



UNESP - Universidade Estadual Paulista
“Júlio de Mesquita Filho”
Faculdade de Odontologia de Araraquara



Juan Francisco Mariscal Muñoz

**Avaliação das mudanças esqueléticas, dentárias e de tecidos moles criadas
após terapia com aparelho de Herbst, em pacientes com má oclusão de Classe
II divisão 1 em diferentes estágios de crescimento puberal**

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Orientador: Dirceu Barnabé Ravelli

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À memória de **Salvador Mariscal Ibarra**, exemplo de luta em vida, homem íntegro e honesto, que nos disse adeus no mesmo dia da finalização deste trabalho

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pandemia

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de 6 anos

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“Se o dinheiro for a sua esperança de independência, você jamais a terá. A única segurança verdadeira consiste numa reserva de sabedoria, de experiência e de competência.”

Henry Ford*

* Baldwin, N. (2001). Henry Ford and the Jews. New York: Public. Affairs.

Mariscal Muñoz JF. Avaliação das mudanças esqueléticas, dentárias e de tecidos moles criadas após terapia com aparelho de Herbst, em pacientes com má oclusão de Classe II divisão 1 em diferentes estágios de crescimento puberal [tese de doutorado]. Araraquara: Faculdade de Odontologia da UNESP; 2020.

RESUMO

Esse estudo retrospectivo, dividido em três publicações diferentes, objetivou comparar através de modelos ortodônticos 3D e radiografias em norma lateral, o resultado das mudanças dentárias, esqueléticas e de tecidos moles geradas após terapia com aparelho funcional fixo de Herbst, na correção da má oclusão de Classe II divisão 1. O estudo comparativo foi desenvolvido em 95 pacientes com crescimento craniofacial ativo. Foram alocados individualmente em 3 grupos, segundo o período de maturação das vértebras cervicais ao início do tratamento: antes, durante e pós surto de crescimento puberal. O material utilizado foi obtido dos arquivos do departamento da Clínica Infantil da Universidade estadual paulista “Júlio de Mesquita Filho” e de uma clínica ortodôntica particular (Aidar Ortodontia). A documentação de cada indivíduo foi escaneada e analisada de maneira qualitativa e quantitativa através de softwares computacionais. Os objetivos desse trabalho foram: (1) Comparar as mudanças cefalométricas em estruturas esqueléticas, dentárias e (2) de tecidos moles, assim como (3) a eficácia na correção da relação de molares e de caninos, em diferentes etapas do crescimento pubertário. Os resultados gerados foram organizados e submetidos a análise estatística, utilizando diferentes testes seguindo a natureza dos dados, sejam estes qualitativos ou quantitativos. O trabalho permitiu identificar algumas diferenças na resposta ao tratamento da má oclusão de Classe II com aparelho de Herbst nas diferentes etapas do desenvolvimento craniofacial.

Palavras chave: Má oclusão de Angle Classe II. Aparelhos ortodônticos funcionais. Crescimento.

Mariscal Muñoz JF. Evaluation of skeletal, dental and soft tissue changes created after therapy with a Herbst appliance in patients with Class II division 1 malocclusion at different stages of pubertal growth [tese de doutorado]. Araraquara: Faculdade de Odontologia da UNESP; 2020.

ABSTRACT

This retrospective study, divided into three different publications, aimed to compare, through 3D orthodontic models and lateral x-rays, the result of dental, skeletal, and soft tissue changes generated after therapy with Herbst's' fixed functional appliance, in the correction of malocclusion of class II division 1. The comparative study was carried out in 95 patients with active craniofacial growth. They were allocated individually in 3 groups, according to the cervical vertebrae's maturation period at the beginning of treatment: before, during, and after a pubertal growth spurt. The used material was obtained from the archives of the Children's Clinic department of the São Paulo State University "Júlio de Mesquita Filho" and from a private orthodontic clinic (Aidar Orthodontics). The documentation of each individual was scanned and analyzed qualitatively and quantitatively through computer software. The objectives of this work were: (1) To compare cephalometric changes in skeletal, dental, and (2) soft tissue structures, as well as (3) the effectiveness in correcting the molar and canine relationship in different stages of pubertal growth. The results generated were organized and submitted to statistical analysis, using different tests according to the data's nature, whether qualitative or quantitative. The work made it possible to identify some differences in response to the treatment of Class II malocclusion with Herbst apparatus in the different stages of craniofacial development.

Keywords: Malocclusion, Angle Class II. Orthodontic appliances, functional. Growth.

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1 INTRODUÇÃO

Estima-se que ao redor de 23% da população do planeta é portadora de má oclusão de Classe II (MOII) na dentição decídua e de 20% na dentição permanente¹, uma alteração orofacial com anomalias nos três planos do espaço com a característica oclusal da presença de um degrau distal que durante a transição da dentadura decídua à permanente, não apresenta tendências de autocorreção². Embora o crescimento craniofacial tem se demonstrado semelhante entre pacientes esqueléticos Classe I e Classe II em magnitude e direção, as discrepâncias oclusais, esqueléticas e de tecidos moles são mantidas através do tempo³.

A Classe II divisão 1 é caracterizada por alterações em estruturas esqueléticas maxilomandibulares e tecidos moles faciais, que resulta em perda da eficiência mastigatória⁴, problemas respiratórios e em alguns casos, desarmonias na estética facial. Pela somatória de todas essas desordens, a MOII, principalmente pela sobressalência oclusal e perfil facial convexo, é associada com problemas de “bullying” nas escolas, tanto em crianças quanto em adolescentes portadores⁵.

Etiologicamente atribuída principalmente a fatores ambientais e genéticos⁶, a MOII divisão 1 pode estar constituída por diversas combinações de estruturas anatômicas atingidas, tanto esqueléticas, dentárias e de tecidos moles. A retrusão mandibular, protrusão maxilar, inclinação anterior dos incisivos superiores, Overjet aumentado, retrusão do lábio inferior, e aumento da convexidade facial são as características mais comuns. A literatura tem relatado de forma consistente que as diferenças entre sujeitos da Classe I e Classe II são devidas principalmente à posição anteroposterior da mandíbula⁷. Embora pode ter sempre outros componentes envolvidos como por exemplo alterações verticais do terço inferior da face⁸ e frequentemente atresias nas dimensões transversais dos arcos dentários.

Dentro das terapias de tratamento atualmente disponíveis encontra-se a cirurgia ortognática, com a limitação da longa espera até o paciente atingir o fim do crescimento esquelético e a extensa recuperação das intervenções traumáticas após cirurgia. Outros métodos alternativos que existem dentro da ortodontia são as terapias de avanço mandibular com o uso de aparelhos intraorais. Embora tenha se demonstrado que a maioria dos efeitos produzidos por esses aparelhos são majoritariamente dentários, o principal objetivo dessas terapias em duas fases é o

tratamento da sobressalência dos incisivos, efeito que comprovou uma diminuição do risco de fraturas por traumatismo⁹.

O dispositivo de Herbst, aparelho funcional fixo para tratamento da MOII, introduzido por Emil Herbst no ano de 1909, consiste em um par de pistões fixos que reposicionam a mandíbula anteriormente, permitindo a abertura bucal e movimentos de lateralidade, mas impedindo o deslocamento posterior¹⁰. O mecanismo de correção que o dispositivo promove inclui uma remodelação na morfologia e posicionamento da fossa glenóide, mudanças no direcionamento e intensidade do crescimento mandibular, inclinação anterior dos incisivos inferiores, redução do Overjet, movimentação mesial dos primeiros molares e redução do ângulo ANB¹¹.

A pesar de a eficácia do aparelho de Herbst no tratamento da MOII ter sido demonstrada, devido principalmente às mudanças na discrepância dentária e aumento do comprimento mandibular¹², existe uma controvérsia atual entre a escolha da etapa de crescimento ideal para o uso do aparelho de Herbst. Pancherz pesquisador que reintroduziu a utilização do dispositivo no final dos anos 70, preconizou a utilização do aparelho de Herbst logo depois do surto de crescimento puberal baseado na premissa de que pelo fato de ter mais dentes permanentes presentes na dentadura, o resultado teria uma maior estabilidade oclusal¹³.

Devido ao comprimento mandibular ter uma maior magnitude e velocidade de crescimento durante o surto de crescimento pubertário¹⁴, muitos profissionais têm identificado esse período como o mais eficiente e eficaz para o tratamento com ortopedia funcional. Complementando, existem também evidências científicas, que descrevem uma maior eficiência dos aparelhos ortopédicos durante o surto de crescimento puberal¹⁵. Porém o ganho em magnitude no crescimento do corpo mandibular durante o surto de crescimento puberal não deve ser estudado isoladamente, já que o crescimento condilar superior e posterior produzido pelo aparelho de Herbst^{16,17} pode não produzir totalmente um avanço puro, devido à dificuldade para obter uma rotação anterior verdadeira da mandíbula¹⁸, a direção do alongamento passa a ter importância.

Por outro lado, quando o tratamento de uma má oclusão de Classe II é realizado na dentadura mista, durante a fase pré-puberal, é necessário um tempo de contenção ativa, evitando possíveis recidivas indesejadas. Porém, como descrito previamente, algumas vantagens têm sido descritas na literatura, principalmente a diminuição da

sobressalência anterior característica marcante da Classe II divisão 1, diminuindo assim a prevalência de fraturas dos dentes anteriores(9).

Na tentativa de comparar os diferentes resultados após correção da MOII com aparelho de Herbst em cada uma das fases do crescimento puberal, Pancherz e Hägg, identificaram um mecanismo de correção semelhante nas três fases, com maior intensidade do crescimento condilar em direção sagital durante o surto e maior inclinação anterior no pós-surto¹⁹. Entretanto, a pesquisa apresentou uma distribuição amostral dos três grupos (n=31, 26, e 12) assim como distribuição de gênero (18 mulheres e 52 homens) categoricamente desequilibrada.

Portanto, o intuito desse trabalho foi comparar através de modelos ortodônticos 3D e radiografias em norma lateral as mudanças dentárias, esqueléticas e de tecidos moles, geradas após correção da má oclusão de Classe II divisão 1 com aparelho de Herbst em pacientes que começaram tratamento em etapas de crescimento diferentes: antes, durante e pós surto de crescimento puberal.

2 PROPOSIÇÃO

2.1 Proposição Geral

Comparar os efeitos dentários, esqueléticos e de tecidos moles do aparelho de Herbst na correção da má Oclusal de Classe II divisão 1, em pacientes nas três etapas do crescimento craniofacial.

2.2 Proposição Específica

- Comparar entre grupos, através de medidas cefalométricas e nos modelos ortodônticos, efeitos do tratamento nas estruturas esqueléticas e dentárias, incluindo:
 - Relação Maxilomandibular;
 - Posição anteroposterior (AP) maxilar;
 - Posição AP mandibular;
 - Posição AP queixo mandibular;
 - Mudanças verticais no terço inferior da face;
 - Inclinação dos incisivos maxilares e mandibulares;
 - Overjet e Overbite;
 - Etc.

- Comparar a eficiência do aparelho de Herbst na correção da relação molar e de caninos, correlacionando o grau de severidade AP da MOII inicial e as etapas do crescimento craniofacial com a qualidade da correção final.

- Comparar entre grupos, através de medidas cefalométricas, efeitos do tratamento nas estruturas de tecidos moles faciais, incluindo:
 - Mudanças na convexidade facial esquelética e de tecidos moles;
 - Mudanças na profundidade do sulco mentolabial;
 - Posição AP do lábio superior e inferior, pogônio mole;
 - Mensurar a interferência das mudanças na espessura dos tecidos moles na correção do perfil facial;
 - Avaliar a correlação entre as mudanças na convexidade facial esquelética e de tecidos moles;

- Avaliar a correlação entre as mudanças AP na posição do pogônio esquelético e o pogônio mole;

3 PUBLICAÇÕES

Este trabalho de tese de doutorado foi subdividido em três artigos científicos que serão posteriormente publicados em periódicos da área.

3.1 Publicação 1*

Skeletal and dental changes after Class II malocclusion treatment with Herbst therapy at different stages of skeletal maturity.

* Artigo segue as normas do periódico "Journal of Orofacial Orthopedics" ao qual foi submetido.

Abstract

Purpose To compare the skeletal and dental changes after Herbst appliance therapy in Class II malocclusion patients at different stages of skeletal maturity.

Materials and methods. Ninety-five patients with Angle Class II division I malocclusion, of both genders, previously treated with the Herbst appliance, were distributed according to the cervical vertebrae maturation (CVM) into three groups: pre-pubertal (24), circumpubertal (33) and post-pubertal (38). Both lateral radiographs before (T0) and after appliance removed (T1) were analyzed with customized cephalometric measurements. The normal distribution of the variables was evaluated through the Shapiro Wilks test. Cephalometric changes (T1-T0) between groups were compared with the multivariate analysis of covariance (MONCOVA), using gender as a covariable.

Results. The multivariate test showed a statistical difference in the Global comparison between treatment changes of the three groups ($P=0.000$; $1-\beta=1$; $f=0.50$). The covariable gender showed no global interaction in the comparison ($P=0.386$; $1-\beta=.901$). A similar correction mechanism was shown in all groups, with magnitude differences in supramentale advancement, mandibular length, posterior and anterior facial height, overjet correction, and upper incisors retrusion and lower incisor proclination. A relevant difference was detected in mandibular length changes, being the circumpubertal 1.55 mm higher than the post-pubertal group and 1.87 mm than the pre-pubertal group.

Conclusion. The more significant increase in mandibular length in the circumpubertal stage did not reflect more pogonion projection. The Herbst appliance therapy was different in some skeletal and dental changes. Herbst appliance can be indicated in any phase of craniofacial growth with predominantly similar dental improvements in class II malocclusion patients.

Keywords: Malocclusion, Angle Class II; Herbst appliance; Craniofacial development.

