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Long-term evaluation of soft tissue profile changes induced by Herbst appliance followed by fixed appliances

Avaliação a longo prazo das alterações no perfil facial tegumentar induzidas pelo aparelho de Herbst seguido de aparatologia fixa

Evaluación a largo plazo de cambios en tejidos blandos inducidos por el aparato de Herbst seguido de aparatología fija

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Paulo Guilherme Bittencourt Marchi
ORCID: https://orcid.org/0000-0002-5726-4803
Universidade Estadual Paulista, Brazil
E-mail: paulomarchi06@hotmail.com
Juan Francisco Mariscal Muñoz
ORCID: https://orcid.org/0000-0003-0494-9988
Universidade Estadual Paulista, Brazil
E-mail: jfrmm@hotmail.com
Felipe Gustavo de Bastiani
ORCID: https://orcid.org/0000-0002-6733-123X
Universidade Estadual do Oeste do Paraná, Brazil
E-mail: felipe_debastiani@hotmail.com
Luís Antônio de Arruda Aidar
ORCID: https://orcid.org/0000-0001-5930-7777
Universidade Santa Cecília, Brazil
E-mail: luisaidar@uol.com.br
Luiz Carlos Marchi
ORCID: https://orcid.org/0000-0002-0676-5587
Universidade Estadual do Oeste do Paraná, Brazil
luizcmarchi@yahoo.com.br
Gladys Cristina Dominguez
ORCID: https://orcid.org/0000-0002-8221-4912
Universidade de São Paulo, Brazil
E-mail: cdomingu@uol.com.br
Dirceu Barnabé Raveli
ORCID: https://orcid.org/0000-0002-0409-3481
Universidade Estadual Paulista, Brazil
E-mail: draveli@foar.unesp.br

Abstract
The present investigation aimed to evaluate, by cephalometric analysis, the soft tissue profile changes in adolescents with Class II Division 1 malocclusion, treated with Herbst appliance (Stage I) and fixed appliances (Stage II), followed-up for an average of 4 years (Stage III). The adolescents were divided into two groups: treated group (TG) - 33 adolescents with Class II malocclusions (17 boys and 16 girls) consecutively treated with Herbst appliance and fixed appliances; control group (CG) - 28 adolescents (13 boys and 15 girls) with untreated Class II malocclusions. Lateral cephalograms were obtained immediately before (T1) and after (T2) Herbst treatment, after fixed appliances (T3), and on average, 4 years after orthodontic treatment. Intergroup comparison was evaluated by *t* or Mann-Whitney tests. The TG was evaluated by analysis of variance followed by Tukey test or Friedman test followed by Dunn's test. Compared to the CG, the TG showed significant favorable changes at Stage I: decrease in facial convexity, upper lip retrusion, lower lip protrusion, improvement of soft tissue pogonion and increase in mentolabial angle. The total posttreatment period (T2-T4) of the TG showed: increase in H line-Prn, and upper and lower lips retrusion, while the others variables remained stable. This study suggests that Herbst therapy improved features of soft tissue facial profile, which were maintained after fixed appliances and for an average of 4 years posttreatment, although the convex facial characteristic has prevailed.
Keywords: Orthodontics; Malocclusion, Angle Class II; Mandibular Advancement; Cephalometry; Follow-Up Studies.

Resumo
O presente estudo teve como objetivo avaliar, por análise cefalométrica, as alterações do perfil facial tegumentar em adolescentes com má oclusão de Classe II divisão 1ª, tratados com aparelho de Herbst (Estágio I) e aparatologia fixa (Estágio II), acompanhados por, em média, 4 anos (Estágio III). Os adolescentes foram divididos em dois grupos: grupo tratado (GT) - 33 adolescentes com má oclusão de Classe II (17 meninos e 16 meninas) tratados consecutivamente com aparelho de Herbst e aparatologia fixa; grupo controle (GC) - 28 adolescentes (13 meninos e 15 meninas) com má oclusão de Classe II, sem tratamento. Telerradiografias em norma lateral foram obtidas imediatamente antes (T1) e após (T2) o tratamento com Herbst, após aparatologia fixa (T3), e em média, 4 anos após o tratamento ortodôntico. A comparação intergrupos foi realizada por teste *t* ou Mann-Whitney. O GT foi avaliado por análise de variância seguida do pós-teste de Tukey ou teste de Friedman seguido do pós-teste de Dunn. Comparado ao GC, o GT apresentou alterações favoráveis significativas no Estágio I: redução da convexidade facial, retrusão do lábio superior, protrusão do lábio inferior, melhora no pogônio tegumentar e aumento do ângulo mentolabial. No período total pós-tratamento (T2-T4), o GT apresentou: aumento da linha H-Prn e retrusão dos lábios superior e inferior, enquanto as demais variáveis permaneceram estáveis. O tratamento com o aparelho de Herbst melhorou as características do perfil facial tegumentar, que foram mantidas após aparatologia fixa e 4 anos após o tratamento, embora a característica facial convexa tenha prevalecido.
Palavras-chave: Ortodontia; Má oclusão Classe II de Angle; Avanço mandibular; Cefalometria; Seguimentos.

