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Skeletal and Dental Changes Following the Use of the Frankel Functional Regulator

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Abstract: *The purpose of this study was to assess the relative contributions of skeletal and dental components in correction of Class II division 1 malocclusions when treated with Frankel's functional regulator (FR).*

This was a retrospective study involving analyses of pre- and post-treatment cephalograms of 63 Class II division 1 patients treated with the FR to demonstrate the relative maxillary, mandibular, incisor, and molar movements during treatment compared with normal growth within a control group of untreated 39 Class II division 1 cases drawn from the same demographic population.

All cephalograms were digitized and subjected to a Pitchfork analysis, which measured individual anteroposterior skeletal and dental changes during the period of study.

It was shown that the FR was effective in treating Class II division 1 cases with the studied group being corrected to a clinically acceptable overjet and overbite of 2–3 mm. The majority of the correction came from dental movements, the most significant being the retroclination of the upper incisor teeth (mean 4·1 mm, 95 per cent CI ± 0·44) and proclination of the lowers (mean 2·2 mm 95 per cent CI ± 0·57). As regards skeletal correction, the most significant contribution was the restraint of normal maxillary forward growth (mean –0·2 mm, 95 per cent CI ± 0·62) with forward mandibular growth not being a significant factor.

Index words: Class II division 1, Frankel, Functional Regulator, Pitchfork Analysis.

Introduction

Functional appliances have been used for many years in the treatment of Class II division 1 malocclusions, the selection of which varies with the type of skeletal and dental anomaly, the growth pattern, and the operator's preference (Andresen, 1936, cited in Schmuth, 1983; Teuscher, 1978; Eirow, 1981; Bimler, 1983; Clark, 1988).

The Functional Regulator (FR) was developed by Dr Rolf Frankel of Zwickau, East Germany, as an alternative to the activator-type appliances (Frankel, 1966). Frankel believed that poor postural behaviour and activity of the orofacial musculature was the primary aetiological factor in producing a malocclusion. He felt that if the abnormal musculature could be altered, then so surely would the dentition be released from its influence and allow normal development to take place. As the name implies, the actions of the FR are intended to change or regulate the muscular environment of the face and teeth, to stretch facial musculature to normal dimensions, impede abnormal activity of the lips, tongue, and cheeks, and thus allow development of the jaws and teeth in all three planes (Frankel, 1980). Little doubt exists that the FR is an effective method of treatment for Class II division 1 malocclusions, but there is considerable uncertainty regarding the mechanism of the correction. It has been claimed that the FR promotes forward growth of the mandible (Frankel, 1966; McNamara, 1982a,b,c) and restriction of the maxilla (Owen, 1983a,b,c), while others claim that the effects are purely dentoalveolar with little or no skeletal effects (Gianelly *et al*., 1983; Righellis, 1983).

The majority of researchers agree that there is retroclination of the upper incisor teeth during treatment (Schulhof and Engel, 1982; Creekmore and Radney, 1983; Robertson, 1983), as well as agreeing that proclination of the lower incisors is a common finding, although it is maintained that this is an effect of a poorly constructed and handled appliance (Eirow, 1981; Frankel, 1984). There is no consensus of opinion on how the molar teeth behave in moving mesiodistally with some researchers finding restriction of the upper molars and mesial movement of the lowers (Schulhof and Engel, 1982; Creekmore and Radney, 1983), other findings refuting this (Frankel, 1969a, Hamilton *et al*., 1987).

In a review of the literature Bishara and Ziaja (1989) suggest that 60–70 per cent of Class II correction is orthodontic tooth movement, only 30–40 per cent orthopaedic. This purpose of this study was to assess the relative contributions of skeletal and dental components in correction of Class II division 1 malocclusions when treated with the FR.

Materials and Methods

The material for this study consisted of standardized cephalometric radiographs taken from the records of the

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orthodontics departments of Dumfries and Galloway Royal Infirmary, the Garrick Hospital, Stranraer, and Carlisle City General Hospital.

The records of 115 consecutive Class II division 1 cases treated between 1989 and 1992 with the Functional Regulator of Frankel were examined. All patients were of Caucasian origin.

