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A Cephalometric Study of the Class II Correction Effects of the Eureka Spring

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ABSTRACT

The effect of the Eureka Spring (ES) appliance was investigated on 37 consecutively treated, noncompliant patients with bilateral Class II malocclusions. Lateral cephalographs were taken at the start of orthodontic treatment (T1), at insertion of the ES (T2), and at removal of the ES (T3). The average treatment interval between T2 and T3 was four months. The Class II correction occurred almost entirely by dentoalveolar movement and was almost equally distributed between the maxillary and mandibular dentitions. The rate of molar correction was 0.7 mm/mo. There was no change in anterior face height, mandibular plane angle, palatal plane angle, or gonial angle with treatment. There was a 2° change in the occlusal plane resulting from intrusion of the maxillary molar and the mandibular incisor. Based on the results in this sample, the ES appliance was very effective in correcting Class II malocclusions in noncompliant patients without increasing the vertical dimension.

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KEY WORDS: Class II, Noncompliant interarch force, Intrusion.

INTRODUCTION Return to TOC

Correction of Class II malocclusions has been accomplished by headgear, elastics, and various removable functional appliances.[1,2 (pp249–254),3–7] All of these methods require good patient cooperation for success. However, because of a trend toward reduced patient compliance, these methods often fail to correct the Class II malocclusion in a timely fashion.[8–10] Consequently, there is great interest in techniques that minimize the need for patient cooperation. Interarch springs,[11] Herbst (Dentaurum Inc, Newton, Pa),[12–16] Jasper Jumpers (American Orthodontic, Sheboygan, Wis),[17–22] Edgewise Bioprogressive Herbst (Terry Dischinger, DDS, Lake Oswego, Ore),[23,24] and the Adjustable Bite Corrector (Orthoplus Inc, Santa Rosa, Calif)[25] have been developed in response to this noncompliance phenomenon. The latest addition is the Eureka Spring (ES) (Eureka Spring Co, San Luis Obispo, Calif), which is reported to have significant advantages over all of the aforementioned appliances.[26] Before the ES can be used with confidence, it is important that its treatment effects are assessed. The purpose of this report is to evaluate cephalometrically the skeletal and dental treatment effects of the ES in a group of noncompliant patients.

MATERIALS AND METHODS Return to TOC

The initial data pool consisted of 50 noncompliant, consecutively treated patients with Class II malocclusions. Six patients were eliminated because of difficulties in cephalometric landmark identification, and seven were excluded because of insufficient initial Class II molar relationships. Thus, 37 patients (14 male patients and 23 female patients) were selected for cephalometric analysis. All patients had bilateral Class II malocclusions of at least three mm measured from the mesial buccal cusp of the maxillary first molar. All were treated by a single clinician with a pretorqued (Roth prescription) 0.018 × 0.025–inch edgewise appliance, using only 0.016 × 0.022–inch archwires with 10° to 15° of added labial root torque to the mandibular anterior teeth. All patients had either a transpalatal arch on the maxillary molars or 15° of buccal root torque placed in the maxillary molars. The initial mean pretreatment age was 13 years nine months, while the age at insertion of the ES was 16 years zero months. The noncompliance of this patient pool is evident from this long time interval. The sample included growing and nongrowing patients. The ES treatment was terminated when an acceptance Class I molar and cuspid relationship had been obtained and the overjet had been reduced accordingly.

Cephalographs were obtained on all patients at the start of orthodontic treatment (T1), at insertion of the ES (T2), and at removal of the ES (T3). All cephalographs were obtained from a single machine with an anode-to-midsubject distance of 152.4 cm (five feet) and a midsubject-to-film distance of 14.5 cm. No adjustments were made for the 9.5% enlargement factor.

Figure 1 shows the components of the ES.[27]

Evaluation

To avoid investigation bias, we used a blinded protocol that has previously been described.[28,29] Landmarks for superimposition included the sella, pterygoid maxillary fissure, porion, orbitale, nasion, and basion. From these landmarks, the following planes were constructed: (1) nasion-basion, (2) Frankfort horizontal, and (3) pterygoid vertical. These planes provided the growth constant grid that was used as the reference for the superimpositions for each patient.

