

Functional appliance treatment assessed using the PAR Index

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The aims of this study were, first, to determine in children with Class II, division 1 malocclusions treated with functional appliances if, according to the Peer Assessment Rating (PAR) Index, lower incisor proclination affects the assessment of treatment outcome; and, second, to evaluate the effectiveness of such treatment before and after adjustment for any lower incisor proclination.

Fifty-one children (32M, 19F; age and gender matched; 10 to 13 years) were randomly assigned to either an untreated group, one treated with Fränkel function regulators or one treated with Harvold activators. Study casts were assessed at the start, and after 6, 12, and 18 months of treatment/observation. The inclination of the upper and lower incisors was measured on lateral cephalometric radiographs taken at the start and 18 months later. There was wide variation in treatment response. The PAR scores decreased by more than 30% in 33% of the Fränkel group and by 75% in the Harvold group. When the score was adjusted to remove the effects of lower incisor proclination on the overjet, the treatment outcomes were "worse/no different" in 66% and "improved" in 33%, in both groups. It was concluded that functional appliances be used only on selected cases.

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Introduction

When the aim of an investigation is to determine the cost and benefits, and/or the effectiveness or value of an orthodontic appliance or therapy, a randomised trial is used.^{1–3} A randomised trial is the best method we have for avoiding many of the biases that lead to the false results found in many non-randomised trials, and for identifying appliances that do more good than harm.⁴ When, however, the intention is to obtain a biological explanation of the action of an appliance, a case-series study of successfully treated cases has been the usual method of investigation. Both approaches require a valid measure of outcome.⁵

The Peer Assessment Rating Index (PAR) is the most popular method for assessing treatment success,^{5–9} although doubt has been expressed about its validity because the intra-examiner agreement in the original validating panel was poor.^{6,10} The scores and weights of the PAR Index define occlusal traits on a subject's study casts. The difference between the pre treatment and post-treatment total PAR scores indicates the degree of improvement in the alignment and the occlusion of the teeth and, hence, the treatment outcome.^{6,7}

Some traits, such as overjet, are assigned a high weight by the Index and, therefore, attract a high score.^{6,7,11} Because the Index does not take into account the type/character of the tooth movements obtained and/or their effect on stability,^{5,12} it may provide an optimistic estimate of effectiveness, particularly when the teeth are moved into positions where they are unstable. Many functional appliances reduce an increased overjet by tipping the upper incisors palatally and the lower incisors labially.^{13–20} The latter movement is of interest because proclined lower incisors are likely to be unstable.^{21–25}

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Table I. Progress of subjects through trial

	Control		Fränkel		Harvold		Total
	Boys	Girls	Boys	Girls	Boys	Girls	
Number of subjects recruited	11	6	11	6	10	7	51
Number of subjects lost from the trial:							
Moved from the area			1		1	1	3
Failed to attend	1				1		2
Failed to wear appliance			1		1	1	3
Number of subjects left in the trial at:							
6 months	10	6	10	6	10	7	49
12 months	10	6	10	6	9	6	47
18 months	10	6	9	6	7	5	43

The aims of this study were to determine in children with Class II, division 1 malocclusions treated with functional appliances, first, if lower incisor proclination affects the assessment of treatment outcome using the PAR Index and, second, to evaluate the effectiveness of functional appliances after adjusting the PAR score for any lower incisor proclination.

Subjects and methods

The subjects in this study were 51 consecutively treated children (32 boys and 19 girls) who attended the Orthodontic Clinic at Otago University, Dunedin, New Zealand, and were between 10.0 and 12.8 years of age (mean age: 11.5 years), with Class II, division 1 malocclusions.²⁶ They were age and gender matched, and randomly assigned to triads. One subject in each triad was assigned to either an untreated group, a group treated with Fränkel function regulators, or a group treated with Harvold activators (Table I). Three orthodontists with experience in functional appliance therapy were randomly assigned to treat/observe the subjects in each triad, one to each triad. Two subjects were lost from the trial between the start and 6 months, two between 6 and 12 months, and four between 12 and 18 months. Subjects were only removed from the trial if they were no longer available for supervision at the Orthodontic Clinic, or after repeated failure to attend appointments or repeated failure to wear the appliance given to them. Further details of the subjects and methods are given elsewhere.^{18,19,20} This report is based on the 43 subjects who completed the trial.