Standardized cephalometric radiographs had been taken using a Siemens Orthophos-C cephalostat with settings of 14 mA, and between 73 and 77 kV. Exposure times varied between 0·5 and 0·63 seconds. The film used was either Kodak TMG-RA1 or DuPont Ultravision G, with a developing time of 90 seconds using a Kodak N35 developer.

To be included the following criteria had to be met:

1. Availability of adequate case records with pre- and post-treatment cephalograms.
2. Start radiographs taken 1 month or less prior to, or no more than 1 month following the start of treatment.
3. Initial malocclusion Class II division 1 as described by the British Standards Institution (1983), with an overjet greater than or equal to 6 mm.
4. No retroclination of the upper incisors.
5. Patient between 9 and 12 years at the start of treatment.
6. Pre- and post-treatment cephalograms taken with no more than 2 years between them.
7. Patient treated with the FR by one operator (JCA) by means of a standardized design and clinical technique.
8. No dental extractions or any adjunctive orthodontic treatment during the period of functional treatment

The records from 52 originally selected cases were discarded for the following reasons:

1. The operator judged that the patient's co-operation was poor during treatment. This was judged from both patients' and parents' reports, from the lack of any significant clinical improvement and from clinical signs of poor compliance—poor speech, lack of signs of wear on appliances, etc.
2. Dental extractions had been carried out during the course of treatment.
3. The cephalometric landmarks necessary for the analysis were not readily identifiable.

This left a sample of 63 treated cases, 42 girls and 21 boys in the study. For the purposes of comparison, records were obtained from 58 untreated Class II division 1 subjects, 19 boys and 39 girls, from the same demographic population.

Criteria for inclusion was the same as for the treated patients except that no treatment at all was carried out. Patients within this group had either been offered orthodontic treatment and declined, or had been deemed unsuitable for orthodontic treatment.

Exclusion criteria of poorly defined cephalometric landmarks and if any patient had had any dental extractions for any reason during the period between radiographs were applied. This resulted in the exclusion of 19 cases, leaving 39 cases, 14 boys and 25 girls, as the studied control group.

The appliance design was to the FR specification as described by McNamara and Huge (1983) with only one slight modification that being the lingual acrylic pad, originally recommended by Frankel, replaced by a connecting wire as this was found to be better tolerated by patients.

The use of the FR had been discontinued when the overjet and overbite was reduced to 2–3 mm, when the patient was either deemed to have finished active treatment or went on to further appliance therapy.

The pitchfork analysis used in this study is designed to measure the individual antero-posterior dental and skeletal changes that contribute to the correction of a Class II malocclusion. This analysis has been described in detail by Johnston (1986, 1996).

It uses the method of superimposing a later radiograph on an earlier one to measure the physical movement of the upper and lower buccal segments, and incisors relative to their dental bases, both bodily and angular movements, as well as the displacement of the maxilla and mandible relative to the cranial base. The individual components of change are all designated positive or negative appropriate to its impact on treatment: positive if it would help to correct a Class II malocclusion, and negative if it tends to move the skeletal or dental relationship further towards Class II.

The algebraic sum of the various components will equal the change in the molar relationship and overjet. This analysis cannot only measure the magnitude of changes during treatment, but also the source of the changes, dental or skeletal.

The pitchfork diagram is generated to show a summary of the various components of change that come together at the occlusal plane (Figure 1).

Pre- and post-treatment films were traced for each patient with a 4H 0·3-mm pencil on acetate sheets and, as suggested by Johnston (1996), both films from each patient were traced at the same time with the films side by side on the viewer to try and minimize errors in locating cephalometric landmarks. In order to execute the analysis used, the following structures were traced:

(i) Setric centre of the symphysis (Bjork's point);
(ii) maxillary outline;
(iii) upper and lower first molars;
(iv) upper and lower incisors;
(v) mandibular symphysis including 'D' point, the geomPTMF—the pterygomaxillary fissure.
(vi) E point—the intersection of the averaged greater wings and the planum of the sphenoid;

For the execution of the analysis, the tracing of the later cephalogram was laid on top of the earlier and the maxillae superimposed by orientating on the palatal plane (ANS–PNS), and registering on the palatal trabeculae and lingual palatal curvature as described by Johnston (1986). Care was taken to ensure that the PTMF of the later film lay at or posterior to the PTMF of the earlier. In order to ensure future accurate re-superimposition if necessary, three registration crosses were marked on the first film and transferred to the later film once the maxillary registration had been established.