Resumen
La presente investigación tuvo como objetivo evaluar, vía análisis cefalométrico, los cambios en tejidos blandos en adolescentes con maloclusión de Clase II división 1, tratados con aparato de Herbst (Etapa I) y aparatología fija (Etapa II), seguido de un acompañamiento de 4 años (Etapa III). Los adolescentes fueron divididos en dos grupos: grupo tratado (GT)- 33 adolescentes con maloclusión de Clase II (17 hombres y 16 mujeres) consecutivamente tratados con aparato de Herbst y aparatología fija; grupo control (GC) 28 adolescentes (13 hombres y 15 mujeres) con maloclusión de Clase II sin tratamiento. Cefalogramas laterales fueron trazados inmediatamente antes (T1), después (T2) del tratamiento con Herbst, después de aparatología fija (T3), y 4 años después del tratamiento ortodóntico (T4). Comparación entre grupos fue evaluada a través del test *t* o test Mann-Whitney. GT fue evaluado vía análisis de variancia seguido por test Tukey o test de Friedman, seguido de la prueba de Dunn. Comparado con el grupo GC, la GT mostro cambios favorables en etapa I: disminuyendo su convección facial, retracción de labio superior, protrusión de labio inferior, mejora de pogonion tejido blando e incremento en el angulo mentolabial. El periodo total de post tratamiento (T2-T4) de GT mostro: incremento en línea H-Prn, retrusión de labio inferior y superior, mientras que otras variables se mantuvieron estables. La terapia de Herbst mejora rasgos de tejido blando en el perfil, los cuales se mantuvieron estables después del uso de aparatología fija y 4 años postratamiento, aunque las características faciales convexas prevalecieron.
Palabras clave: Ortodoncia; Maloclusión Clase II de Angle; Avance mandibular; Cefalometría; Estudios de seguimiento.

1. Introduction

Orthodontists and patients consider the improvement in facial esthetics as a key goal of orthodontic therapy (Rains et al., 1982). One of the constant situations that prompt this search is Class II skeletal malocclusion, which is estimated to occur in 25 to 30% of the general population (Proffit et al., 1998). Some specific clinical characteristics in individuals presenting Class II Division 1 malocclusions are observed, such as unfavorable profile with high degree of facial convexity and increased overjet, which may produce negative feelings of self-image and difficult social interactions (Tung et al., 1998; Rego et al., 2017). Besides that, the Class II Division 1 malocclusions may increase the probability of developing dysfunctions of the stomatognathic system and the risk of maxillary incisors trauma (Rego et al., 2017; Martins et al., 2021; Silva et al., 2021). For these reasons, achieving a favorable facial esthetic through dentoskeletal disharmony treatment should be one objective in appliance therapy to correct Class II division 1 malocclusions (Pancherz et al., 1994; Quintão et al., 2006).

Mandibular growth modification induced by functional appliances in growing individuals can be considered a viable treatment option (Valant et al., 1989; McNamara et al., 2001). This treatment modality can successfully affect the soft tissue profile by alteration of skeletal and dentoalveolar structures, providing better relationship of soft tissues with craniofacial structures, resulting in a more favorable facial profile (Bishara, 2001). One of the most studied functional appliances is the

Herbst appliance (Flores-Mir et al., 2006), that mostly produces dentoalveolar alterations, in which the retroclination of maxillary incisors and proclination of mandibular incisors may change the lip profile relationship (O'Brien et al., 2003).

Considering the great number of studies investigating the dentoskeletal changes induced by the Herbst appliance therapy (Pancherz et al., 1986), only a small proportion takes into account soft tissue profile changes (Flores-Mir et al., 2006; Zymperdikas et al., 2016). The number of studies evaluating facial profile changes after Herbst appliance therapy followed by fixed appliances is even lower. Besides, the stability over time is not clarified (D'Antò et al., 2015). Therefore, the aim of this longitudinal retrospective investigation was to evaluate the long-term stability of the Herbst appliance therapy effects in soft tissue profile in adolescents with Class II Division 1 malocclusions and mandibular retrognathism.

