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Cephalometric changes after maxillary expansion in children and adolescents with Angle class III malocclusions: systematic review and clinical implications

Alterações cefalométricas após expansão maxilar em crianças e adolescentes com maloclusão de classe III de Angle: revisão sistemática e implicações clínicas

Cambios cefalométricos tras la expansión maxilar en niños y adolescentes con maloclusión de Angle clase III: revisión sistemática y implicaciones clínicas

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Abstract

It is consensus that Class III treatment is clinically challenging considering, mainly, bone growth. Its diagnosis requires correct assessment of maxillary and mandible involvement since treatment must be directed to the bone base responsible for the malocclusion in order to correct it and provide improvement in the facial pattern. One of the main academic gaps in this subject is the approach to its treatment. In this context, this study aimed to group randomized clinical trials (RCTs) on cephalometric changes observed after maxillary expansion in these dental-skeletal disharmonies. RCTs published in English whose subjects were children and adolescents with Angle class III malocclusion and maxillary atresia were collected. In addition, at least one of the randomized groups should have maxillary (palatal) expansion and the measurement of cephalometric changes observed after palatal expansion as intervention. After inserting the PICO strategy and performing the systematic search, a total of 708 results were retrieved, of which 416 came from Scopus, PubMed, Cochrane, and Web of Science databases. When analyzing cephalometric results, mainly associated with the use of face mask, and considering the limiting factors of this review, it is clear that this type of intervention has become a viable option in clinical practice; however, new qualitative and meta-analytical reviews should be carried out in view of the publication of new randomized clinical trials in order to infer more accurate results and with greater power of evidence.

Keywords: Dentistry; Angle class III malocclusion; Cephalometry; Palatal expansion technique.

Resumo

É consenso que o tratamento Classe III é clinicamente desafiador considerando, principalmente, o crescimento ósseo. Seu diagnóstico requer uma avaliação correta do envolvimento maxilar e mandibular, pois o tratamento deve ser direcionado à base óssea responsável pela má oclusão, a fim de corrigi-la e proporcionar melhora no padrão facial. Uma das principais lacunas acadêmicas neste assunto é a abordagem de seu tratamento. Neste contexto, este estudo visou agrupar ensaios clínicos aleatórios (ECR) sobre as alterações cefalométricas observadas após a expansão maxilar nestas desarmonias dentário-esqueléticas. Foram coletados RCTs publicados em inglês cujos sujeitos eram crianças e adolescentes com má oclusão Classe III de Angle e atresia maxilar. Além disso, pelo menos um dos grupos randomizados deveria ter expansão maxilar (palatina) e a medida das alterações cefalométricas observadas após a expansão palatina como intervenção. Após a inserção da estratégia PICO e a realização da busca sistemática, um total de 708 resultados foram recuperados, dos quais 416 vieram das bases de dados Scopus, PubMed, Cochrane e Web of Science. Ao analisar os resultados cefalométricos, principalmente associados ao uso de máscara facial, e considerando os fatores limitantes desta revisão, fica claro que este tipo de intervenção tornou-se uma opção viável na prática clínica;

entretanto, novas revisões qualitativas e meta-analíticas devem ser realizadas em vista da publicação de novos ensaios clínicos randomizados, a fim de inferir resultados mais precisos e com maior poder de prova.
Palavras-chave: Odontologia; Má oclusão classe III de Angle; Má oclusão; Cefalometria; Técnica de expansão palatina.

Resumen
Es un consenso que el tratamiento de la Clase III es un reto clínico teniendo en cuenta, principalmente, el crecimiento óseo. Su diagnóstico requiere una correcta valoración de la afectación maxilar y mandibular ya que el tratamiento debe ir dirigido a la base ósea responsable de la maloclusión para corregirla y proporcionar una mejora en el patrón facial. Una de las principales lagunas académicas en este tema es el abordaje de su tratamiento. En este contexto, este estudio tuvo como objetivo agrupar los ensayos clínicos aleatorios (ECA) sobre los cambios cefalométricos observados tras la expansión maxilar en estas desarmonías dentoesqueléticas. Se recopilaron ECA publicados en inglés cuyos sujetos fueran niños y adolescentes con maloclusión de clase III de Angle y atresia maxilar. Además, al menos uno de los grupos aleatorizados debía tener como intervención la expansión maxilar (palatina) y la medición de los cambios cefalométricos observados tras la expansión palatina. Tras insertar la estrategia PICO y realizar la búsqueda sistemática, se recuperaron un total de 708 resultados, de los cuales 416 procedían de las bases de datos Scopus, PubMed, Cochrane y Web of Science. Al analizar los resultados cefalométricos, principalmente asociados al uso de la máscara facial, y teniendo en cuenta los factores limitantes de esta revisión, queda claro que este tipo de intervención se ha convertido en una opción viable en la práctica clínica; sin embargo, se deben realizar nuevas revisiones cualitativas y meta-analíticas en vista de la publicación de nuevos ensayos clínicos aleatorios para inferir resultados más precisos y con mayor poder de evidencia.
Palabras clave: Odontología; Angle clase III; Maloclusión; Cefalometría; Técnica de expansión palatina.

1. Introduction

The malocclusions are one of the most prevalent dental problems nowadays, and in 1899 Edward Hartley Angle classified it into three main groups: class I, class II, and class III. The class I malocclusion occurs when the mesiobuccal cusp of the upper first permanent molar occludes at the level of the buccal groove of the lower first permanent molar. Class II is when the lower molar is distally positioned in relation to the upper molar, without considering the tooth position in relation to the occlusion line. Class III was defined when the lower molar occludes mesially in relation to the upper molar, without considering the relationship of these molars to the occlusion line (Martins, *et al.*, 2022).

It is consensus that Class III treatment is clinically challenging considering, mainly, bone growth: great ally in orthodontics in other corrections; in Class III, it is a strong opponent and the more intense and lasting, the greater the case severity (Araújo & Araújo, 2008). For this reason, orthopedic and orthodontic intervention requires careful evaluation as to the time of therapeutic implementation. In this regard, the scientific community still lacks technical agreement: while many authors suggest waiting for the growth phase to only perform surgically assisted orthodontic treatment, other authors such as Bacetti, Franchi and McNamara Jr. state that treatment must be performed during growth phase considering that a non-interventional scenario can lead to the worsening of the patient's clinical condition (Araújo & Araújo, 2008).

At the same time, its diagnosis requires correct assessment of maxillary and mandible involvement since treatment must be directed to the bone base responsible for the malocclusion in order to correct it and provide improvement in the facial pattern (Gallão, et al., 2013). This morphological evaluation is decisive for the proper choice of the therapeutic approach: in patients with mandibular prognathism, treatment can be performed with the aid of a chincap, whereas in patients with maxillary deficiency, its traction is indicated in order to accelerate the growth of this arch (Cha, 2003).

Another factor that should be considered in the treatment of Class III with maxillary retrusion is the use of the palatal expansion appliance since maxillary atresia is commonly associated with malocclusion and, in addition, in young patients, maxillary expansion appears to produce effects that favor the correction of class III (Gallagher, *et al.*, 1998). Palatal expansion causes maxillary movement in the anterior and descending directions through the rupture of the intermaxillary and circumaxillary sutures, which allows a more favorable reaction to traction forces (Cha, 2003). This remodeling in the region of craniofacial sutures was described as a bone restructuring of secondary growth after the application of non-physiological forces, since due to the high vascularization of these fibrous joints, it is possible to observe the stretching of ligaments, which stimulated the bone deposition in its attachments, whereas their compression caused bone resorption (Kambara, 1977).

Based on cephalometric changes interpreted after palatal extension in patients with mixed dentition, it could be inferred that maxilla and mandible undergo changes in their positions, and changes in the position of maxillary molars and in facial height are observed (de Silva Fo, *et al.*, 1991). With regard to the epidemiological issue, class III malocclusion has low incidence (Stojanovic, *et al.*, 2013) and can vary according to ethnicity: in Caucasians, class III ranges from 1% to 5% (5 % among Italians); from 5% to 8% in blacks; and 14% among Asians (Poletti *et al*., 2013).

However, even with such clinical relevance, the scientific literature still lacks studies on the subject. One of the main academic gaps in this subject is the approach to its treatment. In this context, this study aimed to gather, in the form of a systematic review, information concerning randomized clinical trials on the cephalometric changes observed after maxillary expansion in these dental-skeletal disharmonies, thus providing a comparative parameter among intervention methods in different clinical Angle Class III malocclusion conditions.

2. Methodology

This systematic review was previously registered with the International Prospective Register of Systematic Reviews (PROSPERO) under public protocol number CRD42020166687 and was conducted in accordance with recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) (Moher, *et al.*; 2015). All methodological steps were carried out by two different authors with the decision of a third author in cases where divergences occurred.

The main question for this systematic review was to study cephalometric changes observed after orthodontic treatment performed using rapid maxillary expansion in patients with Angle's class III malocclusion. To perform the study, this review collected randomized clinical trials (RCTs) (1) published in English (2), whose subjects were, at the time of acceptance, children and adolescents (5) with Angle class III malocclusion (3) and maxillary atresia (4) according to the age classification criteria of the World Health Organization (World Health Organization, 1986). In addition, at least one of the randomized groups should have maxillary (palatal) extension (6) and measurement of the cephalometric changes observed after palatal expansion (7) as intervention. Cross-over studies were also included conditionally on the existence of maxillary extension and cephalometric analysis intervention.

Central search strategy was performed on 4 online databases: PubMed, Cochrane (Central), Scopus, and Web of Science. The strategy as shown in Table 1 was built based on the PICO structure (population, intervention, comparator and outcome), using uniterms and their most common synonyms.

Table 1 - PICO Structure.