The superimposed films were stabilized on a GTCO digitizing pad and the points individually digitized in sequence using a GTCO digitizer linked to a Compaq Prolinea 4/335 computer, which executed the analysis from a program specially written for the purposes of producing a pitchfork diagram, using GeLa 1·7, a computer language designed for writing programs to analyse cephalograms. The data was stored on floppy disc and later used to generate pitchfork diagrams using a Hewlett Packard HP560 printer.

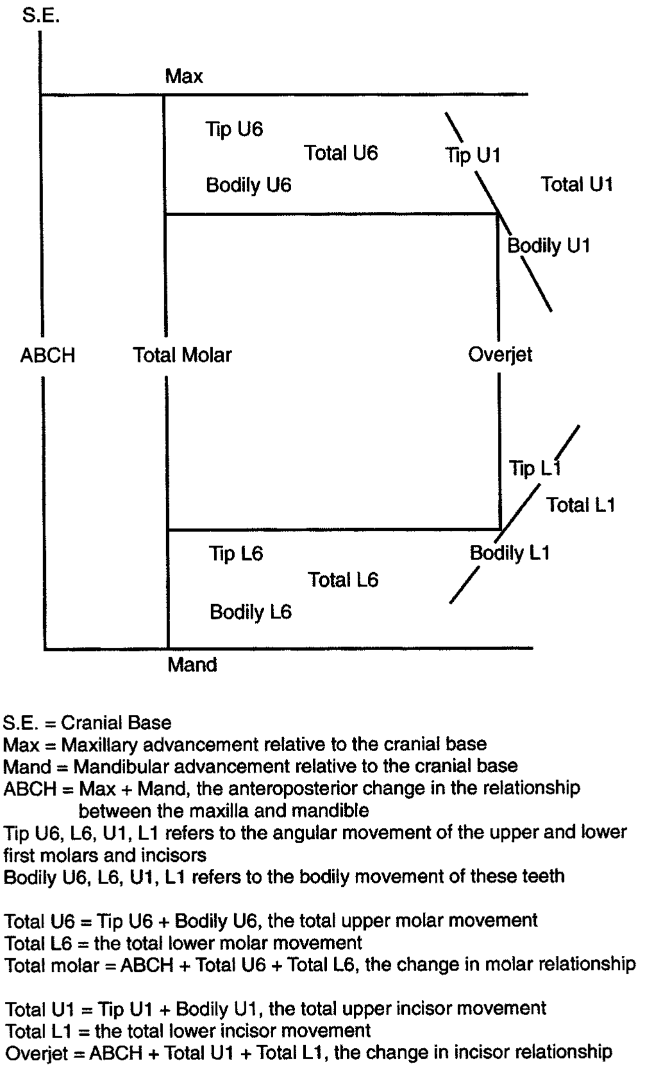

FIG. 1 The pitchfork analysis. SE = cranial base; Max = maxillary advancement relative to the cranial base; Mand = mandibular advancement relative to the cranial base; ABCH = Max + Mand, the anteroposterior change in the relationship between the maxilla and mandible; Tip U6, L6, U1, L1 refers to the angular movement of the upper and lower first molars and incisors. Bodily U6, L6, U1, L1 refers to the bodily movement of these teeth. Total U6 = Tip U6 + Bodily U6, the total upper molar movement. Total L6 = the total lower molar movement. Total molar = ABCH + Total U6 + Total L6, the change in molar relationship. Total U1 = Tip U1 + Bodily U1, the total upper incisor movement. Total L1 = the total lower incisor movement. Overjet = ABCH + Total U1 + Total L1, the change in incisor relationship.

Results

The mean ages, length of treatment and period of study of the Frankel and control groups are shown in Table 1.

