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Post-treatment evaluation of a magnetic activator device in Class II high-angle malocclusions

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SUMMARY The purpose of this study was to evaluate changes in dentofacial growth before, during, and after use of a magnetic activator device (MAD) II in high-angle Class II division 1 patients.

Lateral cephalometric and hand–wrist radiographs of 10 patients (six girls and four boys) with an average chronological age of 10 years 5 months were obtained at the beginning of the observation period (T1, 9.5 months), beginning of MAD II application (T2), at the end of the treatment (T3), and approximately 4 years after the end of treatment (T4). Thirteen linear, 1 ratio, and 10 angular measurements were evaluated. Paired *t*-tests were used for statistical evaluation of differences that occurred between the time points.

The increase in gonial angle, GnGoAr angle, S–N, Co–Gn, Go–Ar, ANS–Me, S–Go, and N–Me distances and the decrease of overjet, U1–NA distance, and ANB angle were statistically significant during the treatment. At T4, there was a decrease in gonial angle and U1–NA distance, which was significant. The changes as a result of treatment were stable at T4.

Introduction

It is known that treatment of skeletal Class II malocclusions with increased vertical dimensions is more difficult than in Class II subjects with normal facial development. Nanda (1988) stated that the vertical pattern of facial development was established before the eruption of the first permanent molars and long before the adolescent growth spurt. Changes in the anterior facial bones play a key role in determining the vertical growth pattern direction of the face (DeBerardinis *et al.*, 2000).

Patients exhibiting an increased lower anterior vertical face height usually have a mandible tending to rotate downward and backward during growth. Current treatment methods are aimed at restricting further dentoskeletal vertical growth or intrusion of the posterior teeth in order to reduce lower anterior face height and cause the mandible to rotate forward (DeBerardinis *et al.*, 2000).

An increase in lower face height can be accompanied by increased alveolar growth, dental extrusion, lack of ramal growth, insufficient vertical condylar growth, underdevelopment of the middle cranial fossa, and insufficient alveolar growth in the anterior portion of the maxilla (DeBerardinis *et al.*, 2000). Factors such as underdevelopment of the middle cranial fossa that produce an elevation of the glenoid fossa and inadequate alveolar growth in the anterior portion of the maxilla have been shown as potential causative factors for excessive vertical eruption of the maxillary dentoalveolar region that hinges the mandible down and back (Sassouni and Nanda, 1964; Björk, 1969; Isaacson *et al.*, 1971; Speidel *et al.*, 1972). In addition, airway problems can sometimes cause abnormal muscle and soft tissue development, which increase anterior face height and lead to an open bite (Bresolin *et al.*, 1983; Trask *et al.*, 1987).

Treatment of skeletal Class II subjects with increased vertical facial dimensions can be performed in various ways (Teuscher, 1978; Dinçer, 1989; Darendeliler, 2006). Inhibiting maxillary forward growth and stimulating growth of mandible in a forward and upward direction are key determinants of this treatment. Providing an appropriate intermaxillary relationship without using extraoral appliances can be a better treatment approach, which may enhance patient tolerance to functional therapy.

The use of magnets that can be positioned according to the required direction and form of motion, that would not restrict maxillary and mandibular movement, and that would apply no-friction forces allowing functions such as talking and swallowing, has been the focus of attention for a number of years (Darendeliler, 2006). Use of magnetic forces, although not common and still controversial, will open new horizons in the field of orthodontic treatment and biomechanics (Darendeliler *et al.*, 1995). Although subjects with a vertical facial face type can be recognized at a very early stage, it remains as a characteristic of the individual, i.e. each individual has his/her own growth pattern.

No data concerning the long-term maintenance of Class II magnetic activator therapy could be found in the literature. The objective of this study was therefore to evaluate the changes in dentofacial growth before, during, and after application of the magnetic activator device (MAD) II on Class II division 1 high-angle patients.

Subjects and methods

Sample selection

The sample in this study consisted of 10 Class II division 1 high-angle (ANB ≥ 4 degrees and SN–GoGn ≥ 38 degrees) patients (six girls and four boys) caused by mandibular retrognathism. Informed consent to participation in the study was given by the parents/guardians of the subjects. The average chronological age of the patients at T1 was 10 years 5 months. According to hand–wrist radiographic evaluation, determined using the atlas of Greulich and Pyle (1959), their skeletal ages ranged between 9 years 3 months and 11 years 1 month at the beginning of the observation period (T1). The minimum calculated growth potential of the patients was 80.0 per cent, whereas the maximum was 88.4 per cent. All patients had an increased overjet and slightly increased overbite at T1.

