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Functional-orthopaedic therapy of Class II malocclusion: diagnostic tools and evaluation of treatment outcomes

PROMOTORE
Chiar.mo Prof.
Roberto Martina

CANDIDATO
Dott. Vincenzo D'Antò

Candidate:
Dr. Vincenzo D’Antò

Promotor:
Prof. Roberto Martina

Co-promotors:
Prof. Ambrosina Michelotti
Prof. Rosa Valletta

Department of Neurosciences, Reproductive Sciences and Oral Sciences, School of Orthodontics and Temporomandibular Disorders, University of Naples Federico II, Naples, Italy.

This thesis was the result of a PhD program attended at the Department of Neurosciences, Reproductive Sciences and Oral Sciences, School of Orthodontics and Temporomandibular Disorders, University of Naples Federico II.

It is the theory that describes what we can observe.

Albert Einstein

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Summary

The aim of this PhD project was to study the diagnostic tools and the treatment outcomes of class II malocclusion functional-orthopaedic treatment.

The thesis is composed of five studies.

The aim of the first study (chapter 1) was to summarise the current evidence on class II malocclusion orthopaedic treatment, performing an overview of the systematic reviews on this topic.

In chapter 2, it is reported a research on the reproducibility of the Fränkel manoeuvre, that is a procedure by which the mandible of Class II individuals is postured forward in dental Class I relationship. The evaluation of the resulting facial profile provides information concerning the components determining the sagittal discrepancy.

The third study aimed to evaluate the influence of the sagittal jaw relationship, in Class I and Class II individuals, on the perception of facial attractiveness by people with different background.

In chapter 4 and 5 two researches focused on the outcomes of class II patients treated by means of a Sander II appliance are reported.

Chapter 1

Class II orthopaedic treatment: what existing research does (and does not) say.

Abstract

This Systematic Review (SR) aims to assess the quality of SRs and Meta-Analyses (MAs) on functional orthopaedic treatment of Class II malocclusion and to summarise and rate the reported effects. Electronic and manual searches were conducted until June 2014. SRs and MAs focusing on the effects of functional orthopaedic treatment of Class II malocclusion in growing patients were included. The methodological quality of the included papers was assessed using the AMSTAR (Assessment of Multiple Systematic Reviews). The design of the primary studies included in each SR was assessed with Level of Research Design scoring. The evidence of the main outcomes was summarised and rated according to a scale of statements. 14 SRs fulfilled the inclusion criteria. The appliances evaluated were as follows: Activator (2 studies), Twin Block (4 studies), headgear (3 studies), Herbst (2 studies), Jasper Jumper (1 study), Bionator (1 study) and Fränkel-2 (1 study). Four studies reviewed several functional appliances, as a group. The mean AMSTAR score was 6 (ranged 2–10). Six SRs included only controlled clinical trials (CCTs), three SRs included only randomised controlled trials (RCTs), four SRs included both CCTs and RCTs and one SR included also expert opinions. There was some evidence of reduction of the overjet, with different appliances except from headgear; there was some evidence of small maxillary growth restrain with Twin Block and headgear; there was some evidence of elongation of mandibular length, but the clinical relevance of this results is still questionable; there was insufficient evidence to determine an effect on soft tissues.

This chapter is based on “D'Antò V, Bucci R, Franchi L, Rongo R, Michelotti A, Martina R. Class II functional orthopaedic treatment: a systematic review of systematic reviews. J Oral Rehabil. 2015;42:624-42.”

Background

Class II malocclusion is one of the most frequently encountered orthodontic issue as it occurs in about one-third of the population [1]. The efficacy of the functional orthopaedic treatments for such malocclusion is a widely debated topic, with controversial results in orthodontic literature [2].

Systematic Reviews (SRs) and Meta-analyses (MAs) are generally considered appropriate study design for offering a strong level of evidence [3], especially on controversial topics. In addition, SRs are one of the best ways to stay up to date with current medical literature [4] instead of reading an average of 17–20 articles per day [5]. A well-conducted SR aims to collect and synthesise all the scientific evidence on a specific topic, according to strict predetermined inclusion and exclusion criteria [6]. When possible, SRs might be integrated with MAs to statistically contrast and combine results from different individual studies and to increase the statistical power of the analysis [7]. Approaching the scientific literature using such methodology might reduce the possibility of systematic errors (bias) [8]. However, the validity of the results of SRs or MAs might be influenced by different factors; among those, the lack of methodological quality of the individual studies included in the review [9], and the methodological flaws in the development of the SR or MA itself must be take into consideration. In 2010, it has been estimated that about 75 trials and 11 SRs of trials were being published every day [10]. Moreover, it is likely to find different SRs on the same topic, conducted with different aims and methodologies and leading to conflicting results [11]. In this scenario, the need of overviewing and comparing the results from the existent SRs in a single paper takes place [12]. To point out the importance of such 'third level' of evidence, the Cochrane Collaboration has introduced the guidelines for *Overview of Reviews* [6], to summarise multiple Cochrane reviews addressing the effects of two or more potential interventions for a single condition.

The aims of the present study were:

1. To evaluate the methodological quality of SRs and MAs on functional orthopaedic treatment of Angle Class II malocclusion in growing patients. More specifically, to determine the methodological quality level of the SRs and MAs and to assess the design of the primary studies included in each SR or MA.
2. To provide an overview of the reported effects of the treatments and to rate the evidence on which these results are based.

Materials and methods

The questions to be answered in the present SR are as follows:

1. What is the methodological quality level of the SRs and MAs addressing the effects of functional orthopaedic treatment of Class II malocclusion?
2. What are the main effects reported in the SRs and MAs about functional orthopaedic treatment of Class II Malocclusion in growing patients and what is the evidence underlying these results?

Search strategy

For the current study, all the SRs and MAs concerning functional and orthopaedic treatment of Angle Class II malocclusion were analysed. The databases investigated for the systematic literature search were as follows: Medline (Entrez PubMed, www.ncbi.nlm.nih.gov), Latin American and Caribbean Health Sciences (LILACS, http://lilacs.bvsalud.org), Scientific Electronic Library Online (SciELO, http://www.scielo.org) and the Cochrane Library (www.cochranelibrary.com). The survey covered the period from the starting of the databases (1966 for PubMED, 1997 for SciELO, 1982 for LILACS and 1993 for the Cochrane Library) up to September 2013. No language restrictions were set. A further hand-search of orthodontic journals (*European Journal of Orthodontics*, *American Journal of Orthodontics and Dentofacial Orthopedics* and *The Angle Orthodontist*) was performed starting from the first volume available on the digital archives, to include possible overlooked or *in press* papers. Moreover, an exploration of the grey literature (unpublished studies) was performed among the conference abstracts of scientific congresses (European Orthodontic Society and International Association of Dental Research).

The following keywords were used and adapted according to the database rules: 'Functional Orthodontic appliance', 'Angle Class II', Malocclusion, Review, Systematic Review. The search strategies applied for each database are shown in Table 1.1. The search was later updated, applying same strategies but customising the publication date range from September 2013 to June 2014.

