Dentoskeletal effects and facial profile changes in young adults treated with the Herbst appliance

Sabine Ruf, DDS, Dr. med. dent; Hans Pancherz, DDS, Odont. Dr.

Abstract: This prospective Herbst study analyzed the sagittal dental and skeletal changes contributing to Class II correction in young adults. Additionally, the alteration in skeletal and soft tissue convexity occurring during treatment was assessed. Early adolescent subjects in the permanent dentition who had been treated with the Herbst appliance were used for comparison. Lateral headfilms from before and after an average treatment period of 8.5 months for the young adults and 7.1 months for the adolescents were evaluated. All adult and adolescent subjects were treated to either Class I or overcorrected Class I occlusal relationships. In both groups the improvement in sagittal incisor and molar relationships was achieved more by dental changes than by skeletal ones. The amount of skeletal change contributing to overjet and molar correction was smaller in the young adult group (22% and 25%, respectively) than in the early adolescent group (39% and 41%, respectively). Skeletal and soft tissue facial profile convexity was reduced in adults and adolescents. Facial profile improvement did not differ between the two groups. The results of this study revealed that the Herbst appliance is most effective in the treatment of Class II malocclusion in young adults. It is suggested that this treatment method could be an alternative to orthognathic surgery in borderline Class II cases.

Key Words: TMJ adaptation, Growth stimulation, Young adults, Class II malocclusion, Herbst appliance, Orthodontics, Dentofacial orthopedics, Dentoskeletal treatment effects, Facial profile

Mandibular protrusion experiments have demonstrated that condylar growth can be stimulated and the glenoid fossa remodeled in growing animals.[1-10] Some experiments show that condylar[11-13] and glenoid fossa[4,10,11-13] remodeling in adult animals is similar to that of growing animals, while other studies show that adaptive changes in adult animals are negligible or nonexistent.[5-7,14-18]

Our knowledge about dentofacial adaptation in human adults following functional appliance treatment is limited. In a case report of three young adult Class II patients treated with removable functional (Fränkel) appliances, McNamara[19] described no major improvements in skeletal and posterior dental relationships. Recent studies, using magnetic resonance imaging (MRI), of adolescent and young adult patients treated with the fixed Herbst appliance suggest similar tissue responses (condylar and glenoid fossa remodeling).[20,21] Proof that the adult human TMJ is capable of remodeling is also derived from observations in connection with condylar fracture therapy,[22,23] mandibular osteotomies,[24,25] and anterior mandibular repositioning in disc displacement therapy.[26-29]

In adults, contemporary treatment of Class II malocclusion is confined to dentoalveolar orthodontic correction (with or without extractions). Skeletal changes can be accomplished only by orthognathic surgery. While dentoalveolar orthodontic correction does not improve facial esthetics, orthognathic surgery entails higher risks and greater costs. If Herbst appliance treatment in young adults proves to be effective and mandibular skeletal changes could be accomplished, the above-mentioned disadvantages of conventional adult Class II treatment might be overcome.

The purpose of the present study was to use cephalometric roentgenography to investigate dentoskeletal and facial profile changes in young adults with Class II malocclusion treated with the Herbst appliance.

Author Address
Dr. Sabine Ruf
Abteilung für Kieferorthopädie
Zentrum für ZMK
Justus-Liebig-Universität Giessen
Schlangenzahl 14
D-35392 Giessen, Germany
E-Mail: Sabine.Ruf@dentist.med.uni-giessen.de

Sabine Ruf, assistant professor, Department of Orthodontics, University of Giessen, Germany.

Hans Pancherz, professor and head, Department of Orthodontics, University of Giessen.