Target	Description	Operator	Uniterms
Population	Children and adolescents with Angle Class III malocclusion	--	--
Intervention	Maxillary expansion	AND	maxillofacial development; Habsburg jaw; mandibular prognathism; Angle class III; malocclusion; tooth crowding; crossbite; open bite; retrognathia; maxillary retrusion; mandibular retroposition; malocclusion; under bite; maxillary atresia
Comparator	Randomized Clinical Trials (cross-over or parallel arms)	AND	controlled clinical trial; RCT; clinical trial; randomized clinical trial; group control; placebo; comparative study; cross-over; crossover; cross over; double-blind; factorial; controlled clinical trial; randomized controlled trials; random allocation; prospective studies
Outcome	Cephalometric changes	AND	Craniometry; cephalometry; cephalometric; craniology

Source: Authors.

Descriptors were chosen from the results of previous preliminary searches under the critical evaluation of dental professionals who are members of this team of reviewers. Once eligibility criteria were defined, the screening of this preliminary search was performed - independently and blindly - and the keywords of the resulting randomized clinical trials were extracted and, in turn, inserted in the MeshTerms platform for consultation of the more incidental scientific synonyms. The literature on systematic reviews in the same area was also searched. The final criterion for the selection of uniterms was the search sensitivity: more comprehensive strategies were always preferred over more specific strategies. For this reason, no keywords were adopted for population.

The search strategy was adapted to the standard of each database regarding the use of filters, Boolean operators and wildcards. Selection filters for the comparator were preferred over the application of uniterms, in cases the database allowed it.

The search was carried out on two different access networks on February 14, 2020 and, after a cumulative process between both, the results were forwarded for screening.

In order to guarantee the efficiency and rigor of the process, screening was carried out in three sequential stages, each with its own checking points; respectively: title (for criteria 1 and 2), abstract (for 3, 4 and 5), and full text (6 and 7) using, for that, the EndNote® X7 quote manager (Clarivate Analytics, USA).

Three RCTs discarded from the screening were randomly chosen and a preliminary spreadsheet was developed, containing the main fields provided for both parametric and non-parametric data, already categorized. Only when both authors responsible for this stage showed equivalent results, the extraction started.

Data were collected regarding study type; methodology used in the research; details of intervention and control; recruitment process; sociodemographic characteristics of the study population, when available; possible losses of surveyed individuals; results obtained, as well as time and measurement method; inclusion and exclusion criteria for participants; information that allowed risk of bias analysis; and measures of effect in addition to the method chosen for its calculation.

Studies of possible duplicate population were rigorously analyzed for the following criteria: authors and year of publication; study location and clinical condition; details of the intervention such as dose, frequency and time; number of participants and baseline sample characteristics; and, recruitment method and study duration. As the outcome of interest in this review does not change in case of multiple publications, after confirmation of the duplicate contained in the sample, only the first published study was selected.

All data missing in the text, in supplementary material or whose information did not allow calculation by appropriate methods, were requested from corresponding authors.

The qualitative assessment of RCTs was carried out using Cochrane's risk of bias analysis instrument: the ROB 2.0 tool for randomized clinical trials and its additional version for cross-over studies (Higgins, 2018). Randomly, 10 RCTs discarded from the final screening were selected and sent to the authors responsible for this step and only when they returned equivalent results, the evaluation of studies that compose this review started.

All aspects foreseen by the tool were analyzed: bias due to the randomization process, bias due to deviations from intended interventions, due to the lack of data on results, bias in the measurement of the outcome, and in the selection of reported result. In all domains, predefined signaling questions were observed, indicating, for each one, the response corresponding to the judgment of each evaluator according to the analysis suggestion flowchart.

At the end of the process, as recommended by the guide, each study was classified into one of three global judgment categories: low risk of bias (if all domains were so), worrying (if at least one domain is so and if none of them shows high risk), or high risk of bias (if at least one domain is so).

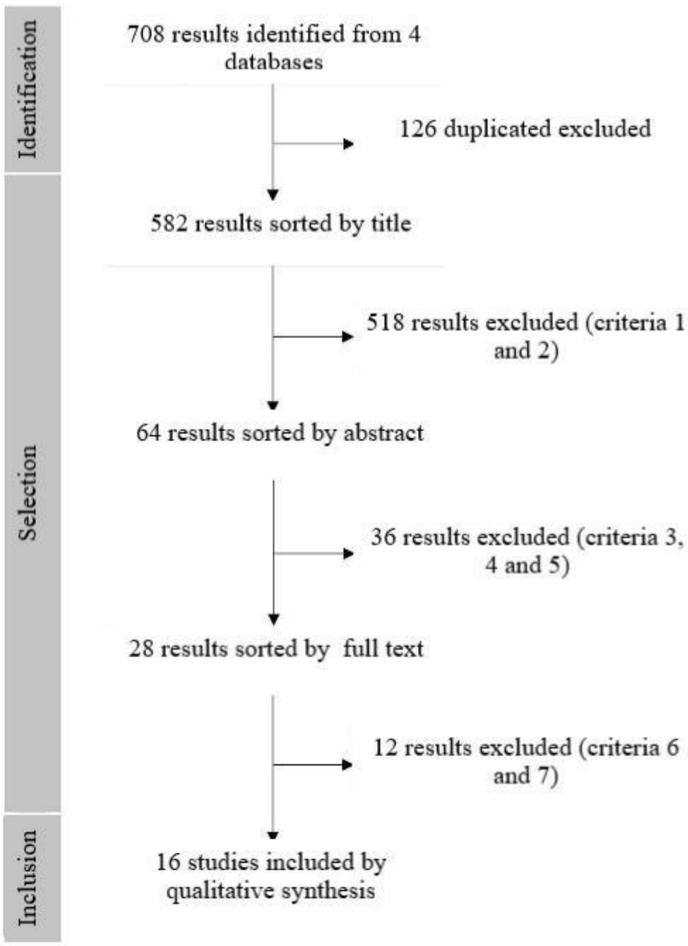
In all methodological steps of quantitative nature, the Kappa statistic (McHugh, 2012) was calculated in order to determine the coefficient of agreement among authors responsible for its execution.

3. Results and Discussion

After inserting the PICO strategy and carrying out the systematic search, a total of 708 results were retrieved, of which 416 were from the Scopus database, 235 from the PubMed database, 56 from Cochrane, and 1 from the Web of Science database. Due to the quantitative expressiveness of preliminary searches, specifically and solely on the PubMed basis, two filters were adopted in the final search for raw results: "clinical trials" and "humans", in order to restrict the scope of retrieved studies.

The automatic duplicate checking performed by the EndNote® software identified 300 positive results and, of these, 118 were confirmed through manual analysis that, in turn, took into account a comparison between title, authors and year of publication, keywords and registration number on the DOI platform. In addition, 8 duplicates were manually found; thus, 582 results were included in the screening. After the systematic application of eligibility criteria, a total of 16 clinical trials were selected to compose the review. Figure 1 represents the PRISMA flowchart of the quantity of studies resulting from each step.

Figure 1 - PRISMA flowchart.



Inclusion criteria not met by results, leading to exclusion: (1) to be a randomized clinical trial (RCT); (2) article published in English; (3) subjects surveyed were, at the time of acceptance, Angle class III and patients (4) with maxillary atresia; (5) individuals surveyed were, at the beginning of the study, children and adolescents according to the age classification criteria of the World Health Organization (World Health Organization, 1986); (6) presence of at least one intervention group with maxillary (palatal) extension; and, finally, (7) presence of measurement of cephalometric changes observed after palatal expansion. Source: The authors.

The total number of participants in the 16 selected studies was 650 individuals. The average age was 8.76 years, except for one study (Saadia & Torres, 2003) that did not provide this information; still on the average age, it was not possible to demonstrate the standard deviation value since none of studies presented this information. With the exception of one article (Nartallo-Turley & Turley, 1998) that included only female individuals, all the others investigated populations of both sexes; in total, of the 650 participants, 233 are male and 354 are female; however, the study by Farronato et al (2011), despite reporting mixed inclusion, did not report the specific amount of each sex within its sample population.

Regarding the design of clinical trials included in the review, 56% have parallel arms design (Ngan, *et al*., 1992; Kapust *et al.*, 1998; Baccetti, *et al.*, 1998; Macdonald, *et al*., 1999; Westwood, *et al*., 2003; Arman, *et al.*, 2006; Kilinç, *et al.*, 2007; Mucedero, *et al.*, 2009; Bavbek, *et al.*, 2014) with at least one intervention group (palatal extension), and 44% (Ngan, *et al.*, 1996; Williams, *et al*., 1997; Nartallo-Turley & Turley, 1998; Saadia & Torres, 2003; Cha, 2003; Farronato, *et al.*, 2011; Pavoni, *et al.*, 2014) are uni or bilateral cross-over studies that evaluated individuals before and after controlled intervention. Further details on the baseline characteristics of the 16 eligible clinical trials included in this review can be found in Table 2.

Table 2 - Baseline characteristics of studies.

N	IDENTIFICATION	COUNTRY OF ORIGIN	DESIGN	GRUPO CLASSE III				COMPARATIVE GROUP			
				n	Sex		Average age	n	Sex		Average age
					M	F			M	F	
1	NGAN *et al* (1992)	USA	Parallel arms	10	3	7	8.06	10	3	7	8.06
2	NGAN *et al* (1996)	Hong Kong	*Crossover*	20	10	10	8.1	-	-	-	-
3	WILLIAMS et al (1997)	USA	*Crossover*	28	11	17	8.3	-	-	-	-
4	NARTALLO-TURLEY & TURLEY (1998)	USA	*Crossover*	21	0	21	7.26	-	-	-	-
5	KAPUST et al (1998)	USA	Parallel arms	63	25	38	8	32	NA	NA	NA*
6	BACCETTI et al (1998)	Italy	Parallel arms	46	20	26	8.5	32	14	18	7.9
7	MACDONALD et al (1999)	USA	Parallel arms	24	12	12	7.4	27	NA	NA	8.7
8	SAADIA & TORRES (2003)	Mexico	*Crossover*	112	45	67	NA*	-	-	-	-
9	CHA (2003)	Korea	*Crossover*	85	26	59	Gp 1 = 9.82 / Gp 2 =11.3 / Gp 3 = 13.07	-	-	-	-
10	WESTWOOD et al (2003)	Italy	Parallel arms	34	14	20	8.3	12	6	6	8.1
11	ARMAN et al (2006)	Turkey	Parallel arms	14	5	9	11.5	15	5	10	1.5
12	KILINÇ et al (2007)	Turkey	Parallel arms	18	7	11	10.9	17	8	9	10.9
13	MUCEDERO et al (2009)	Italy	Parallel arms	17	7	10	7.1	20	12	8	8.1
14	FARRONATO et al (2011)	Italy	*Crossover*	63	NA	NA	8.1	-	-	-	-
15	PAVONI et al (2014)	Italy	*Crossover*	79	44	34	7.7	-	-	-	-
16	BAVBEK et al (2014)	Turkey	Parallel arms	Parallel arms	4	12	10.8	18	11	7	10.2

Source: Authors.