Studies selection and data collection

Inclusion criteria:

1. To be a Systematic Review or a Meta-Analysis;

2. Studies on the effects of functional orthopaedic appliances on Class II skeletal malocclusion;
3. Studies on growing patients.

Exclusion criteria:

1. Dual publication;
2. Systematic Review of SRs;
3. SR updated in a later publication;
4. Treatment protocol not involving functional orthopaedics.

Two investigators (V.D. and R.B.) independently read all titles and abstracts. Two of four databases (LILACS and SciELO) were analysed by only one investigator, due to language limitations. Subsequently, full-texts of the references that seemed to fulfil the inclusion criteria were acquired and analysed thoroughly. Finally, only the papers that completely satisfied all the inclusion criteria were selected. Disagreements between the two examiners were discussed and resolved to reach a unanimous consensus. In addition, the reference lists of the included SRs were analysed to identify any further relevant missing papers.

From the included papers data about Authors, Year of Publication, Study Design, Diagnosis, Number of Patients, Intervention, Control, Outcome, Quality of the included studies, Results, Author's Conclusions and Author's Comments on Quality of Studies were independently extracted by two authors, and the consensus was reached through discussion.

Table 1.1: Search strategy for each database and relative results

Database	Search strategy	Results
PubMed	((‘Activator Appliances’ [Mesh]) OR ‘Orthodontic Appliances, Functional’ [Mesh] OR ‘Orthodontic Appliances, Removable’ [Mesh]) AND (‘Malocclusion, Angle Class II’ [Mesh])) AND (Review* OR Meta-Analys*)	94
Cochrane Library	Malocclusion Angle Class II; Filter: Review	2
SciELO	Angle Class II Malocclusion AND (Review OR Meta-Analysis)	4
LILACS	(tw:(Angle Class II Malocclusion)) AND (tw:(Review))	2

Quality assessment of the included systematic reviews

For each included SR, the methodological quality was assessed using the AMSTAR (Assessment of Multiple Systematic Reviews) [13]. AMSTAR is composed by 11 items, each one can be answered 'Yes', when clearly done, 'No', when clearly not done, 'Not Applicable', when the item is not relevant, such as when a MA was not attempted by the authors, 'Can't answer', when the item is relevant, but not described by the authors. Each 'Yes' answer is scored 1 point, while the other answers are scored 0 point. According to the number of criteria met, the quality of the included paper was rated as 'Low' (AMSTAR ≤3); 'Medium' (AMSTAR 4–7); 'High' (AMSTAR ≥8) [14, 15].

Moreover, to assess the design of the primary studies included in each SR the LRD (Level of Research Design scoring) was used [16, 17]. The interpretation of such score, which is based on the hierarchy of evidence, is shown in Table 1.2.

Table 1.2: Interpretation of the LRD scores. The scores are based on the type of studies included in the SR

LRD score	**Studies included**
I	Systematic Review of RCT
II	Randomised clinical trial
III	Study without randomisation, such as a cohort study, case–control study
IV	A non-controlled study, such as cross-sectional study, case series, case reports
V	Narrative review or expert opinion

For each included study, both investigators (V.D. and R.B.) independently assessed the methodological quality. There was no blinding for the authors during both quality assessment and data extraction. The interexaminer reliability for the AMSTAR scores was calculated by means of Cohen's k coefficient. Nonetheless, disagreements and discrepancies on the AMSTAR items were discussed and solved to reach a unanimous score.

Synthesis of the results and rating of the evidence

The main results of the included SRs were summarised according to the appliances examined in the study. Afterwards, the evidence on which such results are based was rated according to a modified predetermined scale of statements [14,15]. The statements applied took into account: the way the data were pooled (MA or narrative synthesis), the statistical significance of the result and the number of studies/participants on which the result was based. A full explanation of the statements adopted is reported in Table 1.3. Moreover, a downgrade of the rating was performed (i.e. from sufficient evidence to some evidence) whenever the quality of most of the individual studies addressing a specific outcome was low. The quality of the individual studies was not re-assessed, but reported as assessed by the authors of the reviews.

Table 1.3: Scale of Statements adopted to rate the evidence of the outcomes retrieved from each SR

Sufficient evidence	Meta-analysis: statistically significant pooled result that is based on a large number of included studies/participants or Narrative synthesis: large number of studies and/or study participants showing a statistical significance *When these conditions are applied to a non-significant result, the interpretation is 'evidence of no effect' (ineffectiveness)*.
Some evidence	Meta-analysis: statistically significant pooled result that is based on a small number of included studies/participants or Narrative synthesis: small number of studies and/or study participants showing a statistical significance.
Insufficient evidence to support	Underpowering of the included studies to be able to detect an effect of the intervention (small number of studies/participant supporting significant or non-significant results) *Not to be interpreted as the first statement. This is about 'no evidence of effect or no evidence of no effect'*.
Insufficient evidence to determine	Gap in the evidence (controversial results)

Results

Papers selection

The updated electronic search of all databases resulted in 123 references. One article was retrieved from sources other than database, and it was an '*in press'* paper provided by the authors. After duplicates were removed, 115 references were left. Eighty-six references were excluded because the topic was not pertinent or because they were not SRs. The remaining eligible 29 articles were entirely read, and 15 of them were excluded (Fig. 1, Table 1.4). The most common exclusion criterion was the absence of a systematic search strategy, especially among the oldest papers.