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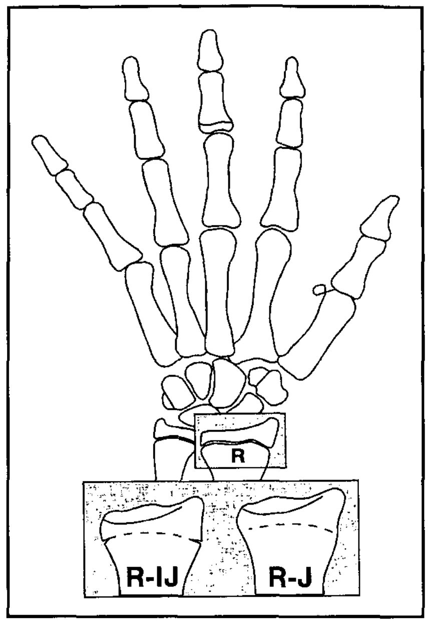

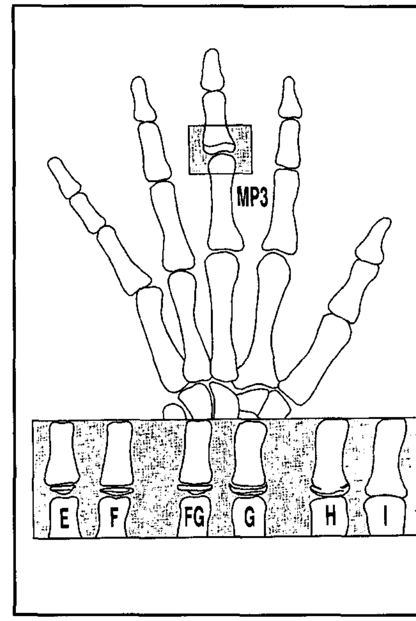

Figure 1 Figure 2

Figure 1
Skeletal maturity stages of the radius[30] used to define young adulthood. Stage R-IJ: fusion of the epiphysis with its metaphysis is almost complete (residual small gap at one or both margins). Stage R-J: fusion of the epiphysis with its metaphysis is complete

Figure 2
Skeletal maturity stages of the middle phalanx of the third finger (MP3) in progressive order used to define adolescence:[30]
Early adolescence
Stage E: The epiphysis is not yet as wide as the metaphysis
Stage F: The epiphysis is as wide as the metaphysis
Stage FG: The epiphysis is as wide as the metaphysis and there is a distinct medial and/or lateral border of the epiphysis forming a line of demarcation at right angles to the distal border
Stage G: The sides of the epiphysis have thickened and also cap its metaphysis, forming a sharp edge distally at one or both sides
Late adolescence
Stage H: Fusion of epiphysis and metaphysis has begun
Stage I: Fusion of epiphysis and metaphysis is completed

Materials and methods

The first 14 young adult subjects (10 girls and 4 boys) with a Class II malocclusion in the permanent dentition applying for treatment at the Department of Orthodontics of the University of Giessen in 1995 were prospectively selected for Herbst treatment. Young adulthood was defined by hand-wrist radiographic stages[30] R-IJ and RJ (Figure 1). Another group of 25 consecutive early adolescent Herbst patients in the permanent dentition (12 girls and 13 boys) served as controls. Early adolescence was defined by hand-wrist radiographic stages[30] MP3-E to MP3-G (Figure 2). All patients in both maturity groups were treated with a fixed cast-splint Herbst appliance.[31] The mean pretreatment age was 16.5 years (range 13.6 to 19.8 years) for the young adult subjects, and 12.8 years (range 11.4 to 15.7 years) for the adolescent controls. At the start of treatment, the mandible was advanced to an incisal edge-to-edge position in all subjects. Treatment time averaged 8.5 months for the young adults and 7.1 months for the adolescents. The distribution of subjects in relation to skeletal maturity is given in Figure 3.

Lateral headfilms in habitual occlusion from before and after Herbst treatment were evaluated. Tracings were made and linear and angular measurements were performed to the nearest 0.5 mm and 0.5 degrees, respectively. All registrations were done twice. For the final evaluation, the mean value of the duplicate registrations was used. No correction was made for linear enlargement (approximately 6% in the median sagittal plane).