Observation period (T1–T2)

The material comprised the lateral cephalometric and hand–wrist radiographs obtained at T1 and at the beginning of treatment (T2). The patients were observed for 9.5 months without any orthodontic or orthopaedic approach to define the direction of facial growth (T2–T1). No extraction of primary or permanent teeth was performed during this time. At the end of this period, lateral cephalometric and hand–wrist films were taken to evaluate dentofacial growth (T2). The growth potential of the patients was between 81.2 and 91.0 per cent.

MAD II appliance

The MAD II appliance consisted of removable upper and lower plates, seated onto the mandibular and maxillary dental arches, each of which contained three cylindrical neodymium iron boron magnets coated with stainless steel (Kuster and Ingervall, 1992; Figures 1 and 2).

The MAD II appliance was modified by positioning the lower posterior repelling magnets 1 mm mesial, and the lower anterior attractive magnets 4 mm distal to their upper antagonists in the sagittal direction in order to increase the efficiency of the functional orthopaedic forces (Figure 3). Anterior midline magnets were placed in a configuration where 300 g attractive magnetic force was achieved when the magnets were in full contact.

A 5.5–6 mm vertical bite opening was generated to accommodate the posterior magnets. The four posterior magnets were placed in a repelling configuration, which produced a continuous intrusive and distal force on the upper posterior segments and a continuous intrusive force on the lower posterior segments while pushing the mandible forward. The initial force produced between each posterior magnet pair was approximately 250 g.

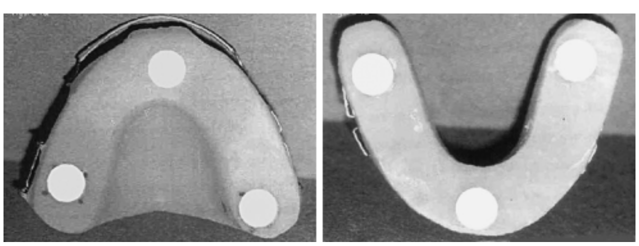

Figure 1 Magnets on the removable upper and lower plates of the magnetic activator device II appliance.

Treatment period (T2–T3)

The patients in both groups were instructed to wear the magnetic appliances 24 hours per day, except during meal times. The patients were monitored monthly. The average treatment time was 10.8 months. When a normal dental relationship was obtained, treatment was ended and records were taken (T3). The growth potential of the patients had reached 84.3 and 94.0 per cent. The patients were instructed to use the appliances at night-time because of the high remaining growth potentials.

Post-treatment period (T3–T4)

Approximately 4 years after the end of retention, post-treatment records were obtained (T4). None of the patients used any retention appliance during this period. The growth potential of the patients calculated from the hand–wrist

Figure 2 Frontal view of the magnetic appliance. Posterior parts of the upper and lower plates tend to repel from each other, whereas anterior parts are in full contact due to the magnetic field.

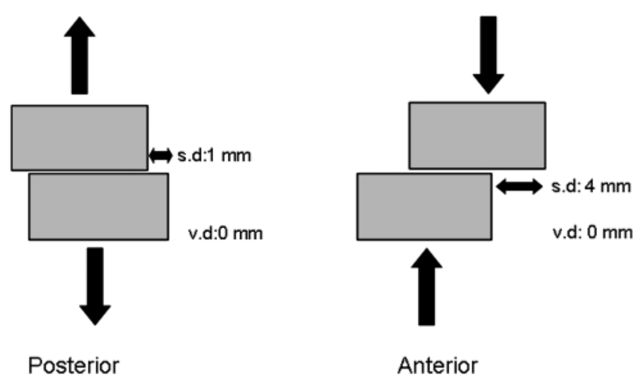

Figure 3 Diagram showing the position of the magnets (sagittal view). s.d, sagittal distance; v.d, vertical distance.

radiographs had reached 96.9–100 per cent of overall growth.

Cephalometric and statistical analysis

The lateral cephalograms and hand–wrist radiographs used for this study were collected at the beginning of T1, T2, and T3 and at the end of T4. All cephalograms were taken in the natural head position with the lips relaxed and the teeth in occlusion. The cephalograms were traced by the one author (EK) and superimposed on the anterior curvature of sella turcica, and *x*, *y* co-ordinates were traced to maintain reproducibility of measurements. The distances of some anatomic landmarks to these co-ordinates were also measured in order to evaluate the treatment changes (Figure 4).