Ethical approval for the study was obtained from the Otago Hospital Board Ethics Committee, Otago Hospital Dunedin, New Zealand.

Study casts were taken at the start of treatment and at 6-, 12- and 18-month intervals of treatment/observation. The alignment and occlusion of the teeth were assessed with the PAR Index, using the weights recommended by Richmond *et al.*^{6,7} and confirmed for this sample by Webster *et al.*²⁰ The study casts were arranged in random order and scored twice by the same examiner on separate occasions approximately seven days apart. Treatment outcome was assessed on the difference between the initial and 18-month PAR scores. The percentage reduction in the scores was used to assess the degree of improvement or the effectiveness of treatment. It was classified into three categories: "worse or no different" (< 30% reduction), "improved" (≥ 30% reduction) and "greatly improved" (a reduction of at least 22 points). The score was adjusted to remove the effect of lower incisor proclination, which was calculated by adding the amount of labial movement (mm) of the lower incisors during treatment to the overjet recorded at 18 months. The percentage improvements in the adjusted PAR score were calculated also.

The reference points and planes (Figure 1 and Table II) were transferred with the aid of templates from the initial and 18-month lateral cephalometric radiographs to a single sheet of mylar film.²⁰ The reference planes were based on anatomically stable structures in the maxilla and

Table II. Reference points, planes and cephalometric measurements

Reference points

- | | |
|--------------------|---|
| 1 IZ ₁ | Inferior zygoma 1: the lowest point on average of the right and left outlines of the zygomatic processes. |
| 2 IZ ₂ | Inferior zygoma 2: the constructed point 2 cm anterior to IZ ₁ along the line parallel to the floor of the nose through IZ ₁ . |
| 3 Uie | Upper incisal edge: the incisal tip of the most prominent maxillary central incisor. |
| 4 Uia | Upper incisor apex: the root tip of the most prominent maxillary central incisor. |
| 5 Fid ₁ | Fiducial point 1: a constructed point located within the mandibular symphysis based on anatomically stable markers in the symphysis. |
| 6 Fid ₂ | Fiducial point 2: a constructed point located in the posterior body of the mandible based on anatomically stable markers in the region of the developing third molar and/or the superior surface of the mandibular canal. |
| 7 Lie | Lower incisal edge: the incisal tip of the most prominent mandibular central incisor. |
| 8 Lia | Lower incisor apex: the root tip of the most prominent mandibular central incisor. |

Reference planes

- | | |
|------------------------------------|--|
| IZ ₁ -IZ ₂ | Maxillary reference plane: the line joining IZ ₁ and IZ ₂ . |
| Fid ₁ -Fid ₂ | Mandibular reference plane: the line joining Fid ₁ and Fid ₂ . |

Cephalometric measurements

- | | |
|-----|--|
| UIA | The angle between Uie-Uia and IZ ₁ -IZ ₂ , in degrees. |
| LIA | The angle between Lie-Lia and Fid ₁ -Fid ₂ , in degrees. |
| LID | The perpendicular distance from Lie to the perpendicular bisector for Fid ₁ -Fid ₂ , in millimetres. |

mandible.²⁷⁻²⁹ The co-ordinates of each point on the tracings were digitised three times with a reflex metrograph,³⁰ and the means converted to angular and linear measurements by a microcomputer linked to the metrograph. All radiographs were retraced and redigitised approximately four weeks apart by the same examiner.