Dentoskeletal changes

Pre- and posttreatment lateral headfilms were analyzed according to the method of Pancherz.[32] For all the recordings on pre- and posttreatment radiographs, the occlusal line (OL, defined by the incisal tip of the most protruded mandibular incisor and the distobuccal cusp of the first permanent mandibular molar) and the occlusal line perpendicular (OLp) from the first headfilm were used as a reference grid. Superimposition of the radiographs was performed on the stable bone structures of the anterior cranial base.[33] The roentgenographic analysis comprised the following linear variables (Figure 4):

1. is/OLp minus ii/OLp = Overjet
2. ms/OLp minus mi/OLp = Molar relationship (positive value indicates distal relationship, negative value indicates normal or mesial relationship)
3. is/OLp = Position of the maxillary central incisor
4. ii/OLp = Position of the mandibular central incisor
5. ms/OLp = Position of the maxillary permanent first molar
6. mi/OLp = Position of the mandibular permanent first molar
7. ss/OLp = Position of the maxillary jaw base
8. pg/OLp = Position of the mandibular jaw base
9. ar/OLp = Position of the condyle
10. pg/OLp plus ar/OLp = Mandibular length

Changes in the different measuring

points in relation to OLp during treatment were calculated as the "after-minus-before" difference (d) in landmark position. Changes in variables 3 to 6 represent a composite effect of skeletal and dental changes, while changes in variables 7 to 10 represent skeletal changes. Variables for dental changes within the maxilla and mandible were obtained by the following calculations (variables 11 to 14):

11. is/OLp (d) minus ss/OLp (d) = Changes in position of the maxillary incisor within the maxilla
12. ii /OLp (d) minus pg/OLp (d) = Changes in position of the mandibular incisor within the mandible
13. ms/OLp (d) minus ss/OLp (d) = Changes in position of the maxillary permanent first molar within the maxilla
14. mi/OLp (d) minus pg/OLp (d) = Changes in position of the mandibular permanent first molar within the mandible

Facial profile convexity changes

Facial profile convexity was evaluated by the following angular variables (Figure 5):

15. N-Ss-Pg Skeletal convexity (nasion–subspinale–pogonion)
16. N'-Ss'-Pg' Soft tissue convexity (soft tissue nasion-soft tissue suspinale-soft tissue pogonion)

Statistical methods

The arithmetical mean (mean) and standard deviation (SD) were calculated for the different variables. Student's *t*-tests for unpaired samples were performed to assess skeletal maturity group differences. The statistical significance was determined at the 0.1% (***), 1% (**) and 5% (*) levels of confidence. A confidence level larger than 5% was considered statistically not significant (n.s.)

Error of the method

The method error (ME) of the double registrations (tracings and measurements) from pre- and post-treatment roentgenograms of all sub-