The method error was assessed by the same author retracing and redigitizing 24 randomly selected cephalometric radiographs after a period of 15 days. Method error coefficients for all measurements were calculated and were within acceptable limits (range 0.98–0.99; Winner, 1971). Statistical analysis was performed with the Statistical Package for Social Sciences 15.01 for Windows (SPSS Inc., Chicago, Illinois, USA). Repeated measures analysis of variance was used to evaluate significant longitudinal changes during T1, T2, T3, and T4.

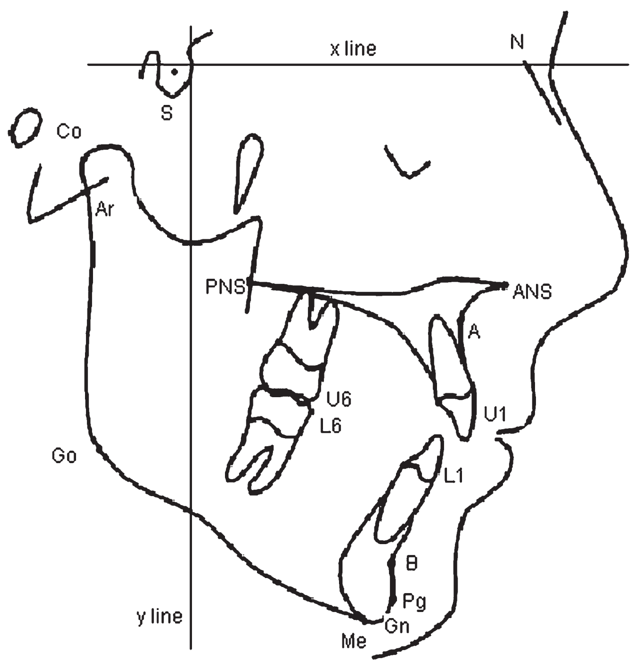

Figure 4 (1) S–N distance (millimetre), (2) SNA angle (degrees), (3) maxillary plane angle (SN–ANS–PNS), (4) CoA distance, (5) ANB angle, (6) CoA–CoGn (difference), (7) SNB angle, (8) Co–Gn distance, (9) Y angle (frankfort plane–SGn), (10) GoAr distance, (11) Go–Me distance, (12) SN–GoGn angle, (13) esthetic plane of Ricketts-lower lip distance, (14) GnGoAr angle, (15) upper incisor (U1)–NA distance, (16) U1–NA angle, (17) overjet, (18) overbite, (19) lower incisor (L1)–NB distance, (20) L1/NB angle, (21) occlusal plane/SN angle, (22) S–Go distance (posterior face height), (23) N–Me distance (anterior face height), and (24) S–Go/N–Me × 100 per cent (postero-anterior face height ratio).

Results

The mean, standard error of the mean, significance of the measurements, and the changes during T1, T2, T3, and T4 are shown in Table 1.

Cranial, maxillary, and maxillomandibular changes

Anterior cranial base length (SN distance) increased for all periods, but changes during T1–T4 and T2–T4 were more significant ($P < 0.001$). ANB angle did not change during the observation period but decreased significantly during treatment ($P < 0.01$). Although the decrease in ANB continued at T4, it was not statistically significant. Maxillary effective length (Co–A) increased significantly during the observation period ($P < 0.05$). The increase in Co–A was not significant during T2–T3 and T3–T4, but the overall change (T1–T4) was statistically significant ($P < 0.01$).

Mandibular changes

The change in SNB angle was not statistically significant, although a total increase of 2.3 degrees was measured between T1–T4. Mandibular effective length (Co–Gn) showed a significant increase during T1–T2, T2–T3, and T3–T4 ($P < 0.05$) and the overall change during T1–T4 was statistically significant ($P < 0.001$). Gonial angle showed a significant decrease in all periods, except for T2–T3 ($P < 0.05$). Corpus (Go–Me) and ramus (Go–Ar) lengths increased significantly during T1–T3 ($P < 0.05$). Corpus length continued to increase during T3–T4 ($P < 0.01$) and the change during T1–T4 and T2–T4 was significant ($P < 0.001$). The increase in ramus length during T1–T4 and T2–T4 was also significant ($P < 0.01$).