Introduction

The effectiveness and efficiency in the correction of Class II malocclusion with orthopedic devices are related to the beginning of treatment in the ideal period of craniofacial development. However, the choice of this phase remains a topic of discussion. The proposal by Ruf and Pancherz [1] consists of Herbst appliance use in the permanent denture at or just after the peak of pubertal growth. On the other hand, the systematic review of Perinitti et al. [2] suggested the effective treatment with functional fixed appliances in the pubertal growth phase and a lack of evidence in post-pubertal patients. The necessity of a direct comparison between Herbst therapy treatment changes at the different craniofacial growth phases was detected by the authors.

Studies reporting class II malocclusion therapy with different devices have used various or no one skeletal maturation classifications in sample standardization. This fact has hindered the search for a consensus in the literature, complicating the systematical comparison between studies [3]. As a parameter of choice for the starting point of treatment, some authors have used chronological age, others the stage of development of the dentition, and finally, they reached skeletal maturity, assessed through radiographic examinations. There is high variability between the studies due to methods of choice to select the patient's development, as well the individual variabilities. Nevertheless, the standardization of skeletal maturity through the analysis of cervical vertebrae is a reproducible method, accessible in the clinical routine and without interference from variables such as genetics, nutrition, gender, ethnicity, and socioeconomic strata [4].

Within the existing literature on correction of Class II malocclusion in two stages, there are definite advantages in the literature for both early (pre-growth spurt) and late (post-growth spurt) treatment. The main advantage of early treatment justified in the literature is to reach the proclination of the upper incisors, reducing the risk of trauma fractures [5]. However, the treatment beginning at the post-pubertal stage is recommended by other authors, relating the progression of the development of the dentition with the reduction of the treatment time [6] and long-term stability (6).

This study aimed to compare skeletal and dental cephalometric changes, after therapy with the Herbst appliance, in patients with class II malocclusion treated at different stages of skeletal maturity. The study was performed via cephalometric measures.

Materials and methods

This study was ethically approved with the number 29320919.6.0000.5416. MANOVA power analysis for our sample was calculated via G*Power, 3.0.10 (Dusseldorf University, 1992-2008). Using an alpha value of 0.05 and a power of 0.80 (1- β err prob), sensitivity to small size effects ($f = 0.253$) was calculated. Ninety-five patients, previously treated with Herbst Appliance, were included in the study with similar craniofacial characteristics: (1) Class II division 1 malocclusion, (2) Overjet > 4 mm, (3) Hypodivergent or mesofacial phenotype with an SN. GoMe angle <36°, (4) ANB > 4°, (5) at a minimum of incisors and first permanent molars fully erupted, (6) mandibular incisor crowding < 3 mm. After the first selection, the patients were allocated depending on cervical vertebral maturation in three groups: pre-pubertal (PRE; between stages CS1 and CS 2), circumpubertal (CIR; between CS3 and CS4 stages), and post-pubertal (POS; between CS5 and CS6 stages) according to McNamara and Franchi [4]. Anteroposterior Class II severity in each group at the beginning of the treatment was also described, following the Andrews classification [7], the sample baseline characteristics were resumed in Table 1.

All 95 patients were treated by three Ph.D. experienced orthodontics between 2000 and 2012 using a Herbst appliance. The telescopic mechanism was coming out from the first upper molar to an occlusal rest between canine (or mandibular first deciduous molar in PRE-group) and mandibular first premolar of the steel lower lingual arch. The two bands or crowns on the first upper molars were attached to a cantilever device or a hyrax expansion screw in the palatal area, depending on the transversal necessity of the patient. When necessary, the maxillary expansion protocol started with the first activation one week after device installation until it achieved a transversal overcorrection. The technical construction of the Herbst appliance was to achieve an edge to edge position when possible, with a maximum advancement of 6 mm and increment of 2 mm when necessary. The Herbst appliance treatment time was, on average, 10.8 months.

The parameters for the acquisition of the before (T0) and after (T1) lateral cephalometric radiograph were between 73 kV/15 mA and 85 Kv/10 mA depending on the patient's weight, in maximum intercuspation occlusion and always using a chepalostat device. Those images were digitally scanned in a 300 DPI resolution (Scanjet® G4050, Hewlett-Packard, Palo Alto, California) with a physical dimension rule of 100 mm presented during the scan to avoid magnification of the structures. In

a blinding procedure, 19 cephalometric measures were traced by a single calibrated investigator identifying 24 landmarks (Table 2) in different craniofacial structures using the Radiocef 2 software (Radio Memory, Belo Horizonte, MG, Brazil), Figure 1. Overjet, overbite, and class II molar millimeter relation were obtained from the digital models of each patient, scanned from the plastic model in the 3Shape's R700™ (Copenhagen, Denmark) in patient's habitual occlusion.

Statistical analysis

An alpha level significance of 0.05 was used to perform the statistical analysis using the Statistical Package for the Social Sciences software package (SPSS for Windows, version 20.0; IBM, Armonk, NY). The intra-rater reliability was evaluated in 60 cephalograms randomly selected with a tracing repeated 30 days after the first measurement. First, the categorical distribution of the patients in the three different growth periods was evaluated based on Cohen's Weighted kappa coefficient ($K = 0.95$). The Systematic and random errors were tested individually in all the variables using a one-sample paired t-test ($p\text{-value} > 0.225$), correlation coefficient ($ICC > 0.87$), and Dahlberg formula (linear measures $D < 1.20$ mm, angular measures $D < 1.65^\circ$).

The Shapiro-Wilk test showed that continuous dependent variables satisfied the normal distribution for the three groups. Using a multivariate analysis (MANCOVA), including the growth stage as a fixed factor and genre as a covariate, differences between T1- T0 cephalometric measures were compared. Homogeneity of group variances tested with Levene test showed significant results, suggesting that the variables variance outcome was not equal amongst the groups; therefore, a Games-Howell intergroup post hoc analysis was used. Internal statistical significance between treatment times (T0 and T1) was tested in each variable using a paired t-test.

Results

The groups were compatibles in terms of gender and anteroposterior Class II molar severity. Pretreatment measurements (T0) showed a statistical difference only in Overbite measure with a .50 mm difference between the post-pubertal group with the other two groups (Table 1). The multivariate test showed a statistical difference in the Global comparison between groups in treatment changes (T1-T0), $F(36,146) = 4.583$; $P=0.000$; $1-\beta=1$; $f= 0.50$. The covariate gender showed no global interaction in the comparison $F(36, 146) = 1.064$; $P=0.386$; $1-\beta=.901$; $f= 0.20$. Descriptive statistical and Pos hoc analysis applied in all variables were resumed in Table 3.

Anteroposterior skeletal effects

The Herbst appliance effects on the anteroposterior position of the maxillary bone using the cranial base as a reference showed no intra or inter significant statistical differences (SNA: $P=0.91$; ALVRL: $P=0.53$). However, the mandibular bone response demonstrated a significant forward constant movement in all groups without differences amongst them using the SNB angle measure ($P=0.268$). However, using the linear measure BLVRL, a significant intergroup difference ($P=0.036$) was shown, being higher in PRE-group ($M=2.83$ mm, $SD=2.43$) than in POS-group ($M=1.39$ mm, $SD=1.46$). There was an anterior forward movement of the Chin represented with a Pg-VRL measure, without statistical difference between groups ($P=0.081$), as well as N-Pg on HRL measure ($P=0.678$). The Co-Gn linear measure was statistically different ($P=0.020$) between groups, being higher in CIR group ($M=4.46$ mm, $SD=3.17$) than in PRE ($M=2.59$ mm, $SD=1.86$) and POS groups ($M=2.91$ mm, $SD=3.12$). A significant clinical difference was detected in mandibular length; being the circumpubertal 1.55 mm higher than the post-pubertal group and 1.87 mm higher than the pre-pubertal group. Nevertheless, that did not reflect an increase in pogonion projection.

Vertical skeletal effects

There was a vertical downward movement of the anterior maxillary bone, represented by ANS-HRL measure. Significant differences between groups were detected ($P=0.000$), the POS group ($M=0.80$ mm, $SD=2.09$) was different to PRE ($M=1.31$ mm, $SD=2.09$) and CIR ($M=2.91$ mm, $SD=1.89$) groups. The downward movement of the posterior region of the maxillary bone, represented by PNS-HRL measure showed significant differences between groups ($P=0.000$), POS-group was dissimilar ($M=0.39$ mm, $SD=1.09$) to PRE ($M=0.70$ mm, $SD=1.21$) and CIR groups ($M=1.06$ mm, $SD=1.11$).

There were no statistically significant intergroup changes in the SN/GoMe measure ($P=0.648$), representing the vertical movements of the mandibular bone with the cranial base as a reference. The anterior facial height (AFH) changes were significant in internal comparisons of all groups but without differences between them ($P=0.062$). Instead, in posterior facial height (PFH) the PRE-group ($M=0.95$ mm, $SD=2.15$) showed an intergroup difference ($P=0.020$) with the CIR ($M=2.43$ mm, $SD=1.91$) and POS groups ($M=1.83$ mm, $SD=1.88$).

Dental effects

In all groups, there was a significant proclination of the mandibular incisor (IMPA measure) with statistical differences ($P=0.005$), the CIR group ($M=5.61^\circ$, $SD=2.28$) presented more incisor proclination than the PRE ($M=4.20^\circ$, $SD=1.63$) and POS groups ($M=4.26^\circ$, $SD=1.49$). L1-VRL distance measure confirmed a different movement of the mandibular incisor ($P=0.000$) between CIR group ($M=4.56$ mm, $SD=2.13$) PRE ($M=3.1$ mm, $SD=2.33$) and POS groups ($M=2.30$ mm, $SD=2.30$). The significant intragroup retroclination of the maxillary incisor (U1/SN measure) was statistically equal between groups ($P=0.174$).

The first upper molar movement was always backwards, without a statistical difference ($P=0.214$) between groups, PRE ($M=-2.22$ mm, $SD=4.52$), CIR ($M=-1.46$ mm, $SD=4.52$), POS ($M=-1.78^\circ$ mm, $SD=4.52$). Meanwhile, the first lower molar moved forward in the three groups without a statistical difference ($P=0.21$) between them, PRE ($M=4.09$ mm, $SD=1.69$), CIR ($M=4.02$ mm, $SD=4.52$), POS ($M=3.38$ mm, $SD=2.10$). At last, an Overjet decrease was presented in all the growth stages with differences ($P=0.016$) between CIR group ($M=-4.62$ mm, $SD=1.33$) and POS group ($M=-3.55$ mm, $SD=1.85$); the PRE group ($M=-3.99$ mm, $SD=1.20$) was statistically equal to the other groups.

Discussion.

The craniofacial growth stage chosen to initiate Class II malocclusion therapy using Herbst device had a significant influence in skeletal and dental changes ($P=0.0001$) with a larger effect size ($f=0.50$) in our investigation. There was no interaction between gender and development during Herbst therapy in our study ($P=0.386$) that was not expected. According to Rothstein et al. [8], the magnitude and direction of growth in Class II malocclusion patients differ from male and female. That was previously explained by Pancherz and Hägg [9], showing similar results but with a methodological disproportion between the number of males and females.

The cervical vertebral maturation (CVM) method used in this study to evaluate the craniofacial skeletal maturity [4], showed a large Cohen's Weighted kappa coefficient ($K=0.95$) indicating an acceptable reproducibility. The CVM method is useful in replacing the Hand-wrist maturation (HWM) method to determine skeletal maturation of C2, C3, and C4 vertebral features [10]. This analysis made in the lateral craniofacial radiography simplifies and with a less irradiation necessity. Engel et al. [11] suggested

that the CVM protocol should be used with caution to predict the amount of craniofacial growth in girls with Class II malocclusion due to the low literature support. However, a high agreement of the inter-observer method has been demonstrated when the radiography type, the experience level, and operator training are controlled [12]. In 2018, in order to improve the reliability, reproducibility, and easy access to the CVM method, McNamara and Franchi published the CVM "user's guide" that was used for this study.

The anteroposterior skeletal changes

The incisor inclination movement influences A point position only when a 10° or more position modification [13] occurs, the validity of SNA and A1VRL measures in this study were trustworthy. Agreeing with some authors [14–18], our research did not reveal any maxillary bone retraction effect after Herbst therapy. No differences between Inter or intra groups in SNA and A1VRL measures were found; neither was the interaction between gender or growth period. Despite these findings, the headgear effect of the Herbst appliance could be suggested because the SNA angle is expected to increase with age in class II growing patients [19]. In a similar study with different results, Hansen et al. [20] suggest a forward constant anterior movement of the point A, they showed the more significant value in the post-pubertal group (M=1.9, SD= 1.7) than circumpubertal (M=0.7, SD= 1.1) and pre-pubertal (M=1.7, SD= 1.1) groups, although these findings may have been influenced by the number of participants in each group: six, fifteen and nineteen respectively. Contrasting with our results, other studies found a forward movement of the maxillary bone [21–24].

Available literature indicates a mandibular length (ML) increase represented by Condylion-Gnathion measure (Co-Gn) could be primarily explained due to the direction of the natural growth, but some studies report that this represents the effect of the Herbst appliance [18]. In pre-pubertal patients, Almeida et al. [16] and VanLeaecken et al. [25] reported an ML increase of 4.8 mm and 4.6 mm, respectively, with a statistically significant difference to the control group. In contrast, in the same phase of growth, other studies reported an ML increase without statistical differences to their control group [21, 26]. In circumpubertal patients, some studies reported an ML increase without statistical differences to natural growth [22–24]. In contrast, Pancherz [27] and Marchi et al. [28] showed a statistical ML increase of 3.1 mm and 4.67 mm, with a significant difference when compared with natural circumpubertal growth.