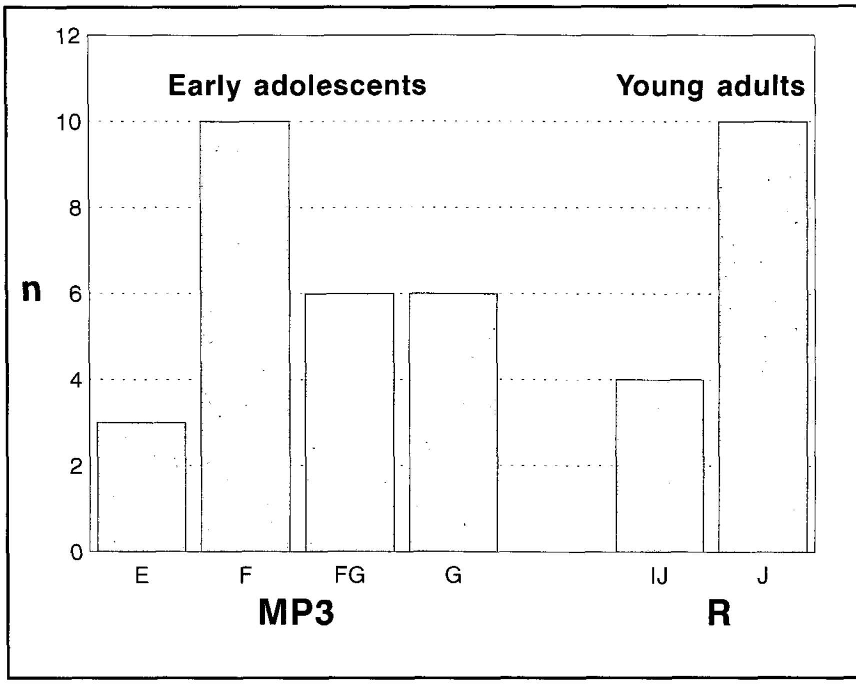

Figure 3
Distribution of subjects in relation to skeletal maturity stages of the middle phalanx of the third finger (MP3) and of the radius (R)[30] in the young adult (n=14) and early adolescent (n=25) groups

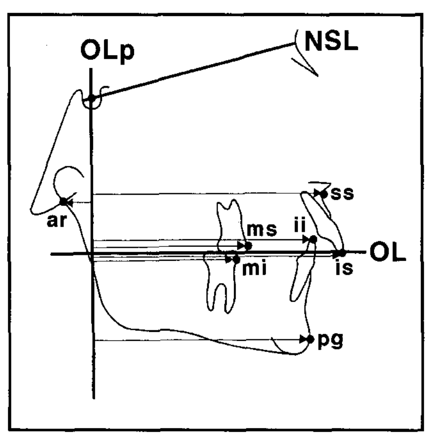

Figure 4
(Above) Measuring points and the reference grid (OL and OLp) used in the cephalometric analysis. For definition of the landmarks see Materials and methods section

Figure 5
(Right) Assessment of the skeletal and soft tissue facial convexity. For definition of the landmarks see Materials and methods section

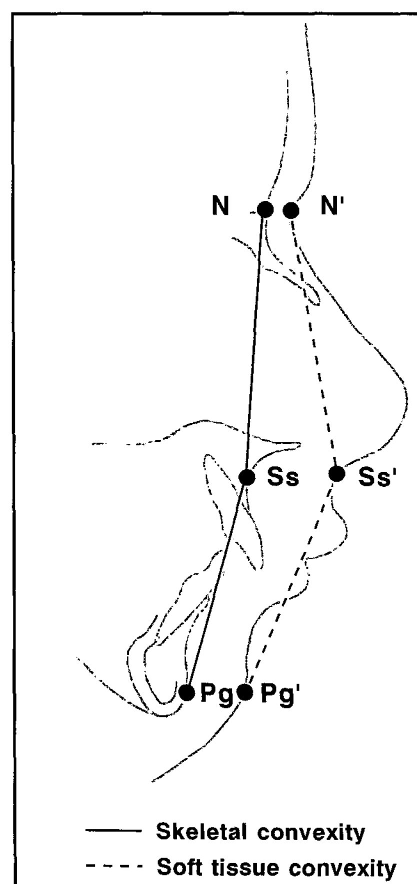

Figure 5

Table 1
Dentoskeletal (mm) and facial profile convexity (degrees)records before and after Herbst appliance treatment in 14 young adult and 25 early adolescent Class II malocclusions