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The analysis of the risk of bias of studies included in the qualitative synthesis revealed a worrying factor: all 16 trials were classified, according to the ROB 2.0 tool, as high risk, which demonstrates serious methodological flaws in conducting and reporting information in these studies, detailed in Table 3.

Table 3 - Details of the risk of bias analysis

N	IDENTIFICATION	ANALYSIS DOMAIN					GLOBAL EVALUATION
		1	2	3	4	5	
1	NGAN *et al* (1992)	High risk	Low risk	Worrying	High risk	Worrying	High risk
2	NGAN *et al* (1996)	High risk	High risk	High risk	High risk	High risk	High risk
3	WILLIAMS et al (1997)	High risk	Worrying	High risk	Low risk	High risk	High risk
4	NARTALLO-TURLEY & TURLEY (1998)	High risk	High risk	High risk	Worrying	High risk	High risk
5	KAPUST et al (1998)	High risk	High risk	High risk	High risk	High risk	High risk
6	BACCETTI et al (1998)	High risk	High risk	Low risk	High risk	Low risk	High risk
7	MACDONALD et al (1999)	High risk	High risk	High risk	Worrying	High risk	High risk
8	SAADIA & TORRES (2003)	High risk	High risk	High risk	High risk	High risk	High risk
9	CHA (2003)	High risk	Worrying	High risk	High risk	High risk	High risk
10	WESTWOOD et al (2003)	High risk	High risk	High risk	High risk	High risk	High risk
11	ARMAN et al (2006)	High risk	Low risk	High risk	High risk	Worrying	High risk
12	KILINÇ et al (2007)	High risk	High risk	High risk	High risk	High risk	High risk
13	MUCEDERO et al (2009)	High risk	High risk	High risk	High risk	High risk	High risk
14	FARRONATOA et al (2011)	High risk	High risk	Worrying	High risk	High risk	High risk
15	PAVONI et al (2014)	High risk	High risk	High risk	High risk	High risk	High risk
16	BAVBEK et al (2014)	High risk	High risk	Low risk	Worrying	High risk	High risk

Source: Authors.

The verification of the Kappa statistic indicates satisfactory level of agreement in the execution of this systematic work. Only two of the 8 methodological steps in this review had minimal agreement between executors, as reported in Table 4.

Table 4 - Result of the Kappa statistics

STEP	KAPPA STATISTICS *	AGREEMENT POWER*
Systematic search	0.98	Almost perfect
Elimination of inter and intra base duplicates	0.93	Almost perfect
1st Screening (title)	0.22	Minimal
2nd Screening (abstract)	0.38	Minimal
3rd Screening and final selection (full text)	0.60	Moderate
Data extraction	0.92	Almost perfect
Risk of bias by individual criteria	0.72	Moderate
Final risk of bias	1.00	Almost perfect

Source: Authors.

Through the introduction of cephalostat to the radiographic equipment with the contribution of Broadbent in 1931, it was possible to standardize radiographic shots in lateral norm, the well-known teleradiography, which enabled measuring planes, lines and angles of the various anatomical points of the skull and face, with the valuable intention of helping in a correct diagnosis of orthodontic malocclusions and consequently the correct planning of the case to be treated (Silveira, 2007).

The cephalometric analyses most useful in class III diagnosis are those that make a correlation between maxilla and mandible, with each other and both with the base of the skull, including ANB (2nd), Wits (0 mm), linear measurement of the condylon to point A and condylon to gnathion (23 mm at 12 years of age), Nasion perpendicular to point A (+ 2.3 mm), and Nasio perpendicular to Pogonion (0 mm). Referenced values of each cephalometric measurement of individuals are within the normal range (Zere, *et al.*, 2018).

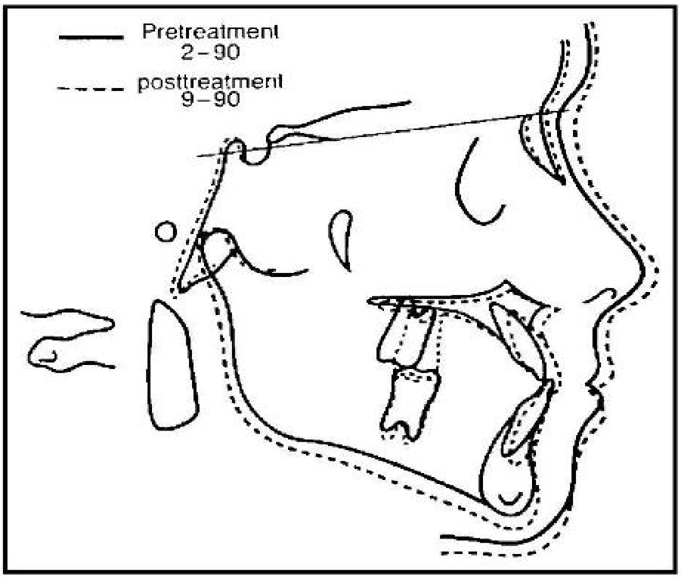
In class III malocclusion corrections, the main cephalometric changes that can be expected after rapid maxillary expansion, which is generally associated with the use of face mask in order to pull the maxilla in the anterior direction, are the projection from point A downwards and forward in approximately 1.5 mm and the mandible can be expected to move in clockwise rotation, which promotes an increase in the vertical dimension of the lower third of the face (Vaughn, *et al.*, 2005).

During cephalometric analysis, it should be taken into account that the measurement of cephalometric angles and planes can be influenced by projection errors during radiography, errors in the location of cephalometric points and errors made during the drawing of the trace and errors made during cephalometric measurements (Baumrind & Frantz, 1971). It is also necessary to be aware that the set of cephalometric analyses present in studies are likely to contain systematic and random errors and must be submitted to validation and reproducibility tests.

To minimize random errors, cephalometric tracings must be replicated and not their linear and angular measurements, since most errors result from the identification of cephalometric points. Baumrind and Miller recommend replicating it four times. Systematic or bias errors can occur when several persons are used to make measurements or even when the practice of a single professional increases over time. The analysis of errors allows the results of studies to be interpreted in light of the magnitude of these errors (Houston, 1983).

Analyzing the results of the 16 selected articles, cephalometric changes in the maxillary arch, in the mandibular arch, dental changes, changes in the height of the lower third of the face and changes in soft tissues can be highlighted. The study by Ngan, *et al.* (1992) makes a comparison between a group of 10 class III patients with maxillary retrusion, 3 boys and 7 girls with mean age of 8.06 years and a control group containing 10 untreated Class III patients, as shown in Figure 2.

Figure 2 - Overlapping of pre-treatments and post-treatment cephalometric radiographs.



Source: adapted from Ngan, *et al.* (1992).

Patients in the treatment group underwent maxillary expansion with Hyrax device, which was activated twice a day (0.25 mm per activation) for one week. In addition to Hyrax, patients used face mask for 12 to 16 hours a day with the use of bilateral elastics attached to hooks in the upper canine region at an angle of 45 ° below the occlusal plane, with strength from 14 to 18 oz on each side. Cephalometric analyses were performed before and after the maxillary expansion phase combined with its protraction and compared between groups involved in the study.

In the treatment group, among cephalometric changes observed before and after treatment, in the maxillary tooth, the mean SNA value increased by 0.81 °, the Nasion perpendicular distance up to point A decreased by 0.51 mm, the maxillary molar was previously displaced by 0.56 mm, the incisors were moved in the anterior direction by 1.78 mm. In the same study, no significant mandibular changes were observed when compared to the control group; however, in the maxillomandibular relationship, the ANB angle showed increase of 1.64 °. A difference in the vertical direction of the face was observed, with increase of 2.74 ° in the ANS-Me angle, the mandibular plane showed increase of 1.16 ° and increase of 3.35 ° in the SN-Me angle.

In their cross-over type study, Ngan, *et al.* (1996) concluded that after 6 months of treatment, the following changes in the sagittal skeletal relationship occurred: N-Pog / FH decreased by 1.5 °, N-A-Pog decreased by 2.9 °, N-Ans increased by 1.5 mm, NB decreased by 3.2 mm and N-Pog decreased by 1.9 mm. In the vertical skeletal relationship, Tgo-M-FH increased by 1.9 °, N-M by 3.1 mm and N-Ans bt 1.6 mm. The same study also showed changes in the incisal relationship, where the horizontal Iii-Isa increased by 6.8mm, Lii-Lia / FH by 3.3 °, Lii-Lia / A-Pog by 2.9 mm and, finally, Lii-Lia / Tgo-M decreased by 5.2°. Regarding the sagittal relationship of soft tissues, the following data were observed: Ns-Pos / FH decreased by 1.7 °, Ns-Sls / Sls-Pos decreased by 6.9 °, Ls / Pn-Po increased by 2.2 mm, Ns / li showed decrease of 10.4 mm, Ns / Lls reduced by 2.2 mm and Ns / Pos also showed reduction of 2.7 mm.

The vertical relationship of soft tissues showed positive changes in Sn-Ms in 2.3 mm and Ns-Ms in 11.5 mm. The thickness of face soft tissues increased by 1.8 mm in Ls-U1 and 11.6 mm in Li-L. The lip structure decreased 3.6 ° in LI-LLs / FH and increased 1.5 ° in Li / Pos-Ls. The same study used the following strategy to subtract from the measured values the natural growth of respective patients: 6 before starting treatment, radiographic measurements were taken and the desired cephalometric measurements were performed, which were subtracted from cephalometric values measured before treatment. These values were subtracted from those obtained from the result of measures described above and presented in Table 5.