At last, in Class II post-pubertal malocclusion patients, Jakobsone et al. [17] demonstrated a significative ML increase of 4.0 mm. Our study presented a significantly higher value of ML increase in CIR group (4.46 mm) when comparing with PRE (2.59 mm) and POS (2.91 mm) groups. The ML appears to increase more in the circumpubertal growth stage, and that difference was previously reported in a Metanalysis by Perinetti et al. [2], with a clinically significant difference of 1.86 mm favoring the circumpubertal subjects when comparing with post-pubertal.

The response of the Herbst treatment over the retrognathic mandibular position, one common Class II malocclusions characteristic, is influenced by the facial divergence pattern. Due to the undesirable backward true mandibular rotation created by Herbst therapy [15], hyperdivergent patients were excluded from the study. In our investigation, there was always a forward movement of the mandibular bone with the cranial base as a reference, the SNB angle, Pg $\perp$ VRL and NPg on HRL measures showed intrasubject statistical significance in all groups without an intergroup difference. The B $\perp$ VRL linear measure showed a significant statistical difference between PRE (2.83 mm) and POS (1.39 mm) group. Contrasting with our results, Hansen et al. [20] showed a significant statistical difference between post-pubertal (4.5 mm) and pre-pubertal (2.9 mm) groups, however, these comparisons were made with a statistical direct t-Test application between the three growth phases, increasing the error type I probability [29]. Statistical differences between Herbst treatment effects and control groups in pogonion position were reported by some authors [27, 30, 31] contrasting with others [15, 16, 21, 22, 32] The literature review of Yang et al. [18] reported an incremental random effect of 1.45 mm in pogonion position.

The increase in mandibular length (Co-Gn) was high in the circumpubertal group. Although the increase may not be entirely in the desired direction, explaining the pogonion advancement equal between the groups. The advancement of the pogonion during growth correlates with the vertical modeling of the condylion generating a true rotation of the mandibular bone. The condylion modeling is more superior in Class I malocclusion than Class II[33], and the Herbst effect seems not to change this growth difference.

The vertical skeletal changes.

A downward movement of the maxillary bone was expected due to the natural maxillary bone growth pattern. The ANS $\perp$ HRL and PNS $\perp$ HRL measures showed an increase in all groups with the statistical difference ($P= 0.000$ both) between the Post-pubertal group with the other two growth stages, although this slight difference could be explained by the slowdown in the post-pubertal growth. Similar results in direction and magnitude were reported in post-pubertal [22], pre-pubertal [21, 26], and circumpubertal patients [23]. The maxillary growth restriction (headgear effect) was described by other authors [14, 25, 32] reporting a distance reduction between the palatal bone and the cranial base, which seems to be a transitional effect compensated after Herbst appliance removal [26].

According to the majority of the studies, the Herbst effects over the mandibular plane angle have been reported with similar values as their respective control groups [15, 16, 18, 30, 34, 35]. Mandibular plane changes were not detected by our study, without gender interaction. The Herbst appliance therapy seems to be unable to change the brachyfacial or mesofacial vertical facial pattern, regardless of gender or stage of growth.

In our study, the anterior and posterior facial height (AFH and PFH) were increased continuously, with a statistical difference between the post-pubertal group with the other two groups. This increase represents a downward movement of the mandibular base that could be influenced by natural growth. Some studies in different growth periods showed the same incremental values ($>1.5\text{mm}$) after Herbst therapy in AFH [22, 26, 28, 36, 37]. In contrast, other investigations showed no treatment effects [16, 21]. The increase in the AFH dimensions may not be desirable for the anterior projection of the pogonion since a true mandibular rotation is produced; this effect occurs in hyperdivergent Class II patients after Herbst treatment [15]. In our study, the mandibular plane did not change, and this fact could be explained by the PFH increase, compensating the AFH increase.

The dental changes.

The mandibular incisors inclination is the most reported movement in the literature as a Herbst appliance correction mechanism. The circumpubertal growth group in our study presented a significant ($P=0.005$) higher IMPA value (5.61°) when comparing with the other two groups (4.20° and 4.26°). The same difference was reflected in L1-VRL distance, the circumpubertal group (2.53 mm) was statistically

different ($P= 0.000$) to pre-pubertal (1.12 mm) and post-pubertal group (1.09 mm). In pre-pubertal patients, Almeida et al. [16] showed very similar incisor proclination values (5.0°) and incisor protrusion (1.1 mm), contrasting Wigal et al. [21] presented higher values than us (7.6° and 4.8 mm). Pancherz [27] and Bacetti et al. [37] found in circumpubertal patients, a mandibular incisor protrusion of 1.8 mm and 0.7 mm, respectively. In post-pubertal patients, Kinzinger et al. [22] reported the same movement direction (3.03 mm). At last, contrasting with our results, Hansen et al. [20] reported very low incisor proclination changes (0.2 mm to 0.8 mm) without significant differences between the growth classification phases.

The retraction of the maxillary incisor (U1/S-N measure) was always constant in our study without statistical differences ($P=0.174$). The upper molar movement was always backward instead of the lower molar movement, both independent variables without intergroup statistical significance. In Hansen et al. report [20], the mandibular molars showed more anterior movement in pre-pubertal (1.8 mm) and circumpubertal (1.5 mm) groups than in the post-pubertal group (0.7 mm).

There was a consensus in the literature about the Herbst appliance overjet correction (OJ), with different intensities from -2.70 mm to -7.0 mm [18]. Our study presented a statistically significant difference between the circumpubertal group (-4.62 mm) and the post-pubertal group (-3.55), the pre-pubertal group (-3.98 mm) was statistically equal to both. Contrasting with our study, Hansen et al. [20] reported a higher OJ correction in circumpubertal (CIR) and post-pubertal groups (5.8 mm and 5.6 mm) than pre-pubertal group (4.2 mm). The OJ reduction in Herbst appliance is a reality and seems to be the principal benefit to the patient, even in early mixed dentition, decreasing the risk of dental fracture due to trauma [5].

The limitation of this study was the lack of randomized allocation patients due to the retrospective nature of the investigation. The strengths were the blindness in the cephalometric and statistical evaluation process and the qualitative calibrated allocation of the patients into the growth phases groups.

Conclusions

-The immediate changes in the class II malocclusion produced by Herbst appliance presented the same mechanism of correction in the three CVM classification phases. Mandibular incisor proclination, maxillary incisor retrusion, upper molar backward movement, lower molar forward movement, and minor skeletal effects over

the mandibular length and pogonion and supramentale (B) advance represents the mechanism of correction.

- The vertical changes in the mandibular plane remained without significant alterations. The Herbst appliance therapy seems to be unable to change the brachyfacial or mesofacial vertical facial pattern, regardless of gender or growth stage.

- A significant clinical difference was detected in mandibular length, being the circumpubertal 1.55 mm higher than the post-pubertal group and 1.87 mm than the pre-pubertal group. Nevertheless, that not reflect an increase in pogonion projection.

- The Herbst appliance therapy can be indicated in any phase of craniofacial growth with similar predominant dental improvement

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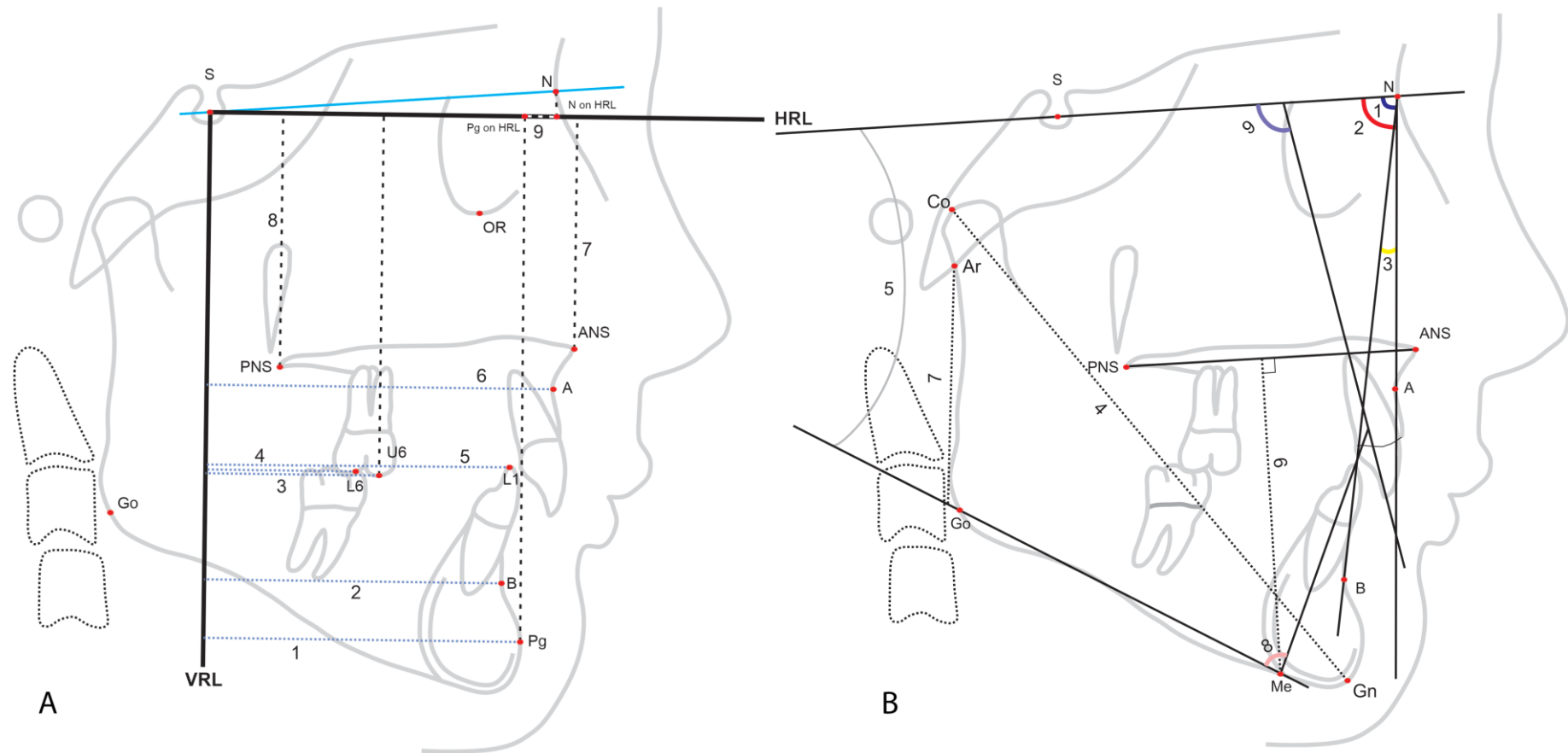
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Figure Legends.

Fig. 1. Anatomic points and cephalometric skeletal and dental measurements. A) linear measures (mm) using the horizontal reference plane (HRL: plane SN-7°) and the vertical reference plane (VRL: perpendicular to HRL). 1) Pg $\perp$ VRL; 2) B $\perp$ VRL; 3) L6 $\perp$ VRL; 4) U6 $\perp$ VRL 5) L1 $\perp$ VRL; 6) A $\perp$ VRL; 7) ANS $\perp$ HRL; 8) PNS $\perp$ HRL; 9) N-Pg on HRL. B) Complementary angular and linear measurements 1) SNA (°); 2) SNB (°); 3) ANB (°); 4) Co-Gn (mm); 5) SN. GoMe (°); 6) AFH: Me $\perp$ PP; 7) PFH: Ar-MP (mm); 8) IMPA: Axis L1.GoMe (°)

Figure.



Tables

Table 1. Baseline characteristics and intergroup comparison. Mean, Standard Deviation (SD), and confidence interval values before treatment (T0) Herbst Appliance

Groups		Prepubertal (n=24)						Circumpubertal (n=33)						Postpubertal (n=38)						
Variable		Mean	n	%	SD	Inf (CI95%)	Sup (CI95%)	Mean	n	%	SD	Inf (CI95%)	Sup (CI95%)	Mean	n	%	SD	Inf (CI95%)	Sup (CI95%)	P value
Age (years)	Average	9.04	A		0.92			12.64			1.22			15.98			0.99			0.000
Sex	Female		11	45.8					15	45.5					16	42.1				0.944†
	Male		13	54.2					18	54.5					22	57.9				
Cephalometric Values	S-N.A (°)	83.21			3.14	81.88	84.53	82.47			4.00	81.05	83.89	82.39			1.55	81.86	82.92	0.819
	S-N.B (°)	76.91			3.03	75.63	78.19	76.93			2.80	75.94	77.93	77.37			3.78	76.08	78.67	0.794
	A-N.B (°)	6.09			1.74	5.35	6.82	5.84			1.27	5.39	6.30	5.76			1.36	5.29	6.22	0.728
	S-N.Go-Me (°)	32.37			3.94	30.71	34.03	32.82			4.27	31.30	34.33	31.84			5.52	29.94	33.73	0.498
	U1/.SN (°)	107.99			5.09	105.84	110.14	108.05			4.07	106.61	109.49	106.90			5.71	104.94	108.86	0.581
	IMPA (°)	98.87			5.23	96.67	101.08	99.88			4.61	98.24	101.52	100.43			3.77	99.14	101.73	0.871
Dental cast measures	Overjet	7.24			1.03	6.80	7.67	7.56			1.27	7.11	8.02	6.91			1.36	6.40	7.36	0.096
	Overbite	2.02	A		1.18	1.53	2.52	2.63	B		1.17	2.22	3.05	1.93	A		1.10	1.55	2.31	0.013
Anteroposterior Class II malocclusion severity (both sides)	1/2 Class II or less		16	33.3					22	33.3					24	31.6				0.744†
	3/4 Class II		15	31.3					24	36.4					29	38.2				
	Full Class II		17	35.4					20	30.3					23	30.3				

SD, Standard Deviation; CI 95%, confidence interval of 95%; †Chi Square test application for categorical distribution; MANOVA test application for the rest of the variables ($\alpha=5\%$); different letters indicates statistically significant differences between groups

Table 2. Cephalometric landmarks, planes and measurements description**Anteroposterior**