Variable	Young adult group (n=14) Before Mean	S.D.	After Mean	S.D	Adolescent group (n=25) Before Mean	S.D.	After Mean	S.D.	Group difference Before Mean	p-value	After Mean	p-value
1. Overjet is/OLp minus ii/Olp	8.1	2.6	-1.4	2.6	7.7	2.9	-2.1	2.2	0.4	n.s.	0.7	n.s.
2. Molar relationship * ms/OLp minus mi/OLp	3.1	1.7	-5.5	1.1	3.3	2.2	-6.0	2.2	-0.2	n.s.	0.5	n.s.
3. Maxillary incisor is/OLp	83.5	5.5	80.1	6.0	84.4	4.1	81.6	3.9	-0.9	n.s.	-1.5	n.s.
4. Mandibular incisor ii/OLp	75.4	6.1	81.4	5.0	76.6	4.1	83.6	4.5	-1.2	n.s.	-2.2	n.s.
5. Maxillary molar ms/OLp	54.2	5.5	51.7	5.3	53.5	3.1	50.9	3.5	0.7	n.s.	0.8	n.s.
6. Mandibular molar mi/OLp	51.1	5.4	57.2	5	50.2	3.4	57.0	3.2	0.9	n.s.	0.2	n.s.
7. Maxillary base ss/OLp	76.6	4.4	76.8	4.4	76.6	3.3	77.1	3.1	0.0	n.s.	-0.3	n.s.
8. Mandibular base pg/OLp	76.3	6.9	78.5	6.7	74.7	4.7	79.0	4.6	1.6	n.s.	-0.5	n.s.
9. Condyle ar/OLp	12.6	4.1	11.9	4.4	11.0	3.2	10.7	3.0	1.6	n.s.	1.2	n.s.
10. Mandibular length pg/OLp + ar/OLp	88.9	7.5	90.4	7.9	85.7	5.3	89.7	5.9	3.2	n.s.	0.7	n.s.
15. Skeletal convexity N-Ss-Pg	173	5.9	175.9	5.9	169.9	5.7	174.1	6	3.1	n.s.	1.8	n.s.
16. Soft tissue convexity N'-Ss'-Pg'	156.8	3.9	159.6	4.7	156.4	4.7	160.4	4.9	0.4	n.s.	-0.8	n.s.

* Positive values indicate a distal molar relationship; negative values indicate a normal or mesial molar relationship

jects was calculated using the formula:

$$ME = \sqrt{\frac{\sum d^2}{2n}}$$

where d is the difference between two measurements of a pair and n is the number of subjects (n= 39). The method error for treatment changes did not exceed 0.6 mm or 0.4 degrees for any of the variables investigated.

Results

All subjects in both skeletal maturity groups were treated or overcorrected to a Class I dental arch relationship.

Due to the small number of males (n=4) in the young adult group, differences between sexes were not assessed. In the presentation of results, the male and female subjects in each maturity group were pooled.

Dentoskeletal and facial profile convexity characteristics

Cephalometric variables in the two skeletal maturity groups before and after Herbst appliance treatment are shown in Table 1. No statistically significant differences in dentoskeletal morphology or skeletal and soft tissue profile convexity could be found when comparing the young adults and early adolescents.

Dentoskeletal and facial profile treatment changes

Treatment effects for the Herbst appliance are shown in Table 2. The amount of overjet and Class II molar correction was comparable in the young adult and early adolescent groups. Adolescents exhibited a greater increase in mandibular length (variable 10, mean = +2.5 mm; $p<0.001$) and greater advancement of the mandibular base (variable 8, mean = +2.0 mm; $p<0.01$) than young adults. Young adults showed more anterior mandibular molar movement (variable 14, mean = +1.3 mm; $p<0.01$). Furthermore, in young adults there was a greater tendency for increased mandibular incisor protrusion (variable 12, mean +1.1 mm; n.s.)

In both young adults and early adolescents, skeletal and soft tissue facial profile convexity were significantly ($p<0.001$) reduced during Herbst treatment. No difference existed when the two maturity groups were compared.

The relationship between dental and skeletal changes contributing to Class II correction in the incisor and molar regions is shown in Figures 6 and 7. In both the young adult and adolescent groups, the improvement in sagittal occlusion was achieved more by dental changes than by skeletal ones. The amount of skeletal change contributing to overjet and molar correction was greater in the early adolescent group (39% and 41%, respectively) than in the young adults (22% and 25%, respectively).