2. Methodology

This retrospective investigation analyzed lateral cephalometric headfilms (Pancherz et al., 1994) of 61 brazilian white adolescents with Class II Division 1 malocclusions, and was approved by the Ethics Committee of São Paulo State University (FOAr-UNESP), School of Dentistry, Araraquara, São Paulo, Brazil (protocol number 72758717.4.0000.5416). The sample was selected according to the following inclusion criteria: 1) Clinical appearance of retrognathic mandible; 2) Angle Class II Division 1 malocclusions at early permanent dentition; 3) ANB angle greater than or equal to 4 degrees; 4) Skeletal pubertal growth peak (S stage until FM_3cap stage of Björk and Helm (1967) on hand and wrist radiography). The exclusion criteria were: 1) Markedly vertical growth pattern associated with open bite; 2) Individuals who had undergone any previous orthodontic therapy.

The sample was divided into two groups, treated group (TG) and control group (CG). The TG consisted of 33 adolescents (17 boys and 16 girls) consecutively selected and treated by an unique experienced orthodontist (LAAA), using a modified Herbst appliance: steel crowns (Ormco, Glendora, USA) on the maxillary first molars and mandibular first premolars, orthodontic bands on the maxillary first premolars and mandibular first molars, maxillary Hyrax expander and mandibular lingual arch (Figure 1). Occlusal support was used when the second maxillary or mandibular molars were present. Mean age at the start of treatment was 12.87 ± 1.15 years (minimum: 10.92 years; maximum: 15.83 years) and treatment time was 12 months (Stage I). Rapid maxillary expansion was required in all adolescents, which took place during the first 2 weeks after the Herbst appliance placement, simultaneously with the initial mandibular advancement. At treatment onset, up to 6 mm mandibular advances were carried out. When necessary, 2 mm to 3 mm complementary advances were performed in the third month. In all the 33 adolescents, the Herbst appliance treatment resulted in Class I molar overcorrected relationship. Immediately after Stage I, 25 of the 33 adolescents (14 boys and 11 girls) continued treatment with fixed appliances (Stage II), during 2.1 ± 0.9 years. After Stage II, upper removal retainer (Hawley) and lower bonded lingual retainer (3x3) were placed. Out of the 25 individuals, 18 (10 boys and 8 girls) were followed-up to a mean age of 19.79 ± 1.45 years (minimum: 17.75 years; maximum: 23.00 years). The CG comprised 28 adolescents (13 boys and 15 girls), that strictly met the same inclusion criteria of the TG. The adolescents were consecutively selected and followed up for 12 months by an unique experienced orthodontist (LCM). Mean age at onset of follow-up was 12.21 ± 1.35 years (minimum: 10.33 years; maximum: 14.83 years). The CG was compared to the TG at Stage I. Immediately after the follow-up period, the adolescents started orthodontic treatment.