The PAR means at each stage and the PAR differences between the stages were compared with the Student's *t*-test for paired data, which was also used to compare the cephalometric measurements at the start and after 18 months of treatment/observation. The one-way ANOVA with Fischer's Protected Least Significant Difference *post hoc* test was used to compare the measurements of the control and treatment groups. The Student's *t*-test for unpaired data was used to compare the measurements of the boys and girls.

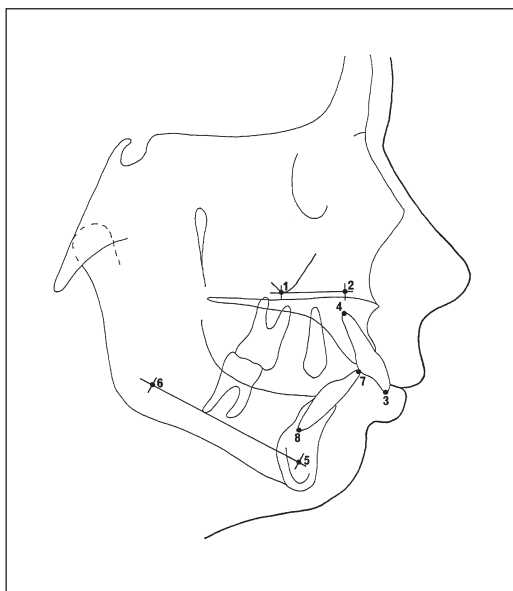


Figure 1. Reference points and planes

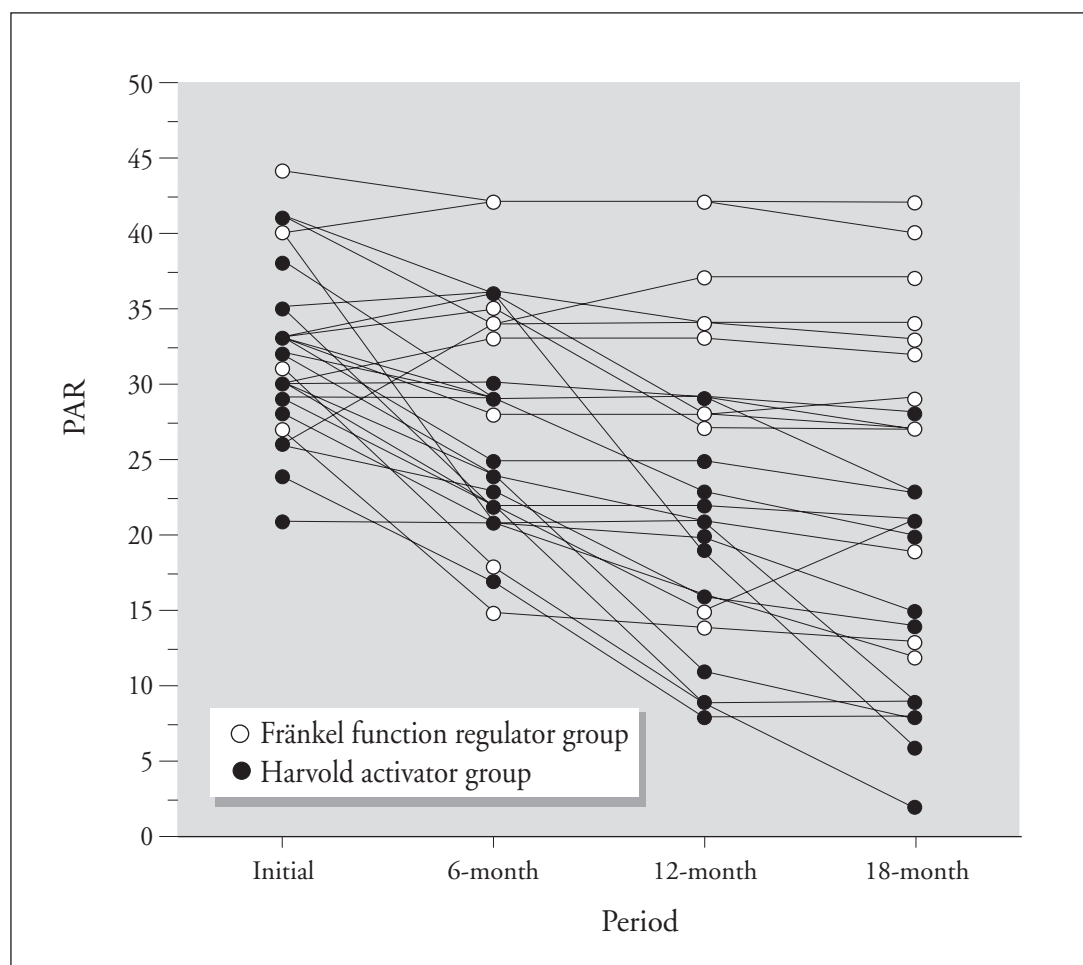


Figure 2. PAR changes in individual subjects in the treatment groups

Results

There were no statistically significant differences between the PAR scores obtained on the two occasions and the duplicate radiographic measurements. Using Dahlberg's formula,³¹ the errors in the scores were: 1.63 (initial), 1.35 (6 months), 1.54 (12 months) and 1.01 (18 months). The errors in the radiographic measurements were: UIA: 2.07° and 2.28° (initial and 18 months, respectively); LIA: 2.65° and 2.84° (initial and 18 months, respectively); and LID: 1.33 mm and 1.47 mm (initial and 18 months, respectively). The reliability of the PAR scores and the cephalometric measurements were comparable to those reported by others.^{32–35} To improve the reliability of the cephalometric measurements and the PAR scores, the means of both sets of measurements were used in the calculations.

Comparison of PAR scores