Table 2
Changes in dentoskeletal (mm) and facial profile convexity (degrees) records during Herbst appliance treatment in 14 young adult and 25 early adolescent Class II malocclusions

Variable	Young adult group (n = 14) Mean	S.D.	Adolescent group (n= 25) Mean	S.D	Group difference Mean	*p*-value
1. Overjet is/OLp(d) minus ii/Olp (d)	-9.5	3.4	-9.8	3.4	0.3	n.s.
2. Molar relationship ms/OLp (d) minus mi/OLp(d)	-8.6	1.5	-9.3	2.2	0.7	n.s.
7. Maxillary base ss/OLp (d)	0.2	1.5	0.5	1.3	-0.3	n.s.
8. Mandibular base pg/OLp (d)	2.3	1.7	4.3	2.2	-2.0	<0.01
9. Condyle ar/OLp (d)	-0.8	0.7	-0.3	1.2	-0.5	n.s.
10. Mandibular length pg/OLp (d) + ar/OLp (d)	1.5	1.8	4.0	1.9	-2.5	<0.001
11. Maxillary incisor is/OLp (d) minus ss/OLp (d)	-3.6	2.8	-3.3	2.5	-0.3	n.s.
12. Mandibular incisor ii/OLp (d) minus pg/OLp (d)	3.8	1.6	2.7	1.8	1.1	n.s.
13. Maxillary molar ms/OLp (d) minus ss/OLp (d)	-2.7	1.4	-3.0	1.8	0.3	n.s.
14. Mandibular molar mi/OLp (d) minus pg/OLp (d)	3.8	1.1	2.5	1.4	1.3	<0.01
15. Skeletal convexity N-Ss-Pg	2.9	2.5	4.5	3.0	-1.6	n.s.
16. Soft tissue convexity N'-Ss'-Pg'	2.8	2.6	4.0	3.0	-1.2	n.s.

Discussion

In the present study, the dentoskeletal and facial profile treatment changes during Herbst appliance treatment were assessed in young adult and early adolescent Class II patients. Young adulthood, defined by the hand-wrist radiographic stages R-IJ and R-J, implied that the subjects were at the end of the postpubertal growth period (Figure 8) with either minimal (R-IJ) or no residual (R-J) growth.[30] Early adolescence, defined by hand-wrist radiographic stages MP3-E to MP3-G, implied that the subjects were in the acceleration phase of the pubertal growth spurt[30] (Figure 8). This group was intentionally chosen in order to have a control group with optimal conditions for TMJ adaptation to Herbst treatment.[34,35]

Several investigations have made it apparent that craniofacial growth may extend beyond puberty in both males and females.[36-43] Even though condylar cartilage matures with age to an adult nonhypertrophic form,[45-49] zones of unmineralized growth cartilage[50] and undifferentiated mesenchym[45-51] are seen in the adult mandibular condyle. Thus, the increase in mandibular length in the young adult group could possibly be due to a reactivation of the cells in the prechondroblastic zone.

Both skeletal maturity groups exhibited a large pretreatment overjet and Class II molar relationship and were thus comparable in terms of malocclusion severity (Table 1). In agreement with previous Herbst studies,[32,52,53] Class II correction in the present subjects was a result of both dental and skeletal changes. However, skeletal changes (mandibular length increase and mandibular base advancement) contributed to a relatively greater amount of overjet and molar correction in the early adolescent group than in the young adults. This is most likely due to the basically larger mandibular growth rate in adolescents.[54]

During the 8.5 months of Herbst treatment, the young adult group exhibited an increase in mandibular length (Ar-Pg) that was twice that observed during a four-year period of normal growth (age 16 to 20) in untreated Class I females.[36] The large increase in mandibular length in young adults in the present study seems even more remarkable given the deficient mandibular growth rate in Class II malocclusions compared with Class I.[55]

The favorable skeletal reaction of the present young adult sample contrasts with the findings of McNamara,[19] who demonstrated limited, if any, changes in skeletal and molar relationships following removable functional appliance (Fränkel) treatment, despite 20 hours/day wear time and longer total treatment time. This difference in findings is most probably due to the removability of the Fränkel appliance. Even though McNamara[19] reported that cooperation was excellent, the adults might have avoided the protruded position of the appliance, such as reported for nonresponding adult monkeys,[4,12] thus reducing the stimulus for adaptation.