The Ricketts template (Dome, Tarzana, Calif) was used to trace all teeth. A permanent horizontal mark was placed in the template, on the distal-most contour of the molar outline. This mark allowed the distal-most contour of the molar to be consistently located in both horizontal and vertical position. When there was a double image of the teeth on the radiograph, the most distal molar was traced. Double occlusal plane images due to a cant were traced by tracing equidistance between the two images. To minimize systematic error, all tracings of a particular patient were completed in one sitting.[30] All tracings were checked for accuracy of landmark location by a second investigator with 15 years of cephalometric experience. Once completed the radiographic landmarks and points were digitized on Quick Ceph Image Pro (Orthodontic Processing, Coronado, Calif) according to the instruction manual for computer analysis.[31]

Linear and angular measurements from the lateral cephalographs were those patterned after Pancherz[14] and later used by Wieslander[32,33] and Chang.[23] The cranial base was represented by the sella-nasion distance. Measurements were computed using a vertical line from sella, constructed perpendicular to the occlusal plane.[14] Dental and skeletal changes in the maxilla and mandible were measured in reference to this perpendicular line. The measurements that were taken from the sella occlusal plane vertical in this study are shown in Figure 2 and have been described previously.[14,33] Additionally, a separate group of measurements were made using pterygoid vertical as a reference line (Figure 3) because of decreased distortion that would occur (Figure 4).[23]

Additional linear measurements included the maxillary and mandibular incisors to the APo line and the vertical distance of the incisors and molars to Frankfort horizontal. Additional angular measurements included measurement of the mandibular, palatal, and occlusal planes from Frankfort horizontal.

In an effort to more clearly evaluate the effects of ES treatment, the sample was divided into extreme subgroups. The subgroups were months in treatment (time between T2 and T3), anterior face height at T2, mandibular plane angle at T2 (defined as SN-GoGn), and incisor movement based on the original mandibular plane angle.

In this study, pterygoid vertical reference line was used to calculate changes between skeletal and dental measurements.

Statistics

Statistical analysis included calculations of means and SDs for each variable. Analysis of variance tests for repeated measures were performed to detect any significant changes between T1, T2, and T3 measurements. The sample was divided into subgroups, and paired *t*-tests were conducted to determine if there were significant changes between T2 and T3 within each subgroup. Independent *t*-tests were conducted to determine significant differences in the amount of change between the subgroups from T2 to T3. Five patients were randomly selected to determine measurements of error. These lateral radiographs were redigitized on Quick Ceph Image Pro. Paired *t*-tests were conducted to determine significant differences between the original and retraced lateral radiographs. Measurements did not vary more than 0.5% from the original measurement ($P < .05$).

RESULTS Return to TOC

A Class I molar and cuspid relationship with normal overjet and overbite was achieved in all 37 patients after treatment with the ES. The mean treatment time for ES therapy was 4.0 ± 1.3 months compared with 27 ± 8.2 months from the initiation of orthodontic treatment to insertion of the ES. The range of the treatment time during ES therapy was two to 14 months.

The angular and linear measurements and levels of significance at T1, T2, and T3 are presented in Tables 1 and 2.

With ES treatment (T2–T3), no significant difference occurred in the following measurements: length of the mandible (condylion-gnathion), length of the condyle (condylion-cranial base), Xi point to pogonion, Xi point to hinge axis, vertical condylar position, nasion-menton distance, gonial angle, mandibular plane angle, and palatal plane angle. Basically, ES treatment resulted in dentoalveolar changes of approximately equal magnitude in both arches with no change in the vertical skeletal dimensions. Intrusion of the maxillary molars of one mm along with two mm of lower incisor intrusion, as recorded from Frankfort horizontally, were observed (Table 2). The maxillary incisors retroclined 3° when measured from the palatal plane, whereas the mandibular incisors proclined an equal amount, based on the mandibular plane. Likewise, the maxillary incisor was retracted one mm, whereas the mandibular counterpart was protracted the same amount when measured at the APo plane. Similar amounts of movement were observed in the maxillary and mandibular molars.

The effects of the ES treatment can be analyzed further from the information obtained from the subgroup evaluations (Table 3).

In comparing changes in the maxillary and mandibular incisors relative to the APo plane with the duration of ES therapy, the subgroup that received ES for less than 2.5 months (n = 13) had incisor changes that were half of those obtained with a treatment duration of greater than four months (n = 15). Using either overjet or mandibular plane angle at T2 for subgroup selections and analyzing changes in the incisors relative to the APo plane, no differences were observed.