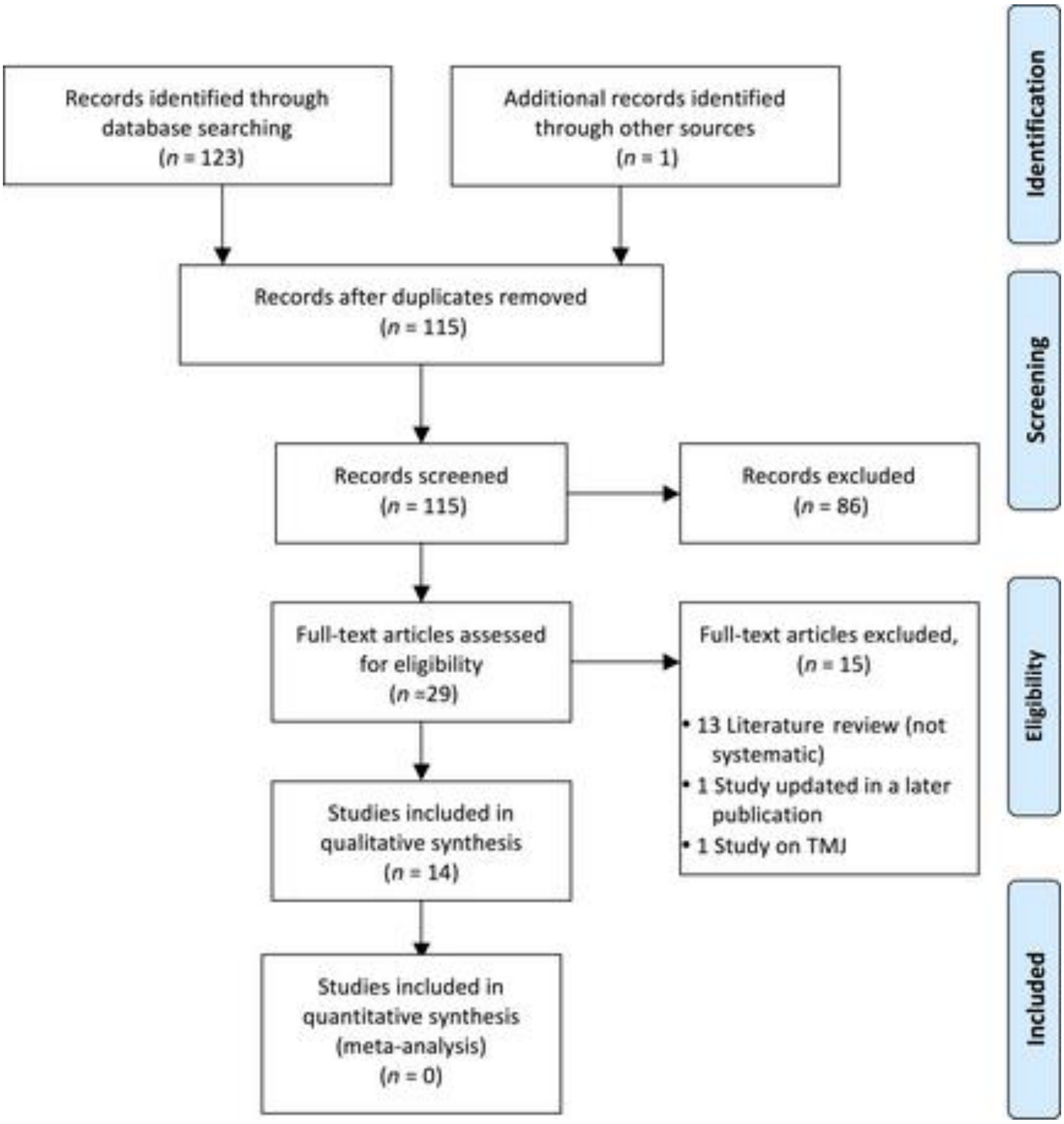

Figure 1.1: PRISMA Flow Diagram of the included and excluded records.

Table 1.4: References excluded after the full-text reading and reason for the exclusion

Reference	Reason for the exclusion
Harrison JE, O'Brien KD, Worthington HV. Orthodontic treatment for prominent upper front teeth in children. (2007)Cochrane Database Syst Rev. 18:CD003452.	Updated in a later publication
Tadic N, Woods M. Contemporary Class II orthodontic and orthopaedic treatment: a review. (2007) Aust Dent J. 2007;52:168-74.	Non-systematic Review
Popowich, K., Nebbe, B., Major, P.W. (2003) Effect of Herbst treatment on temporomandibular joint morphology: a systematic literature review. *American Journal of Orthodontics and Dentofacial Orthopedics* 123, 388-394	Focus on TMJ
Jacobs, T., Sawaengkit, P. (2002) National Institute of Dental and Craniofacial Research efficacy trials of bionator class II treatment: a review. *The Angle Orthodontist* 72, 571-575	Non-Systematic Review
Dyer, F.M., McKeown, H.F., Sandler, P.J. (2001) The modified twin block appliance in the treatment of Class II division 2 malocclusions. *Journal of Orthodontics* 28, 271-280	Non-systematic Review
McSherry, P.F., Bradley, H. (2000) Class II correction-reducing patient compliance: a review of the available techniques. *Journal of Orthodontics* 27, 219-225	Non-systematic Review Focus on the classification of the appliances
Collett, A.R. (2000) Current concepts on functional appliances and mandibular growth stimulation. *Australian Dental Journal* 45, 173-178	Non-systematic Review
Rudzki-Janson, I., Noachtar, R. (1998) Functional appliance therapy with the Bionator. *Seminars in Orthodontics* 4, 33-45	Non-systematic Review
Pancherz, H. (1997) The effects, limitations, and long-term dentofacial adaptations to treatment with the Herbst appliance. *Seminars in Orthodontics* 3, 232-243	Non-systematic Review
Barton, S., Cook, P.A. (1997) Predicting functional appliance treatment outcome in Class II malocclusions-a review. *American Journal of Orthodontics and Dentofacial Orthopedics* 112, 282-286	Non-systematic Review
Aelbers, C.M., Dermaut, L.R. (1996) Orthopedics in orthodontics: Part I, Fiction or reality--a review of the literature. *American Journal of Orthodontics and Dentofacial Orthopedics* 110, 513-519	Non-systematic Review
McNamara JA Jr, Peterson JE Jr, Alexander RG.(1996) Three-dimensional diagnosis and management of Class II malocclusion in the mixed dentition. *Semininars in Orthodontics* 2:114-137.	Non-systematic Review
Ball, J.V., Hunt, N.P. (1991) Vertical skeletal change associated with Andresen, Harvold, and Begg treatment. *European Journal of Orthodontics* 13, 47-52	Non-systematic Review Focus only on vertical growth modification
Mills, J.R. (1991) The effect of functional appliances on the skeletal pattern. *British Journal of Orthodontics* 18, 267-275	Non-systematics Review
Bishara, S.E., Ziaja, R.R. (1989) Functional appliances: a review *American Journal of Orthodontics and Dentofacial Orthopedics* 95, 250-258	Non-systematic Review

The 14 SRs included and the data extracted from each SR are shown in Table 1.5 [18-31]. One-third of the included SRs (5 of 14) were integrated with MA [18, 20, 28, 30, 31]. The number of patients included ranged from 59 to 1763. The diagnosis reported in most of the paper was generally 'Angle Class II malocclusion'; six SRs [19, 23-26, 3] more specifically evaluated Class II Division 1 malocclusion and only in one study [27] vertical facial growth was taken into account as inclusion criterion (Class II hyperdivergent patients). Six SRs [18, 19, 21, 22, 27, 30] included only papers with a comparable Class II untreated group. The appliances studied in the included SRs were as follows: Activator [18, 26]; Twin Block [18, 22, 25, 29]; headgear [18, 20, 27]; Herbst [19, 23]; Jasper Jumper [24]; Bionator [26]; Fränkel-2 [30]. Four papers evaluated several functional orthopaedic appliances, as a group [20, 21, 28, 31]. The primary outcome of most of the articles (7 SRs) was the effect of treatment on the mandible, measured through different cephalometric methods and reference points.

Quality of the included systematic reviews

The Cohen's k coefficient for the AMSTAR items was 0.91, thus indicating very good interexaminer agreement.

The AMSTAR score ranged from a minimum of 2 to a maximum of 10; the mean score was 6. The single AMSTAR items for each paper and the total AMSTAR scores are shown in Table 1.6. Three papers were rated as 'low quality', 8 papers were rated as 'medium quality', and 3 papers were rated as 'high quality'.