SNA, °	Angle between points: the geometric center of the pituitary fossa (Sella, (S)), the anterior frontonasal suture (Nasion (N)) and other in most posterior point of the premaxillary concavity (subspinale, (A))
SNB, °	Angle between points: Sella (S) , Nasion (N) and other point in the deepest part of the concavity between infradentale and pogonion (supramentale (B))
ANB, °	Angle between points: Subspinale (A) , Nasion (N) and Supramentale (B)
Pg ⊥ VRL (mm)	Perpendicular distance between the most anterior point of the chin (pogonion (Pg)) and the <u>vertical reference line</u> (perpendicular line to HRL (VRL))
A ⊥ VRL (mm)	Perpendicular distance between subspinale point (A) and the vertical reference plane (VRL)
B ⊥ VRL (mm)	Perpendicular distance between supramentale point (B) and the vertical reference plane (VRL)
N-Pg on HRL	Distance between one perpendicular projection of pogonion (Pg) on <u>Horizontal reference line</u> (HRL) : registered on Sella (S) and oriented 7° below the S-N plane) to Nasion (N)
Co-Gn (mm)	Distance between the most posterosuperior part posterior border of the mandibular condyle (Condylion (Co)) and the most downward and forward point on the symphysis (Gnathion (Gn))

Vertical

ANS ⊥ HRL mm	Perpendicular distance between tip of the anterior nasal spine (ANS) and horizontal reference line (HRL)
PNS ⊥ HRL mm	Perpendicular distance between tip of the posterior nasal spine (PNS) and horizontal reference line (HRL)
SN/GoMe mm	Angle between two planes: plane Sella (S) - Nasion (N) and Gonion (Go) - Menton (Me) . Gonion (Go) : Intersection of the line connecting the most distal aspect of the condyle to the distal border of the ramus, and the line at the base of the mandible (MP)
AFH, mm	Perpendicular distance between menton (Me) to <u>palatal plane</u> (PP) created through ANS and PNS points, anterior facial height AFH
PFH, mm	Distance between a point in the posterior border of the ramus and the inferior border of the posterior cranial base (Articulare (Ar)) and the mandibular plane (MP) parallel to posterior ramus border, posterior facial height PFH

Dental

IMPA	Angle between long axis of the mandibular central incisor and the plane Gonion (Go) - Menton (Me)
L1-VRL	Perpendicular distance between tip of the upper incisor (L1) to VRL plane
U1/SN	Angle between long axis of the maxillary central incisor and Sella (S) - Nasion (N) plane
U6 ⊥ VRL	Perpendicular distance between mesial cusp of the upper first molar (U6) to VRL plane
L6 ⊥ VRL	Perpendicular distance between mesial cusp of the lower first molar (L6) to VRL plane
Overjet	Horizontal distance between the incisal edge of the most prominent upper central incisor and the buccal surface of the antagonist lower incisor

Table 3. Comparisons of cephalometric changes after Herbst appliance therapy (T1-T0) in three different stages of cervical maturation growth (paired t test and MANCOVA).

Groups	Prepubertal PRE (n=24)				Circumpubertal CIR (n=33)				Postpubertal POS (n=38)				MANCOVA	Gender interaction
Variable	Mean	SD	Inf (CI95%)	Sup (CI95%)	Mean	SD	Inf (CI95%)	Sup (CI95%)	Mean	SD	Inf (CI95%)	Sup (CI95%)	P value	P value
Anteroposterior														
SNA, °	-0.20	1.76	-0.90	0.51	-0.09	3.03	-1.13	0.94	-0.29	1.12	-0.64	0.07	0.911	0.414
SNB, °	1.47	1.68	0.80	2.14	0.88	1.62	0.33	1.43	0.96	0.83	0.69	1.22	0.268	0.621
ANB, °	-1.67	1.66	-2.24	-0.91	-0.97	2.35	-2.01	-0.40	-1.25	1.05	-1.44	-0.77	0.372	0.713
Pg ⊥ VRL (mm)	2.89	2.68	1.82	3.96	2.23	2.61	1.34	3.12	1.48	2.03	0.84	2.13	0.081	0.944
A ⊥ VRL (mm)	0.82	1.91	0.05	1.58	0.61	2.73	-0.32	1.54	0.25	1.00	-0.07	0.56	0.536	0.832
B ⊥ VRL (mm)	2.83 A	2.43	1.86	3.80	1.98 AB	2.51	1.12	2.84	1.39 B	1.46	0.91	1.87	0.029	0.967
N-Pg on HRL	1.82	2.55	0.81	2.84	1.20	3.36	0.05	2.35	1.35	1.78	0.78	1.91	0.678	0.908
Co-Gn (mm)	2.59 A	1.89	1.84	3.35	4.46 B	3.17	3.38	5.54	2.91 A	3.12	1.92	3.90	0.020	0.290
Vertical														
ANS ⊥ HRL mm	1.31 A	2.09	-2.15	-0.48	1.61 A	2.48	-2.45	-0.76	0.80 B	1.10	-1.15	-0.45	0.000	0.976
PNS ⊥ HRL mm	0.70 A	1.21	-1.18	-0.21	1.06 A	1.11	-1.44	-0.68	0.39 B	1.09	-0.73	-0.04	0.000	0.071
SN/GoMe mm	0.19	1.38	-0.36	0.74	0.31	2.31	-0.48	1.10	-0.10	1.81	-0.68	0.47	0.648	0.934
AFH, mm	2.13	1.63	1.48	2.79	2.62	1.88	1.98	3.26	1.69	1.35	1.26	2.12	0.062	0.897
PFH, mm	0.95 A	2.15	0.09	1.81	2.43 B	1.91	1.78	3.09	1.83 B	1.88	1.23	2.43	0.020	0.542
Dental effects														
IMPA, °	4.20 A	1.63	3.52	4.89	5.61 B	2.28	4.81	6.42	4.26 A	1.49	3.78	4.76	0.005	0.970
L1-VRL, mm	1.12 A	0.33	0.98	1.26	2.53 B	1.02	2.18	2.90	1.09 A	0.84	0.82	1.37	0.000	0.688
U1/S-N, °	-3.87	2.29	-4.84	-2.91	-4.86	2.77	-5.84	-3.88	-3.90	2.43	-4.70	-3.10	0.174	0.436
U6 ⊥ VRL, mm	-2.22	3.36	-3.56	-0.87	-1.46	1.80	-2.10	-0.82	-1.05	2.33	-1.80	-0.32	0.214	0.893
L6 ⊥ VRL, mm	4.09	1.69	3.42	4.77	4.02	1.88	3.38	4.66	3.38	2.10	2.71	4.04	0.210	0.959
Over Jet correction, mm	-3.98 AB	1.12	-4.46	-3.51	-4.62 A	1.33	-5.09	-4.15	-3.55 B	1.85	-4.17	-2.95	0.016	0.070

MANCOVA indicates a multivariate analysis of covariance, global test results: $F(36,146) = 4.583$; $P=0.000$; $1-\beta=1$; $f=0.50$; SD, standard deviation; n, patients include in each group; CI 95%, confidence interval of 95%; **Bold**, represent a statistical intra group difference of the variable ($\alpha < 0.05$); Gender interaction: represent the P value of the interaction between growth phase and gender; Different letters indicates statistical significant differences in the intergroups comparisons

3.2 Publicação 2*

Association between Class II malocclusion occlusal severity and craniofacial growth phase with treatment effectiveness after Herbst therapy in growing patients.

* Artigo segue as normas do periódico "Dental Press Journal of Orthodontics" ao qual será submetido.

Abstract

Introduction:

The purpose of this study was to evaluate the effectiveness of correcting class II malocclusion with a Herbst functional device considering [1] the anteroposterior occlusal severity (APOS) and [2] the craniofacial growth phase (CGP) of the patients at the beginning of treatment.

Methods

Data from the orthodontic documentation of 87 patients with Class II malocclusion treated consecutively with Herbst appliance therapy was analyzed. Through qualitative observation of dental study models and cephalometric measures, the patients were allocated in different categories according to the initial APOS and CGP. APOS was classified based on the first permanent molar occlusal relationship as Half Class II, three-quarter Class II, and Complete Class II. CGP was assessed by the cervical maturation method and classified as prepubertal, circumpubertal, and postpubertal. The association between the effectiveness of Class II correction with the CGP, the APOS, treatment time, and gender was tested using Pearson's correlation and the chi-square test.

Results.

Herbst appliance therapy effectiveness presents a small positive correlation between the patient's CGP at the beginning of the treatment ($p < .002$, $r_s = .206$) and its initial APOS ($p < .002$, $r_s = .231$). Treatment time and gender were not statistically correlated.

Conclusions.

The effectiveness of Herbst functional therapy has a small association with the CGP and the APOS at the start of therapy. The beginning of treatment in the prepubertal CGP and Half with Class II APOS showed a higher number of desire overcorrections in Class II malocclusion therapy with Herbst appliance.

Keywords: Class II Malocclusion, Division 1; Functional jaw orthopedics; Herbst, appliance;

Introduction

The satisfactory Class II malocclusion correction with Herbst appliance therapy has been shown for many years. The device's effectiveness is extensively described in the literature with remarkable dental, skeletal, and soft tissue effects (1). The majority of the studies about Herbst appliance were made based on cephalometric or dental cast measures, disregarding the anteroposterior occlusal severity (APOS) before and after treatment.

Class II malocclusion prevalence has been reported with a Global distribution of 20% in the permanent dentition (2). In the literature, a wide variety of etiological factors, ethnicity, environment, and genetics have been described as the main contributors. The need for malocclusion treatment arises from all functional and aesthetic problems related to skeletal and dental discrepancies. These facts contribute that many Class II malocclusion patients are routinely seen in orthodontic practice. Once the patients are in the dental office, the orthodontist has the imperative necessity of classifying the affected structures, their intensity, and the morphologic patients' characteristics.

Andrews's malocclusion classification introduced in 1979, a complement to the original Angle's classification, allows a more precise clinical evaluation of the severity of the Class II malocclusion, impacting diagnosis and treatment planning decisions (3). There were indications that treatment time and the effectiveness of correcting Class II malocclusion were associated with the severity of the anteroposterior occlusal discrepancy. A bilateral half Class II malocclusion seems to have a better treatment success rate than the treatment of a bilateral complete Class II malocclusion without extraction (4).

The controversy over the most efficient time for intervention with functional appliances remains current. Some evidence supports the class II malocclusion treatment in the prepubertal growth phase, with satisfactory overjet and molar relationship correction (5), and mainly to its direct relation to reducing the incidence of incisor trauma (6). On another note, functional appliances in the peak of craniofacial growth have been associated with more skeletal effects in mandibular length compared with the other phases (7). Finally, Ruf and Pancherz (8) proposed the young permanent dentition just after the pubertal peak of growth as an ideal period for Herbst appliance treatment, due to the efficiency observed in the treatment (better result in less time of treatment) (9). Notably, all of these studies used quantitative measures without considering the initial anteroposterior occlusal severity.

This study aims to assess the association between [1] initial CGP and [2] initial APOS, with the effectiveness correction of the Class II malocclusion with Herbst appliance therapy. This study was performed via cephalometric measurements and orthodontic models' observation.

Material and methods.

This study was approved in the human ethical committee with the protocol number 29320919.6.0000.5416. This retrospective study used orthodontics' documentation of previous prospective nature studies. Eighty-seven patients in the course of Herbst Class II malocclusion therapy were selected following the next criteria: (1) Class II division 1 malocclusion, (2) Pretreatment Overjet > 4 mm, (3) Hypodivergent or mesofacial phenotype with SN.GoMe angle <36°, (4) ANB angle > 4°, (5) at least the mandibular and maxillary permanent incisors and first permanent molar eruption, (6) mandibular incisor crowding < 3 mm, (8) the proper physical condition of lateral radiographs and orthodontic' plastic models with the correct registration of the habitual occlusion of the patient.

Using the G*Power Version 3.1.9 software (Franz Faul, Germany), the goodness of fit test for contingency tables were evaluated. The sensitivity of the sample was calculated with an α error of 0.05, power of 0.80 (1- β err prob), Df 5, and total sample size of 84, the final effect size sensitivity was medium ($w = 0.32$).

All 87 patients were treated by three Ph.D. experienced orthodontists. The Herbst appliance was constructed with a telescopic mechanism coming out from the first upper molar to an occlusal rest between canine (or mandibular first deciduous molar in PRE-group) and mandibular first premolar of the steel lower lingual arch. The two bands or crowns on the first upper molars were united per one cantilever device or a hyrax expansion screw in the palatal area, depending on the transversal necessity of the patient. When needed, the maxillary expansion protocol started with the first activation one week after device installation until it achieved a transversal overcorrection. The Herbst appliance's construction was to achieve an edge to edge position when possible, with a maximum advancement of 6 mm and increment of 2 mm when necessary.

Data from orthodontic documentation pretreatment (t1) and post-treatment (t2) lateral cephalometric radiographs and plaster models of 87 patients with Class II malocclusion treated with Herbst appliance therapy was analyzed.

Pretreatment (T1) and post-treatment (T2) plater study models were scanned (3Shape's R700™, Copenhagen, Denmark) with the patient in the maximum intercuspation occlusion to obtain an STL image of the digital models. Through qualitative dental study models observation, the patients were allocated in three different categories according to the initial APOS using the visual Andrews'

malocclusion classification(3). APOS was classified based in the first permanent molar relationship as half or less than Class II (Group 1), three-quarter of Class II (group2), and Full Class II (Group 3)(Figure 1). Overjet and overbite quantitative values were measures using the VistaDent 3D software (Dentsply GAC, New York, USA). The relationship of the first permanent molars of the patients in maximum intercuspation occlusion after Herbst therapy (T2) were evaluated on both sides of the dental arch, defining four categories of treatment effectiveness: Overcorrection (Angle Class III), Correction (Angle Class I), Moderate correction (1/4 of Class II) and deficient correction (Half Class II).