At the start of the study, there were no statistically significant differences in the PAR scores between the eight subjects who were lost from the trial and the 43 who were in the trial at 18 months ($p = 0.552$). Furthermore, there were no statistically significant differences between the boys and girls ($p = 0.807$), or between the groups when the initial scores for the boys and girls in each group were combined ($p = 0.190$).

At 6, 12, and 18 months, the PAR scores for the boys and girls were combined, and the control and treatment groups compared (Table III). Statistically significant differences were found between the mean scores of the control and Harvold activator groups, and between the Harvold activator and the Fränkel function

Table III. Comparison of the control and treatment groups, using the mean PAR score at the start, and after 6, 12 and 18 months.

PAR	Control (<i>n</i> = 16)		Fränkel (<i>n</i> = 15)		Harvold (<i>n</i> = 12)		Control vs Fränkel	Control vs Harvold	Fränkel vs Harvold
	Mean	SD	Mean	SD	Mean	SD	<i>p</i>	<i>p</i>	<i>p</i>
Initial	30.75	4.33	33.67	5.33	30.50	5.71	0.119	0.898	0.116
6-month	30.44	4.49	29.93	8.37	24.92	5.20	0.825	0.027	0.046
12-month	30.75	4.77	27.27	10.29	19.33	7.13	0.217	0.000	0.011
18-month	30.94	5.86	26.80	10.19	14.75	8.21	0.170	0.000	0.001

Table IV. Changes in the PAR scores in the control and treatment groups.

PAR	Control (<i>n</i> = 16)		Fränkel (<i>n</i> = 15)		Harvold (<i>n</i> = 12)	
	Mean difference	<i>p</i>	Mean difference	<i>p</i>	Mean difference	<i>p</i>
Initial minus 6 months	0.31	0.641	3.73	0.067	5.58	0.006
6 months minus 12 months	-0.31	0.370	2.67	0.016	5.58	0.010
12 months minus 18 months	-0.19	0.714	0.47	0.418	4.58	0.003

Significant values are in bold type.