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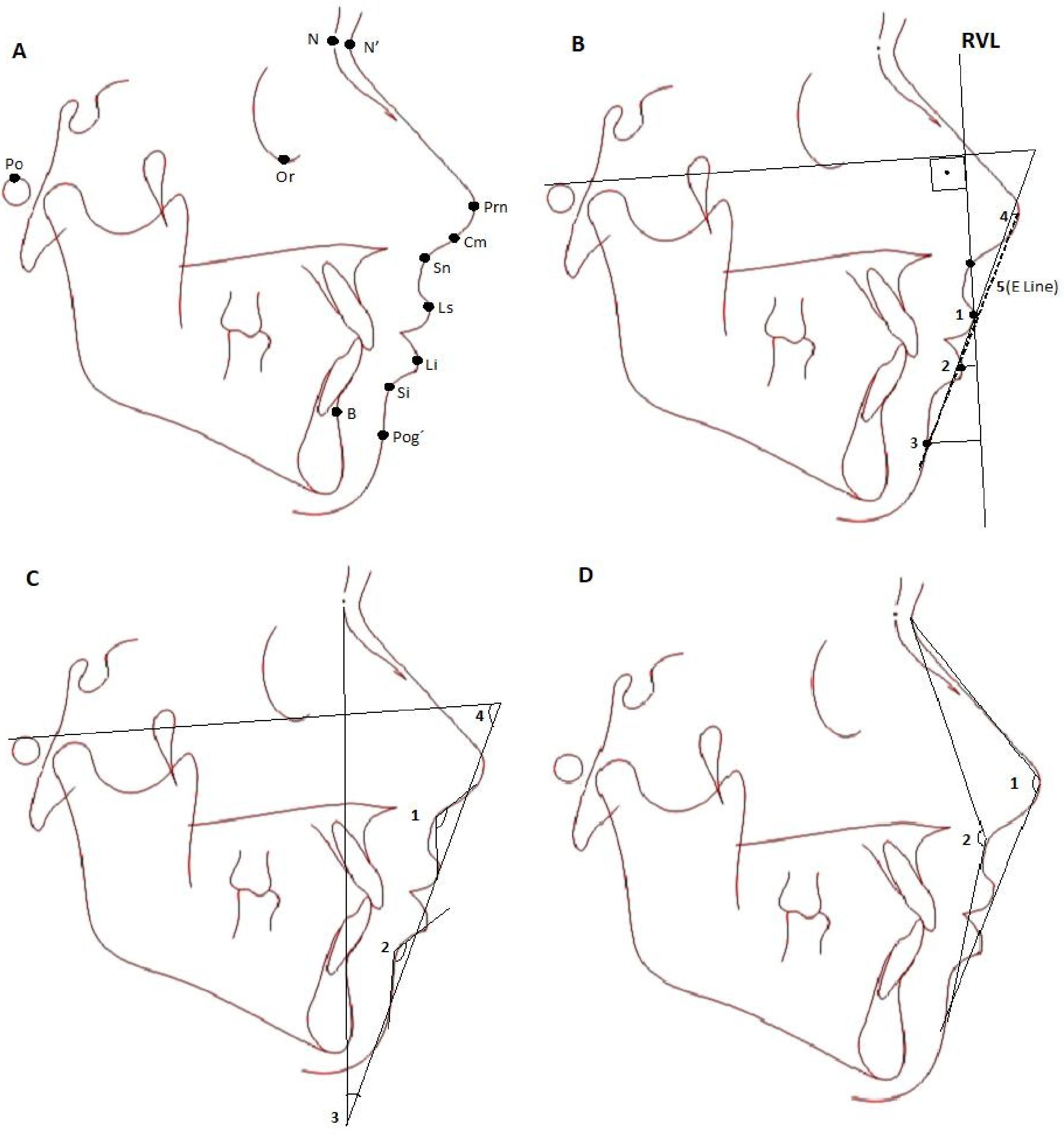
Figure 1. Herbst appliance with steel crowns in right lateral (A), frontal (B) and left lateral (C) views.

Source: Authors.

Lateral cephalometric headfilms were obtained in habitual occlusion at 4 moments: T1, at start of Herbst therapy (TG) or follow-up (CG); T2, at the end of Herbst therapy (Stage I-TG) or follow-up (CG); T3, at the end of fixed appliances treatment (Stage II-TG); T4, on average, 4 years after orthodontic treatment (Stage III- TG). For cephalometric analysis, the lateral headfilms were digitized on a scanner (HP Scanjet® G4050). A customized digitization regimen was created for the landmarks location and to measure and collect the cephalometric parameters (Radiocef 2.0® Memory studio software) by a blinded examiner (PGBM). The cephalometric landmarks, angles and lines used to measure the variables, including a Reference Vertical Line (RVL) (Silvestri et al., 2004) are shown in Figure 2. To visualize the changes during the different examination periods, superimposed cephalometric tracings on stable skull structures of the anterior cranial base (skull-structure method) (Björk et al., 1983) from one patient are shown in Figure 3.

Figure 2. Landmarks, lines and angles used in the investigation.



(A) N=nasion, N´=soft tissue nasion, B=B point, Prn=pronasale, Cm=columella, Sn=subnasale, Ls=labrale superior, Li=labrale inferior, Si=sulcus inferior, Pog´=soft tissue pogonion, Or=orbitale, Po=porion. (B) RVL=reference vertical line, traced through Sn and perpendicular to the skeletal Frankfort plane (Silvestri et al., 2004). Soft tissue linear measurements: (1) VRL-Ls, (2) VRL-Li, (3) VRL-Pog´, (4) H line-Prn; (5) E line. (C) Soft tissue angular measurements: (1) nasolabial angle, (2) mentolabial angle, (3) H line-NB, (4) Z angle. (D) Soft tissue angular measurements: (1) N´- Prn – Pog', (2) N´- Sn – Pog'. Source: Authors.