Pretreatment (T1) and post-treatment (T2) lateral cephalometric radiographs were scanned (Scanjet® G4050, Hewlett-Packard, Palo Alto, California) with a standard resolution of 300 DPI and using a 100 mm ruler to avoid size image distortion. Cephalometric analyses were performed with the Radiocef 2 software (Radio Memory®, Belo Horizonte, MG, Brazil) (Table 1). The CGP of the patient at the beginning of the treatment (T1) was accessed by the cervical vertebrae maturation (CVM) method and classified into three categories: prepubertal, circumpubertal, and postpubertal.

The association between the effectiveness of Class II correction with the CGP, the APOS, treatment time, and gender was tested using Pearson's correlation and the chi-square test.

Statistical analysis.

In a blinding process, the data was analyzed with a general five percent alpha ($\alpha=0.05$) using the Statistical Package for the Social Sciences software package (SPSS for Windows, version 20.0; IBM, Armonk, NY). The categorical group allocation was replicated in one hundred models, and APOS intra-reliability was evaluated via Cohen's Weighted kappa coefficient ($K=0.94$). Quantitative measures were replicated in 60 lateral cephalograms with a thirty-day interval by one blinding operator. The systematic and random errors of the variables were individually tested using a one-sample paired t-test ($p\text{-value} > .352$), correlation coefficient ($ICC > .87$), and Dahlberg formula ($D < .40\text{ mm}$, $D < 1.85^\circ$).

Quantitative baseline characteristics and cephalometric changes after treatment were analyzed using a multivariate variance teste (MANOVA), previously the Shapiro-Wilk test showed the required normal distribution. The categorical proportions at T1 between groups were analyzed via the Chi-square test. The changes in the molar and

canine anteroposterior relationship (T1-T2) that represent the effectiveness of the treatment after Herbst therapy were correlated with other variables (Table 2) via the Spearman correlation test. The treatment time was used as a covariable in correlation analysis between the pretreatment patient growth phase and correction effectiveness. Finally, the association between the effectiveness of the Class II correction, APOS, and CGP at the beginning of the treatment were tested using Chi-square or Fisher exact test. Cramer's V test was used to measure the association level in cases of significance ($p < .05$).

Results.

Baseline comparison between groups before Herbst therapy are resumed in Table 1. The categorical distribution in gender and craniofacial growth phase at the beginning of the treatment was equilibrated. Only one statistical difference was presented in quantitative variables. The Overbite was 0.76 mm different ($P = .030$) in the circumpubertal group when compared with the other two groups.

The cephalometric changes comparison amongst groups were resumed in Table 2. The treatment changes in mandibular incisor proclination ($P = .010$), mandibular length ($P = .020$), and Overbite ($P = .010$) measures were different amongst groups.

Correlation between quality results after Herbst therapy and different variables are resumed in Table 3. Molar quality correction after treatment presented a positive correlation with patient growth phase at the beginning of the treatment ($p < .002$, $rs = .206$), and initial anteroposterior Class II severity ($p < .002$, $rs = .231$). In Canine quality correction, only the patient growth phase at the beginning of the treatment ($p < .002$, $rs = .206$) was positively correlated. Treatment time and gender were not statistically correlated. These associations were confirmed in the Chi-square or Fisher Exact, and Cramer's V tests resumed in Figure 2 and Table 4.

Discussion.

The beginning of the Herbst therapy in different growth phases has a small association with the quality of the anteroposterior Class II molar correction. Forty-six percent of the patients in our sample treated in the prepubertal phase finished the treatment with angle molar Class III indicating an overcorrection of the molar relationship; this is the main desired result in functional Class II treatment due to the expected relapse after Herbst appliance removed (10). In contrast, only twenty-three and twenty percent in circumpubertal and postpubertal patients, respectively, were overcorrecting.

The functional orthopedic treatment of Class II malocclusion with the Herbst appliance has been investigated with similar correction mechanisms in all phases of craniofacial growth. Early treatment in mixed dentition has been demonstrated to contribute to an upper incisor trauma reduction associated with the diminution of overjet excess (6). Although the correction effect of the Class II malocclusion during the prepubertal phase has been demonstrated (5,11–13), remaining craniofacial growth cannot be ignored, and the active retention period can be more extensive (14).

Wigal et al. (5) reported the stability of Class II correction after Herbst therapy in the mixed dentition. The study reported a positive overjet correction of 7.0 mm and a molar relation correction of 6.6 mm. With a similar correction mechanism previously reported in other CGP, the authors described maxillary restriction (0.4 mm) forward movement of the mandible (2.0 mm), maxillary incisors retroclination (3.7 mm), and forward movement of the mandibular incisor (0.9 mm). In the second phase of the treatment with fixed appliances, they reported a posterior movement of the mandible (1.6 mm), showing the retention period necessity.

It has been demonstrated that accelerated modifications in the mandibular bone occur during circumpubertal growth, between stages Cvs3 to Cvs4 of the cervical vertebral maturation method (15,16). Some authors have been proposed this growth spurt as the most efficient phase for skeletal Class II malocclusion treatment (17–19). In our study, agreeing with the literature, the circumpubertal group presented a statistically different mandibular length increase, higher than other groups. In our qualitative association, this growth increase appears not to influence a better occlusal response when compared with the prepubertal and postpubertal phases. However, fifty percent of the patients showed a favorable correction resulting in an Angle Class I molar relationship.

Previous studies of Herbst therapy in postpubertal Class II patients report successful treatment, mainly in dental effects (20–22). Konik et al. (20) describe some advantages of the functional treatment in the postpubertal phase; the necessity of active retention is short, and better occlusal stability can be achieved due to more intercuspation. Although more incisor proclination was reported when compared with early treatment. In our results, the majority of patients beginning treatment in this growth phase present a “moderate correction” in the molar relationship, indicating one-quarter of Class II malocclusion at treatment final. However, this final occlusal severity can be easily corrected with fixed appliances in the second phase of the treatment.

The treatment time appears not to be a decisive factor in improving a better-quality correction of class II malocclusion with Herbst appliance. The correlation between patient growth phase at the beginning of the treatment with the canine and molar correction quality remains statically significant, even using the treatment time as a covariable. Furthermore, in the direct correlation test between treatment time and quality, results were not statistically significant. In previous reports, Herbst appliance using time has been reported at intervals from 5 to 15 months (23–27). Tomblyng et al., in a study where the treatment time was doubled to 1.5 years, reported a class II malocclusion correction mechanism mainly with a dental response with Herbst therapy. In contrast, Wieslander reported (27) similar results in patients who received therapy in a period of five months.

A small association was found between initial occlusal severity and the class II molar relationship correction quality with Herbst appliance. In half Class II malocclusion, the majority of the molar relationships were overcorrected (forty-two percent) or corrected (thirty-three percent) after functional therapy. The better treatment success rate in bilateral half Class II malocclusion has been reported previously by Janson et al. (4) in no extraction therapies, our findings supported this data. However, three quarters and complete molar Class II severity groups achieved a moderate or complete correction in most of the cases. The deficient correction (half or more Class II severity at final treatment) was presented only in thirteen percent of the complete class II severity group cases, the more significant relative frequency of all groups.

The study limitation is the lack of randomized sample selection due to the retrospective nature of the research. In compensation, the allocation of individuals in the sample groups, qualitative and qualitative measures, and statistical analysis was done in a blinding process.

Conclusions.

- Exist a small association between the initial stage of growth and the anteroposterior occlusal severity at the start of therapy, with the effectiveness' correction of class II malocclusion with Herbst functional device.
- The beginning of treatment in the prepubertal growth phase represented a higher number of overcorrections in the class II molar relationship.
- Half Class II malocclusion severity have a better prognosis in Herbst functional treatment, with the majority of the cases overcorrected. However, three quarters and complete molar Class II severity also can be satisfactorily corrected.
- Treatment time appears not to have a direct relationship with the final occlusal quality correction, and craniofacial growth and occlusal severity may have more influence in Class II malocclusion correction with Herbst therapy.

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Tables

Table 1. Baseline characteristics and intergroup comparison. Mean, Standard Deviation (SD), and confidence interval values before Herbst Appliance treatment (T1)

Groups		Prepubertal (n=21)						Circumpubertal (n=32)						Postpubertal (n=34)						
Variable		Mean	n	%	SD	Inf (CI95 %)	Sup (CI95%)	Mean	n	%	SD	Inf (CI95%)	Sup (CI95%)	Mean	n	%	SD	Inf (CI95%)	Sup (CI95%)	P value
Age (years)	Average	9 A			0.93	8.58	9.42	12.60 B			1.2206 5	12.16	13.04	15.9 C			1.01316 2	15.58	16.29	0.000
Sex	Female		10	47.61					14	43.7 5					13	38.23				0.944*
	Male		11	52.38					18	56.2 5					21	61.76				
Cephalometric Values	S-N.A (°)	83.50			3.21	82.03	84.96	82.52			4.06	81.05	83.98	82.37			1.56	81.82	82.92	0.389
	S-N.B (°)	77.27			2.88	75.96	78.58	77.00			2.81	75.99	78.02	77.31			3.81	75.98	78.64	0.922
	A-N.B (°)	5.99			1.73	5.20	6.78	5.83			1.29	5.36	6.30	5.81			1.35	5.34	6.28	0.890
	Witts (mm)	6.30			1.93	5.48	7.11	5.54			2.65	4.60	6.47	5.50			2.05	4.83	6.18	0.345
	1/.SN (°)	107.7 3			5.10	105.4 1	110.06	107.8 6			3.98	106.42	109.29	106.7 2			5.69	104.73	108.70	0.797
	IMPA (°)	98.76			5.30	96.35	101.17	99.90			4.69	98.21	101.59	100.4 7			3.82	99.14	101.81	0.607
	S-N.Go-Me (°)	32.49			4.20	30.58	34.40	32.70			4.29	31.16	34.25	31.92			5.58	29.98	33.87	0.399
Molar Class II malocclusion severity (both sides)	1/2 Class II or less		14	33.33					22	34.3 75					21	30.88				0.878*
	3/4 Class II		13	30.95					24	37.5					27	39.70				
	Full Class II		15	35.71					18	28.1 25					20	29.41				
Dental cast measures	Over Jet (mm)	7.24			1.11	6.74	7.75	7.50			1.22	7.06	7.94	6.98			1.40	6.49	7.47	0.258
	Over Bite (mm)	1.89 A			1.10	1.39	2.40	2.56 B			0.99	2.20	2.92	1.80 A			0.97	1.47	2.14	0.007

SD, Standard Deviation; *Chi Square test application; MANOVA test application for the rest of the variables ($\alpha=5\%$); different letters indicates statistically significant differences ($p<0.05$) between groups

Table 2. Comparisons of cephalometric changes after Herbst appliance therapy (T2-T1) in three different stages of cervical maturation growth (paired t test and MANCOVA).

Groups	Prepubertal PRE (n=24)				Circumpubertal CIR (n=33)				Postpubertal POS (n=38)				Manova
Variable	Mean	SD	Inf(CI95%)	Sup(CI95%)	Mean	SD	Inf(CI95%)	Sup(CI95%)	Mean	SD	Inf(CI95%)	Sup(CI95%)	P value
SNA, °	-0.18	1.68	-0.95	0.58	-0.01	3.05	-1.11	1.08	-0.33	1.23	-0.76	0.09	0.837
SNB, °	1.45	1.60	0.72	2.17	0.92	1.62	0.34	1.51	0.88	0.88	0.57	1.19	0.291
ANB, °	-1.63	1.83	-2.46	-0.79	-0.94	2.78	-1.94	0.06	-1.22	0.94	-1.55	-0.89	0.474
SN/GoMe mm	0.29	1.40	-0.34	0.93	0.26	2.33	-0.58	1.11	0.08	1.77	-0.54	0.69	0.893
Co-Gn (mm)	2.59 A	1.89	1.84	3.35	4.46 B	3.17	3.38	5.54	2.91 A	3.12	1.92	3.90	0.020
IMPA, °	4.41 AB	1.58	3.70	5.13	5.5 A	2.25	4.71	6.34	4.17 B	1.52	3.64	4.70	0.010
U1/S-N, °	-3.79	2.44	-4.90	-2.68	-4.78	2.78	-5.79	-3.78	-4.04	2.52	-4.92	-3.16	0.334
Over Jet (mm)	-3.99	1.20	-4.54	-3.44	-4.56	1.30	-5.03	-4.09	-3.64	1.89	-4.30	-2.99	0.058
Over Bite (mm)	-0.39 A	0.94	-0.82	0.04	-1.59 B	1.17	-2.01	-1.17	-0.58 A	1.16	-0.99	-0.18	0.000

SD, standard deviation; n, patients include in each group; CI 95%, confidence interval of 95%; **Bold**, represent a statistical intra group difference ($\alpha < .05$); Different letters indicates statistically significant differences in the intergroups comparisons in the same line

Table 3. Correlation coefficient of the Molar and Canine final correction (T2) with the listed variables.