Table V. Comparison of the control and treatment groups using the mean incisor inclinations at the start of the study and at 18 months.

Variable	Control (<i>n</i> = 16)		Fränkel (<i>n</i> = 15)		Harvold (<i>n</i> = 12)		Control vs Fränkel	Control vs Harvold	Fränkel vs Harvold
	Mean	SD	Mean	SD	Mean	SD	<i>p</i>	<i>p</i>	<i>p</i>
LIA Initial (°)	94.63	7.66	96.48	6.41	97.64	5.12	0.440	0.239	0.652
18-month (°)	94.87	8.19	96.78	5.27	102.18	6.58	0.443	0.008	0.048
UIA Initial (°)	114.08	4.75	112.11	6.08	115.51	7.07	0.363	0.531	0.148
18-month (°)	115.22	5.90	108.30	5.22	109.01	6.18	0.002	0.007	0.751

Significant values are in bold type.

regulator groups. There were no significant differences between the control and the Fränkel function regulator groups.

There were significant reductions between 6 and 12 months in the PAR scores of the children in the Fränkel group, and between the start of treatment and 6 months, between 6 and 12 months, and between 12 and 18 months in the Harvold activator group (Table IV).

The largest mean reductions in scores occurred during the first 6 months of treatment in the Fränkel function regulator group, and during the first year of treatment in the Harvold activator group.

The changes in the PAR score in individual subjects in the treatment groups are shown in Figure 2.

Inclination of the incisors

There were no significant differences in the inclinations of the lower incisors in the control and the Fränkel function regulator groups (Table V). At 18 months, the lower incisors were more proclined in the Harvold activator group than in the control group (LIA mean difference: 7.31°; $p < 0.008$). After 18 months of treatment/observation, the upper incisors were more retroclined in both the Fränkel function regulator group (UIA mean difference: 6.92°; $p < 0.002$) and the Harvold