TABLE 1 *Mean ages and length of study*

	Frankel	Control
Mean start age (years)	10·7	10·7
Mean end age (years)	12·2	12·4
Length of study (months)	16·4	17·3

Within both the treated and control groups, the following statistics were produced for each variable :

(i) arithmetic mean;
(ii) standard deviation;
(iii) minimum value;
(iv) maximum value;
(v) the unpaired Student's *t*-test was used to make a comparison between the two groups for all variables to test for any significance of the differences seen between them.

It should be remembered that when analysing a pitchfork diagram and values, that positive values are those contributing to correction of the Class II malocclusion and negative values are non-contributory or antagonistic.

The results for all measurements are shown in Table 2.

Maxillary changes

In the treated group the mean movement of the maxilla of –0·2 mm indicates a slight increase of forward growth, the range being from –7·1 to 5·8 mm, the latter figure indicating either a restraint of the maxilla with continued growth at the cranial base or distal movement of the maxilla with the appliance. In the control group, the maxilla was seen to come forward in all cases, as would be expected with normal growth (mean –3·1 mm; range –1·1 to –10·2 mm). Comparison of the treated with control group demonstrates a statistically significant difference ($P < 0{\cdot}001$) in the mean values of maxillary movement.

Mandibular changes

The mean change of the mandible was seen to increase in both the treated (4·1 mm) and control (5·0 mm) groups, the small difference between the two not being statistically significant. The amount of movement in the treated group ranged from 12·8 mm of advancement to –1·4 mm of relative backward movement. The maximum change in the controls was greater than the treated group at 14·8 mm, the minimum value being –0·2 mm.

ABCH changes

ABCH, the anteroposterior change in the relationship between the maxilla and mandible, made a mean positive contribution in both the treated (4·0 mm, range 0–8·9 mm) and control (1·9 mm, range –2·0 to 4·7 mm) groups. The difference between the two groups (2·1 mm) was statistically significant ($P < 0{\cdot}001$).

All skeletal changes are shown in Figure 2.

Molar changes

With regard to the upper molars, the mean movement in the FR group was in a mesial direction (-1·1 mm), which did not help in correcting the Class II buccal segment relationship, although the range was between 3·7 mm of distal contributory movement down to –6·0 mm in a mesial direction.

TABLE 2 *Treatment changes for all measurements—Frankel versus control group*

	Frankel Mean	95% CI	Min.	Max.	Control Mean	95% CI	Min.	Max.	*t*-Test	Significance
ABCH	4	±0·49	0	8·9	1·9	±0.47	–2	4·7	5·61	P <0·001
MAX	–0·2	±0·62	–7·1	5·8	–3·1	±0·60	–10·2	–1·1	6·18	P <0·001
MAND	4·1	±0·74	–1·4	12·8	5	±0·82	–0·2	14·8	1·48	NS
U6 TIP	–0·4	±0·47	–4·1	3·8	–1·1	±0·47	–4·7	1·6	2·04	0·02 <P <0·05
U6 BODILY	–0·7	±0·59	–6·7	6·5	0	±0·63	–3·3	5·7	0·93	NS
TOTAL U6	–1·1	±0·54	–6	3·7	–1·1	±0·50	–4·6	2·3	0	NS
L6 TIP	–0·7	±0·47	–4·6	5·2	–0·8	±0·56	–3·8	5·1	0·26	NS
L6 BODILY	1·6	±0·72	–8·8	8·9	0·2	±0·69	–6·3	4	2·49	0·01 <P <0·02
TOTAL L6	0·9	±0·54	–8·2	7·2	–0·6	±0·50	–4·8	2·3	3·92	P <0·001
TOTAL MOLAR	3·8	±0·40	0·4	7	0·2	±0·31	–2·8	2·1	12·61	P <0·001
U1 TIP	4·1	±0·44	–1	8·2	–0·6	±0·35	–3	1·1	14·48	P <0·001
U1 BODILY	–0·9	±0·47	–4·9	3·7	–0·2	±0·41	–3·8	2·8	2·05	0·01 <P <0·02
TOTAL U1	3·2	±0·54	–2·9	7·3	–0·8	±0·44	–4	2	10·15	P <0·001
L1 TIP	2·2	±0·57	–9·3	7·4	–0·6	±0·35	–2·9	2·2	7·3	P <0·001
L1 BODILY	–0·8	±0·35	–4·2	2·5	–0·5	±0·35	–2·5	2·1	1·14	NS
TOTAL L1	1·4	±0·52	–6·8	7·2	–1·1	±0·41	–4·9	1·6	6·97	P <0·001
OVERJET	8·7	±0·69	–0·7	16·6	1·1	±0·35	–2·4	2·3	18·4	P <0·001

Significance level established at $P < 0{\cdot}05$.
t-Tests carried out at 100 degrees of freedom.