Tooth	Variable	<i>P</i> value	<i>r</i>
Molar	Patient Growth phase at T1	0.002	0.206*
	Treatment time	0.494	-0.052
	Gender	0.172	0.104
	Initial Class II Molar severity	0.002	0.235*
Canine	Patient Growth phase at T1	0.001	0.292*
	Treatment time	0.555	-0.045
	Gender	0.22	0.093
	Initial Class II Canine severity	0.463	0.056*

r= Spearman's correlation coefficient; *indicates partial correlation with treatment time or patient growth phase as a covariable

Table 4. Variables associated with the effectiveness of anteroposterior Class II occlusion severity correction after Herbst Appliance Therapy

Variable		Overcorrection		Correction		Moderate correction		Deficient		Row totals		Chi ² ; df	P value
		n	%	n	%	n	%	n	%	n	%		
Molar APOS (both sides)	1/2 Class II or less	22	38.6	21	36.8	10	17.5	4	7.0	57	100	*	0.035*
	3/4 Class II	17	26.6	23	35.9	22	34.4	2	3.1	64	100		
	Full Class II	8	15.1	20	37.7	18	34.0	7	13.2	53	100		
	Colum totals	47	27.0	64	36.8	50	28.7	13	7.5	174	100		
Canine APOS (both sides)	1/2 Class II or less	9	16.1	15	26.8	20	35.7	12	21.4	56	100	9.690; 6	0.157
	3/4 Class II	8	11.1	12	16.7	39	54.2	13	18.1	72	100		
	Full Class II	2	4.5	15	34.1	18	40.9	9	20.5	44	100		
	Colum totals	19	11.0	42	24.4	77	44.8	34	19.8	172	100		
Craniofacial growth phase (Molar association)	Prepubertal	18	42.9	14	33.3	4	9.5	6	14.3	42	100	27.350; 6	.000
	Circumpubertal	15	23.4	32	50.0	15	23.4	2	3.1	64	100		
	Postpubertal	14	20.6	18	26.5	31	45.6	5	7.4	68	100		
	Colum totals	47	27.0	64	36.8	50	28.7	13	7.5	174	100		
Craniofacial growth phase (Canine association)	Prepubertal	13	31.0	13	31.0	11	26.2	5	11.9	42	100	2.037; 6	.000
	Circumpubertal	4	6.3	13	20.3	33	51.6	14	21.9	64	100		
	Postpubertal	2	2.9	16	23.5	35	51.5	15	22.1	68	100		
	Colum totals	19	10.9	42	24.1	79	45.4	34	19.5	174	100		

APOS, anteroposterior Class II occlusal severity; Chi², Chi-square test; df, degrees of freedom; * indicates Fisher's exact test

Figueres and Illustration Legends.

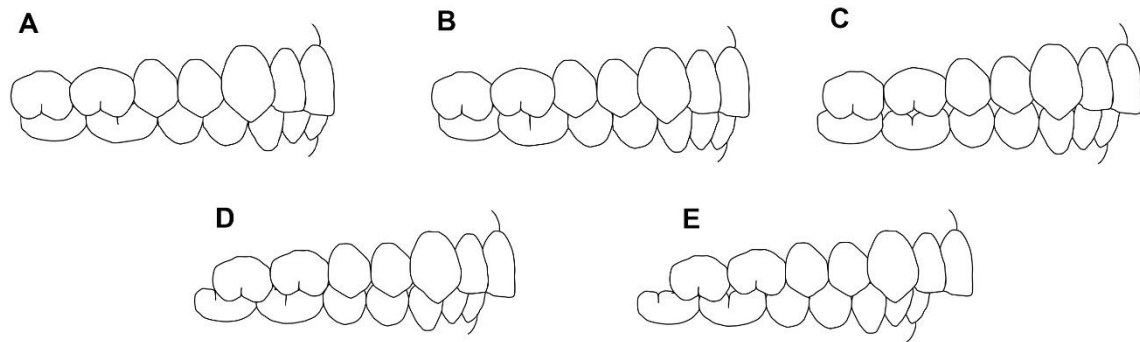


Fig 1. Class II malocclusion occlusal severity. A) Angle Class I relationship; B) Quarter Class II C) Half Class II; D) Three-quarter Class II; E) Complete Class II.

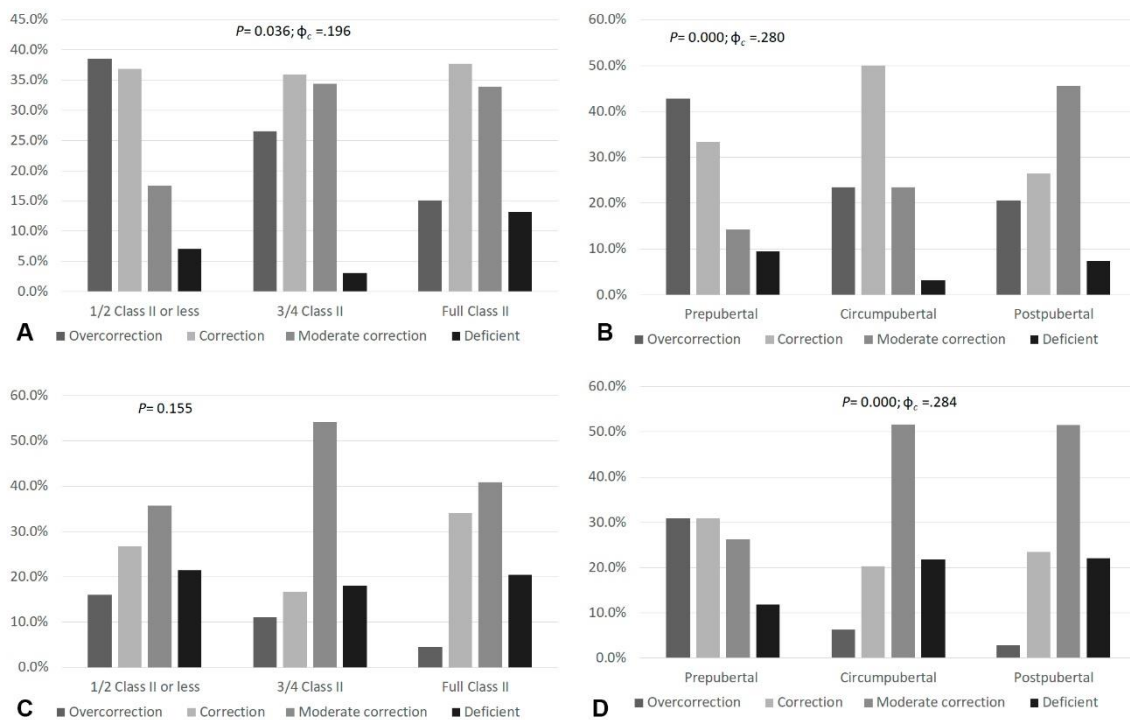


Fig 2. Relative Frequency Graphics and association tests between listed variables with quality correction categories (overcorrection, correction, moderate correction, deficient) after Herbst appliance therapy in Class II malocclusion patients. A) Initial molar occlusal severity and quality correction; B) Initial Growth phase and molar quality correction; C) Initial canine occlusal severity and quality correction; D) Initial Growth phase and canine quality correction; P value of Chi-square association test; ϕ_c = Cramer's V value

3.3 Publicação 3*

Comparisons of soft tissue changes after Herbst appliance treatment in three different growth phases.

*Artigo segue as normas do periódico "European Journal of Orthodontics" ao qual foi submetido.

Abstract

Objectives: This study aimed to compare the Herbst appliance soft tissue changes in Class II malocclusion patients treated in three different craniofacial growth phases: prepubertal, circumpubertal, and postpubertal.

Materials and Methods: Ninety-five patients with Class II division 1 malocclusion previously treated with Herbst appliance were analyzed. Through the cervical vertebral maturation method at the beginning of the treatment, patients were allocated into three groups: prepubertal (PRE), circumpubertal (CIR), and postpubertal (POS). Fifteen cephalometric measures were obtained from each lateral radiograph before (T1) and after (T2) Herbst therapy using the Radiocef 2 software (Radio Memory, Belo Horizonte). Intragroup and Intergroups treatment changes (T2-T1) were compared statistically using a paired t-test and MANOVA test, respectively.

Results: Although all three groups presented significant decreasing in the facial convexity, PRE and CIR groups showed significant more decreasing than Pos group. Soft facial convexity and mentolabial sulcus depth decreased significantly for all groups, but reduced more in the PRE and the CIR groups than in the POS group. Significant soft tissue thickening were related to the mandible; PRE group showed thickening of the CL1_LL, B_B', and Pog_Pog', while POS group showed thickening only for CL1_LL'. In addition, PRE group showed larger thickening of soft tissue than POS group (B_B' and Pog_Pog') and CIR group (CL1_LL', B_B', and Pog_Pog'). Skeletal and soft facial convexity changes presented a moderately low positive correlation, and skeletal and soft pogonion presented a moderately high positive correlation.

Conclusions: The Herbst appliance therapy produces soft tissue improvements in the three phases of craniofacial growth, being more intense in prepubertal and circumpubertal patients

Introduction

Class II malocclusion is observed in approximately one-third of growing subjects (1). When evaluated based on overjet, approximately 23% of the children (between 8 and 11 years of age) and 16% of the teenagers (between 12 and 17 years of age) present Class II malocclusion (2). The literature has consistently reported that differences between Class I and Class II subjects are due primarily to the anteroposterior (AP) position of the mandible (3,4), and a therapy able to enhance mandibular growth should be indicated.

Animal studies have shown that mandibular skeletal sagittal changes could be produced by posturing the mandible forward (5,6). In addition, orthodontists were taught that superior and posterior condylar growth would result in an inferior and anterior displacement of the mandible (7), and this idea undoubtedly influenced the development of functional appliances to treat Class II malocclusion. Then, mandibular advancement devices began to be used for the correction of the AP discrepancies. Among the functional appliances, the Herbst appliance has been demonstrated its capacity to improve sagittal intermaxillary discrepancy present in Class II malocclusion subjects (8).

Eliminating patient compliance Herbst appliance has effectivity treated Class II malocclusion (9). However, the literature is controversial in regards to the extent of skeletal and dentoalveolar adaptations in Class II correction with fixed functional appliances. The skeletal component of Class II correction has been reported ranging from approximately 15% to 85% (9–11). Herbst device decreases sagittal skeletal discrepancy due to skeletal effects, mainly due to headgear effect (12–16). Additionally, there is an overall increase in total mandibular length has been shown (13,14,17), but the mandible is not displaced anteriorly (14). Also, it has been very well documented that the Herbst appliance redirects posteriorly the condylar growth (14,18,19) making the forward true rotation of the mandible harder to obtained (20). Dentoalveolar changes include mandibular incisor proclination (12), maxillary incisor retrusion (21–23), maxillary molars distalization (12), and mesial movement of the first mandibular molars (17).

Inconsistencies could be influenced by the best skeletal growth period to begin the fixed functional therapy. (24). Although a very similar correction mechanism has been reported in each Craniofacial Growth phase (GCP), the corrections' intensity remains controversial. Early Herbst therapy before the pubertal peak was reported as a

successful and stable treatment (14,25,26), demonstrating significant incidence reduction of incisal trauma (27). Due to the accelerated length growth of the mandibular bone during growth peak, other authors associated the circumpubertal GCP as the optimal to functional appliance therapy (9,28). Furthermore, with less literature evidence, the postpubertal GCP Herbst treatment has been reported as useful in overjet reduction (21,22,29). The clinical signs of the Class II malocclusion are evident in the deciduous dentition and persist through the mixed dentition (30) until the permanent dentition. In terms of craniofacial growth, on which the effectiveness of the functional orthopedic treatment depends, the orthodontist's performance time is quite extensive. The selection of the ideal craniofacial growth phase (CGP) for the start of orthodontic treatment seems to be confusing and based on clinical experiences or isolated studies. Some authors have presented some evidence of effectiveness in Herbst therapy in this CGP, with a very sharp dentoalveolar correction (21,29,31,32). The effect of functional appliance therapy on soft tissue also have been studied. The influence of the Herbst therapy on soft tissue changes consist mainly of a reduction of the facial convexity and improvement on the mentolabial sulcus depth (32–36). Some authors reported an anterior displacement of soft tissue pogonion and lower lip (22,33), contrasting with others (35–37). All these profile changes are visually desired by orthodontists, general dentists and laypersons(38). Nevertheless, soft tissue changes due to Herbst therapy have not been evaluated extensively. Knowing the effects of the Herbs appliance on soft tissue in each CGP could assist the orthodontist selection of the most efficient treatment phase.

This study aimed to compare the Herbst appliance soft tissue effects in Class II malocclusion patients treated in three different craniofacial growth phases: prepubertal, circumpubertal, and postpubertal. The null hypothesis was that there are no differences in soft tissue convexity and soft tissue thickness changes due to Herbst therapy among the prepubertal, circumpubertal, and postpubertal groups.

Material and method

Trial design and any changes after trial commencement

This observational longitudinal retrospective study was performed at the Department of Orthodontics at Sao Paulo State University School of Dentistry (UNESP), Araraquara, Brazil, and approved by the ethics committee of the university (protocol #29320919.6.0000.5416). Informed consent was obtained from the parents of all patients who agreed to participate in this study.

Participants, eligibility criteria, and settings

The sample comprised 95 growing patients who were treated using a fixed functional Herbst appliance by three experienced orthodontists. Patients were selected based on the following criteria: Class II division 1 malocclusion, overjet > 4 mm, mandibular plane angle <36°, ANB angle > 4°, all first molars in occlusion, mandibular and maxillary permanent incisors in eruption, mandibular crowding < 3 mm, no dentofacial deformities, syndromes, no temporomandibular joint dysfunction, and good visual condition of lateral radiographs.

Based on cervical vertebral maturation stage (CS),(39) the patients were allocated in three groups: PRE (prepubertal, stages CS1 and CS2), CIR (circumpubertal, CS3 and CS4, and POS (postpubertal, CS5 and CS6). Group PRE included of 24 patients (11 females and 13 males), mean age of 9.04 years, Group CIR comprised 33 patients (15 females and 18 males), mean age of 12.64 years, and the Group POS composed of 38 patients (16 females and 22 males), mean age of 15.98 years (Table 1). To better evaluate the sagittal discrepancy, each group was also described under Andrews classification(40), and no significant difference among groups was shown (Table 1).