Likewise, when comparing treatment effects on vertical height changes, no differences were observed between subgroups. Using the nasion-menton distance at T2 as the basis for forming the subgroup, neither the “short face” subgroup (116.4 mm, n = 14) nor the “long face” subgroup (130.4 mm, n = 15) experienced any change with treatment.

When forming the subgroups on the basis of the T2 mandibular plane angle (SN-GoMe), no change occurred in the short face subgroup (26.5°, n = 14) and the long face subgroup (38.6°, n = 14). Although incisor movement was significant within the high- and low-angle subgroups (Table 3), there was no significant difference in incisal movement between these two subgroups (not shown).

An overall analysis of the relative maxillary and mandibular skeletal and dental contribution to the correction of the overjet and molar relationship is shown in Figures 5 and 6. Of the 2.1 mm overjet correction, 0.2 mm (10%) was contributed by skeletal changes, and 1.9 mm (90%) occurred by dental compensation (Figure 5). Likewise, similar proportions of skeletal and dental changes in molar relations also were observed (Figure 6).

DISCUSSION Return to TOC

Many studies have used the sella-occlusal plane vertical as a reference line.[12–14,23,32–34] If the occlusal plane constructed from the cephalogram changed significantly in the treatment group or during the treatment interval, dramatic effects on the maxillary and mandibular bases and on sagittal changes would be observed (Figure 4). For example, if the occlusal plane changed 2°, the actual value observed in this study, there would be a 3-mm change in the distance to the maxillary and mandibular incisors. This effect is depicted in Figure 4. This could explain the disagreement between measurements utilizing the occlusal plane compared with the pterygoid vertical reported by Chang[23] and also observed in our data.

The occlusal plane vertical is a reference plane generated by dental structures, and it should not be used to measure skeletal changes. For these reasons, the pterygoid vertical reference line was used in this study to calculate dental and skeletal changes. However, in the future, the cephalometric analysis used by DeVincenzo et al[4] should be considered because it does not rely on the landmark identification weaknesses of constructing Frankfort horizontal and identifying condylion and pterygoid fissure. Six patients were eliminated from this study because of difficulty in locating these structures.

The correction of Class II discrepancies with interarch elastics has an adverse impact on some facial forms by extruding maxillary anterior and mandibular posterior teeth. The resultant downward and backward rotation of the mandible and thus increased anterior face height[2(p264),35,36] contrasts with the treatment results of the ES. Even when the sample was divided into long face and short face subgroups, there still was no statistically significant increase in anterior face height between T2 and T3. That there was neither an increase in the mandibular plane angle nor in anterior face height is notable and may be attributed to the intrusive forces generated by this appliance. Similar results have been reported with the Herbst appliance[37] but differ from findings of other functional appliances[38–40] and Class II elastics.[2,35,36,41–44]

A modified twin block showed 70% skeletal and 30% dental movement in the mandible after nine months of treatment.[4] Previous studies using the Herbst appliance[14,32,33,45] have reported approximately 60% skeletal and 40% dental changes in seven to nine months. Jasper Jumper treatment have resulted in 40% skeletal and 60% dental effects after six months of treatment.[34] In contrast, the ES produced a correction that was 90% dental and 10% skeletal during a treatment time of four months. (A smaller percentage change due to skeletal influences would be expected because of the shorter treatment interval and the inclusion of nongrowing patients.) Although the skeletal response was small, in the long run, skeletal changes in the mandible resulting from functional appliance treatment during the growth period may not be lasting.[29,33,46]

Despite precautions taken to provide anchorage to the mandibular anterior teeth, the mandibular incisors proclined. This movement is similar in both magnitude and direction to that reported for functional appliances.[12,14,34,38–41,47]

The force vector of the ES is backward-upward on the maxillary arch and downward-forward on the mandibular arch. One of the effects of this force is a tipping of the occlusal plane, the extent of which is comparable to that reported when using the Herbst appliance[14,32,33] and Jasper Jumper.[34] The 10°–15° of labial root torque may have retarded mandibular incisor proclination.

The palatal plane remained stable with ES treatment. This has been reported previously for the Herbst appliance and Jasper Jumper regimes. Other functional appliances, Class II elastics, and cervical traction headgear all tip the maxilla downward and backward.[38,42,47–49]

Molar movement was greater in the mandible (60%) than in the maxilla (40%), whereas with overjet correction, the opposite was noted. A similar effect has been noted with the Jasper Jumper.[34]

During ES treatment, the mandibular molars moved mesially further than the incisors, thereby reducing the mandibular arch length. This has been previously reported with the Wilson appliance during molar distalization.[50]

This study focused on the short-term effects of the ES on the correction of Class II malocclusion. The results are encouraging as it is seldom that complete Class II correction can be obtained in every consecutively treated noncompliant patient. An increased sample size would have improved this study, particularly since the subgroup sample sizes were small.