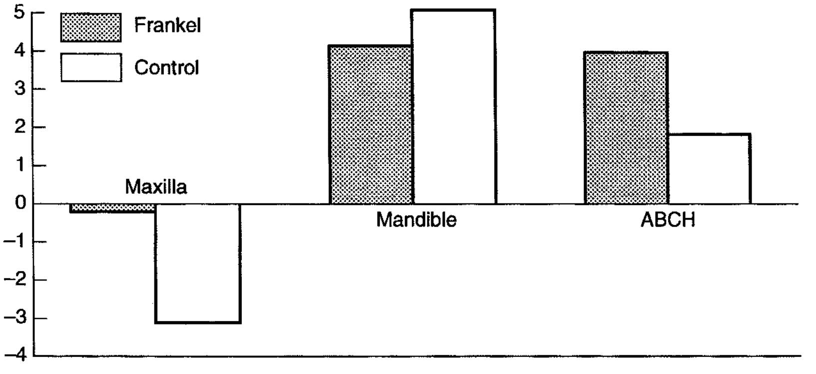

FIG. 2 Comparison of skeletal changes.

The relative contributions to total upper molar movement were a mean –0·4 mm of tip and –0·7 mm of bodily movement, both antagonistic to the correction of the Class II relationship. In the control group the mean movement of the upper molars was again –1·1 mm (range –4·6 to 2·3 mm), the contributory elements all being tipping movements (–1·1 mm), the mean bodily movement being 0 mm. There was thus no difference seen in the total movement of the upper molar, the only significant difference ($P < 0{\cdot}05$) being in the tip (–0·4 mm in FR, –1·1 mm in control).

With regard to the lower molar, there was a significant difference between the total amount of movement in the treated group (mean 0·9 mm) and the control group (–0·6 mm). The net correction of the position of the lower molar in the FR group was due to the bodily movement(1·6 mm), the mean tip (–0·7 mm) opposing the Class II correction. In the FR group a mean total molar correction of 3·8 mm was calculated, the same calculation being only 0·2 mm in the control group. The correction seen in the FR group, however, was due to the ABCH change, the relative movement of the molars being –0·2 mm not contributing to buccal segment correction at all and, in fact, being slightly antagonistic. The minimal overall mean change seen in the control group (0·2 mm) is a good example of dentoalveolar compensation, the molar relationship change (–1·7 mm) maintaining the buccal segment relationship in the face of relatively favourable skeletal growth (ABCH change of 1·9 mm).

Incisor change

The greatest movement of the incisors in the treated group was their tip, 4·1 mm of retroclination in the upper incisors, 2·2 mm of proclination in the lower. The range of retroclination of the upper incisors was from –1·0 to 8·2 mm, the tip of the lowers ranging from a proclination of 7·3 mm to a retroclination of –9·3 mm. This last figure was somewhat aberrant and was probably due to an error in the method, the likelihood of so much retroclination occurring with FR treatment being very low indeed.

Bodily movement of the upper incisors ranged from –4·9 to 3·7 mm with a mean movement of –0·9 mm (forward direction). These figures give a correction value of 3·2 mm for the total upper incisor movement and 1·4 mm for the lower incisors, both being seen to contribute favourably to the correction of the Class II malocclusion.