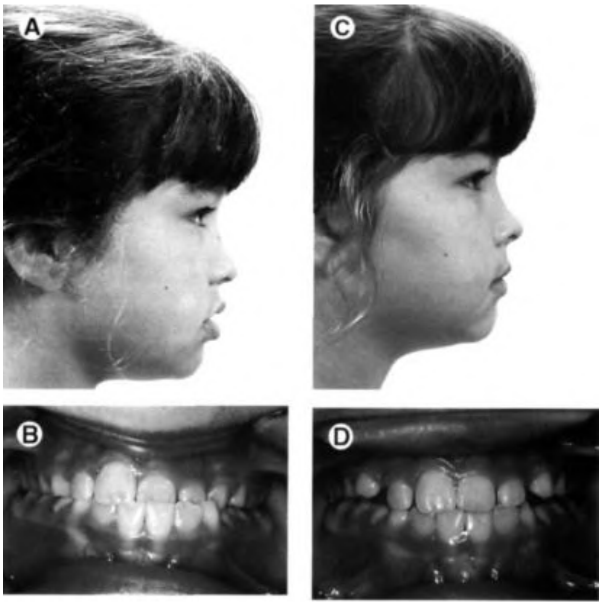
Table 5 - Variables and values from the study by Ngan, *et al*. (1996)

ANALYSIS	VARIABLES	VALUES
Sagittal skeletal relationship	N-Pog/FH	-2.1°
	A-N-Pog	-3.3°
	N-Ans	1.4mm
	N-B	-4mm
	N-Pog	-2.7mm
Vertical skeletal relationship	Tgo-M/FH	2.6°
	N-M	1.9mm
	N-Ans	1.0mm
	(Incisal relationship)	
	Iii-Isa horizontal	6.8mm
	Iii-Iia/Tgo-M	-5.6°
	Iii-Iia/FH	3.0°
	Iii-Iia/A-Po	3.3mm
Sagittal relationship of soft tissues	Ns-Pos/FH	-2.3°
	Ns-Sls/Sls-Pos	-6.9°
	Ls/Pn-Pos	1.7mm
	Ns/Li	-5.4mm
	Ns/Ils	-3.3mm
	Ns/Pos	-3.8mm
Vertical relationship of soft tissues	Sn-Ms	2.2mm
	Ns-Ms	4.9mm
Thickness of soft tissues	Ls-U1	-2.5mm
	Li-L1	1.6mm
Lip structure	Li-Ils/FH	-7.7°
	Li/Pos-Ls	1.2°

Source: Authors.

Figure 3 shows maxillary, mandibular cephalometric changes, changes in the maxillomandibular relationship and dental changes in the study developed by Williams, *et al.*, (1997). In the sagittal plane, the SNA angle increased by 0.87 °, point A was previously displaced by 1.55 mm, the ANB value increased by 1.39 ° and WITS appraisal accounted for reduction of 1.94 mm. Maxillary incisors moved in the anterior direction (Mx Incisor) and downward (Max Incisor-SN), presenting variation of 2.73 mm and 5.23 °, respectively.

Figure 3 - Pre-treatment (A and B) photographs of patient treated with RPE and protraction mask; post-treatment (C and D) of the patient.



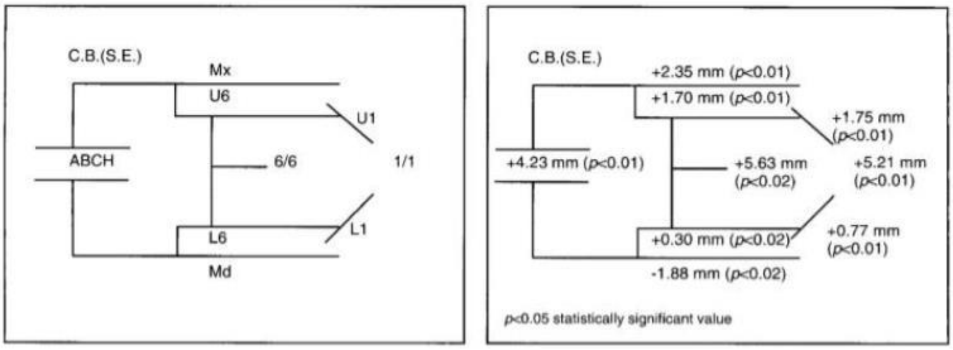
Source: adapted from Williams, *et al.* (1997).

Overjet increased by 2.89 mm from a negative to a positive value. Maxillary molar (Max Molar) showed a gain in the anterior displacement of 2.49 mm, which caused a change in the relationship between maxillary and mandibular molars, represented by variation of 1.96 mm. In the vertical plane, it was possible to point out Occ P1-SN changes with reduction of 1.45 °, MP-SN accounted for a positive variation of 1 °, the y-axis showed increase of 1.18 °, the ANS-Me distance varied positively by 2.15 mm, the Max Incisor-PP value increased by 1.15 mm, M and Incisor-MP and Max Molar-PP obtained positive oscillation of 0.88 mm and 0.48 mm in that order. As a last vertical change, it was possible to observe in the M and Incisor-OL distance of 0.93 mm to -0.5 mm.

Nartallo-Turley E Turley (1998) used the method of overlapping the cephalometric tracings and an X-Y coordinate system and observed the following cephalometric changes: displacement of the maxilla in the anterior direction confirmed by changes in the locations of point A at 3.34 mm, ANS at 3.17 mm, increase of 2.35 °, change in maxillary depth by + 2.22 °; maxilla displacement in the clockwise direction proven by greater lower displacement of PNS (-2.21mm) when compared to the displacement of ANS (-0.82mm), with change in the SN-PP angle of - 1.9 °; the mandible suffered a movement in the inferior direction with displacements of point B in -3.85 mm, Me in -4.34 mm and Pg in -4.06 mm and decrease of 1.32 ° of SNB and 1.63 ° of the facial axis.

Figure 4 shows the reported results of the height of the lower third of the face increased by 2.07 ° as well as the increase in the angle of the mandibular plane - FH by 1.7 °. The maxillomandibular relationship showed alteration confirmed by an increase of 3.66 ° in the ANB angle. Statistically significant changes were also observed along the occlusal plane, with change of 4.23 mm in the total apical base (ABCH), while the maxilla moved in the anterior direction in 2.35 mm, the maxillary molars moved 1.70 mm and incisors 1.75 mm. The mandible showed a backward movement in 1.88 m, the mandibular molars forward in 0.3 mm and incisors 0.77 mm.

Figure 4 - Representation of cephalometric changes in the study by Nartallo-Turley & Turley (1998)



Source: Nartallo-Turley e Turley (1998).

The same study showed changes in the middle third of the face, with increase in its length (TMJ-ANS, 3.53 mm) and anterior displacement of the Or (2.04 mm) and the Key Ridge (1.12 mm). In the soft profile, it was possible to observe changes in the pronasale, which was displaced in the anterior direction by 3.43 mm, as well as the subnasale (3.08 mm) and the labrale superius (3.67 mm). The soft tissue Me was displaced downwards by 3.49 mm.

In their study, Kapust, *et al.* (1998) observed cephalometric changes that occurred in the treatment group and compared it to an untreated group and comparisons were also made between treatment and control group, dividing them by age group, 4-7 years, 7-10 years and 10-14 years. The main cephalometric changes observed in the combination of the entire treatment group (without differentiation in terms of age) were observed in the maxilla by a movement in the anterior direction, with increase in ANS by 2.37 °, maxillary depth by 2.5 ° and perpendicular nasion - Point A, with 2.31 mm, in combination with the rotation of the palatal plane (SN - palatal plane -1.53 °). The mandible responded with a backward displacement (SNB -1.66 °, Nasion perpendicular to Pg -2.35mm) accompanied by the maxillary movement, which resulted in ANB alteration of 4.04 ° and in Wits apprasial of 6.41 mm. In vertical measurements, there was an increase in the easy axis (-1.87 °), Go-Gn-Sn + 1.59 °, LFHmm +3.80 mm and lower FH% + 1.36%.

As dental changes, maxillary molars showed extrusion in relation to the palatal plane (Mx6-palatal plane + 1.86 mm) and mandibular incisors showed decrease in inclination (Md1-NB -5.54 °). When comparing the measurements between treatment group and control group in relation to the age group, the highest change can be observed in the SNA angle between age groups of 4-7 years and 7-10 years (SNA of 4-7 years = 3.71 ° and SNA 7-10 years = 1.98 °). The same study used X-Y coordinates and changes were observed in both axes (vertical and horizontal). Without taking into account age group, the treatment group presented horizontal movement of the maxilla (ANS + 2.34 mm and point A + 2.79 mm) and mandible (Pg - 2.12 mm). Vertically, PNS (-2.24mm) moved downwards more than ANS (-0.9mm) and also showed lower Me movement (-3.75mm).

In relation to soft tissues, there was horizontal and anterior displacement of the upper lip (upper Labrale 3.25 mm) and a backward movement of the lower lip (lower Labrale -0.68mm) and chin (Pg in the soft tissue - 2.28mm). In relation to the occlusal plane, the treatment group presented maxillary forward movement of 3.39 mm and backward mandibular displacement of 5.54 mm, which resulted in ABCH of 3.93 mm. Maxillary and mandibular molars moved forward (U6 2.44 mm, L6 1.33 mm) and in combination with ABCH, resulted in 6/6 of 5.04 mm. The maxillary incisor moved 1.83 mm in the anterior direction while the mandibular incisor moved in the opposite direction by 0.95 mm and in combination with ABCH resulted in 1/1 of 6.71 mm. When comparing changes in the coordinate system in the treatment group by separating by age group, greater change in ABCH and 6/6 is perceived in 4-7 and 7-10 age groups.