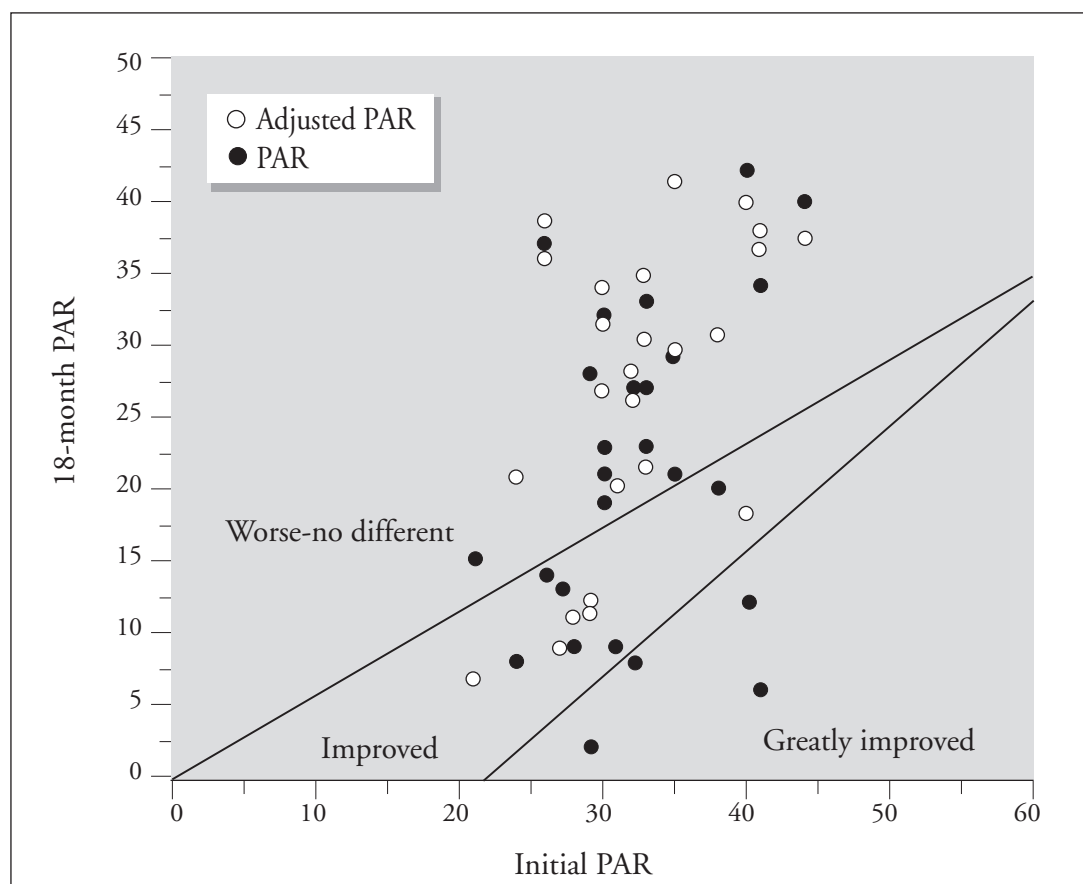


Figure 3. PAR and adjusted PAR compared. Initial PAR plotted against the 18-month PAR on the nomogram (Richmond *et al.*, 1992b).

activator group (UIA mean difference: 6.21° $p < 0.007$) than in the control group. From the start of treatment to 18 months, the lower incisors proclined approximately 0.30° in the Fränkel function regulator group, and 4.53° in the Harvold activator group (Table VI). During the same period, the upper incisors retroclined between 3.81° in the Fränkel regulator group and 6.49° in the Harvold activator group. The mean labial movement at the incisal edges of the lower incisors from the start of treatment to 18 months was 0.22 mm in the Fränkel function regulator group and 1.43 mm in the Harvold activator group (Table VI).

Treatment outcome

The amount of labial movement (mm) of the lower incisors during treatment was added to the overjet recorded at 18 months, and the 18-month PAR score recalculated. The percentage improvements in the score and the adjusted score are given

in Table VII. The treatment outcome was "improved/greatly improved" in 33 per cent of the Fränkel subjects; in the Harvold activator group, however, "improved/greatly improved" outcomes dropped from 75 per cent to 33 per cent. The initial and 18-month unadjusted PAR scores are plotted in Figure 3.

Discussion

The increasing interest shown by the orthodontic specialty in quality control and accountability has led to the development of indices to assess the outcome of treatment.^{5,12,36} The PAR Index, developed by Richmond and co-workers,⁶ is the most widely used of these indices.^{8,9,20,37,38} The Index assesses the alignment and occlusion of the teeth on the initial and end-of-treatment study casts, the difference between the two PAR scores reflecting the success or otherwise of treatment. In a random trial such as the present study, when a range of malocclusions is treated and all subjects

Table VI. Incisor changes in the control and treatment groups.

Variable*	Control (n = 16)		Fränkel (n = 15)		Harvold (n = 12)	
	Mean difference	p	Mean difference	p	Mean difference	p
LIA (°)	-0.24	0.729	-0.30	0.751	-4.53	0.007
UIA (°)	-1.15	0.082	3.81	0.007	6.49	0.004
LID (mm)	-0.32	0.319	0.22	0.526	1.43	0.040

*Initial minus 18 months

Significant values are in bold type

Table VII. Percent improvement in the PAR score (P) and adjusted PAR score (A) in the control and treatment groups after 18 months of treatment.