The mean movement of the control incisors was –0·8

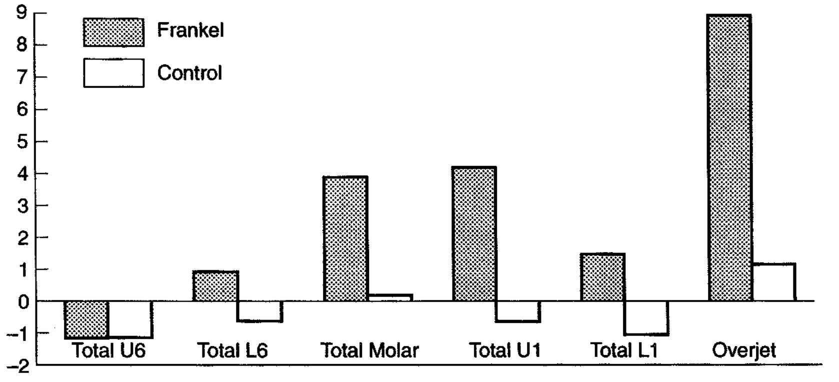

FIG. 3 Comparison of dental changes.

mm, the components both being antagonistic to correction of the overjet, being –0·6 and –0·2 mm for tip and bodily movement, respectively. The lower incisor movement was again slightly antagonistic, with a mean tip of –0·6 mm and bodily movement of –0·5 mm, adding up to a total movement of –1·1 mm.

The change in overjet is the total change in incisor relationship and is the algebraic sum of ABCH + Total U1 + Total L1. This works out at 8·7 mm for the treated group, the ABCH contributing a little under half this correction. The control group's overjet reduction was a mean 0 mm demonstrating no change in the incisor relationship. This difference between the two groups was highly significant ($P < 0{\cdot}001$).

The changes in molar and incisor positions are shown in Figure 3.

Discussion

Treatment with the FR started at a mean age of 10·7 years, which is usually just prior to or around the pubertal growth spurt. Because the criteria for inclusion included a start age of between 9 and 12 years, the oldest patient to commence treatment was 11·9 years, the youngest being 9·2 years. Although Cohen (1980) seems to suggest that 9·4 years is the optimum age for any functional appliance treatment, he agrees with Tanner (1951) that growth spurts are very variable and that variation between individuals are very common. The range in this study of 9·2–11·9 years is seen to be representative of patients being treated at the optimum age around the pubertal growth spurt.

The treatment time ranged from 10 to 23 months, with a mean length of 16·4 months. When compared with other studies this seems to be slightly shorter than average, McNamara *et al.* (1990) studying over 18 months, Schulhof and Engel (1982) over 21 months, and Creekmore and Radney (1983) over 29 months, however, variation in response to treatment with the FR has to be considered. One of the main determining factors in the length of treatment time is the co-operation and compliance of the patient—if the appliance is not worn full time, then the treatment time is obviously increased. The growth in the untreated control group was studied over a similar period (mean 17·3 months, range 11–23 months) and matched well the starting age of the FR group.

Skeletal changes

The way in which the FR is held in the mouth when the mandible is postured forwards places a reciprocal force acting distally on the maxilla. The theory is that the normal forward growth of the maxilla is inhibited or even reversed to effect distal movement of the maxilla relative to the cranial base, a situation which Hotz (1970) said would be ideal for correction of a Class II skeletal discrepancy.

In this study the mean movement of the maxilla was –0·2 mm, which in terms of the pitchfork analysis represents a very small increment of forward growth in an antero-posterior direction in spite of the forces redirected via the FR. The equivalent result in the control group of –3·1 mm represents the normal mean maxillary growth relative to the cranial base. As would be expected all the control cases demonstrated negative values for Max., this representing normal forward growth of the maxilla (range –1·1 to –10·2 mm). That the FR is unable reliably to fully restrain forward maxillary growth is evident from the most unfavourable value recorded of –7·1 mm. and the fact that 32 out of the 63 FR cases demonstrated a negative result. The most favourable value of 5·8 mm on the other hand represents a significant restraint and probably distal movement of the maxilla. These findings agree with some authors, Owen (1981, 1983a,b,c), Neilson (1984), and Creekmore and Radney (1983) all finding some degree of decrease in forward growth taking place. The difference between the mean maxillary movement of the two groups was a highly statistically significant factor and suggests that a good deal of the Class II skeletal correction was restraint of the maxilla.