Dental and dentoalveolar changes

Overjet showed a significant decrease during T2–T3 and T1–T4 ($P < 0.001$), but the change in overbite was not significant. A significant decrease in U1–NA distance during the treatment period changed to a significant increase during T3–T4 ($P < 0.05$). A significant decrease was observed in U1–NA during T2–T3 ($P < 0.01$). During T1–T2, both L1–NB distance and L1–NB angle significantly increased ($P < 0.05$). The change in L1–NB angle between T1 and T4 was also significant ($P < 0.05$).

Vertical changes

Posterior face height (S–Go) increased significantly during T1–T2 and T3–T4 ($P < 0.01$). Anterior face height (N–Me) also increased significantly during T1–T2 ($P < 0.05$), T2–T3 ($P < 0.05$), and T3–T4 ($P < 0.001$); however, increases in postero-anterior face height ratio (S–Go–N–Me ×100) were not significant except for T1–T4 ($P < 0.05$). SN–GoGn angle decreased during all periods, although the change was not statistically significant.

Table 1 Changes in the descriptive statistics, the mean value (X), standard error (Sx), and their statistical significance in the observation, treatment, and post-treatment periods. T1: beginning of observation; T2: beginning of treatment; T3: end treatment; and T4: post-treatment.

Regions	Descriptive statistics	Periods								Statistical significance (P)				
		T1		T2		T3		T4		T1–T2	T2–T3	T3–T4	T1–T4	T2–T4
		X	Sx	X	Sx	X	Sx	X	Sx					
Cranial	S–N (mm)	69.9	1.1	70.5	1.2	71.5	1.3	74.2	1.5	*	*	**	***	***
Maxillary	SNA (°)	77.6	0.7	78.1	0.7	77.3	0.9	77.2	1.1	NS	NS	NS	NS	NS
	SN–ANS–PNS (°)	7.9	0.8	7.6	0.6	7.7	0.6	7.9	0.7	NS	NS	NS	NS	NS
	Co–A (mm)	83.2	1.1	85.6	1.3	87.3	1.0	87.9	1.7	*	NS	NS	**	NS
Maxillo-mandibular	ANB (°)	6.8	0.6	6.8	0.4	5.1	0.5	4.7	0.5	NS	**	NS	***	NS
	CoA–CoGn (mm)	22.1	1.4	23.5	1.5	26.6	2.0	30.7	1.4	NS	NS	NS	***	NS
Mandibular	SNB (°)	70.8	0.5	71.3	0.5	72.2	0.7	72.1	0,9	NS	NS	NS	NS	NS
	CO–Gn (mm)	105.3	1.4	109.1	2.0	113.9	2.4	117.1	1.9	*	*	*	***	NS
	Y angle (°)	74.0	0.8	74.1	0.8	73.8	1.1	73.9	1.4	NS	NS	NS	NS	NS
	Go–Ar (mm)	40.0	1.3	42.0	1.6	43.7	1.6	46.5	2.3	*	*	*	**	**
	Go–Me (mm)	65.9	1.3	67.7	1.6	69.6	1.1	73.8	1.4	*	*	**	***	***
	REP–LL (mm)	2.1	1.2	1.2	1.0	0.6	1.1	0.1	0.7	NS	NS	NS	NS	NS
	GnGoAr (°)	130.0	1.3	128.0	1.5	129.9	1.4	126.4	1.6	**	*	*	**	NS
Dental and dentoalveolar	U1–NA (mm)	5.5	0.8	5.0	0.6	4.2	0.8	6.2	0.8	NS	*	*	NS	NS
	U1–NA (°)	23.3	2.4	26.7	2.3	23.4	2.3	24.9	2.8	NS	**	NS	NS	NS
	Overjet (mm)	8.2	0.4	8.0	0.5	4.4	0.4	5.5	0.4	NS	***	NS	***	NS
	Overbite (mm)	2.9	0.9	3.1	1.0	2.3	0.7	2.1	1.1	NS	NS	NS	NS	NS
	L1–NB (mm)	5.7	0.7	6.5	0.7	6.7	0.6	8.1	0.9	*	NS	NS	NS	*
	L1–NB (°)	24.5	2.2	27.8	1.8	30.6	2.4	29.6	1.8	*	NS	NS	*	NS
	Occlusal plane–SN (°)	20.4	0.6	20.1	0.9	20.2	0.7	19.6	0.9	NS	NS	NS	NS	NS
Vertical changes	PFH (SGo, mm)	67.9	1.7	70.8	1.6	73.8	1.7	78.5	2.3	**	**	**	***	NS
	AFH (NMe, mm)	117.2	2.3	120.5	2.7	123.9	3,2	130.6	3.5	*	*	**	***	***
	SGo–NMe (%)	58.0	0.8	58.7	0.7	59.4	0,5	60.3	1.0	NS	NS	NS	*	NS
	SN–GoGn (°)	41.0	0.9	40.2	1.2	39.9	1.3	39.3	2.0	NS	NS	NS	NS	NS