In 1998 in Italy, Baccetti, *et al.* in their randomized study, compared class III individuals who underwent maxillary expansion concomitantly with the use of face mask for maxillary protraction with untreated Angle class III patients. Both treatment and control groups were divided into patients with mixed dentition in the initial stage (permanent incisors, first permanent molars or both) and patients in more advanced mixed dentition stage (eruption of permanent canines and pre- molars or both) and compared.

The comparison made in the treatment and control group of mixed dentition in the initial stage showed displacement in the anterior direction of the maxilla in the treatment group, shown by positive changes in ANS – VertPtm, A – VertPtm, A – VertT, and Pr– VertT. Increase in the length of the middle third of the face (Co-A) was also observed. The mandible showed small backward movement (B– VertT, Gn – VertT) and a small increase in total length (Co-Gn). In the vertical plane, increase in the inclination of the mandibular line in relation to the nasal line (NL – ML) associated with high decrease in the angulation of the nasal line with the cranial base (NL – SBL) was possible to observe the inclination of the condylar axis with the cranial base showed small decrease (CondAx – SBL) and the inclination of the condylar axis with the mandibular line (CondAx – SBL) showed small increase in the treatment group for the early mixed dentition.

When comparing treatment group and control group, both with patients in advanced stage of the mixed dentition, no change in maxillary growth was observed, only changes in the upper alveolar region with increase in the distance from the Pr point to VertT. However, in the mandibular region, small increase in B – VertT, Gn – VertT, and Id – VertT was observed. The inclination between the nasal line in relation to the mandibular line (NL – ML) exhibited a large increase in the treatment group of patients with dentition at advanced stage of development. In a comparison between advanced mixed dentition and early mixed dentition treatment groups, significant increases in ANS – VertPtm, A – VertT, A – VertPtm, PNS – VertPtm, Ptm – VertT and Pr – VertT were observed in the group of early mixed dentition and significant decrease in CondAx – ML and significant increase in CondAx – SBL, which shows upward and forward movement in condylar growth as a result of early treatment.

Macdonald, *et al.* (1999) conducted a study comparing a group with class III patients who underwent maxillary extension combined with maxillary traction using face mask to an untreated Class I group and another class III group that was also not submitted to treatment. When comparing treatment groups with class I groups, anterior displacement of the maxilla was observed, confirmed by increase in SNA by 2.61 ° / year, Nasion perp to point A in 2mm / year and ANS of 1.21m / year, in addition to a counterclockwise rotation (SN-PP -1.33 ° / year, PNS -0.75mm / year). The mandible has shifted clockwise (SNB -1.1 ° / year), which led to a downward and backward movement of the chin (Nasio perp to Pog -1.86 ° / year and Pog -1.69mm), which also increased the angle of the mandibular plane (FMA 1.42 ° / year) and the lower facial height (LFH 1.27 ° / year).

Similarly, the maxillomandibular relationship showed improvement (ANB 3.38 ° / year) and also increased facial convexity by 2.87 mm / year. Regarding dental changes, the maxillary incisor showed extrusion (Mx1PP 1.40 mm / year) and a movement in the buccal direction (Mx1 crown.x 2.64 mm / year; Mx1 root.x 3.02 mm / year). Maxillary molars showed anterior movement (Mx6 crown.x 2.30 mm / year) while mandibular incisors suffered verticalization (Md1-NB –0.93 mm / year), which resulted in increase in the overjet by 3.66 mm / year. The following significant changes were observed in the soft tissues in the treatment group: movement in the upper direction of the nose tip (pronasaley 1.40 mm / year) and the soft tissue of point A (A.y1.80 mm / year), the soft tissue of the chin moved in the posterior direction (Point Bx – 1.45 mm / year; Pog.x –2.11 mm / year), which increased the facial height of the lower third by 2.73% / year.

The cephalometric changes perceived when comparing the treatment group and untreated class III group were as follows: the posterior portion of the maxilla moved downwards (SN-PP –1.31 ° / year; Pns.y –1.40 mm / year) as well as the mandible (facial axis –2.18˚ / year; Pog.y –1.34 mm / year), which caused an increase in the height of the lower third of the face (2.36 ° / year) in the treatment group. In the horizontal plane, a combination of skeletal and dental changes resulted in an advance of the maxillary incisors (Mx1-NA 0.71 mm / year; Mx1 crown.x 4.18 mm / year; Mx1 root.x 3.69 mm / year) and molars (Mx6 crown.x 3.44mm / year) and slight retroinclination of mandibular incisors (Md1-NB –0.60 mm / year).

All of these modifications caused the overjet to increase by 5.38 mm / year in the treatment group. The vertical dimension of the same group has changed, as maxillary incisors underwent major movements (Mx1-PP 2.00 mm / year; Mx1 crown.y –2.70 mm / year) in addition to molars (Mx6 crown.y –1.19 mm / year) and mandibular incisors (md1-menton 0.98 mm / year) and mandibular molars (md6-mandibular body 0.87 mm / year). The soft tissues also showed significant changes: nose and the upper lip showed anterior displacement (pronasale.x 0.85 mm / year; labrial sup.x 1.35 mm / year; Ax point 1.22 mm / year) while the soft tissue of the chin suffered displacement in the posterior direction (Point Bx –2.17 mm / year ;; Pog.x – 2.83 mm / year).

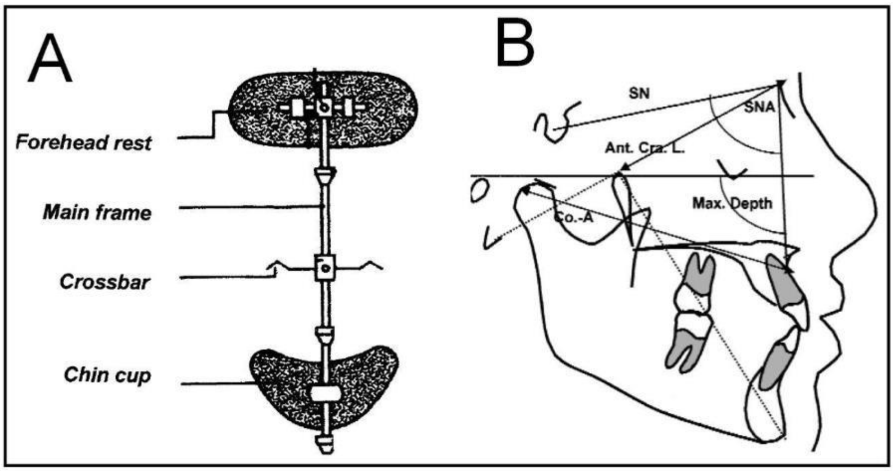
In the study developed by Saadia & Torres (2000), treatments were performed with maxillary extension combined with the use of face mask and this sample was divided into 3 groups according to age group (3-6 years, 6-9 years and 9-12 years). The changes observed when comparing cephalometric tracings before and after treatment were maxillary sagittal, mandibular sagittal and, finally, the relationship between the maxilla and mandible and can be better analyzed in Table 6 and Figure 5.

Table 6 - Changes in anteroposterior relationships of patients * in the study by Saadia & Torres (2000).

TYPE OF CHANGE	ANALYSIS	BEFORE	AFTER
Maxillary changes	SNA (°)	80.91	82.02
	C.C-N (mm)	52.33	53.43
	SN line (mm)	65.81	66.87
	Co-A (mm)	78.01	80.41
	Maxillary depth (°)	91.3	92.29
Mandibular changes	SNB (°)	79.19	78.67
	Co-Gn (mm)	103.4	106.8
	Xi-Pm (mm)	64.5	66.71
	Go-Me (mm)	62.1	64.48
	Facial depth (°)	89.34	89.05
Intermaxillary changes	ANB (°)	1.72	3.34
	Wits (mm)	-4.33	-2.78
	Dif. Co-A/Co-Gn (mm)	1.76	2.96
	Facial convexity (mm)	25.38	26.38

* 3-12 years (n = 112). Source: Saadia & Torres (2000).

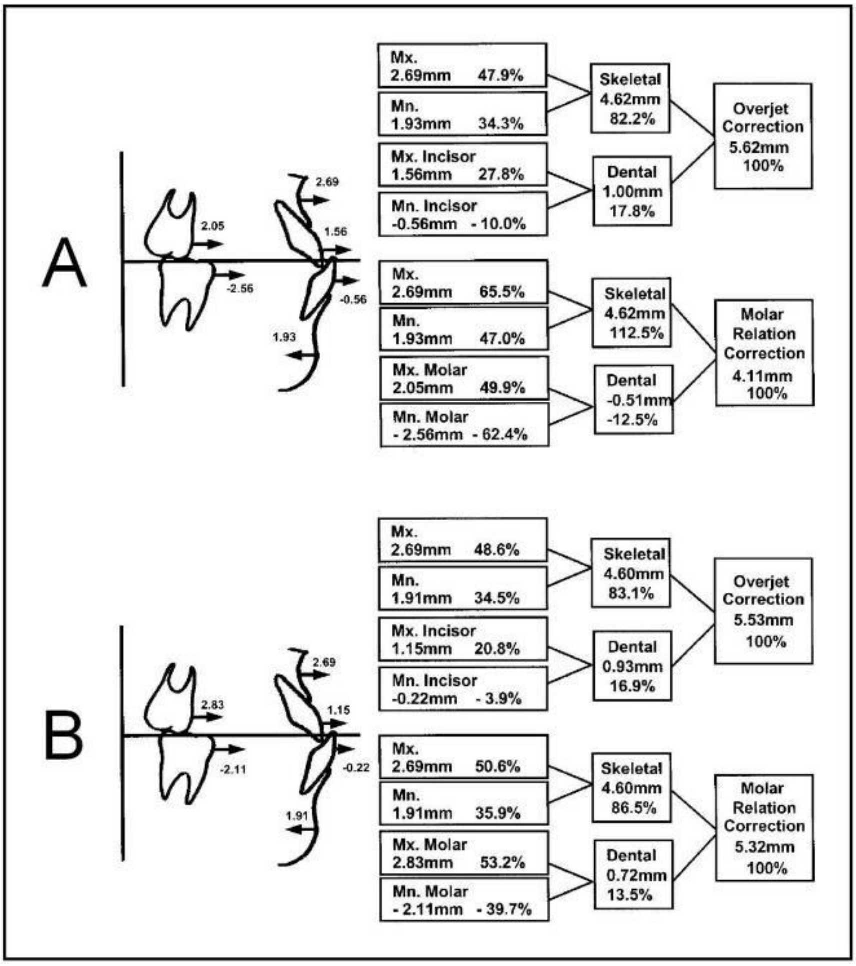
Figure 5 - Components of the Petit-type mask (A) and angular and linear cephalometric measurements of the sagittal maxilla relationships.