Treatment outcome	Control (P) (n = 16)	Fränkel (P) (n = 15)	Harvold (P) (n = 12)	Frankel (A) (n = 15)	Harvold (A) (n = 12)
No change (< 30%)	16 (100.0%)	10 (66.7%)	3 (25.0%)	10 (66.7%)	8 (66.7%)
Improved (≥30%)	0 (0.0%)	3 (20.0%)	6 (50.0%)	4 (26.6%)	4 (33.3%)
Greatly improved (>–22 points)	0 (0.0%)	2 (13.3%)	3 (25.0%)	1 (6.7%)	0 (0.0%)

who complete the trial are assessed according to the Index, we learn how effective functional appliances are in the treatment of Class II division 1 malocclusions.

In the present study, approximately 50 per cent of the subjects treated with the two appliances “improved” when assessed by the PAR Index. There was, however, a difference in treatment outcome according to the appliance used: 75 per cent of the subjects in the Harvold activator group “improved”, compared with 33 per cent of the subjects in the Fränkel function regulator group. Tulloch *et al.*,³⁸ using the Par Index reported that functional appliance treatment produced, on average, a “modest” improvement in the occlusion and a wide variation in response. However, a shortcoming of the PAR Index is that it does not take into account the nature of the tooth movements obtained, and/or their effect on post-treatment stability.^{5,12} Treatment procedures that reduce an increased overjet by a combination of upper incisor retroclination and lower incisor proclination may place the lower incisors in positions where they are unstable^{21–25} and, consequently, require long-term retention to maintain both the labio-lingual position and the alignment of the incisors. This conclusion is reinforced by the findings of a recent study by McKnight *et al.*,³⁹ who reported a 50 per cent reduction in the PAR score after

functional appliance treatment, but an increase nine years post-treatment. They attributed the latter to relapse of the lower incisors, leading to an increase in overjet.

Many functional appliances, including those used in the present trial, reduce an increased overjet by tipping the upper incisors palatally and the lower incisors labially.^{13–17} The question that interested us was the extent to which lower incisor proclination affected assessments of the outcome of functional appliance treatment when the PAR Index was used. We postulated that proclination of the lower incisors could contribute to overjet reduction in some subjects. Because overjet is assigned a high weight (6 points per mm) by the Index, changes in the lower incisors could have an important impact on assessments based on it. Regression analysis in this study confirmed that a 5 degree proclination of the lower incisors was associated with a 2 mm reduction in overjet and, consequently, a reduction in the PAR score of 12 points. Therefore, several millimetres of lower incisor proclination will make a substantial and, apparently, favourable contribution to treatment outcome assessed with this Index.

The Harvold appliances proclined the lower incisors, on average, 4.53° but the range was considerable: from 0.5° to 13.8°. If one accepts the view that the pre treatment position of the

lower incisors gives us the best datum from which to plan treatment, the effectiveness of the Harvold appliance in treating Class I, division 1 malocclusions must be questioned. Lower incisor proclination was, in fact, a conspicuous feature in the subjects "successfully" treated with this appliance: in six out of the nine subjects who "improved", the lower incisors were proclined by more than five degrees. The Fränkel appliances, on the other hand, produced no lower incisor proclination and little improvement in the PAR score. When the overjet measurements were adjusted by removing the amount due to lower incisor proclination (maximum: 5.3 mm), the "improved/greatly improved" outcomes were reduced to one-third of the cases treated with each appliance (Figure 3). In the large randomised control trial of a functional appliance referred to earlier,³⁸ the treatment outcomes using PAR assessment of the subjects in the functional appliance group were markedly poorer than those of subjects treated with a single phase of conventional fixed appliance treatment, leading the researchers to conclude that functional appliances are ineffective and should be reserved for selected cases only.¹⁹

Conclusion

The PAR Index showed that improvements were made by treatment with functional appliances in 50 per cent of the cases in this study; however, cephalometric analysis, which is not part of the PAR assessment, showed that in a proportion of cases the overjet reduction was achieved by lower incisor proclination, which is considered by some authorities to be unstable. Where a treatment modality may induce unstable tooth movements, this must be acknowledged in the treatment. Furthermore, the interpretation of indices assessing the outcome of such treatment should be made with caution.

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