Six papers included only Clinical Controlled Studies (CCTs), three papers included only Randomised Controlled Studies (RCTs), four papers included both CCTs and RCTs, and one paper included also book chapter and expert opinions. The LRD scores are shown in Table 1.7.

Table 1.5. Data extracted from the 14 systematic reviews and meta-analysis included

Authors, year, reference	Study design, diagnosis No. of patients	Intervention (I) Control groups (C)	Outcome measures	Quality tool and quality of the individual studies	Results	Authors' conclusions (C) Authors' comments on quality of studies (Q)
Antonarakis and Kiliaridis, 2007	SR and MA of 9 P CTs and RCTs; Class II; 670 subjects	I1: Act (HA; Schwarz; Bio); I2: TB; I3: EOT; I4: Combination (EOT/functional); C: Untreated Class II subjects	Maxillary effect (SNA); Mandibular effect (SNB); Intermaxillary relation (ANB); Overjet	Petren *et al*.: Medium–High* (9/9)	Maxillary effect: Both I2 and I3 control maxillary growth; higher control with I3 (I3:1·03°, I2:1·01°), with lower homogeneity. No significant effect on SNA with I1 and I4 Mandibular effect: I1, I2 and I4 increase mandibular growth; greater effects and high homogeneity with I2(I1:0·66°; I2:1·53°;.I4: 1·05°). No significant results on SNB with I3 Intermaxillary relation: All I1, I2, I3 and I4 reduce ANB angle; highest reduction with I2 (I1:0·92°; I2:2·61°; I3:1·38°; I4:1·8°), highest homogeneity with I4. Overjet: I1, I2 and I4 show a significant decreasing of the OJ; highest decrease with I2(I1:3·88 mm; I2:6·45 mm; I4:4·37), highest	C: All appliances showed an improvement in sagittal intermaxillary relationships (decrease in ANB) when compared to untreated Class II subjects. The use of functional appliances and/or extraoral traction acts mostly in one of the two jaws (mandible for activators and combination appliances and maxilla for extraoral traction) while the twin block group, shows changes on both jaws. Besides the small sagittal skeletal base improvement influencing overjet, the dentoalveolar effect on overjet is brought about by palatal tipping of maxillary and labial tipping of mandibular incisors, respectively Q: Heterogeneity of age, sample size, control groups and appliances

					homogeneity with I4. No significant difference in OJ with I3	
Barnett *et al.*, 2008	SR of 3 CCTs; Class II Division 1; 102 subjects	I1: Crown- or Banded-Type Herbst C: Untreated Class II subjects	Dental and Skeletal cephalometric changes	–	I1 determines increase of several mandibular sagittal skeletal variables (2–3 mm); minimal maxillary skeletal effects (few variables were statistically significant different), proclination/anterior movement of the lower incisors, retroclination/posterior movement of the upper incisors, extrusive and anterior direction of movement of the mandibular first molars; distal movement and intrusion of the maxillary first molars (clinically questionable). Overjet and overbite were also reduced	C: Dental changes have more impact than skeletal changes Q: No RCT, Poor methodological quality of the studies; frequent use of condylion as reference point for mandibular length measurement, which is well-known to be difficult to determine cephalometrically. Different landmarks/measurements, different group age ranges, different treatment duration
Chen *et al*., 2002	SR and MA of 6 RCTs; Class II; Not Reported	I1: Functional appliances (Bass, Bio, Fr-2, TB); C: No treatment and/or EOT	Mandibular growth (horizontal and vertical dimension)	–	I1 significantly increases only in Ar-Pg and Ar-Gn distances. No effect of the type of appliance	C: There is the need to re-evaluate functional appliance use for mandibular growth enhancement. The clinical effect on mandibular length is little, and probably influenced by reference point. (Ar moves posteriorly and superiorly after functional therapy) The absence of statistically significant difference of angular values (SNB and LIA) was unexpected and might be because all

						appliances were analysed as a group Q: Methodological limitation; heterogeneity of skeletal age, treatment durations; lack of treatment-control match and patient compliance evaluation
Cozza *et al*., 2006	SR of 4 RCTs and 18 CTs (2 P and 16 R);Class II; 1763 subjects	I1: Functional appliances (Act, Bass, Bio, Fr-2, Herbst, MARA, TB) C: Untreated Class II subjects	Mandibular sagittal position, Total mandibular length, Mandibular ramus height, and Mandibular body length; Efficiency of the appliances	Modified Jadad scale: Low (3/22) Medium (13/22) Medium–High (6/22)	I1 increases mandibular growth in two-thirds of the samples. Changes in mandibular position in relation to the cranial base were not clinically significant The Herbst appliance showed the highest coefficient of efficiency (0·28 mm month) followed by the Twin block (0·23 mm month). Lowest coefficient of efficiency for the Frankel appliance (0·09 per month)	C: The amount of supplementary mandibular growth appears to be significantly larger if the functional treatment if performed at the pubertal peak in skeletal maturation. Q: Quality of the studies from low to medium/high, rare RCTs (neglecting the skeletal maturation)
Ehsani *et al.*, 2014	SR of 10 CTs (6 P and 4 R) and Meta-Analysis of 5 studies; Class II; 664 subjects	I1: TB C: Untreated Class II subjects	Skeletal, Dental and Soft tissues effects	Modified risk of bias: High risk (1/10) Medium risk (5/10) Low risk (4/10)	Data from the meta-analysis: I1 controls maxillary growth (SNA: 0·8°), projected the low jaw slightly forward (SNB: 1·2°), increments the mandibular body length (CoGn: 3 mm) and increases the anterior facial dimensions (ALFH: 2 mm). Moreover, reduces the upper incisor proclination	C: Dental effects are consistently reported. A clinically significant restraint of maxillary growth was not found. Although the mandibular body length is increased, the facial impact of it is reduced by the simultaneous increment of the face height. Q: Highly heterogeneous and biased studies (various

					(U1-AnsPns: 9·2°) and increases the lower incisor inclination (L1-GoGn: 3·8°)	measurements and treatment times, use of historical controls)
Flores-Mir *et al*., 2007	SR of 3 CCTs; Class II div 1; Not Reported	I1: Splint-Type Herbst; C: No treatment	Dental and Skeletal cephalometric changes	Self-produced checklist: Low (3/3)	Skeletal Effects: I1 increases anteroposterior length of the mandible (0·7- to 2·9-mm), increases mandibular protrusion (1·2° to 2·9°), decreases intermaxillary discrepancy (−1·5° to −2·1° and −4·2- to −4·9 mm), retrudes maxillary anteroposterior position (<1 mm) and increases posterior (1·4- to 2·5-mm) and anterior (1·2- to 3-mm) facial height Dental effects: I1 reduces OJ (−4·6- to −5·6-mm) and OB (−2·5 mm), determines mandibular incisor proclination (3·2° to 4·5°), protrusion (1·5- to 4-mm) and extrusion (5·3°) determines mesial movement of lower molars (0·8- to 3·6- mm) (no extrusion), and distal movement of upper molars (2·5- to 5·4- mm) with intrusion (−0·9 mm) and retroclination (5·6°). No significant changes for upper incisors	C: The combination of several small (statistically significant) changes in different skeletal and dental areas produces the overall reported positive change, but they are not likely clinically significant. Q: Secondary level of evidence. Small sample size. Use of different variables and reference points of cephalometric analysis. No homogeneity in treatment and control groups (race, gender, age). Few studies using control group that included Class II patients