2.1 Statistical analysis

Using GraphPad^{TM} Prism statistical software, normal distribution (Shapiro-Wilk test) and homogeneity (F-test) of all variables were tested. Statistical comparisons between TG and CG for starting forms were analyzed using Chi-square (qualitative variables) and Student's paired *t*-test (quantitative variables). Student's paired *t*-test (parametric data) and

Wilcoxon test (non-parametric data) were used to identify intragroup differences (T2-T1). Student's *t*-test (parametric data), and Mann-Whitney test (non-parametric data) were used to identify treatment differences (T2-T1) between the groups. Comparisons of the TG between the different observation periods were analyzed using repeated measures analysis of variance (ANOVA) followed by Tukey test (parametric data) and Friedman test followed by Dunn's test (non-parametric data). Using G*Power Version 3.0.10 software (Dusseldorf University, 1992-2008) the detectable effect size was obtained by ANOVA with a probability of 0.05 and power (1-β err prob) of 0.95 for a sample of 18 individuals per group, resulting in a value of 0.5 mm. The levels of significance used were p <0.001, p <0.01 and p <0.05.

Method errors of the measurements were estimated by a single blinded operator (PGBM) with Intraclass Correlation Coefficient (ICC) and Student´s paired *t*-tests. 20% of the sample was randomly selected and measured twice, with an interval time of two weeks. ICC values ranged between 0.84 and 0.99, and Student´s paired *t*-tests showed no difference between the two measurements (p >0.05).

3. Results and Discussion

Statistical comparisons between TG and CG for the starting forms (T1) are presented in Table 1.

Table 1. Comparison of baseline characteristics (T1).

	Treated Group (n=33)		**Control Group (n=28)**		**p value**	**Significance**
	Mean	SD	Mean	SD		
Initial Age (Years)	12.90	1.14	12.52	1.20	0.20	NS
Gender						
Female	16.00	-	15.00	-	0.89^	NS
Male	17.00	-	13.00	-		
Cephalometric characteristics						
Hard tissues values						
SNA (◦)	82.84	3.06	82.54	3.69	0.72	NS
SNB (◦)	76.54	2.93	75.92	3.03	0.42	NS
ANB (◦)	6.30	1.29	6.62	1.50	0.37	NS
SN/GoGn (◦)	32.14	4.77	32.48	5.25	0.79	NS
1/.SN (◦)	110.23	8.53	103.72	9.27	>0.01	*
IMPA (◦)	97.50	6.43	98.01	5.72	0.74	NS
Soft tissues values						
N´- Prn - Pog´ (◦)	153.26	3.02	154.73	3.12	0.06	NS
N´- Sn - Pog´ (◦)	157.83	2.82	157.29	3.54	0.52	NS
RVL-Ls (mm)	2.74	1.38	1.70	1.64	0.01	*
RVL-Li (mm)	-3.95	1.81	-3.12	2.82	0.18	NS
RVL-Pog´ (mm)	-12.14	2.97	-11.81	2.13	0.62	NS
Nasolabial angle (◦)	116.40	10.20	119.83	7.81	0.15	NS
Mentolabial angle (◦)	117.74	10.63	114.93	10.42	0.25	NS

Legend: SD=Standard Deviation;^ = Chi Square test application (with Yates correction); Student´s t-test application for the rest of the variables; NS=Not Significant; *p <0.05. Source: Authors.

Statistical comparisons between TG and CG (T2-T1) are shown in Table 2.

Table 2. Comparison of changes (T2-T1) between Treated Group and Control Group.

	Treated Group (n=33)		Control Group (n=28)		Difference between groups		
Variable	Mean difference	SD	Mean difference	SD	Mean difference	p value	Significance
N´- Prn - Pog´ (◦)	0.47	1.82	-0.95	1.95	1.43	0.004	**
N´- Sn - Pog´ (◦)	**1.94**	2.21	0.39	1.52	1.55	0.002	**
H line - NB (◦)	**-2.80**	2.29	**-0.75**	1.35	-2.05	<0.001	***
H line -Prn (mm)	**3.52**	1.62	**1.30**	1.26	2.22	<0.001	***
Z Angle (◦)	**2.20**	3.69	**2.43**	3.18	-0.23	0.798	NS
E line - Ls	**-2.02**	0.98	**-0.79**	0.70	-1.23	<0.001	***
E line - Li	-0.15	1.11	**-0.97**	1.01	0.83	0.003	**
RVL-Ls (mm)	**-0.54**	0.85	-0.30	1.03	-0.25	0.312	NS
RVL-Li (mm)	**1.27**	1.75	-0.20	0.72	1.47	0.015	*
RVL-Pog´ (mm)	**1.68**	1.55	-0.05	1.99	1.74	<0.001	***
Nasolabial angle (◦)	1.08	3.80	0.54	3.24	0.54	0.557	NS
Mentolabial angle (◦)	**12.81**	8.82	1.25	6.18	11.56	<0.001	***

Legend: Bold indicates intragroup statistically significant differences (p <0.05) from T1 to T2; mm= millimeters; NS=Not Significant; * p <0.05; ** p <0.01; *** p <0.001. Source: Authors.

