggest that optimum timing for functional/orthopedic treatment of Class II malocclusion is during or slightly after the pubertal growth spurt. From the point of view of occlusal development, this period correlates in most patients with the late mixed or early permanent dentition. The clinical consequence is that active treatment of the skeletal disharmony with the functional appliance can be followed almost immediately by a phase of fixed appliance therapy to refine occlusion and to give stability to the newly established intermaxillary relationship. In fact, while waiting for the appraisal of posttreatment changes in patients treated with the Twin-block at different stages of skeletal maturity, long-term data for the Herbst appliance already exist indicating that a stable Class I intercuspation is an efficient factor in counteracting occlusal relapse.⁵⁸ As stated by Pancherz,⁵⁹ late functional/orthopedic therapy of Class II malocclusion just after the onset of the peak in growth velocity is recommended to favor maximum treatment effect and reduce the time of posttreatment retention. Furthermore, early treatment may be fruitless in the long run because the growth pattern of severe Class II discrepancies seems to strive constantly to reassert itself,^{60,61} most significantly when the retention or postretention period coincides with the pubertal spurt in skeletal growth.

CONCLUSIONS

Optimum treatment timing for Twin-block therapy of Class II disharmony appears to be during or slightly after the onset of the pubertal peak in growth velocity. Major favorable effects induced by functional therapy at this time in comparison with earlier phases are:

- Greater skeletal contribution to the correction of the molar relation;
- Larger and clinically significant increments in total mandibular length and in ramus height;
- More posterior direction of condylar growth, a biological mechanism enhancing supplementary mandibular lengthening and reducing the amount

of forward condylar displacement in favor of effective mandibular growth and reshaping.

Data regarding the posttreatment changes after Twin-block therapy are needed to further define ideal treatment timing and actual therapeutic effectiveness for this appliance. In the meantime, the importance of the assessment of skeletal maturity and the onset of the pubertal growth spurt in individual patients has to be emphasized as a fundamental diagnostic and decision-making tool in treatment planning for Class II malocclusion.

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