Source: adapted from Saadia e Torres (2000)

Figure 6 shows skeletal and dentoalveolar changes that contribute to overjet and molar relationship correction in group 1 (A) and group 2 (B) from the study by Cha (2003), which divided the treatment group according to the SMA index developed by Fishman verified on hand and wrist radiographs, into three groups, SMI 1-3 (group 1), SMI 4- 7 (group 2) and SMI 8-11 (group 3).

Figure 6 - Skeletal and dentoalveolar changes that contribute to overjet and molar relationship correction in group 1 (A) and group 2 (B).



Source: adapted from Cha (2003).

When comparing groups regarding observed cephalometric and linear changes, no statistically significant difference was observed between groups 1 and 2; however, when comparing the effects of treatment performed between groups 1 and 3 and 2 and 3, changes in SNA, ANB, YA, YM.x1, and U1 / FH were reported, as shown in Table 7.

Table 7 - Variables measured in the study by Cha (2003).

VARIABLES	GROUP 1	GROUP 2	GROUP 2
SNA	2.18°	2.03°	0.53°
ANB	3.44°	3.48°	1.77°
Y-A	2.69 mm	2.69mm	0.97mm
Y-Mx1	4.25mm	3.84mm	2.20mm
U1/FH	4.04°	3.38°	6.47°

Source: Cha (2003).

The study shows that change in overjet correlates to changes in FMA, LFH, YA, Y-Mx.1, X-Mn.1, and X-Pg in groups 1 and 2 with changes in U1 / FH, Y-Mn1 in group 3, and SNB, Facial Axis, Y-Pg, YB, and U6-PaPl in all groups. The same study points out that the correction of overjet, characteristic of class III malocclusion, was due to 80.1% of the skeletal effects of treatment and 19.9% of the dentoalveolar effects in group 1. In group 2, the same overjet correction was 84% resulting from the skeletal effects of treatment and 16% from dentoalveolar effects, while in group 3, this proportion decreased to 63.6% from skeletal effects and 36.4% from dentoalveolar effects. Regarding correction of the class III molar relationship, it was 112.5% skeletal and 12.5% dentoalveolar in group 1, 86.5% skeletal and 13.5% dentoalveolar in group 2 and 60% skeletal and 40% dentoalveolar in group 3.

The next study resulting from the screening process of this systematic review was developed by Westwood, *et al.* (2003) and showed that after REM associated with the use of face mask, most skeletal measures have undergone significant changes. Treatment induced significant increase in the length of the middle third of the face with increase in Co-PtA and displacement in the sagittal direction of the maxilla (SNA and PtA-NaPerp). This maxillary movement can be observed by advancing point A by 1.5 mm in the treatment group while the same cephalometric point moved only 0.3 mm in the control group. In mandibular measurements, it was possible to observe difference of -2.5 mm in the mandibular length (Co-Gn) when comparing control group to treatment group, also observing a decrease in SNB and Pog-NaPerp in the latter group.

These bone changes, both mandibular and maxillary, produced a better relationship between tooth arches (Wits appraisal, and ANB) in patients undergoing treatment. In the vertical direction in the treatment group, the palatal plane in relation to the Frankfort plane and the mandibular plane suffered considerable increases. During treatment, overjet and overbite showed significant increase, as well as a significant improvement in the molar ratio (3.2 mm) when compared to the control group (-0.6 mm). A decrease in the position of mandibular incisors in the anteroposterior direction in relation to the Point A-pogonion line and the mandibular plane was also reported at the end of treatment. In relation to soft tissues, in the group submitted to treatment, the position of the lower lip in relation to the E-plane showed decrease while the nasolabial angle suffered significant increase.

Arman, *et al.* (2006) observed skeletal, dentoalveolar and soft tissue changes when comparing samples that performed maxillary extension combined with the use of face mask and samples from patients who did not undergo any intervention. Among skeletal changes in the treatment group, increase in the lower facial height (ANA-Me) is highlighted, being responsible for the anterior displacement of the maxilla (SNA, A-VR), increase in the length of the middle third of the face (Cd-A) in addition to increase in SNA comparing treatment and control groups.

In the treatment group, mandible showed posterior movement (SNB, B-VR) and posterior rotation (SN.MP) and when compared to the control group, SNB showed a major change in addition to significant improvement in the intermaxillary relationship and increased facial convexity. Dentoalveolar changes in the treatment group were increase in overjet and decrease in overbite, in addition to decrease in the occlusal plane (S-N-OP). When making a comparison with the control group, in the treatment group, maxillary incisors underwent proinclination (U1.NA) and mandibular incisors retrusion (L1.NB). The convexity of soft tissues increased and the sagittal relationship of lips improved during the treatment phase, with significant differences between groups, as shown in Table 8.

Table 8 - Changes in control and intervention groups during the treatment phase (T2-T1)

PARAMETER	TREATMENT	CONTROL
ANS-Me (mm)	3.7	1.8
SNA (°)	1.83	0.14
A-VR (mm)	2.11	-1.68
Cd-A (mm)	3.31	1.49
SNB (°)	-1.11	0.45
B-VR (mm)	-1.25	0.70
S-N-MP (°)	1.25	-0.33
ANB(°)	2.94	-0.31
(A-VR)-(B-VR) (mm)	3.36	-2.36
N.A.Pog (°)	5.7	-0.75
Overjet (mm)	6.11	-0.16
Overbite (mm)	-1.87	0.12
U1.NA(°)	2.60	-0.53
L1.NB (°)	-4.11	-0.53
Ns-Month (mm)	4.55	2.09
Sn- Month (mm)	3.91	0.41
Ns.Sn.Pgs (°)	4.77	-0.11
As-VR (mm)	2.47	-1.46
UL-VR (mm)	2.24	-0.21
UL-E (mm)	1.39	0.05
LL-VR (mm)	-0.16	0.22
LL-E (mm)	-0.39	0.14
Bs-VR (mm)	-1.02	-0.01
(UL-VR)-(LL-VR) (mm)	2.40	-0.43

Source: Authors.

Table 9 shows the main cephalometric changes that occurred after maxillary dysjunction reported in the 16 eligible scientific articles that were part of this systematic review.

Table 9 - Main cephalometric alterations of the eligible studies.

N	IDENTIFICATION	REPORTED CEPHALOMETRIC CHANGES
1	NGAN et al. (1992)	Result of the difference in measurements after maxillary disjunction and the start of treatment. TREATED GROUP - Maxillary changes: SNA had an increase of 0.81°, Nasio-perp distance to Point A decreased 0.51 mm, upper molar moved anteriorly 0.56 mm, Incisors moved forward 1.78 mm. Mandibular changes: no significant changes. Maxillo-mandibular relation: ANB had an increase of 1.64°. Vertical Relationship: SNA-Me increased 2.74°, the mandibular plane increased 1.16° and SN-Me increased 3.35°.
2	NGAN et al. (1996)	Result compared before treatment and after treatment. Sagittal skeletal ratio: N-Pog/FH -1.5°, N-A-Pog -2.9°, N-SNA 1.5 mm, N-B -3.2 mm, N-Pog -1.9 mm. Vertical skeletal ratio: Teg-M-FH 1.9°, N-M3.1 mm, N-SNA1.6 mm. Incisal ratio: Iii-Isa horizontal 6.8 mm, Iii-Iia/Teg-M -5.2°, Iii-Iia/FH 3.3°, Iii-Iia/A-Pog 2.9 mm. Soft tissue sagittal ratio: Ns-Pos/FH-1.7°, Ns-Sls/Sls-Pos-6.9°, Ls/Pn-Po2.2mm, Ns/Li-10.4 mm, Ns/Ils -2.2 mm, Ns/Pos -2.7 mm Soft tissue vertical ratio: Sn-Ms 2.3 mm, Ns-M 11.5 mm. Soft tissue thickness: Ls-U1-1.8 mm, Li-L 11.6 mm. Labial structure: -3.6°, Li/Pos-Ls1.5°.
3	WILLIAMS et al. (1997)	Point A moved anteriorly with an increase of 1.54 mm (from -2 p/3.5 mm), SNA increased 0.87° (from -3° p/3°). Palatal plane without changes measured by SN, therefore SN-PNS and SN-ANS without changes. The occlusal plane, measured by SN, was flattened from 19.15° to 17.70° (1.45° change). Upper tooth changes: Incisors moved anteriorly by an average of 2.73 mm and downward by an average of 1.15 mm measured from the incisal edge. Labial inclination of the incisors from SN was 5.23° on average. All patients went from negative to positive overjet by an average of 2.89 mm. Mandibular response to maxillary protrusion: 1° increase in the mandibular plane. Maxillo-mandibular relations: ANB increased by an average of 1.39°, WITS with a difference of 1.94 mm and ANS-Mentum with an increase of 2.15 mm.
4	NARTALLO-TURLEY& TURLEY (1998)	Maxilla shifted forward: Point A - Increased by 3.34 mm, ANS - Increased by 3.17 mm, SNA - Increased by +2.35°. Maxillary Depth -Increase of 2.22°. Counterclockwise Rotation of Maxilla PNS -moved down -2.21 mm, ANS -(-) 0.82mm, SN-PP-alteration of 1.90°. Mandible shifted