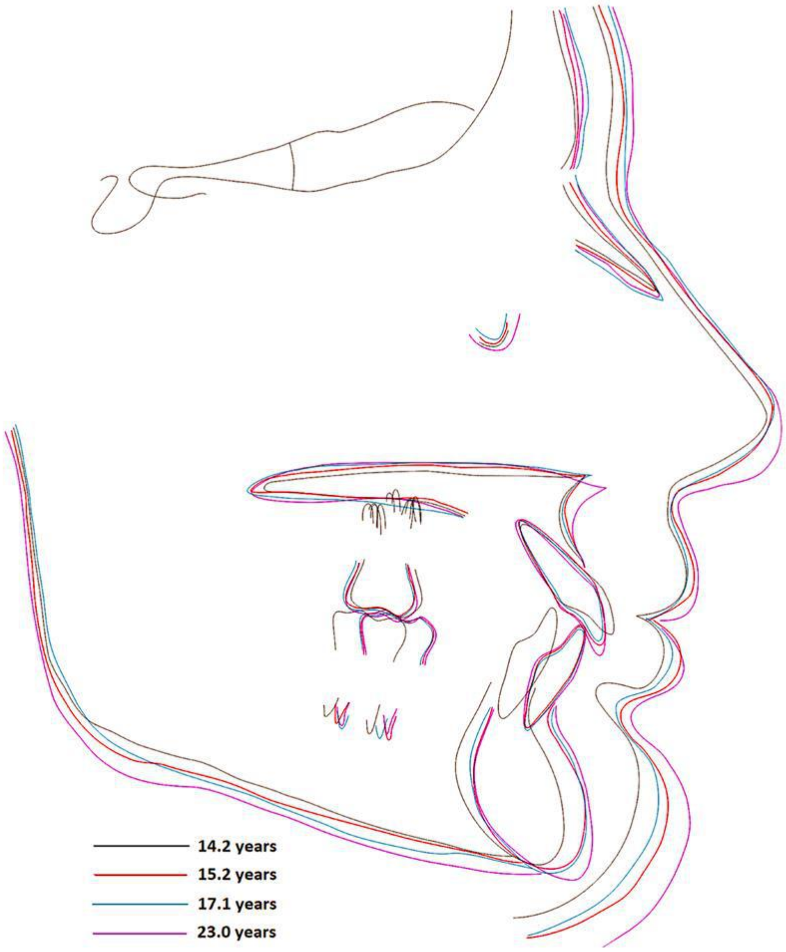
Cephalometric changes of TG at T1, T2, T3 and T4 are shown in Table 3.

Table 3. Longitudinal evaluation of Treated Group at T1, T2, T3 and T4.

	T1 (n=33)		T2 (n=33)		T3 (n=25)		T4 (n=18)			
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD	p value	Significance
N´- Prn - Pog´ (◦)	127.79	2.41	128.36	3.67	125.92	4.63	127.08	5.07	0.113	NS
N´- Sn - Pog´ (◦)	154.79	3.11	156.77	4.90	156.42	3.37	156.56	3.71	0.169	NS
H line - NB (◦)	17.68 **a**	3.44	14.84 **b**	4.56	13.70 **b**	4.51	13.37 **b**	3.99	<0.001	***
H line -Prn (mm)	0.86 **a**	2.95	4.22 **b**	4.20	6.60 **bc**	3.77	7.3 **c**	4.84	<0.001	***
Z Angle (◦)	65.39	8.10	67.81	9.44	69.30	9.89	71.89	8.94	0.094	NS
E line - Ls (mm)	-0.48 **a**	1.62	-2.45 **b**	2.08	-3.38 **b**	2.33	-3.9 **b**	2.65	0.001	**
E line - Li (mm)	0.62 **a**	2.64	0.49 **a**	3.01	-1.03 **ab**	2.31	-2.21 **b**	2.57	0.001	**
RVL-Ls (mm)	1.69 **a**	1.64	1.35 **a**	2.33	0.16 **ab**	2.35	-0.54 **b**	3.05	0.003	**
RVL-Li (mm)	-3.10 **ab**	2.81	-1.62 **a**	3.00	-3.39^ **ab**	-	-4.46 **b**	-	0.041	*
RVL-Pog´ (mm)	-11.63^	-	-10.07	2.94	-11.17	2.99	-11.29	4.14	0.268	NS
Nasolabial angle (◦)	119.75	7.80	120.52	9.35	123.02	10.13	123.60	12.89	0.425	NS
Mentolabial angle (◦)	114.63 **a**	10.42	127.44 **b**	12.31	125.03 **b**	10.07	126.31 **b**	4.84	<0.001	***