CONCLUSION Return to TOC

The ES corrected the remainder of the original Class II malocclusion in all 37 consecutively treated, noncompliant patients in a mean treatment interval of four months. This correction was 90% dentoalveolar and almost equally distributed between the maxillary and mandibular dentitions. The rate of molar correction was 0.7 mm/mo.

The ES treatment resulted in no change in the vertical dimension, as evidenced by neither increased anterior face height nor increased mandibular plane angle. This finding suggests that the ES has clear advantages over Class II elastics and cervical extraoral anchorage in dolichocephalic facial forms.

There was a pronounced change in the cephalometric occlusal plane as a result of one mm of maxillary molar and two mm of mandibular incisor intrusion.

If 3 mm of anteroposterior change were needed for the correction of a Class II malocclusion, extrapolation from the data and using the methods described herein, it could be assumed that the lower incisor to APo would move anteriorly 1 mm, whereas the maxillary incisor would recline an equal amount. Additionally, angular changes of about 3° in the maxillary and mandibular incisors should be anticipated.

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TABLES Return to TOC

TABLE 1. Angular and Linear Cephalometric Measurements at the Start of Orthodontic Treatment (T1) and Insertion of the Eureka Spring (T2) (N = 37)[a]

Variable	T1 Mean	T1 SD	T2 Mean	T2 SD	Mean Change	*P* Value
1. Mandibular length, mm	120.1	7.7	122.5	16.3	2.4	NS
2. Condylar length, mm	13.1	2.6	13.6	2.8	0.5	<.01
3. Nasion-menton, mm	118.0	7.2	123.2	8.1	5.2	<.01
4. ANB, degrees	4.3	1.9	2.8	2.3	−1.4	<.01
5. Gonial angle, degrees	121.6	7.4	118.1	19.4	−3.4	NS
6. Palatal plane–sella, degrees	6.9	3.3	7.3	3.5	0.4	NS
7. Mx 1–palatal plane, degrees	109.5	7.1	115.1	7.0	5.6	<.01
8. SN–mandibular plane, degrees	32.3	6.5	32.8	6.7	0.5	NS
9. Md 1–mandibular plane, degrees	95.2	6.3	94.6	7.5	−0.6	NS
10. PTV–maxillary base, mm	54.9	3.2	54.3	3.7	−0.5	<.05
11. PTV–mandibular base, mm	48.4	5.6	49.0	6.3	0.5	NS
12. PTV–sagittal improvement, mm[b]	6.5	3.4	5.4	4.2	−1.2	<.01
13. PTV–maxillary incisor, mm	59.0	4.3	58.7	4.8	−0.3	NS
14. PTV–mandibular incisor, mm	54.0	4.6	54.5	4.7	0.5	NS
15. PTV–maxillary molar, mm	17.3	3.6	20.2	3.7	2.8	<.01
16. PTV–mandibular molar, mm	16.3	3.9	20.3	4.5	4.0	<.01
17. PTV-porion, mm	−42.0	2.8	−42.4	2.8	−0.4	<.05
18. Xi-pogonion, mm	74.1	5.5	77.2	5.4	3.2	<.01
19. Xi–hinge axis, mm	38.7	3.2	40.9	3.1	2.2	<.01
20. Condyle horizontal position, mm	−28.6	2.6	−28.8	2.9	−0.2	NS
21. Condyle vertical position, mm	−6.8	1.8	−6.5	1.7	0.3	NS
22. Maxillary incisor–APo, mm	6.3	1.2	5.6	1.8	0.6	NS
23. Mandibular incisor–APo, mm	0.9	2.0	1.3	1.9	0.4	NS
24. Maxillary incisor–Frankfort, mm	−51.7	4.9	−53.4	4.7	−1.7	<.01
25. Mandibular incisor–Frankfort, mm	−47.3	4.3	−50.4	4.5	−3.1	<.01
26. Maxillary molar–Frankfort, mm	−41.3	3.9	−44.4	4.0	−3.2	<.01
27. Mandibular molar–Frankfort, mm	−47.5	3.7	−50.9	3.9	−3.4	<.01
28. Mandibular plane–Frankfort, mm	23.0	5.6	22.1	9.6	−0.9	NS
29. Palatal plane–Frankfort, degrees	−2.4	3.2	−2.0	3.3	0.4	NS
30. Occlusal plane–Frankfort, degrees	8.4	3.9	7.5	4.2	0.9	NS

[a] The time interval was 27 ± 8.2 months. NS indicates not significant ($P \geq .05$).