Interventions

The Herbst fixed functional appliance consisted of a telescopic mechanism coming out from the first upper molar to an occlusal rest between canine (or mandibular first deciduous molar in PRE-group) and mandibular first premolar of the steel lower lingual arch (Figure 1). The two bands or crowns on the first maxillary molars were united with a passive transpalatal arch (stainless steel, .036" diameter) or a hyrax expansion screw in the palatal area, depending on the transversal maxillary discrepancy of the patient. In 33 patients the maxillary expansion protocol started with the first activation one week after the device installation until a transversal overcorrection was achieved; two turns a day (1/2 mm). Subjects presenting overjet $\leq$ 6 mm had the Herbst device set to achieve an edge-to-edge position in regards to anterior incisors; in cases subjects presented overjet larger than 6 mm, an increment of 2 mm/month was necessary to reach the edge-to-edge incisor relationship.

Records

Lateral cephalometric radiographs were taken before (T1) and immediately after the Herbst treatment (T2). After acquisition, the radiographs were saved as digital imaging (300 DPI image resolution) using a desktop scanner (Scanjet® G4050, Hewlett-Packard, Palo Alto, California); a 100 mm rule was attached to the radiograph during

the scanning process to adjust for magnification of the structures. Fourteen landmarks were digitized by one calibrated operator (JM). Radiocef 2 software (Radio Memory, Belo Horizonte, MG, Brazil), was used to digitize the radiographs and to make the 15 measurements (Figure 1). Overjet and overbite were obtained from the digital models of each patient, scanned from the plastic model in the 3Shape's R700™ (Copenhagen, Denmark) in the patient's habitual occlusion.

Blinding

The same blinded operator (JM) was calibrated and performed all of the measurements.

Statistical analysis

Using the G*Power Version 3.1.9 software (Franz Faul, Germany), the sensitivity of the sample was calculated with an α error of 0.05, power of 0.80 ($1-\beta$ err prob), and total sample size of 95. The sensitivity of the sample was able to detect small effect sizes ($w=0.15$).

The categorical group allocation reliability was performed by one blinding operator replicating 30 percent of the sample and was evaluated via Cohen's Weighted kappa coefficient ($K=0.92$). In a blinding process, all cephalometric measures were replicated in 60 lateral radiographs with a thirty-day interval after the first measure. The systematic and random errors of the variables were individually tested using a one-sample paired t-test ($p\text{-value} > 0.352$), correlation coefficient ($ICC > 0.87$), and Dahlberg formula ($D < 0.40\text{ mm}$, $D < 1.85^\circ$). Gender and Class II malocclusion severity distribution were evaluated via the Chi-square test in the baseline comparison. All tests were performed in the Statistical Package for the Social Sciences software package (SPSS for Windows, version 20.0; IBM, Armonk, NY) using a general five percent alpha ($\alpha=0.05$).

The variables have the required normal distribution evaluated through the Shapiro-Wilk test. T1 and T2 intragroup differences in each variable were evaluated using a paired student's t-test. Quantitative variables were compared between groups via MANOVA test in the baseline comparison and with a MANCOVA test to compare changes (T2-T1), using the gender as a covariable. Each variable was evaluated via the Levene test, depending on the internal variance, Bonferroni or Games-Howell tests were used as Post-Hoc to identify the intergroup differences.

Results

Prior to treatment, the groups demonstrated some similar characteristics for nine of the 14 measurements (Table 2). The differences were observed at the soft tissue thickness (Table 2). ANS_Sn and A_A' showed significant differences among all three groups. At earlier age (PRE group) the soft tissue at ANS_Sn and A_A' presented the thinner thickness (8.91 mm and 13.82 mm, respectively), increasing in the CIR group (12.20 mm and 16.74 mm) and then slightly decreasing at POS group (10.84 mm and 15.43 mm). The soft tissue thickness related to the mandible also showed differences among groups before the Herbst therapy (Table 2). CL1_LL and B_B' soft tissue thickness were thinner at earlier age (PRE group) than older groups (CIR and POS groups). CL1_LL soft tissue thickened from PRE group (19.88 mm) to CIR and POS groups (22.11 mm and 20.84 mm, respectively). The same pattern was observed for the B_B' soft tissue thickness, which the PRE group (12.02 mm) showed thinner soft tissue thickness than CIR and POS groups (13.95 mm and 13.45 mm, respectively). Soft tissue pogonion thickness (Pog_Pog'') was thicker for the CIR group (13.83 mm) when compared to the PRE (12.01 mm) and POS (13.04 mm) groups.

Herbst therapy produced changes within and among groups (Table 3). SNB angle showed significantly increase for PRE, CIR, and POS groups (1.22°, 0.66°, and 1.20°, respectively). ANB angle decreased for all three groups, ranging from 1.07° to 1.56°. Pogonion moved forward (Pog_HRL) significantly for PRE (2.54 mm), CIR (2.39 mm), and POS (1.54 mm). Although the facial convexity decreased significantly for all three groups, the POS pubertal showed the smallest change (1.39°) when compared to PRE (2.54°) and CIR (2.65°).

Some soft tissue thickness changes that occurred over the observational period were statistically significant (Table 3). A_A' thickness showed significant difference among groups ($p=.048$). CL1_LL increased in both, PRE (1.24°) and POS (0.99°) groups, but not in the CIR group (0.19). B_B' and Pog_Pog' thicknesses increased (2.02 mm and 0.92 mm, respectively) only in the PRE group.

Skeletal pogonion (Pog_HRL) showed moderately high positive correlation with soft tissue pogonion (Pog'_HRL). Interesting, the skeletal facial convexity showed moderately low positive correlation with the soft facial convexity.

Discussion

Herbst appliance reduces soft tissue facial convexity (STFC) in growing patients with smaller changes in postpubertal growing subjects. Prepubertal and circumpubertal

patients presented approximately 52% more reduction on the STFC than postpubertal patients. The most consistent soft tissue effect in the literature is the facial convexity reduction after Herbst therapy (14,22,43,32–37,41,42). The literature has been inconsistent in regards to facial convexity reduction. Amuk and coworkers found a similar STFC reduction in postpubertal patients.(22) On the other hand, Ruf and Pancherz reported a not significant STFC reduction between early adolescents and young adults(41). In a different study, the same authors showed a more significant STFC reduction in postpubertal patients than our study. This difference could be attributed to the sample age variability and the gender sample distribution(32).

Fixed functional therapy does not change the soft tissue thickness (STT) in circumpubertal and postpubertal patients. SFT increased in mandibular reference points almost exclusively in the prepubertal group. Only the lower lip thickness increased in the PRE and POS groups and remained unchanged in the CIR group. Mentolabial sulcus thickness and soft pogonion thickness were presenting a significant increase exclusively in prepubertal patients. In a similar methodological approach, contrasting with our results Baysal and Uysal reported in circumpubertal patients an increase in maxillary and mandibular STT, only without changes in lower lip thickness(35). The authors used the buccal aspect of the maxillary incisor as a cephalometric reference point, explaining the differences with our results in the upper lip's thickness. That point suffers a strong influence from maxillary incisor retroclination(44), Herbst therapy effect. Hourfar et al. (33) reported no STT changes after Herbst therapy in circumpubertal patients, coinciding with our study.

Herbst treatment decreases the mentolabial sulcus depth (MSD) in prepubertal and circumpubertal patients. Prepubertal and circumpubertal patients presented a decrease of the MSD at approximately 50% more than postpubertal patients. The only report in the literature also showed an improvements on MSD in prepubertal Herbst treatment(45). Flattening of the mentolabial angle was previously reported (22,35,46,47). A Systematic review including patients before, at, and after growth spurt described the mentolabial sulcus as the most evident change (14.99 degrees/year) due to fixed functional appliance therapy(47). In addition, more evidence of a greater decrease in MSD was found in circumpubertal patients(7,13) than in postpubertal patients(22), agreeing with our findings.

Herbst therapy does not show high association between skeletal and soft tissue (horizontal changes of the pogonion, and facial convexity and soft facial convexity).

After Herbst appliance treatment, skeletal facial convexity reduction and anterior pogonion movement influence the soft tissue convexity and the soft pogonion projection. The ratio of anterior movement of soft pogonion to skeletal pogonion advancement range was from 0.70:1 in the PRE group, 0.94:1 in the CIR group, and 0.90:1 in the POS group. A medium significant correlation was observed ($r^2 = 78\%$). In the literature, studies that evaluated ratios of pogonion soft to hard tissue advancement showed a range from 0.70:1 to 1:1 (48). The reported individual variations as gender, age, and the quantity of anterior and vertical pogonion movement could explain the differences with our results (49). The ratio of soft facial convexity to skeletal convexity decrease ranged were from 0.91:1 in PRE and CIR groups and 0.74:1 in the POS group. A medium significant correlation was observed ($r^2 = 40\%$). This was the first study to evaluate the influence of the skeletal tissue over soft tissue, in other others, the correlation between hard and soft tissue pogonion changes, and skeletal and facial convexities.

Herbst appliance produced a different downward movement of the upper lip between PRE and POS patients. The upper lip in PRE patients was 56% more retracted than POS patients; CIR was equal to both. The majority of available literature showed the same retraction effect of the Upper lip after Herbst therapy in each phase of craniofacial growth (22,32,33,37,45). Contrasting, other authors showed an Upper lip anterior movement (23,35). The further increase in lip thickness due to natural growth could explain the contradictory results; the variability depends on patients' gender and age (50). On the other hand, the lower lip presented a significant forward movement, only in the PRE-group. This change can be attributed to lip thickness increase.

Soft pogonion (SP) moves more anterior in PRE patients than POS patients. The SP move 61% more anterior in the PRE group when compared with the POS group. The thickness changes contributed to 25 % of the SP advance in PRE pubertal phase. Agreeing with our findings, one study showed an anterior movement of the SP (22), contrasting with others reporting no treatment changes or a forward movement after Herbst therapy (23,36,45).

Conclusions

Based on a sample of 95 Brazilian patients treated with Herbst appliance in three different phases of the craniofacial growth:

- After Herbst treatment, facial convexity and mentolabial sulcus depth were higher reduced in Prepubertal and Circumpubertal patients.

- Exists a significant medium-low correlation between skeletal and soft facial convexity changes and a medium-high correlation between skeletal and soft pogonion advancement.
- Only prepubertal patients showed a significant thickness increase in the mandibular structures in the short treatment period.
- Soft pogonion advancement in prepubertal patients was higher than postpubertal patients, partly due to increased soft tissue thickness.
- The Herbst appliance therapy produces soft tissue improvements in the three phases of craniofacial growth, being more intense in prepubertal and circumpubertal patients.

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Tables

Table 1. Cephalometric points description.

Landmark	Abbreviation	Description
Sella	S	Geometric center of the pituitary fossa
Subspinale	A	The most posterior point of the premaxillary concavity
Walker point	Wal	Contact between the anterior wall of sella turcica and the anterior clinoid process
Supramentale	B	The Deepest part of the concavity between infradentale and pogonion
Supradental	UL1	Supradentale point in the beginning of the anterior premaxillary concavity
Infradental	CL1	Infradentale point in the beginning of the anterior mandibular concavity
Nasion	N	Point in the anterior frontonasal suture
Pogonion	Pg	The most anterior point of the chin
Nasal spine	ANS	Tip of the anterior nasal spine
Menton	Me	Lower point in the mandibular symphysis
Gonion	Go	Intersection of the line connecting the most distal aspect of the condyle to the distal border of the ramus, and the line at the base of the mandible
Upper lip	UL	The Most anterior point of the upper lip
Lower lip	LL	The Most anterior point of the lower lip
Upper incisor apex	U1A	The root apex of the most prominent upper incisor
Lower incisor apex	L1A	The root apex of the most prominent lower incisor
Upper incisor edge	U1	Incisal edge of the most prominent upper central incisor
Lower incisor edge	L1	Incisal edge of the most prominent lower central incisor
Gnathion	Gn	The most downward and forward point on the symphysis
Soft A point	A'	The most posterior point between the nose and upper lip
Glabella soft tissue	G'	The most anterior point of the skull in the sagittal plane
Labiomental	B'	The most posterior point on the concavity between the lower lip and Pg'
Pogonion soft tissue	Pg'	The most anterior point of the soft tissue chin
Subnasale	Sn	The most posterior-superior point where the columella meets the upper lip

Table 2. Baseline characteristics and intergroup comparison. Mean, Standard Deviation (SD), and confidence interval values before treatment (T0) Herbst Appliance