Flores-Mir *et al*., 2006	SR of 5 CTs (1 P and 4 R); Class II div 1; 228 subjects	I1: Jasper Jumper; I2: Herbst; C: No treatment	Soft tissue changes	Self-produced checklist: Low (2/5) Medium (3/5)	I1 increases naso-labial angle, retrudes the position of ‘Labrale Superious’ relative to the vertical reference plane, and protrudes the position of ‘Labrale Inferious’ relative to Aesthetic Plane (E-plane) I2 generates a soft menton protrusion, a ‘Subnasale’ retrusion, contradictory results regarding the anteroposition of the upper lip and no changes in the lower lip	C: There is little of evidence on Jasper Jumper appliance and the results are contradictory. Herbst appliance determines a significant improvement in facial profile. This improvement is not the product of a more forward position of the lower lip but more likely a retrusion of the upper lip. On average, although fixed functional appliances produce some significant statistical changes in the soft tissue profile, the magnitude of the changes may not be perceived as clinically significant. Q: Low level of evidence; reference structures not always reliable
Flores-Mir and Major, 2006a	SR of 2 CCTs; Class II div 1; 59 subjects	I1: TB; C: No treatment	Soft tissue changes	Self-produced checklist: Low (1/2) Medium (1/2)	I1 shows no evidence of change of facial convexity, lower lip, nose and soft tissue menton. Controversial changes in the upper lip for the position of *labrale superius* relative to the aesthetic line, which was in a more retruded position (−1·9 mm)	C: A few studies evaluated the soft tissue profile changes. The twin block appliance seems to not produce a soft tissue profile changes to be perceived as clinically significant. Three-dimensional quantification of soft tissue changes is required Q: Low level of evidence
Flores-Mir and Major, 2006b	SR of 10 CCTs and 1 RCT; Class II div 1; 540 subjects	I1: Act; I2: Bio; C: No treatment	Soft tissue changes	Self-produced checklist: Low (10/11) Medium (1/11)	Contradictory results for both I1 and I2	C: Although some statistically significant soft tissue changes were found, for both I1 and I2 the clinical significance is questionable. Q: Methodological weakness, low level of evidence

Jacob *et al.*, 2013	SR of 4 CCTs; Class II hyperdivergent patients; 221 subjects	I1:Extraoral high-pull headgear (maxillary splints/banded molars) C: Untreated Class II hyperdivergents	Skeletal changes (horizontal and vertical); Dental effects (molar eruption)	Modified Antczak *et al.*: Low – 4 points of 10 (1/4) Medium – 6/7 points of 10 (3/4)	I1 decreases ANB angle (from 0·9 to 1·5°), decreases overjet (2·6–6·5 mm). Statistically significant posterior displacement of the maxilla (0·1–0·5 mm), distalization of the maxillary molar (0·5–3·3 mm), maxillary molar intrusion (0·4–0·7 mm), retroclination (4·4–11·0°) and intrusion of the maxillary incisors (0·2–2·1 mm) were also reported with I1. No effects on the mandible	C: High-pull headgear treatment improved the AP skeletal relationships, by displacing, the maxilla posteriorly but not the vertical skeletal relationships Q: Greater attention to the design and report of studies should be given to improve the quality of such trials
Marsico *et al.*, 2011	SR and MA of 4 RCTs; Class II; 338 subjects	I1: Functional Appliances (Act, HA, Fr-2, Bio, TB); C: No treatment	Mandibular growth (total length)	Assessment of risk of bias: High risk (1/4) Unclear risk (1/4) Low risk (2/4)	I1 increases mandibular growth (1·79 mm in the annual mandibular growth) when compared with C, with statistical heterogeneity	C: The treatment with functional appliances results in change of skeletal pattern (small increases of mandibular length); however, even if statistically significant, appear unlikely to be very clinically significant. The heterogeneity of the results can be attributed to the difference in sample dimension and to the use of different functional appliances). Several benefits must be attributed to the early treatment of Class II malocclusion with functional appliances Q: Heterogeneity regarding cephalometric analyses, variables and reference points

Olibone *et al*., 2006	SR of 45 references (articles and book's chapters) Class II; Not reported	I1: TB; C: Not reported	Mandibular growth; Maxillary effect; Intermaxillary relation; Upper incisor; Lower incisor	–	I1 produces significant reduction of the SNA angle; retroclination of the upper incisors, increase of mandibular length and condyle growth; proclination of the lower incisors; improvement of maxilla-mandibular relation	C: The alterations were the combination of modifications on the condyle, the mandibular fossa, the basal bone and dentoalveolar alterations. Most of the authors recommend the use of the Twin Block during the pubertal peak Q: nr
Perillo *et al*., 2010	SR and MA of 8 CTs (7 R and 1 P) and 1 RCT; Class II; 686 subjects	I1 Fr-2 (FR-2); C: Untreated Class II subjects	Mandibular total length; Mandibular body length; Mandibular ramus height	Modified Jadad scale: Low (7/9) Medium (2/9)	I1 enhances mandibular body length (0·4 mm year), mandibular total length (0·021 mm year) and mandibular ramus height (0·654 mm year)	C: The FR-2 appliance had a statistically significant effect on mandibular growth with a low to moderate clinical impact Q: From low to medium quality of the studies. Heterogeneity in linear measurement, age distribution and treatment duration. Poorly defined initial skeletal diagnosis. Mostly non-randomised and retrospective
Thiruvenjatachari *et al.,* 2013	SR and MA of 17 RCTs; Prominent Upper Teeth (Class II division 1); 721 subjects	AIM 1: I1: Functional Appliance (TB; Forsus; Andreasen; Fr-2; Bass; Bio; R-Appliance; Dynamax; HA; AIBP; Herbst) I2: EOT	OVJ; Intermaxillary relation (ANB); Incisal trauma	Assessment of risk of bias: High risk (11/17) Unclear risk (4/17) Low risk (2/17)	I1 and I2 demonstrate significant difference in OVJ and ANB when compared with C, after the first phase of early treatment. At the end of the treatment, no statistically significant difference, except for a significant reduction in the incidence of incisal trauma Statistically significant reduction in OVJ (−5·22 mm) and ANB (−0·63°) when comparing	C: Early orthodontic treatment for children with prominent upper front teeth is more effective in reducing the incidence of incisal trauma than adolescent orthodontic treatment. There are no other advantages for providing early treatment Q: Overall low quality of the evidence

		C: Adolescent Treatment AIM2: I1: Functional Appliances C: No treatment or different kind of appliance			Late orthodontic functional treatment with no treatment	

SR, systematic review; MA, meta-analysis; CCT, controlled clinical trial; P, propsective; R, retrospective; RCT, randomised controlled trial; Act, activator; TB, twin block; EOT, extra oral traction; Bio, bionator; Fr-2, Frankel-2; MARA, mandibular anterior repositioning appliance; HA, harvold activator; AIBP, anterior inclined bite plate; *stated by the authors. Quality not reported for the individual studies.