It might be argued that the measured increases in mandibular base advancement in the young adult group could be the result of condylar position changes within the fossa rather than condylar remodeling. However, recent studies using magnetic resonance imaging revealed that condylar position was, on average, unaffected by Herbst treatment. This was true both in young adults[21] and in adolescents.[20] Furthermore, condylar remodeling was demonstrated on a regular basis in both young adults and adolescents.[20,21] Additionally, the possibility of glenoid fossa remodeling[20,21] affecting mandibular position could not be excluded.

In comparison with the early adolescent group, the smaller amount of skeletal treatment effects in young adults was compensated for by larger dental changes, especially in the mandible (larger anterior molar and incisor movement). Relatively larger amounts of dental changes have also been reported[53] for subjects treated with the Herbst appliance during late adolescence (MP3-H and MP3-I,[30] Figure 2) when compared with early adolescence (MP3-E and MP3-F,[30] Figure 2).

In both histological animal experiments[12] and in magnetic resonance imaging (MRI) Herbst studies,[20,21] the signs of condylar remodeling appeared later during mandibular protrusion in older animals or subjects than in younger ones (3 to 8 months of treatment and 6 weeks, respectively). The onset of remodeling might be crucial for dental changes. Earlier onset, as in adolescents,[12,20,21] will result in an earlier return of the condyle to its centered fossa position, thus minimizing the forces applied to the dentition and, consequently, reducing dental changes.

A significant improvement in the skeletal and soft tissue profile through Herbst treatment has also been shown in an earlier study.[56] In the present study, skeletal and soft tissue convexity reduction was significant in both young adult and early adolescent groups, and the changes did not differ between groups.

Patients with severe Class II malocclusion with little growth remaining (R-IJ or R-J[30]), such as those treated in the present study, are usually re-

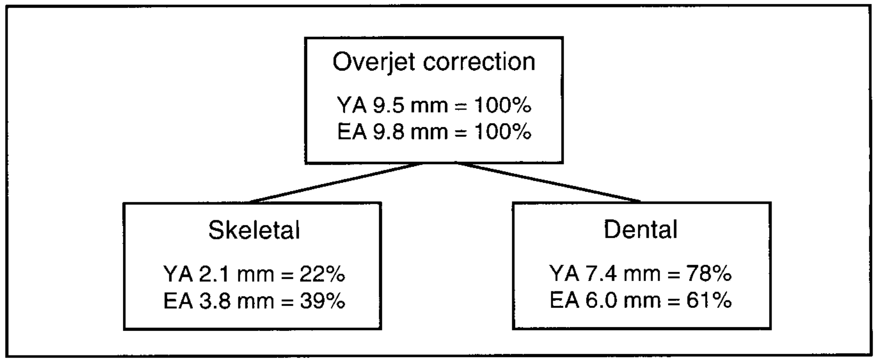

Figure 6
Mechanism of overjet correction in 14 young adult (YA) and 25 early adolescent (EA) Class II malocclusions treated with the Herbst appliance

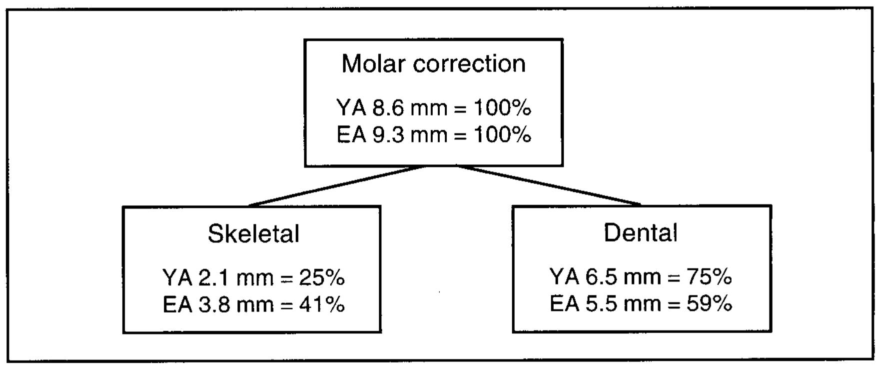

Figure 7
Mechanism of molar correction in 14 young adult (YA) and 25 early adolescent (EA) Class II malocclusions treated with the Herbst appliance