Legend: Different letters indicate statistically significant differences between the groups; Values without standard deviation (SD) represent a median value of the measurement due to the absence of normal distribution; ^ Friedman test application due to the absence of normal distribution at least at one observation time (Dunn's multiple comparisons test); mm= millimeters; NS=Not Significant; *p <0.05; **p <0.01; ***p <0.001. Source: Authors.

Figure 3. Superimposed cephalometric tracings on stable skull structures of the anterior cranial base (skull-structure method) from one patient at T1, T2, T3 and T4.



Source: Authors.

Convex facial profile is a characteristic of subjects with mandibular retrognathism. Thus, one of the goals of orthodontic therapy is to improve facial esthetics by reducing the facial profile convexity (Pancherz et al., 1994). When compared to the CG (Table 2), the TG showed a significant protrusion of the soft tissue pogonion (RVL-Pog´), and favorable reduction of the facial convexity when the following variables were analyzed: H line-NB, H line-Prn, N'-Prn-Pog' and N'-Sn-Pog'. Similar findings have been reported by previous investigations (Pancherz et al., 1994; Flores-Mir et al. 2006). A systematic review followed by meta-analysis (Zymperdikas et al., 2016) evidenced that fixed functional appliances lead to an improvement in facial convexity, inducing an increase in facial convexity angle excluding the nose (N'-Sn-Pog'). Another previous study (Baysal et al., 2013) showed a reduction in facial convexity induced by the Herbst therapy, by change in facial convexity angle excluding the nose (N'-Sn-Pog'), but not in facial convexity angle including the nose (N'-Prn-Pog'), justified by the posttreatment nasal growth. In the analysis of soft tissue profile, the facial convexity angle excluding the nose has the advantage of not being influenced by nasal growth (Bock et al., 2009).

In the TG longitudinal evaluation (Table 3), RVL-Pog´, and N'-Sn-Pog', N'-Prn-Pog' and Z angles showed no significant changes, corroborating previous investigation (Siara-Olds et al., 2010). However, the evaluation of H line-NB and H line-Prn evidenced a significant reduction in facial convexity at Stage I, which remained unchanged longitudinally in H line-NB and decreased even more between T2 and T4 in H line-Prn. This reduction in facial convexity may be largely assigned to posttreatment growth (Subtelny et al., 1959; Bock et al., 2009). Pancherz et al. (1994), in a follow-up of 5-10 years after Herbst therapy, found an increase in N'-Sn-Pog' and a reduction in N'-Prn-Pog. Another previous investigation (Meyer-Marcotty et al., 2012) found similar results, showing a reduction in facial convexity in N'-Prn-Pog' and N'-Sn-Pog' angles after treatment, but only N'-Prn-Pog' remained unchanged after the follow-up period. Distinct follow-up periods may have influence on different facial convexity findings among the investigations (Pancherz et al., 1994).

Soft tissue profile improvement may be associated with upper lip retrusion (Flores-Mir et al., 2006). The TG showed significant greater upper lip protrusion than CG at T1 (Table 1). At Stage I, in the comparison between the groups (Table 2), the TG presented showed retrusion of the upper lip to E line. Similar (de Almeida et al., 2008; Baysal et al., 2013) and different (Ruf et al., 2004) findings have been reported by previous investigations. The uprighting of upper incisors (Schaefer et al., 2004; Baysal et al., 2013) and the restriction in maxillary growth (Valant et al., 1989) induced by the Herbst therapy may be associated with the upper lip retrusion, although the maxillary growth restriction be a controversial subject in the literature (Franchi et al., 1999). No between-group differences were found in upper lip protrusion related to the RVL at Stage I.

In the TG longitudinal evaluation (Table 3), upper lip retrusion (E line-Ls) was found at Stage I, change that remained unchanged at Stages II and III. Similar (Pancherz et al., 1994) and different (Siara-Olds et al., 2010) findings have been reported by previous investigations. Concerning the RVL, the upper lip showed no significant changes between T1, T2 and T3, but a significant retrusion between T1 and T4. The anterior repositioning of the soft tissue pogonion and the nasal growth that occur during the Herbst therapy period, may affect the E line position (Pancherz et al., 1994). This fact could justify the difference in upper lip position related to E line and RVL, because despite the subnasale point retrusion that may occur after the Herbst therapy (D'Antò et al., 2015), this structure is less susceptible to changes induced by growth or treatment (Flores-Mir et al., 2006).