Table 1.6. Quality assessment according the AMSTAR items for each SR and total AMSTAR scores. For each Yes answer: 1 point; all the other answers: 0 point

	Antonarakis and Kiliaridis, 2007	**Barnett *et al.*, 2008**	**Chen *et al.*, 2002**	**Cozza *et al.*, 2006**	**Ehsani *et al.*, 2014**	**Flores-Mir *et al.*, 2007**	**Flores-Mir *et al.*, 2006**	**Flores-Mir and Major, 2006a**	**Flores-Mir and Major, 2006b**	**Jacob *et al.*, 2013**	**Marsico *et al.*, 2011**	**Olibone *et al.*, 2006**	**Perillo *et al.*, 2010**	**Thiruvenja-tachari *et al.*, 2013**
Was an '*a priori*' design provided?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Was there duplicate study selection and data extraction?	N	Y	N	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y
Was a comprehensive literature search performed?	Y	Y	N	N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Was the status of publication (i.e. grey literature) used as an inclusion criterion?	N	N	N	N	Y	N	N	N	N	N	N	N	N	Y
Was a list of studies (included and excluded) provided?	N	Y	Y	N	Y	Y	Y	N	Y	N	Y	N	N	Y
Were the characteristics of the included studies provided?	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	Y	Y
Was the scientific quality of the included studies assessed	CA	N	CA	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y

and documented?														
Was the scientific quality of the included studies used appropriately in formulating conclusions?	N	CA	N	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y
Were the methods used to combine the findings of studies appropriate?	Y	Y	N	NA	Y	Y	NA	NA	NA	NA	Y	NA	Y	Y
Was the likelihood of publication bias assessed?	N	N	N	NA	N	N	NA	NA	NA	NA	N	NA	N	N
Was the conflict of interest stated?	N	N	N	N	N	N	N	N	N	N	N	N	N	Y
Total AMSTAR Score	4	6	3	5	3	7	7	6	7	9	8	2	7	10

Y, yes; N, no; NA, not applicable; CA, can't answer.

Table 1.7. Study design of the primary studies included in each SR, as assessed according to the LRD scores

Authors, Year, Reference	LRD
Antonarakis and Kiliaridis, 2007	II–III
Barnett *et al.,* 2008	III
Chen *et al*., 2002	II
Cozza *et al*., 2006	II–III
Ehsani *et al*., 2014	III
Flores-Mir *et al*., 2007	III
Flores-Mir *et al*., 2006	III
Flores-Mir and Major, 2006a	III
Flores-Mir and Major, 2006b	II–III
Jacob *et al.,* 2013	III
Marsico *et al*., 2011	II
Olibone *et al*., 2006	III–IV–V
Perillo *et al*., 2010	II–III
Thiruvenjatachari *et al.,* 2013	II

I: Systematic Review of RCTs; II: Randomised Clinical Trial; III: Study without randomisation; IV: non-controlled study, V: Narrative review/expert opinion.

Main outcomes and rating of the evidence

For this purpose, the papers showing low quality [20, 27, 29] (AMSTAR <4) were excluded.

Dentoalveolar effects

Three SRs [19, 22, 23] studied the dentoalveolar effects of functional orthopaedic treatment, while two SRs [18, 31] focused only on OVJ changes.

Overjet (OVJ)—There is *some evidence* that functional appliances, considered as a group, significantly decrease the OVJ [−3·88 mm [19] to −4·17 mm [31]], with higher results for the Twin Block when assessed individually [−6·45 mm [19]; −3·3 to −6·9 mm [22]].

There is *insufficient evidence to support* a significant reduction of the OVJ (−4·6 to −5·6 mm) with Splint-Type Herbst appliance [23].

There is *insufficient evidence to determine* an effect of the headgear on the OVJ as controversial results are reported: no significant effect was found by Antonarakis and Kiliaridis [18] while a small significant reduction was reported by Thiruvenkatachari *et al*. [31] (−1·07 mm).

Upper and lower incisors—There is *some evidence* of proclination of the lower incisors (L1.GoGn: +3·9°) and retroclination of the upper incisor (U1.Mx plane: −9·2°) with Twin Block [22].

There is *insufficient evidence to support* a proclination/anterior movement of the lower incisors with both Splint-Type [23] and Crown-Banded-Type Herbst appliance [19].

There is *insufficient evidence to support* a distal movement and intrusion of the upper molars and a mesial movement of the lower molars, reported with Splint-Type [23] and Crown-Banded-Type Herbst appliance [19].

There is *insufficient evidence to determine* a mesio-distal movement of upper and lower molars with Twin Block, due to the controversy of the findings [22].

Maxillary skeletal effects

Four SRs evaluated the effects of treatment on the upper jaw [18, 19, 22, 23].

There is *some evidence* of a small maxillary growth restraint with Twin Block appliance (SNA: −0·7°[22] to −1·03°[18]) and with headgear (SNA: −1·01°[18]). There is *some evidence* of a non-significant effect with other activators, considered as a group (Harvold, Bionator, Schwarz) [19].

There is *insufficient evidence to determine* the effect of both Splint-Type [23] and Crown-Banded-Type Herbst Appliance [19] on the upper jaw, which is reported to be very low or even not significant.

Mandibular skeletal effects

Seven SRs analysed the effects of functional orthopaedic treatment on the lower jaw [18, 19, 21-23, 28, 30].

There is *some evidence* of a significant advancement of mandibular position in relation to cranial base (SNB) with Twin Block appliance (1·2°[22]; 1·53°[18]), while *some evidence* of a very small increase of the same angle was reported with other activators, considered as a group (Harvold, Bionator, Schwarz; 0·66°[18]).

There is *some evidence* of mandibular length increasing after treatment with functional appliances, considered as a group, ranging between 0·8 and 4·7 mm as measured with Co-Gn (or Co-Pg) and between 1·2 and 2·2 mm as measured with Olp-Pg + OLp-Co [21]. The same results was reported with an effect size of 0·61 [28].

There is *some evidence* of a significant elongation of Co-Gn with Fränkel-2 [30] appliance and Twin Block [22] appliance individually (1·07 mm/year and 2·9 mm, respectively).

There is *insufficient evidence to support* a significant mandibular length increasing with both Splint-type [23] (0·7–2·7 mm) and Crown-Banded-Type [19] (1·6–2·2 mm) Herbst appliances.

Soft tissue effects

Four SRs evaluated the effects of functional orthopaedic treatment on soft tissues [22, 24-26].