[b] Indicates difference between PTV–maxillary base and PTV–mandibular base.

TABLE 2. Angular and Linear Cephalometric Measurements at Insertion of Eureka Spring (T2) and Removal of Eureka Spring (T3) (N = 37)[a]

Variable	T2		T3		Mean Change	*P* Value
	Mean	SD	Mean	SD		
1. Mandibular length, mm	122.5	16.3	125.4	8.5	2.9	NS
2. Condylar length, mm	13.6	2.8	13.8	2.7	0.2	NS
3. Nasion-menton, mm	123.2	8.1	123.5	8.4	0.4	NS
4. ANB, degrees	2.8	2.3	2.5	2.4	−0.3	NS
5. Gonial angle, degrees	118.1	19.4	120.5	7.5	2.4	NS
6. Palatal plane–sella, degrees	7.3	3.5	7.5	3.6	0.2	NS
7. Mx 1–palatal plane, degrees	115.1	7.0	112.2	6.6	−2.9	<.05
8. SN–mandibular plane, degrees	32.8	6.7	32.8	6.9	0.0	NS
9. Md 1–mandibular plane, degrees	94.6	7.5	98.0	6.9	3.4	<.01
10. PTV–maxillary base, mm	54.3	3.7	54.0	3.7	−0.3	NS
11. PTV–mandibular base, mm	49.0	6.3	48.9	6.4	−0.1	NS
12. PTV–sagittal improvement, mm[b]	5.4	4.2	5.1	4.3	−0.2	NS
13. PTV–maxillary incisor, mm	58.7	4.8	57.2	5.0	−1.5	<.01
14. PTV–mandibular incisor, mm	54.5	4.7	55.2	4.7	0.7	NS
15. PTV–maxillary molar, mm	20.2	3.7	19.0	3.6	−1.2	<.01
16. PTV–mandibular molar, mm	20.3	4.5	21.8	4.2	1.5	<.01
17. PTV-porion, mm	−42.4	2.8	−42.4	2.8	0.1	NS
18. Xi-pogonion, mm	77.2	5.4	77.8	5.7	0.5	NS
19. Xi–hinge axis, mm	40.9	3.1	40.6	3.0	−0.2	NS
20. Condyle horizontal position, mm	−28.8	2.9	−29.2	2.8	−0.3	NS
21. Condyle vertical position, mm	−6.5	1.7	−6.6	2.0	−0.1	NS
22. Maxillary incisor–APO, mm	5.6	1.8	4.3	1.6	−1.3	<.01
23. Mandibular incisor–APO, mm	1.3	1.9	2.3	1.6	1.0	<.01
24. Maxillary incisor–Frankfort, mm	−53.4	4.7	−54.0	4.8	−0.7	NS
25. Mandibular incisor–Frankfort, mm	−50.4	4.5	−52.6	4.8	−2.1	<.01
26. Maxillary molar–Frankfort, mm	−44.4	4.0	−43.6	4.0	0.9	<.05
27. Mandibular molar–Frankfort, mm	−50.9	3.9	−50.9	3.8	0.0	NS
28. Mandibular plane–Frankfort, mm	22.1	9.6	23.5	5.8	1.3	NS
29. Palatal plane–Frankfort, degrees	−2.0	3.3	−1.8	3.6	−0.2	NS
30. Occlusal plane–Frankfort, degrees	7.5	4.2	9.8	4.3	2.3	<.01

[a] The time interval was 4.0 ± 1.3 months. NS indicates not significant ($P \geq .05$).
[b] Indicates difference between PTV–maxillary base and PTV–mandibular base.