Whether or not there is an increase in size or acceleration of growth of the mandible is one of the major controversies in functional appliance therapy. Although many researchers have claimed that the FR causes extra mandibular growth (Righellis, 1983; McNamara *et al.*, 1985), this study showed that there were no significant differences between the FR and control groups as far as mandibular movement is concerned, the mean FR movement being 4·1 mm, standard deviation 3·0 mm; the control 5·0 mm, and standard deviation 2·6 mm. As the 5·0-mm change in the control was due to normal growth, it can be assumed that the 4·1-mm change in the FR group was no more than normal growth rather than any effect of the appliance. The maximum value seen in the control was 14·2 mm and for the

FR it was 12·8 mm; again, because this change in the controls was due to normal growth it must be assumed that even the maximum FR change was no more than normal growth change. That the size of the mandible is unaffected with the FR is supported by evidence from Creekmore and Radney (1983), and Hamilton *et al.* (1987), who found no significant differences between FR and untreated patient groups.

Negative values seen both in the FR and control groups at first seem difficult to explain, after all, the mandible cannot reduce its size. However, it should be remembered that only anteroposterior movements are measured and no amounts of movements in other directions are accounted for. Rotation of the mandible during growth has previously been reported (Bjork and Skieller, 1983), which probably accounts for the negative values seen. A backwards rotation would worsen a Class II skeletal pattern and, if subjected to a pitchfork analysis, generate a negative value if it exceeds forward growth. Because a backwards pattern of growth rotation is a common finding in Class II discrepancies, one of the aims of FR treatment is to encourage a forward rotation during growth (Isaacson *et al.*, 1977; Harvold and Vagervik 1971). That the FR group demonstrated slightly more negative values than the controls suggests that this aim of FR treatment is unsuccessful.

The ABCH values represent the maxillo-mandibular differential, the movement of the mandible relative to the maxilla. A positive value means that the mandible has outgrown the maxilla, negative values the maxilla outgrowing the mandible. In the FR group where the mean was 4·0 mm in an anteroposterior direction, no negative values were seen, the minimum value of 0 mm being a situation where the forward movement of the mandible matched that of the maxilla, otherwise, in all instances, the mandible came forward further than the maxilla. It would be expected that in the control group, the mean ABCH to be close to 0 mm, with both jaws growing at the same rate, but the mean value was 1·9 mm with a standard deviation of 1·5 mm and a range of –2·0 to 4·7 mm. In fact, only three patients out of the total control group demonstrated a negative ABCH value, and only two out of 39 had a value within 0·5 or 0 mm. This finding perhaps suggests that there is a differential in growth between the maxilla and mandible, the mandible showing greater anteroposterior movement.

Dental changes

Although tissue-borne, it is widely accepted that the FR causes a significant amount of dental movements within the dental bases. The ideal situation for the correction of the buccal segment relationship would be the mesial movement of the lower molars and distal movement of the uppers, or the restraint of the latter as the maxilla comes forward. Frankel (1969a,b) stated that there was no movement of the molars in these directions, a statement that has not proved to be valid in the light of further studies. In this study, the upper molars were seen to move mesially with a mean total movement of –1·1 mm. When this is compared to the movement of the maxilla (–0·2 mm) it would appear that the upper molars have come forward further than the maxilla and that the FR has been fairly ineffective at preventing this. The mean total lower movement of 0·9 mm, being positive, was in a contributory direction, albeit a very small contribution, although when added to the mandibular movement a total forward movement of 5·0 mm was seen to occur.

When comparisons are made with the controls' molar movements, the uppers came forward by the same amount (–1·1 mm), but the lower molars were not seen to come forward, at –0·6 mm total change a statistically significant difference from the FR group.

Johnston (1986) suggested that the FR may act as a bite plane disrupting normal intercuspation, thus allowing free movement of the molars. His findings were that the maxillary molars were held static with mesial drift of the lower molars. He did not find, however, that dental (molar) movements are the most significant factor in correction of the Class II malocclusion and certainly the results from this study seem to agree with this. Regarding the lower molars, the results of this study agree with most researchers, suggesting that while there is slight mesial movement of the lower molar, the majority of its movement is due to the forward movement of its dental base (Hamilton *et al*., 1987; McNamara *et al*., 1990).