NS, not significant. * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; NS $P > 0.05$.

Discussion

Even though determining skeletal change was not the primary goal of this study, it is evident that the MAD II appliance had a significant impact on the maxilla. S–N measurement showed a significant increase for all periods, which might be attributed to spontaneous growth of the subjects rather than the magnetic forces. The forward lengthening of the S–N line might have reduced the changes in S–N-dependent angles (SNA and SNB); therefore, non-significant changes occurred in SNA and SNB.

SNA decreased non-significantly with MAD II application (T2–T3), which might be due to the observed increase in SN distance as a consequence of growth and development. It has been reported that maxillary growth is inhibited during classic functional treatment (Teuscher, 1978). Vardimon *et al.* (2001) found significant backward movement of point A as a result of incisor retroclination in patients treated by functional magnetic appliances. Darendeliler and Joho (1993) treated three patients with Class II division 1 malocclusions with a MAD II and observed that the mandible moved upwards and forwards; however, minimal skeletal changes occurred in the maxilla.

While a significant increase was found in Co–A distance during T1–T2, there were non-significant increases during T2–T3 and T3–T4. Changes in effective maxillary length and SNA showed that the MAD II appliance inhibited maxillary growth.

Releasing the forward growth potential of the mandible with the use of functional appliances is important. Kalra *et al.* (1989) reported improvement in Class II structures with appliances containing posterior repelling magnets, especially when sagittal growth was continuing. Gavish *et al.* (2001) observed a significant increase in SNB in 10 adult patients, treated with functional magnetic appliances. In this study, a non-significant increase in SNB and significant increase in mandibular length (Co–Gn) with the application of the MAD II appliance were observed, which is in agreement with previous studies (Kalra *et al.*, 1989; Gavish *et al.*, 2001). Mandibular corpus (Go–Me) and ramus (Go–Ar) dimensions were also significantly increased in all periods, which were clinically relevant changes.

Barbre and Sinclair (1991) used a magnetic active vertical correction appliance in 25 patients with an anterior open bite and noted a significant increase in SNB and a significant decrease in ANB. In this study, no differences occurred during T1–T2 in ANB, but a significant decrease was observed between T2 and T3, which continued during T3–T4, although not significantly.

Gonial angle (Gn–Go–Ar) increased significantly during T2–T3 as a result of posterior movement of the condyle but decreased significantly between T3 and T4 ($P < 0.05$). SN–GoGn angle decreased non-significantly in all three periods. The alterations in SNB, ANB, SN–GoGn, and gonial angles were favourable changes (anterior rotation) and these were stable at T4. The findings during T2–T3 were in accordance with previous studies in the literature (Darendeliler *et al.*, 1993, 1995; Meral and Yüksel, 2003; Darendeliler, 2006).

The positioning of the magnets in the present study was planned to achieve anterior rotation of the mandible in order to prevent a further increase in vertical facial dimensions. SN–GoGn angle decreased non-significantly, but posterior (S–Go) and anterior (N–Me) face heights increased significantly in all periods, although the increase in the postero-anterior face height ratio (S–Go–N–Me × 100) was not significant. Meral and Yüksel (2003) treated 16 individuals with a skeletal and dental open bite using functional magnetic appliances where the magnets were placed as in the present study and reported that the mandible, which was growing downward and backward, started to move in a forward and upward direction during treatment.

Overjet decreased significantly between T2–T3 and T1–T4 ($P < 0.001$) because of forward movement of the mandible and retroclination of the upper incisors. Non-significant proclination of the upper incisors during T1–T2 changed to a significant retroclination during T2–T3 ($P < 0.05$), which might be attributed to the magnetic forces. Significant protrusion of the lower incisors during T1–T2 ($P < 0.05$) continued non-significantly between T2–T3 and T3–T4. The torque springs that can be seen in Figure 2 might have enhanced proclination of the mandibular incisors. Darendeliler *et al.* (1995) suggested that an anterior open bite was corrected by anterior rotation of the mandible and retrusion of upper incisors. The present findings are in agreement.