There is *insufficient evidence to support* an improvement in facial convexity after treatment with fixed appliances (Jasper Jumper (J) and Herbst (H)) [24]. In particular, the increase of the naso-labial angle (J) or the retrusion of subnasale point (H) and the protrusion of labrale inferious point (J) or the protrusion of the soft menton (H) are reported.

There is *insufficient evidence to determine* an effect of Twin Block [22, 25] on soft tissues due to the controversy of the reported results: in fact, significant effects were reported in the one SR [22] while non-significant findings were pointed out in another paper [25].

There is *insufficient evidence to determine* an effect on soft tissues with Activator and Bionator as controversial results are reported in one SR [26].

Discussion

The present Systematic Review aimed to summarise the current evidence from the SRs and MAs on the orthopaedic functional treatment of Class II Malocclusion. In particular, the focus of the present study concerns the quality and the main results of the SRs and MAs addressing this issue.

Quality of the included systematic reviews

Scientific and rigorous methods are employed in SRs to identify and summarise the literature, to minimise biases that come from narrative reviews. Nonetheless, as with all the other publications, the value of a SR depends on the way it is conducted and on the accuracy of the results [10].

The methodological quality of the included SRs was assessed with the AMSTAR (Assessment of Multiple Systematic Reviews) [13]. AMSTAR is a recent valid and reliable quality tool [32], built upon expert opinion and empirical data collected with a previously developed tool [13].

The item 1 of the AMSTAR (‘*Was an “a priori” design provided’?*) refers to a registered protocol of the review. The databases for protocol registration, such as PROSPERO (International Prospective Register of Systematic Review) [33], have been recently introduced; therefore, in our study, due to a chronological limitation the presence of the protocol registration was neglected. Affirmative answer to the item 1 was assigned whenever clear predetermined research criteria were provided. Ensuring such approach avoids the review method to be influenced by reviewers' expectations [7].

The AMSTAR scores of the SRs included in the current study showed a wide range of values, between 2 and 10, with an average value of 6. Common factors for the included review to lose point in the AMSTAR score were as follows: not performing a grey literature search (item 4), not assessing the publication bias (item 10) and not providing the conflict of interest of the authors (item 11). However, AMSTAR score have to be carefully interpreted as the single AMSTAR items may have different weights in the overall quality of a SR [34]. For instance, reporting the conflict of interest (item 11) has a low impact on the methodology of a SR. On the other hand, the assessment of the scientific quality of the primary study included (item 7) has to be considered a key item, as this evaluation allows the identification of flaws in the primary literature. In 10 of 14 SRs, the quality of the individual studies was documented and reported. Modified

Jadad Scale [35] and Assessment of risk of bias [36] were the most used tools, together with self-produced checklists based on the key of interest, which are also considered valid instruments [24-26, 9]. Among the included studies, only the Cochrane review [31] adopted the GRADE approach [37] suggested from the Cochrane collaboration as system for grading the quality of evidence and providing the strength of recommendation.

The paper with the highest AMSTAR score (AMSTAR 10) is a Cochrane Review [31]. This result is in accordance with what previously pointed out in several studies [38-40] when comparing the methodology of Cochrane SRs with that of SRs published in paper-based journals; the authors found that the SRs published by the Cochrane Collaboration present less flaws and better methodological quality. These findings suggest that standardised instructions and several peer-review levels improve the methodological soundness of literature.

The AMSTAR score evaluates whether a SR is conducted in appropriate way, but still it neglects information regarding the individual articles included in the SR. To overcome this issue, the AMSTAR score was integrated with the LRD score. The Level of Research Design Scoring has been previously adopted in SR of SRs [34], and it assigns a score to the design of the individual studies according to the hierarchy of evidence [16, 17].

Only one SR [29] included non-controlled studies, book chapters and expert opinions (LRD III-IV-V). This SR showed also the lowest AMSTAR score (AMSTAR 2) and presented a structure closer to a narrative review than to a SR, without providing any definite conclusion. However, it was included in our study because the methodology of the literature search reflects some of the principles of a SR.

Most of the included reviews (6 SRs) included only CCTs. Even if RCTs are considered the best way to investigate the efficacy of dental interventions and to compare different treatment alternatives [41], and MAs of RCTs are considered one of the highest level of evidence [7, 42, 43] only 3 of the included SRs [20, 28, 31] investigated only RCTs. The number of RCTs included in these SRs was variable [6 for Chen *et al*. [20], 4 for Marsico *et al*. [28] and 17 for Thiruvenkatachari *et al*. [31]] and only 2 studies overlapped in the 3 searches, because of different inclusion and exclusion criteria.

Interestingly, one of the SR of RCTs [20] was judged of low quality with the AMSTAR score (AMSTAR 3), demonstrating that even the results of a SR of RCTs, which pretends to be the highest level of evidence, have to be carefully interpreted as major methodological flaws can affect the quality of the SR.

Main outcomes and rating of the evidence

To not provide a simple narrative summary of the results and to assess the quality of body evidence, a predetermined scale of statements was adopted for each of the outcomes analysed. This instrument has been previously adopted in a Cochrane SR of SRs [14, 15], to not re-assess the quality of the studies included within reviews. In the current study, it was not possible to adopt the GRADE approach [37] as suggested by the Cochrane Collaboration, as 'Summary of findings' tables were not reported in any of the included SRs, except for the Cochrane SR [31] and frequently raw data were not available.

The difficulties encountered in our study when synthesising the data extracted from the included SRs and MAs were mainly due to the variability of the inclusion criteria and to the heterogeneity of samples, outcomes, cephalometric landmarks and analysis. Our study pointed out a strong weakness in the initial diagnosis of skeletal Class II malocclusion. All the included SRs set 'Class II malocclusion' as inclusion criterion, but none of them clearly stated how the diagnosis was performed. It was observed that treatment success with functional appliances depends on a great number of confounding variables, including the severity of the baseline conditions. Underestimating this factor does not guarantee generalisation of the conclusion, as the sample might not properly represent the target population [44].

Results from SRs and MAs should be the cornerstone for developing practice guidelines, but due to the limited and biased evidence of the primary studies, the clinical recommendations are always reported to be weak. The most frequently reported flaws of the primary studies were as follows: methodological limitations, absence of a control-matched untreated group, variability of the treatment timing, small sample size and variability of cephalometric analysis and landmarks.

Dentoalveolar effects

According to the results provided by the included SRs and MAs, there is a good consensus in literature regarding the effect of reduction of the OVJ after functional orthopaedic treatment. Nevertheless, if the results of the functional appliances in general and of the Twin Block in particular are supported by a good level of evidence, it is not so for the Splint-Type Herbst appliance. Indeed, the SR by Flores-Mir *et al*. [23] which provides results on this outcome is based only on three references judged of low quality by the authors. Regarding the headgear, the evidence supporting the effect on the OVJ was considered insufficient, due to the controversy of results. These controversies are probably related to the different study selection (all studies [18] vs. RCTs [31]) and to the different inclusion criteria of the studies assessing this outcome. In fact, Antonarakis and Kiliaridis [18] chose as diagnostic criterion the Class II malocclusion, while Thiruvenkatachari *et al*. [31] selected the participants as they presented prominent upper front teeth. Therefore, it is likely to observe a greater dental movement when the starting position of the teeth is altered.