Groups		Prepubertal (n=24)					Circumpubertal (n=33)					Postpubertal (n=38)					P value
Variable		Mean	%	SD	Inf (CI95%)	Sup (CI95%)	Mean	%	SD	Inf (CI95%)	Sup (CI95%)	Mean	%	SD	Inf (CI95%)	Sup (CI95%)	
Age (years)	Average	9.04	A	0.92			12.64	B	1.22			15.98	C	0.99			0.00
Sex	Female (n)	11	45.8				15	45.5				16	42.1				0.944†
	Male (n)	13	54.2				18	54.5				22	57.9				
Skeletal Cephalometric Values	SNA, °	83.22		3.22	81.86	84.58	82.35		3.64	81.06	83.64	82.47		4.84	80.88	84.06	0.701
	SNB, °	76.72		3.03	75.44	78	76.46		2.83	75.46	77.47	76.56		4.37	75.13	78	0.965
	ANB, °	6.5		1.97	5.66	7.33	5.88		1.96	5.19	6.58	5.67		2.07	4.98	6.35	0.28
	SN/GoMe, °	33.16		5.17	30.98	35.35	33.27		4.82	31.56	34.98	32.79		6.48	30.66	34.92	0.932
	Pg on HRL, mm	57.32		6.94	54.39	60.25	59.1		7.11	56.58	61.62	58.49		9.39	55.4	61.57	0.712
	Facial Convexity, mm	11.62		5.01	9.51	13.74	10.25		5.21	8.4	12.1	9.48		5.08	7.81	11.15	0.278
Soft Tissues Cephalometric Values	ANS-AN, mm	8.91	A	2.41	7.89	9.93	12.2	B	3.69	10.89	13.5	10.84	C	2.58	9.99	11.69	0.00
	A-A', mm	13.82	A	1.66	13.12	14.53	16.74	B	2.71	15.78	17.7	15.43	C	2.17	14.72	16.15	0.00
	CU1-UL', mm	16.95		2.06	16.08	17.82	17.98		2.57	17.07	18.89	16.66		2.31	15.9	17.41	0.055
	CL1-LL, mm	19.88	A	2.19	18.96	20.81	22.11	B	2.45	21.24	22.98	20.84	B	2.28	20.09	21.59	0.002
	B-B', mm	12.02	A	1.96	11.19	12.85	13.95	B	2.02	13.24	14.67	13.45	B	2.23	12.72	14.18	0.003
	Pg-Pg', mm	12.01	A	2.24	11.06	12.95	13.83	B	1.66	13.24	14.42	13.04	AB	1.9	12.42	13.67	0.003
	Soft Facial Convexity, mm	161.71		4.31	159.89	163.53	157.68		4.34	156.14	159.22	160.63		6.84	158.38	162.88	0.214
	Mentolabial sulcus, mm	-6.04		1.52	-6.68	-5.4	-6.97		1.39	-7.46	-6.47	-6.51		1.54	-7.01	-6	0.07
	Pg' on HRL, mm	68.88		7.05	65.9	71.86	72.22		7.36	69.61	74.83	71.24		9.65	68.07	74.41	0.319
Dental cast measures	Over Jet, mm	7.24		1.03	6.8	7.67	7.56		1.27	7.11	8.02	6.91		1.36	6.4	7.36	0.096
	Over Bite, mm	2.02	A	1.18	1.53	2.52	2.63	B	1.17	2.22	3.05	1.93	A	1.1	1.55	2.31	0.013
Anteroposterior Class II malocclusion severity (both sides)	1/2 Class II or less (n)	16	33.3				22	33.3				24	31.6				0.744†
	3/4 Class II (n)	15	31.3				24	36.4				29	38.2				
	Full Class II (n)	17	35.4				20	30.3				23	30.3				

SD, Standard Deviation; CI 95%, confidence interval of 95%; †Chi Square test application for categorical distribution; MANOVA test application for the rest of the variables ($\alpha=5\%$); different letters indicates statistically significant differences between groups ($p<0.05$)

Table 3. Comparisons of cephalometric changes after Herbst appliance therapy changes (T2-T1) in three different stages of cervical maturation growth (paired t test and MANCOVA).

Groups		Prepubertal PRE (n=24)				Circumpubertal CIR (n=33)				Postpubertal POS (n=38)				MANCOVA
Variable	Mean	SD	Inf (CI95%)	Sup (CI95%)	Mean	SD	Inf (CI95%)	Sup (CI95%)	Mean	SD	Inf (CI95%)	Sup (CI95%)	P value	
Hard Tissues														
SNA, °	-0.29	1.12	-0.77	0.18	-0.48	1.73	-1.09	0.13	0.35	1.29	-0.08	0.77	0.052	
SNB, °	1.22	1.28	0.68	1.76	0.66	1.11	0.26	1.05	1.2	0.95	0.89	1.51	0.069	
ANB, °	-1.56	1.03	-2	-1.13	-1.19	0.77	-1.46	-0.92	-1.07	1.16	-1.45	-0.69	0.171	
SN/GoMe, °	-0.01	1.89	-0.8	0.79	0.57	2.19	-0.21	1.35	-0.4	1.23	-0.8	0.01	0.078	
Pg on HRL, mm	2.54	2.39	1.53	3.54	2.39	2.11	1.64	3.14	1.54	2.07	0.86	2.22	0.135	
Facial Convexity, mm	-2.54 A	2.53	-3.6	-1.47	-2.65 A	1.26	-3.1	-2.21	-1.39 B	1.06	-1.74	-1.04	0.002	
Soft Tissues Thickness														
ANS-Sn, mm	0.05	1.9	-0.75	0.86	0.17	1.89	-0.5	0.84	-0.28	1.98	-0.94	0.37	0.129	
A-A', mm	0.18 A	1.18	-0.32	0.68	-0.44 B	0.78	-0.72	-0.16	-0.16 AB	0.85	-0.44	0.12	0.048	
CU1-UL', mm	0.09	1.88	-0.71	0.88	-0.38	2.07	-1.11	0.36	-0.16	1.82	-0.76	0.44	0.668	
CL1-LL, mm	1.24 A	2.23	0.3	2.18	0.19 B	1.52	-0.35	0.73	0.99 A	1.17	0.6	1.37	0.034	
B-B', mm	2.02 A	1.29	1.47	2.56	0.38 B	0.9	0.07	0.7	-0.07 B	1.51	-0.56	0.43	0	
Pg-Pg', mm	0.92 A	1.2	0.41	1.43	0.03 B	1.07	-0.34	0.42	-0.06 B	1.02	-0.4	0.28	0.002	
Soft Tissues														
Soft Facial Convexity, mm	2.77 A	2.74	1.62	3.93	2.89 A	1.96	2.2	3.59	1.03 B	1.47	0.55	1.51	0	
Upper Lip on HRL, mm	-1.42 A	0.94	-1.82	-1.03	-0.89 AB	0.59	-1.1	-0.68	-0.62 B	1.02	-0.95	-0.28	0.003	
Lower Lip on HRL, mm	0.93	1.71	0.21	1.65	0.19	1.05	-0.18	0.57	0.16	1.46	-0.32	0.64	0.081	
Mentolabial sulcus, mm	-1.07 A	0.92	0.68	1.45	-1.29 A	1.09	0.91	1.68	-0.55 B	0.98	0.22	0.87	0.008	
Pg' on HRL, mm	3.61 A	2.98	2.35	4.86	2.27 AB	2.3	1.46	3.09	1.39 B	2.22	0.66	2.12	0.004	

MANCOVA indicates a multivariate analysis of covariance, global test results: $F(34,150) = 4.433$; $P=0.000$; $1-\beta=1$; $f=0.50$; SD, standard deviation; n, patients include in each group; CI 95%, confidence interval of 95%; **Bold**, represent a statistical internal difference of the variable over the time ($\alpha < 0.05$); Gender interaction: P value of the interaction between growth phase and gender; Different letters indicates statistical significant differences in the intergroups comparisons ($\alpha=5\%$)

Table 4. Correlation coefficient between anteroposterior skeletal and soft tissue treatment changes after Herbst appliance therapy in Growing Class II malocclusion patients

Skeletal	Soft tissue	<i>P</i> value	<i>r</i>
Pog on HRL	Pg' on HRL	<0.001	0.783
Facial Convexity	Soft Facial Convexity	<0.001	0.403*
<i>r</i>= correlation coefficient; *Spearman's correlation coefficient			

Figure caption

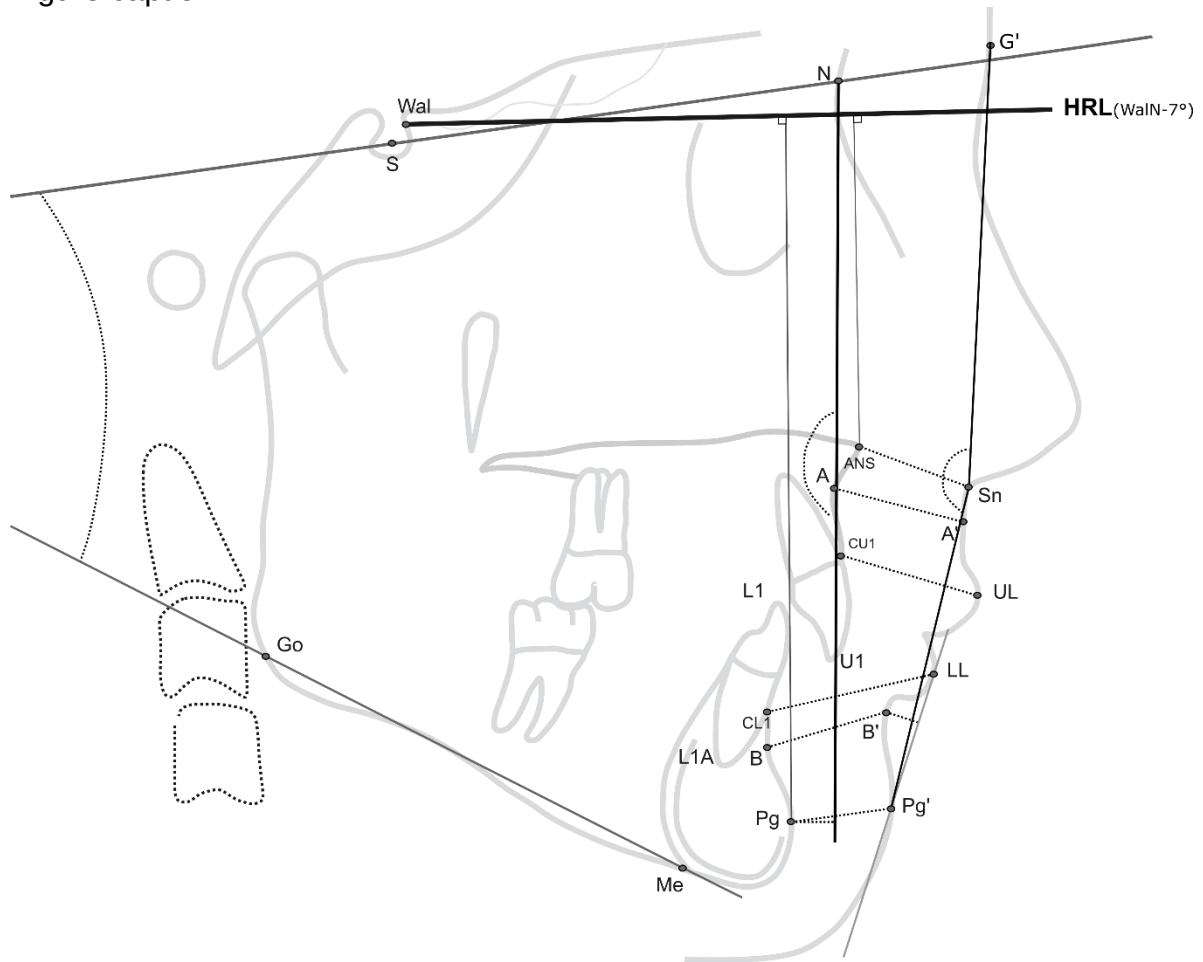


Figure 1. Cephalometric landmarks and measures. (Angle SNA) Anteroposterior maxillary changes; (Angle SNB) Anteroposterior mandibular changes; (Angle ANB) Maxillo-mandibular relationship; (Angle SN/GoMe) Vertical relationship between cranial base and mandibular base; (Distance Pg on HRL) Anteroposterior pogonion position; (Distance NA-Pg) Skeletal Facial convexity; (Distance ANS-Sn) Subnasale thickness; (Distance A-A') Base upper lip thickness; (Distance CU1-UL) Upper lip thickness; (Distance CL1-LL) Lower lip thickness; (Distance B-B') Base lower lip thickness. (Distance Pg-Pg') Pogonion thickness; (Angle G'-Sn-Pg) Soft facial convexity; (Distance UL on HRL) Anteroposterior upper lip position; (Distance LL on HRL) Anteroposterior lower lip position; (Distance B' to LL-Pg') Mentolabial sulcus depth; (Distance Pog' on HRL) Anteroposterior soft pogonion position.

4 CONCLUSÃO

Aparelho de Herbst apresenta-se como uma terapia efetiva na correção da má Oclusão de Classe II nas três fases do crescimento craniofacial. Após a execução das pesquisas relatadas anteriormente, foi possível concluir que:

- As mudanças imediatas produzidas pelo aparelho de Herbst na má oclusão de Classe II apresentaram o mesmo mecanismo de correção nas três fases da classificação de maturação das vertebrae cervicais. A proclinação dos incisivos inferiores, a retrusão dos incisivos superiores, o movimento do molar superior para trás, o movimento do molar inferior para a frente e os efeitos esqueléticos menores sobre o comprimento mandibular e avanço do pogônio e da sínfise mentoniana (B).
- Existe uma diferença significativa no aumento do comprimento mandibular, sendo no grupo surto 35% maior do que o grupo pós-surto e 41% maior do que o grupo pré-surto. No entanto, isso não reflete um aumento na projeção do pogônio.
- A eficácia da correção na má oclusão de Classe II com dispositivo funcional de Herbst está associada com o estágio inicial de crescimento e a gravidade oclusal anteroposterior no início da terapia.
- O início do tratamento na fase de crescimento pré-surto apresentou uma maior quantidade de sobrecorreções na relação molar de Classe II.
- Severidade anteroposterior de meia Classe II tem melhor prognóstico no tratamento funcional de Herbst, com a maioria dos casos finalizados em sobrecorreção. No entanto, e severidade molar de três quartos e severidade completa podem ser satisfatoriamente corrigidos, sem alcançar na maioria dos casos a sobrecorreção.
- O tempo de tratamento parece não ter uma relação direta com a qualidade da correção oclusal. Sendo que a etapa do crescimento craniofacial e a gravidade oclusal podem influenciar mais na qualidade da correção da má oclusão de Classe II com aparelho de Herbst.

- Após o tratamento com Herbst, a convexidade facial e a profundidade do sulco mentolabial foram mais reduzidas em pacientes pré-surto e durante o surto.
- Existe uma correlação média-baixa significativa entre as alterações da convexidade facial esquelética e mole, assim como uma correlação média-alta entre o avanço do pogônio esquelético e de tecido mole.
- Apenas os pacientes pré-púberes mostraram um aumento significativo da espessura das estruturas mandibulares no curto período de tratamento.
- A projeção do pogônio mole em pacientes pré-surto foi maior do que em pacientes pós-surto de crescimento, em parte devido ao aumento da espessura do tecido mole.
- A terapia com o aparelho Herbst promove melhoras nos tecidos moles nas três fases do crescimento craniofacial, apresentando uma maior intensidade em pacientes pré-surto e durante o surto de crescimento.

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