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		downward: Point B = -3.85mm, Mento = -4.34mm, Pogonio=-4.06mm. Mandible shifted backwards SNB=-1.32°. Facial Axis= -1.63°. Vertical dimension and lower facial height = 2.07° increase. Increase of mandibular plane angle with FH = 1.7°. Combination of maxillary and mandibular changes: ANB increase = 3.66°. Occlusal plane: total change of apical base (ABCH) = 4.23 mm; maxilla moved forward by 2.35 mm. Molar sup moved forward 1.70 m
5	KAPUST et al. (1998)	Maxillary changes: SNA 2.37°. Maxillary depth 2.5°, N -point A 2.31 mm, SN -palatal plane -1.53°. Mandibular changes: SNB -1.66°, N -pogonio -2.35 mm. Maxillo-mandibular relation: ANB 4.04°, Wits 6.41 mm. Vertical changes: facial axis -1.87°, Go-Gn-Sn +1.59°. Lower facial height +3.80 mm. Dental changes: maxillary molar extruded in relation to the palatal plane (Mx6palatal plane + 1.86 mm) and lower incisors decreased in inclination (Md1-NB-5.54°).
6	BACCETTI et al. (1991)	Comparisons made with the control group. Change in early treatment group and control groups: Maxillary ANS-VertPtm 2.43 mm, A-VertT3.6 mm, A-VertPtm 2.57 mm, Pr-VertT 4.04 mm, PNS-VertPtm 1.95 mm, Ptm-VertT 1.17 mm, Co-A 3.17 mm, Mandibular: B-VertT 0 mm, Gn-VertT 0.38 mm, Co-Gn 1.59 mm, CondAx-SBL 6.7°, CondAx-ML -5.99°, NL-ML 2.05°, NL-SBL -1.7°. Changes between late treatment group and late control group: Pr-VertT 2.54 mm, Id-VertT -0.55 mm B-VertT -0.54 mm, Gn-VertT -0.36 mm, NL-ML 1.31°.
7	MACDONALD et al. (1999)	Comparison performed between the Cl III treated and Cl III untreated group (post palatal disjunction difference in measurements between groups): SNA 2.59°, SNB -1.28°, AN B 3.85°, Wits 2.74 mm. Maxillary depth 1.72 mm, convexity 3.55, Nas-perp to Point A 1.61, Nas perp to Pog -3.83, FMA 2.26, SN - palatal plane -1.36. Lower facial height 2.8, Overjet 5.38 Mx1 - palatal plane 1.07, Md 1 -Mento 5.62 mm, Mx 1 -NA -5.25°, nasolabial angle 4.12°.
8	SAADIA & TORRES (2003)	Average changes of all groups. maxillary changes: SNA increased by1.11°, anterior cranial length increased by 1.11 mm, SN Line increased by 1.08 mm, Co-A increased by 2.4 mm and facial depth (FH-NA) increased by 0.99°. Mandibular changes: SNB decreased by 0.52°, Co-Gn increased by 3.4 mm, Xi-PM increased by 2.21 mm, Go-Me increased by 2.38 mm, facial depth (FH-N-Pg) decreased by 0.29°. Intermaxillary changes: ANB increased by 1.62°, Wits increased by 1.58 mm, (Co-A)-(Co-Gn) increased by 1.2 mm, and facial convexity (N-Pg -A) increased by 1 mm.
9	CHA (2003)	Average cephalometric changes: Group 1 - Increased: SNA 2.18°, ANB 3.44°, facial convexity 6.07 mm, FMA 1.69°, U1/FH Pl 4.04, LFH 0.91. Decreased SNB -1.09°, FH/PaPl -1.13, facial axis -1.51°, facial angle -1.13°, PMV/Ra Pl -3.15. Group 2 increased: SNA2.03°, ANB3.48°, facial convexity 6.03mm, FMA1.80°, U1/FHPl3.38, LFH 1.73. Decreased SNB -1.33°, FH/PaPl -1.12, Facial axis -1.89°, Facial angle-1.30°, PMV/Ra Pl -3.05. Group 3: increased: SNA 0.53°, ANB 1.77°, Facial convexity 3.13 mm, FMA 1.47°, U1/FH Pl 6.47, LFH 1.30. Decreased SNB -1.03°, FH/PaPl-0.80, Facial axis -1.53°, facial angle-0.1°.
10	WESTWOOD et al. (2003)	Alterações Maxilares entre grupo de tratamento e grupo de controle. Alterações maxilares: Co-Pt 1,1 mm, SNA 1,6°, Pt A tonasionperp 1,8 mm. Alterações mandibulares: Co-Gn -2,5mm, SNB -1,8°, Pgtonasionperp -2,8 mm. Alterações maxilomandibulares: Wits appraisal 4,3 mm, Max/mand diferença -3,7 mm e ANB 3,4°. Alterações verticais: FH para plano palatal 2°, ângulo plano mandibular 1°. Alterações dentárias: Overbite 1,2 mm, Overjet 4,8 mm, relação molar -3,8 mm. Alterações de tecidos moles: LL to E-plane -1,3mm, ângulo nasiolabial 8,2°.
11	ARMAN et al. (2006)	Average cephalometric changes of the difference between the treatment group and the control group. Vertical changes: ANS-Me 1.9 mm. Maxillary changes: SNA 1.69°, Cd-A 1.82 mm, A-VR 3.79 mm. Mandibular changes: SNB -1.56°, B-VR -1.95 mm, S-N.MP 1.58°. Intemaxillary relationship: ANB 3.25°, N.A.Pg 6.45°, (A-VR)-(B-VR) 5.74 mm. Dental changes: Overjet 6.27 mm, Overbite -1.99 mm, U1.NA 3.13°, L1.NB -3.58° and (S-N.OP) 0.23°. Soft tissue changes: Ns-Mes 2.16 mm, Sn-Mes -56 mm, UL-VR -2.56 mm and LL-VR -1.52 mm
12	KILINÇ et al. (2007)	Average cephalometric changes subtracting the change in the treatment group value from the change in the control group value. SNA 0.8°, SNB -2.9°, ANB °3.73, U1 to NSL 8.2°, L1 to ML -3.57°, NSL/ML 3.9° NSL/CVT 3.11°, pns-ad (1) 5.2 mm, pns-ad (2) 5.53 mm, APW-PPW 1.27 mm, APW ′ -PPW ′ 5 mm, NA 59.34 mm, OA 163.52 mm, TA 222.86 mm.
13	MUCEDERO et al. (2009)	Cephalometric changes of the treatment group and control group average difference. Skeletal changes: A-Nasioperp 1.7 mm, Co-A 0.8 mm, Pg-Nasioperp -2.3 mm, Co-Gn -1.9 mm, and palatal-plane mand 1.8°. Changes in airway space dimensions: ADI-Ba 1.1 mm, PNS-AD2 -0.6 mm, AD2-H 1.9 mm, PNS-Ba 1.1 mm, Ptm-Ba 1.0 mm, PNS-H 1.3 mm, Pharynxsup -0.7 mm, Pharynxinf 0.3 mm.
14	FARRONATO et al. (2011)	Cephalometric changes compared in the same group (before and after treatment): SNA (+0.81), SNB (21.35), ANB (+2.16), SN.SNP.SNA (+1.33), and N-Me (+0.84)
15	PAVONI et al. (2014)	The cephalometric changes were not statistically significant when comparing the samples based on the beginning and end of treatment. Differences were noted between the samples when only the final phase was taken into account: SNB 78.5° (NG), 79.7°(HypoG) and 76.1°(HyperG); Pg -NPerp -1.4 mm (HypoG) and -4.4 mm (Hyperg); SN -palatal plane 6.5° (HypoG) and 9.1° (HyperG); SN -mandibular plane 36.6° (NG), 31.3° (HypoG) and 42.3 (HyperG); palatal plane -mandibular plane: 29.3° (NG), 24.7° (HypoG) and 33.2° (HyperG) and Co-Go-Me: 127.8° (NG), 123.9° (HypoG) and131.5° (HyperG)
16	BAVBEK et al. (2014)	Changes observed after treatment between control group and group treated with reverse traction combined with maxillary disjunction - Nose, Underlying skeleton: prn'-prn (nosedepth) 2,2. Maxilla, Upper lip: A-PMV (sagittal depth of maxillary bone) 2,3; PMV-Ls` (hard tissue projection

	of upper lip) 2,3; UL-E (upper lip to Steiner esthetic plane) 1,4; Sn-ULstom (upper lip height) 1,3. Chin projection: Pgs-B'-PMV (inclination of the soft tissue chin)-2.3; Li-B'-Ct (mentolabial angle)-6.6.

Source: Authors.

When comparing all articles selected in this review, cephalometric changes can be grouped and divided into skeletal maxillary changes, skeletal mandibular changes, dental changes, soft tissue changes and changes in the oropharynx space. With regard to maxillary changes, it is possible to emphasize that after extension combined with protraction, maxilla undergoes displacement in the anterior direction and at the same time moves in the inferior direction, which is corroborated by Chang, *et al.* (1997). Unlike what was demonstrated in these studies, de Silva Filho, *et al.* (1991) did not report any significant movement in the anteroposterior direction of the maxilla, being necessary if this maxillary displacement is indicated in this sense, the complementary use of orthopedic appliance.

As a result of palatal expansion, mandible undergoes a clockwise displacement, which results in increase in the angle of the mandibular plane and increase in the lower facial height when band soldered appliances are used (Chung & Font, 2004), in addition to a considered increase in overbite (de Silva Filho, *et al.*, 1991).

Kilinç, *et al.* (2008) proved that the use of rapid maxillary expansion and face mask caused anterior displacement of point A, measured by the SNA angle. The decrease in the SNB angle causes a clockwise rotation of the mandible. The vertical pattern has undergone considerable increase (NSL / ML). Maxillary incisors suffered vestibular inclination while the mandibular ones suffered buccal inclination. Both in the oropharynx and nasopharynx region, increase in its dimensions was observed. The head was in a more extended position in relation to the cervical vertebrae, confirmed by the increase of 2.64 ° in the NSL / CVT. The increase in the nasopharynx region (pns-ad_1, pns-ad_2) was 4.63 mm and 5.6 mm, respectively, and in the oropharynx region (APW-PPW, APW´-PPW´), increase was 1.47 mm and 4.13 mm respectively. Increase of 73.3mm^2 in the nasopharyngeal area was also observed.