TABLE 3. Subgroup Evaluations based on Duration of Treatment Between T2 and T3, AFH at T2, and MPA at T2[a]

Subgroup	No. of Patients	Variable	T2		T3		Difference		*P* Value
			Mean	SD	Mean	SD	Mean	SD	
Duration between T2 and T3									
<10 wk	13	⊥ to APo, mm	5.3	1.4	4.5	1.7	−0.8	1.4	<.05
>16 wk	15		5.6	2.4	4.0	1.7	−1.6	1.2	<.01
<10 wk	13	⟦ to APo, mm	1.8	1.6	2.4	1.6	0.6	1.4	<.01
>16 wk	15		0.8	2.4	2.0	1.9	1.2	1.3	<.01
AFH at T2									
≤115.5 mm	14	Nasion-menton, mm	116.4	5.4	116.4	5.6	0.0	1.2	NS
≥119.5 mm	15		130.4	5.8	131.0	6.1	0.6	1.0	NS
MPA at T2									
≤31°	14	SN-MP, degrees	26.5	4.7	26.5	5.0	0.0	1.0	NS
≥34°	14		38.6	3.8	38.7	4.1	0.1	1.4	NS
Incisor movement based on MPA[b]									
Low angle	14	⊥ to APo, mm	5.5	1.8	4.1	1.6	−1.4	1.2	<.01
High angle	15		6.1	1.8	4.8	1.8	−1.3	1.3	<.01
Low angle	14	⟦ to APo, mm	0.9	2.0	1.9	1.5	1.0	1.2	<.01
High angle	15		2.2	1.6	2.9	1.7	0.7	0.9	<.01

[a] AFH indicates anterior face height; MPA, mandibular plane angle; and NS, not significant.
[b] MPA was classified as low angle (mean, 26.5°) or high angle (mean, 38.6°).

FIGURES Return to TOC

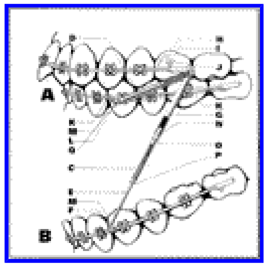

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FIGURE 1. The components of the Eureka Spring as shown diagrammatically in the mouth (magnification ×2). A indicates mouth fully closed in a complete Class II relationship; B, Eureka Spring in extended position when the mouth is open 50 mm; C, plunger assembly extended; D, plunger assembly compressed to within 1.5 mm of full compression; E, spring-driven ram portion of plunger assembly; F, ring clamp attachment of plunger; G, molar assembly; H, molar attaching wire; I, ligature wire for stabilizing molar attachment wire; J, ball joint of cylinder assembly; K, tie-down ligature wire; L, ram elbow; M, neck of ram; N, remaining distance plunger assembly can travel before disengagement; O, plunger assembly cylinder; P, constricted collar of plunger cylinder; and Q, free space.

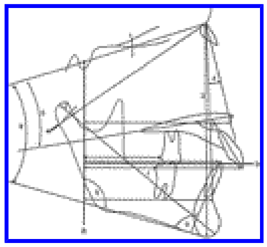

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FIGURE 2. Measurements on lateral cephalograph with sella occlusal plane vertical line (a) and occlusal plane (b). Note that the horizontal measures from vertical line (a) were not used because of changes in the occlusal plane during treatment.

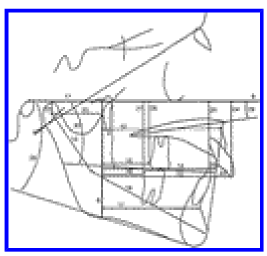

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FIGURE 3. Measurements on lateral cephalograph with pterygoid vertical (a) and Frankfort horizontal (b) as the reference lines

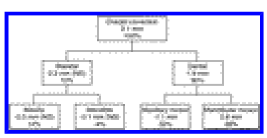

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FIGURE 4. Analysis of relative contribution of maxillary and mandibular skeletal and dental changes in overjet correction with Eureka Spring treatment. (Based on the pterygoid vertical–Frankfort horizontal reference line shown in Figure 3)

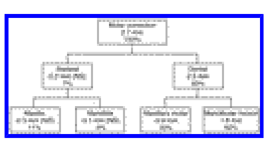

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FIGURE 5. Analysis of relative contribution of maxillary and mandibular skeletal and dental changes in molar correction with Eureka Spring treatment. (Based on the pterygoid vertical–Frankfort horizontal reference line shown in Figure 3)

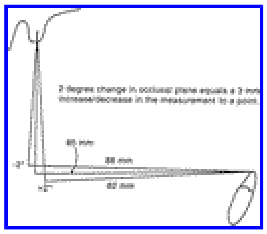

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FIGURE 6. The effect of a 2° change in the occlusal plane on the sella occlusal plane reference line

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