The figure generated for the total molar movement is the sum of the movements of the upper and lower molars with the ABCH change. With reference to the results of skeletal movement, it can be seen that the mean 3·8 mm of correction seen in the FR group is largely due to the mandible outgrowing the maxilla rather than significant dental movements (the –1·1 mm upper and 0·9 mm lower molar movements all but cancelling each other out) and within that differential, the maxillary restraint being the significant factor. The change in the control group was 0·2 mm, which is very close to what would be expected, which would be no change in molar relationships—dentoalveolar compensation appears to have kept the buccal segment relationship fairly static in the light of the mandible outgrowing the maxilla on average.

It is a wide held consensus of opinion that the FR causes proclination of the lower incisors and retroclination of the uppers (McNamara, 1985). This was again shown to be the case in this study, the upper incisors being retroclined on average 4·1 mm, the lowers proclining a mean 2·2 mm. It may also be expected that the teeth would have moved bodily in similar directions, but this was not seen to be the case (–0·9 mm U1 bodily, –0·8 mm L1 bodily), giving the total U1 movement of 3·2 mm and the lower 1·4 mm, both positive values and thus contributing to the Class II correction. Commonly, the overjets seen in patients treated with the functional appliances are greater than 6 mm and further correction in addition to this net incisor movement would be necessary by other means. In the case of this study, the maxillo-mandibular differential of 4·0 mm made up this further correction.

The figures from the control group showed on average no incisor movement aiding a Class II correction and, in fact, the movements, being negative, made the situation slightly worse (total U1 –0·8 mm, total L1 –1·1 mm), although the range was variable. It may be expected that the incisor teeth would have the same dentoalveolar compensatory effect that the Class II molars were shown to have. In fact, when the total incisor change was added to the skeletal change, the difference was seen to be 0 mm with a standard deviation of 1·1 mm and a close range of –2·4 to 2·3 mm. This result would seem to satisfy the belief that the Class II malocclusion will stay much the same in the absence of any orthodontic treatment, dentoalveolar movements maintaining the dental discrepancy even in the face of antagonistic movements.

By comparison the average total overjet difference in the treated group was 8·7 mm, which was a highly significant difference from the controls. This correction was the combination of ABCH and the total incisor movements. Because the mandible has already been seen not to come forward in the FR group more than would be expected in normal growth, it is the anterior movement of the lower incisor, which is the contribution in the lower arch to correction of the Class II malocclusion. In the upper arch, the movement of the upper incisor and restraint of the maxilla are both important factors in Class II correction, and combine to be the most significant treatment change with the FR. It seems reasonable to look at the Class II correction in terms of incisor relationship, as it is based on the incisor relationship that the British Standards Institute define a Class II division 1 malocclusion, and also that an incisor discrepancy is usually the cause of the patients' initial complaint. Creekmore and Radney (1983) reported that in their study the correction of a Class II division 1 malocclusion with a FR, 37 per cent was due to upper incisor retroclination and 26 per cent labial movement of the lower incisors. In the present study, the same percentage contribution was seen regarding the upper incisors (37 per cent), but only 17 per cent of the amount was due to lower incisor movement.

It can be seen that the major effect on the correction of the malocclusion was the incisor movement, contributing to 54 per cent of the total overjet correction, the rest being due to an orthopaedic effect of the appliance, proportions which are similar to those reported elsewhere (Bishara and Ziaja, 1989).

Conclusions

1. The Functional Regulator of Frankel (FR) from this retrospective study would appear to be an effective method of treating Class II division 1 malocclusions in growing children.
2. According to the results of this study, the major skeletal effect of the FR was the apparent restraint of the normal forward growth of the maxilla, the average forward movement was dramatically less than that seen in normal growing controls with no appliances.
3. In this study the mandible did not appear to be significantly affected by the FR, its growth in those treated being similar to the untreated controls.
4. The major effect of the FR on the dentition was the retroclination of the upper incisors and the proclination of the lower incisors which together accounted for 54 per cent of the total correction seen.
5. There did not appear to be any significant change in the position of the molars within their dental bases to aid Class II correction, rather the correction in buccal segment relationship seems to have been due to the observed skeletal changes of which maxillary restraint appeared to be the most influential.

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