Mucedero, *et al.* (2009) also analyzed the effects of extension combined with maxillary protraction on the pharynx and it was possible to conclude that, despite maxillary and mandibular skeletal changes, there was no significant change in the total dimension of the nasopharynx and oropharynx.

The study by Farronato, *et al.* (2011) compared the cephalometric results before and after maxillary extension in class III patients. REM produced significant changes in 5 measures: increase in SNA by 0.81 ° resulted in an anterior movement of the maxilla. Reduction in SNB by -1.35 ° was a consequence of a downward and posterior rotation of the mandible. Increase in SNA and decrease in SNB caused ANB to show increase of 2.15 °, in addition to causing displacement of the palatal plane. Another important change was the increase in the total facial height (N-Me), which also contributes to mandibular rotation in the inferior and posterior direction.

Pavoni, *et al.* (2015) compared the cephalometric discrepancies among three groups according to the vertical skeletal relationship: normal group (NG), hypodivergent group (HypoG) and hyperdivergent group (HyperG). The changes found were: the SNB value showed difference only between HypoG and HyperG and HyperG and NG groups. The Pg-Nperp distance only showed significant difference when comparing HypoG and HyperG groups, as well as the SN- palatal plane in the vertical skeletal pattern. Still in the vertical pattern, changes in the SN-mandibular plane, palatal plane-mandibular plane and Co-Go-Me can be observed among all groups when compared with each other.

Finally, the last study selected in this systematic review was developed by Bavbek, *et al*. (2014), which compared class III patients who underwent maxillary traction (RHg) with patients who underwent maxillary traction combined with palatal extension (RHg + RME) and both groups were compared with a control group (CG) composed of patients who did not undergo any type of treatment - Figure 6. The group to which maxillary traction and expansion was performed presented the following cephalometric changes at the end of treatment: sagittal increase in maxillary depth (PMV-A), and nasal depth (pm-pm`), upper lip protrusion in relation to the PMV line (Ls`-PMV and A´- PMV) and in relation to the Steiner's aesthetic plan (UL-E); significant increase in the upper lip height (Sn-Ulstom); the lower lip thickness at point B increased (LL-BB´) and a considerable decrease in the mentolabial angle was observed.

When comparing groups, the author concluded that there were positive changes in nasal depth (pm-pm`), sagittal maxilla depth (A-PMV) and upper lip length (Sn-Ulstom) in both groups that underwent intervention when compared to the control group. According to the Steiner's aesthetic plan, upper lip protrusion was significant in all groups, with RHg having the highest protrusion and CG the lowest. The Ls-PMV distance that supported the upper lip protrusion and the increase in its thickness was also greater in RHg compared to CG. The inclination of the chin soft tissues (Pg`-B`-PMV) and the mentolabial angle (Li-B`-Ct) in the RHg + RME group decreased, while the inclination of the chin soft tissues decreased and the mentolabial angle increased in the CG and the difference between groups was statistically significant.

When comparing all studies selected in this review, cephalometric changes can be grouped and divided into skeletal maxillary changes, skeletal mandibular changes, dental changes, soft tissue changes and changes in the oropharynx space. With regard to maxillary changes, it is possible to emphasize that after extension combined with protraction, maxilla undergoes displacement in the anterior direction and at the same time moves in the inferior direction, which is corroborated by Chang, *et al.* (1997). Unlike what was demonstrated in these studies, da Silva Filho, *et al.* (1991) did not report any significant movement in the anteroposterior direction of the maxilla, being necessary if this maxillary displacement is indicated in this sense, the complementary use of orthopedic appliance.

As a result of palatal extension, mandible undergoes clockwise displacement, which results in increase in the mandibular plane angle and increase in the lower facial height when band soldered appliances are used (Chung & Font, 2004), in addition to a considered increase in overbite (da Silva Filho, *et al.*,1991).

The result of maxillary and mandibular changes shows improvement in the intermaxillary relationship and improvement in the harmony of the soft tissue profile, decreasing the facial concavity characteristic of Angle class III malocclusion patients (Weissheimer, *et al.*, 2003).

The systematic review with meta-analysis carried out by Lagravère, *et al.* (2006) contrasts with studies selected in this study, as it found that few significant cephalometric changes were observed in the vertical and anteroposterior direction and no clinical changes were significantly reported.

Regarding dental changes, it was possible to conclude that there was a displacement in the mesial direction of maxillary molars, which resulted in better relationship between first maxillary molars when in occlusion with the first mandibular molar. In relation to the horizontal transposition, significant increase was observed, in addition to increase in the pro-inclination of maxillary incisors and in contrast, retro-inclination of mandibular incisors was also observed. Since the patient's profile is directly related to the position of incisors, very significant improvement in the profile harmony of patients undergoing rapid maxillary expansion combined with the use of face mask was observed (Weissheimer, *et al.*, 2003).

Regarding changes observed after rapid maxillary expansion combined with the use of face mask in the upper airway region, including nasopharynx and oropharynx, it was possible to observe that in the study by Kilinç, *et al.* (2008), included in this systematic review and in agreement with Akin, *et al.* (2015), it was possible to conclude that there was significant increase in the pharyngeal airspace dimension. In contradiction to these two studies, the study by Mucedero, *et al.* (2009), also selected to be part of this systematic review, concludes that there were no significant changes in the airspace dimension in the oropharynx as well as in the nasopharynx induced by the rapid expansion of the maxilla associated with maxillary protraction.

Assessing the scope and diversity that permeate the multiple factors related to palatal extension and its implications for clinical practice, it is considered that the conduction of new randomized clinical trials, new systematic reviews and meta-analyses are necessary for a better understanding of the effects of this intervention on outcomes relevant to dental health. Based on the checklist of the Consolidated Standards of Reporting Trials (CONSORT) (Schulz *et al.*, 2010), and in order to contribute to the advancement of knowledge in this area, some recommendations are under analysis, which may support the methodological standardization of future studies.

Of the 16 RCTs included, it is noteworthy that none reported, in an assertive manner, the methodological nature of the work. Explaining to the reader yet in the title, that the study is a randomized clinical trial not only guarantees better dissemination of the research, but also facilitates its inclusion in future systematic reviews. In this sense, it is strongly recommended that in future publications, the authors choose titles more consistent with the real methodology adopted during the research.

After assessing the risk of bias, all RCTs were evaluated with low methodological quality. Almost entirely, the authors did not report in the text information that, although indirectly perceptible in some cases, would contribute to a more positive result of the analysis. A clear example is the absence of reports on participants' eligibility criteria. Even considering the breadth of interpretative limits of the ROB 2.0 tool, and even though it is possible to infer some assumptions through the analysis of other descriptive elements, the simple deduction of the occurrence of a methodological process does not provide enough support to reach a definitive conclusion on the subject. Thus, the importance of the narrative in its completeness, participants' eligibility criteria and aspects related to their selection, is emphasized.

Regarding participants, few studies brought clear information about the place where data were collected. This brings important implications and limitations for a systematic work so that the presence of the team of researchers at all times of the study, including the measurement of outcomes, is one of the evaluation criteria that support better quality and methodological accuracy.

Another aspect that can be improved in future randomized studies and in the sixteen RCTs eligible for this systematic review is the precise and detailed availability of when interventions were actually carried out in each group, thus allowing for data replication in future scientific works.

With regard to randomization, all studies with parallel arms design that were used to carry out this scientific work had flaws, since randomization did not follow a random character, since to be part of the treatment group, patients should follow certain criteria. Also, in relation to randomization, all studies that have a treatment group and at least one control group had limitations in the mechanism for the allocation of elements within intervention or control groups; however, this type of methodological failure is considered inherent to this type of study, also known as inherent bias.

Studies developed by Williams, *et al.* (1997) and Baccetti, *et al.* (1998) used professionals apparently not belonging to the scientific study in order to carry out the necessary treatments, which causes a considerable mistake in the methodology adopted.

None of the sixteen eligible RCTs mentioned any deleterious, side effects or even any complications from the treatment with palatal expansion appliance, and it was not possible to be sure whether in all patients undergoing orthodontic / orthopedic treatment, there was really no effect or if these effects have not been mentioned or even investigated.

All the 16 RCTs failed to register the scientific research carried out on any platform developed for this purpose, since by making such registration, the scientific community is informed about and thus, human and even financial resources can be better allocated.

4. Conclusion

Through the detailed study of the 16 eligible articles included in this systematic review, it could be concluded that in none of the articles, maxillary expansion showed unwanted, deleterious, adverse and / or side effects on angle class III malocclusion patients.

By comparing cephalometric analyses before and after maxillary expansion intervention associated with the use of face mask, it could be inferred that the maxilla undergoes displacement in the inferior and anterior direction at the same time as the mandible moves in clockwise direction. This movement of bone bases causes patients to increase the height of the lower third of the face in addition to improvement in the intermaxillary relationship.

Regarding dental changes after maxillary expansion, studies have shown that molars follow the movements of their respective bone bases. While maxillary incisors undergo proinclination, mandibular incisors undergo retroinclination. It is also possible to conclude that these patients showed decrease in overbite and overjet.

As a consequence of maxillary expansion combined with maxillary protraction, as the use of face mask, the aesthetic profile of patients showed significant improvement, a marked characteristic in Angle class III patients.

Regarding changes of the upper airways after palatal expansion, it was not possible to conclude that there was a gain in the dimensions of the oropharynx and nasopharynx air space, since the two articles that addressed this specific topic eligible for this review are contradictory in their conclusions.

Therefore, when analyzing the cephalometric results obtained after maxillary expansion, mainly associated with the use of face mask, and considering the limiting factors of this qualitative review, it is clear that this type of intervention becomes a viable option in clinical practice for Angle class III malocclusion patients with maxillary deficiency.

However, new qualitative studies and meta-analytical reviews should be carried out in view of the publication of new randomized clinical trials in order to infer more accurate results and provide more power of evidence.

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