Concerning the E line, the lower lip showed retrusion in the CG, while in the TG it remained unchanged. Regarding the RVL, the lower lip showed significant protrusion in the TG, while in the CG it remained unchanged. These two variables showed significant difference between the groups (Table 2). These findings are in agreement with a previous study (de Almeida et al., 2008). Other investigations (Pancherz et al., 1994; Baysal et al., 2013) showed that the lower lip is not affected by the treatment. The absence of protrusion of lower lip in relation to E line in the TG may be due that this line follows the mandibular advancement (Pancherz et al., 1994). On the other hand, the RVL does not follow the mandibular repositioning, thus showing a protrusion of the lower lip at Stage I. The possible causes for the difference in lower lip position between the groups include the mandibular advancement and the proclination of lower incisors after treatment. Besides, the pretreatment distance of upper incisors in relation to the lower lip, may lead to a distortion of the lower lip under or posteriorly to the upper incisor, affecting its position (Veltkamp et al., 2002). The extent and predictability of changes in the axial inclination of the incisors on the soft tissue profile are still debatable. Flores-Mir et al. (2006) state that incisors protrusion is not related to lip protrusion, while Pancherz et al. (1994) showed that both lips are more supported by the upper incisors.

In the TG longitudinal evaluation (Table 3), the lower lip showed no changes in relation to E line between T1, T2 and T3, in agreement with a previous investigation (Siara-Olds et al., 2010). However, there was retrusion between T1 and T4, corroborating another previous investigation (Pancherz et al., 1994). Regarding the RVL, the TG showed lower lip significant retrusion between T2 and T4. During the occlusal settling that occurs after the Herbst therapy, and during the long-term follow-up, the buccal inclination of the lower incisors is susceptible to relapse (Pancherz et al., 1986; Pancherz et al., 2014). Since the lip posture is closely related to teeth and alveolar process (Subtelny et al., 1959), the use of lower bonded lingual retainer (3x3) is relevant to increase the stability (Pancherz et al., 2014).

Nasolabial angle showed no between-group diferences (Tables 2 and 3), corroborating previous investigation (de Almeida et al., 2008). However, decrease (Schaefer et al., 2004) and increase (Pancherz et al., 1994; Flores-Mir et al., 2006) in this angle after mandibular advancement have been found in the literature. An increase in nasolabial angle may be caused by the upper lip retrusion, which is provided by the upper incisors retrusion induced by the Herbst therapy (Pancherz et al., 1994). This fact may explain the lack of difference in nasolabial angle in the present investigation, since there was no difference in upper lip position between the groups at Stage I in relation to the RVL. In the TG longitudinal evaluation, the nasolabial angle remained unchanged between T1 and T4, in agreement with a previous investigation (Siara-Olds et al., 2010).

When compared to the CG, the TG showed an increase in mentolabial angle (Table 2), in agreement with previous investigations (de Almeida et al., 2008; Bock et al., 2009; Baysal et al., 2013). In the TG longitudinal evaluation (Table 3), the TG showed an increase in mentolabial angle at Stage I, which remained unchanged at Stages II and III. This finding could be justified by the alteration in posture and tonus of the perioral muscles and by the overjet improvement. In Class II Division 1 malocclusions, there is distortion of the lower lip under or posteriorly to the upper incisors, leading to an acute mentolabial angle and a deep mentolabial sulcus. When the physical obstruction of the upper incisors is eliminated due to the decrease of overjet induced by functional appliances, the distortion of the lower lip can be avoided. Instructing the patient to maintain the lip seal while using the appliance will lead to an increase in lip tension, changing the tonus and the posture of perioral muscles. Consequently, elimination of lower lip distortion and increase in mentolabial angle will be achieved (Lange et al., 1995).

Among the limitations of the current investigation, at Stages II and III there were the patients drop out and the absence of control group. There is a difficulty or an ethical impossibility in obtaining longitudinal data from control patients with Class II malocclusions. Besides that, the present investigation showed two-dimensional evaluation by lateral cephalograms.

4. Conclusion

The Herbst appliance therapy improved features of soft tissue facial profile, which were maintained after fixed appliances and for an average of 4 years posttreatment. Nevertheless, the convex facial characteristic has prevailed.

We suggest that future three-dimensional investigations should be performed to evidence the soft tissue profile effects of Herbst therapy followed by fixed appliances, and its long-term stability.

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