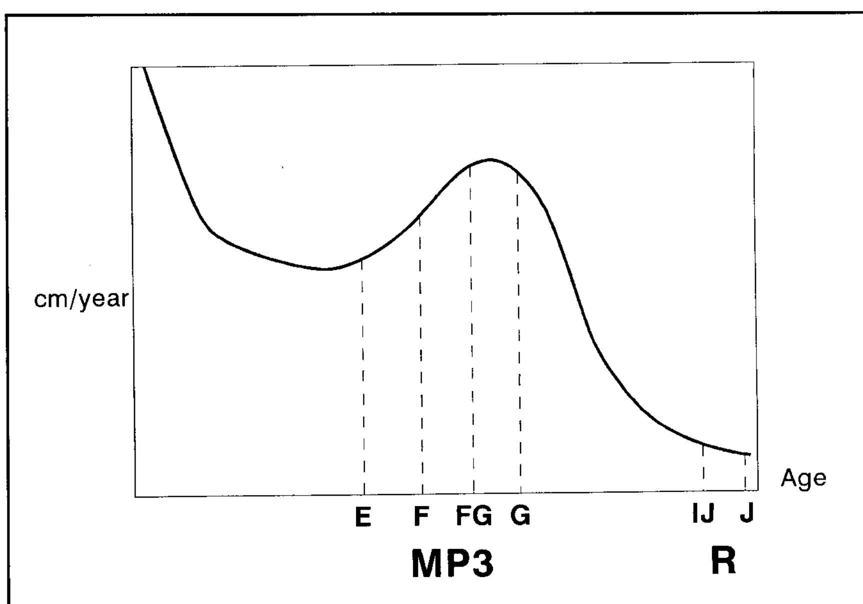

Figure 8
Schematic illustration of the association between the pubertal body height growth velocity and the skeletal maturity stages of the middle phalanx of the third finger (MP3) and the radius (R[30]—see Materials and methods section)

ferred for orthognathic surgery.[57] This is especially true in cases in which facial convexity reduction is one of the treatment goals. It might be argued that in the present study, an even larger improvement in facial convexity might have been achieved in the young adult patients by means of orthognathic surgery instead of Herbst treatment. However, De Clerk and Timmerman[58] could not show any differences in facial convexity reduction when comparing patients treated using headgear-activator with those whose treatment included mandibular advancement osteotomy.

Some mandibular protrusion experiments in adult monkeys suggest the development of TMJ pathology and regressive remodeling,[15,16] but others do not.[4,10-13,59] All patients in the present sample of young adults and adolescents were screened for signs and symptoms of TMD, both clinically and by means of MRI, during the entire treatment period. No pathologic TMJ changes developed during treatment in any of the patients. On the contrary, some patients who did have articular disc displacements pretreatment showed that a reduction could be achieved simultaneously with Class II correction.

Finally it should be pointed out that a larger sample of adult patients would have been more useful. Nevertheless, the present material is the only statistical sample of young adults treated with functional appliances. Therefore, although dentofacial adaptation was a consistent finding and the malocclusion could be successfully corrected in all the young adult patients, further research is required, especially to delineate age limitations, before general recommendations regarding the use of fixed functional appliances in adult patients can be made.

Conclusions

The present study demonstrates for the first time that dentofacial adaptation to fixed functional appliance treatment is possible in young adults. Although the Herbst appliance is most successful in Class II patients at the end of the growth period, this treatment method could be an alternative to orthognathic surgery in borderline skeletal Class II cases.

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