Conclusions

1. The use of a MAD II appliance resulted in a reduction of the skeletal Class II relationship, which was stable 4 years post-treatment.
2. A significant reduction was found in overjet due to retrusion of the upper incisors and protrusion of the lower incisors, although there was a non-significant increase post-treatment.
3. Increases in ramal and posterior face heights were recorded which might be due to normal condylar growth.

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References

Barbre R E, Sinclair P M 1991 A cephalometric evaluation of anterior openbite correction with the magnetic active vertical corrector. Angle Orthodontist 61: 93–101

Björk A 1969 Prediction of mandibular growth rotation. American Journal of Orthodontics 55: 585–599

Bresolin D, Shapiro P A, Shapiro G G, Chapko M K, Dassel S 1983 Mouth breathing in children: its relationship to dentofacial development: a comparison of sibling pairs. American Journal of Orthodontics 83: 334–340

Darendeliler M A 2006 Use of magnetic forces in growth modification. Seminars in Orthodontics 12: 41–51

Darendeliler M A, Joho J P 1993 Magnetic Activator Device II (MAD II) for correction of Class II, division 1 malocclusions. American Journal of Orthodontics and Dentofacial Orthopedics 103: 223–239

Darendeliler M A *et al.* 1993 The use of magnets in orthodontic therapy: panel discussion. European Journal of Orthodontics 15: 421–424

Darendeliler M A, Yüksel S, Meral O 1995 Open-bite correction with magnetic activator device IV. Journal of Clinical Orthodontics 29: 569–576

DeBerardinis M, Stretesky T, Sinha P, Nanda R S 2000 Evaluation of the vertical holding appliance in treatment of high-angle patients. American Journal of Orthodontics and Dentofacial Orthopedics 117: 700–705

Dinçer M 1989 Treatment of Class 2-high angle cases using the combined activator-occipital headgear. Turk Ortodonti Dergisi 2: 114–124

Gavish A, Vardimon A D, Rachima H, Bloom M, Gazit E 2001 Cephalometric and polysomnographic analyses of functional magnetic system therapy in patients with obstructive sleep apnea. American Journal of Orthodontics and Dentofacial Orthopedics 120: 169–177

Greulich W W, Pyle S I 1959 Radiographic atlas of skeletal development of the hand and wrist, 2nd edn. Stanford University Press, Stanford

Isaacson J, Isaacson R, Speidel T, Worms F 1971 Extreme variation in vertical facial growth and associated variation in skeletal and dental relations. Angle Orthodontist 41: 219–229

Kalra V, Burstone C J, Nanda R 1989 Effect of a fixed magnetic appliance on the dentofacial complex. American Journal of Orthodontics and Dentofacial Orthopedics 95: 467–478

Kuster R, Ingervall B 1992 The effect of treatment of skeletal open bite with two types of bite-blocks. European Journal of Orthodontics 14: 489–499

Meral O, Yüksel S 2003 Skeletal and dental effects during observation and treatment with a magnetic device. Angle Orthodontist 73: 716–722

Nanda S K 1988 Patterns of vertical growth in the face. American Journal of Orthodontics 93: 103–116

Sassouni V, Nanda S 1964 Analysis of dentofacial vertical proportions. American Journal of Orthodontics 50: 801–823

Speidel T, Isaacson R, Worms F 1972 Tongue thrust therapy and anterior dental openbite. American Journal of Orthodontics 62: 287–295

Teuscher U M 1978 A growth-related concept for skeletal Class II treatment. American Journal of Orthodontics 74: 258–275

Trask G M, Shapiro G G, Shapiro P A 1987 The effects of perennial allergic rhinitis on dental and skeletal development: a comparison of sibling pairs. American Journal of Orthodontics and Dentofacial Orthopedics 92: 286–293

Vardimon A D, Köklü S, Iseri H, Shpack N, Fricke J, Mete L 2001 An assessment of skeletal and dental responses to the functional magnetic system (FMS). American Journal of Orthodontics and Dentofacial Orthopedics 120: 416–426

Winner B J 1971 Statistical principles in experimental design, 2nd edn. McGraw-Hill Book Co., New York