Changes in molar position were reported to be small and generally supported by insufficient evidence.

Little information is reported about the long-term effects after functional treatment. In one SR [18], it is reported that skeletal changes seem to be more temporary than dentoalveolar changes, which are more stable.

Maxillary skeletal effects

Regarding the evidence provided on maxillary growth restraint, few significant values were reported and most of them were too small to be considered clinically relevant. The best effect of SNA reduction seems to be achieved with headgear [18], while Twin Block shows variable results between significant and non-significant [18, 22]. Non-significant values of maxillary growth control were reported with both Splint-Type and Crown-Banded Herbst, but the evidence supporting this result is insufficient due to the small number of primary studies (2 or 3 studies) on which this result is based. In addition, the quality of the individual studies was low in the SR by Flores-Mir *et al*. [23], and even not assessed in the study by Barnett *et al*. [19]. Therefore, the current evidence from SRs is not adequate to suggest or discourage the use of Herbst appliance for maxillary skeletal growth control.

Mandibular skeletal effects

Enhancement of mandibular length and/or achievement of a more forward position of the mandible, albeit still widely discussed, are frequently desired outcomes as most of the skeletal Class II malocclusion are due to a mandibular retrusion [45].

Addressing all functional appliances as a group Cozza *et al*. [21] reported a wide range of significant and non-significant findings, providing results which are scarcely applicable in the daily practice. The variability of the results in this SR is probably due to the inclusion of retrospective studies, which are susceptible to selection bias, and studies with historical samples, which suffer from the secular growth trends, occurred within the craniofacial region over the past century [46]. Moreover, data from treatment with removable and fixed appliances were pooled in this review: this choice can influence the results as the two techniques differ for working hours, length of treatment time, optimal treatment timing and mode of bite-jumping [47]. Considering the primary studies included in this SR, in which the pubertal peak was included in the treatment timing, clinical significance of supplementary mandibular elongation (>2 mm) was reported in all studies except one. According to this finding, the authors of this SR support the hypothesis that the short-term supplementary mandibular growth appears to be significantly larger when the functional treatment is performed at the adolescent growth spurt.

Even though all the SRs and MAs included in our study set the treatment of growing subjects as inclusion criterion, none of them put efforts in assessing the skeletal age. Only in one MAs [18], the studies were included only if the age of the participants was reported.

Barnett *et al*. [19] and Flores-Mir *et al*. [23] reported a significant elongation of the mandible with Crown-Banded and Splint-Type Herbst Appliance, respectively, but the literature supporting these outcomes was judged to be insufficient due to the small number and low quality of the primary studies. Comparing the effect of Acrylic-Splint Herbst with Crown or Banded Herbst Appliance, the differences seem to be small and not relevant, but more research is needed on this issue.

In the MA by Perillo *et al*. [30] on Fränkel-2 appliance, a significant but small increase of mandibular total length was found. However, the sensitivity analysis pointed out a negative correlation between the quality of the included studies and the retrieved results, making questionable the clinical relevance of the findings.

The most recent MAs [28] points out an effect size of the treatment of 0·61 when comparing Class II subjects treated with different functional appliances with untreated control groups. This finding is the result of the standardisation of different cephalometric measures of mandibular length, which accounts differently for jaw divergence (Co-Pg, Co-Gn and Olp-Pg+OLp-Co). In addition, the amount of mandibular length reported as the result of the conversion of the effect size (1·79 mm) is higher than that reported in the individual studies included in the SR. This controversy pointed out that major flaws could affect also a MA of RCTs rated of high quality with the AMSTAR score.

Soft tissues effects

Regarding soft tissues, better results seem to be obtained with fixed functional appliances than with removable, especially when Herbst appliance is used [24-26]. The authors report the improvement of the profile to be mainly due to the retrusion of the upper lip, rather than to the protrusion of the lower lip. However, all the SRs assessing this outcome reported controversial results based on the low-quality primary studies; hence, this evidence has to be considered insufficient.

In addition, none of the primary studies included in the three SRs assessed the changes in facial profile by means of three-dimensional scanning, which is considered a reliable, non-invasive and free of radiation technique for assessing facial form [48]. Due to the superimposition of the hard tissues, conventional cephalometric analyses are considered not adequately capable to detect the soft tissue structure, so the results regarding the soft tissues effects might have been underestimated.

Future research

According to our findings, the registration of the protocol and the implementation of the use of PRISMA guidelines [10] might improve the methodological quality of future SRs. In addition, the use of the GRADE as tool to assess the quality of the primary studies and to provide the strength of recommendation can give a substantial contribution to the clinical conclusions and give more values to the future evidence from SRs of SRs. Moreover, it seems more useful for future SRs to analyse more homogeneous group of patients (selected according initial diagnosis, skeletal maturation and vertical growth pattern) and appliances, as reporting an aggregate pooled effect might be misleading if there are important reasons to explain variable treatment effects across different types of patients [7]. Finally, the evidence from the included SRs and MAs demonstrates that more research is needed on long-term effects of functional orthopaedic treatment.

Conclusions

1. The SRs on functional orthopaedic treatment of Class II malocclusion present a heterogeneous methodological quality. Only two SRs were judged of high quality.
2. Three of the 14 papers analysed, include *only* RCTs and numerous SRs report a low quality of the individual studies.
3. Clinicians should be aware of the existent tool to assess strength and weakness of the SRs and MAs, to adequately recognise whenever limited information can be obtained from such studies.
4. In general, there is still no sufficient evidence to suggest or to discourage the orthopaedic functional treatment in Class II patients. The lack of definite evidence is mainly due to the small number of primary studies for each outcome and the low quality of most of the individual studies.
5. There is some evidence of reduction of OVJ with several functional appliances, except from Herbst appliance, due to the poor quality of literature, and headgear, due to the controversial results reported with this appliance.
6. There is some evidence of a small maxillary growth control with headgear and Twin Block.
7. In the short term, there is some evidence of mandibular length increasing after treatment with several functional appliances, but not with Herbst appliance, which presents poor quality of literature. However, the clinical relevance of the reported results is still questionable and long-term data are not available.
8. There is insufficient evidence to support the effect of functional orthopaedic treatment on soft tissue.

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Chapter 2

Class II orthopaedic treatment: back or forth? - Part I
The assessment of the *Fränkel manoeuvre* in daily practice

Abstract

Aim: The Fränkel manoeuvre is a procedure by which the mandible of Class II individuals is postured forward in dental Class I relationship. The evaluation of the resulting facial profile provides information concerning the components determining the sagittal discrepancy. Data concerning the reproducibility of its assessment are not available. This study aimed to evaluate the intra-observer and inter-observer reproducibility of the assessment of the manoeuvre and to assess whether the amount of clinical experience affects its reproducibility.

Methods: Two lateral photographs, one in centric occlusion, and the other with the mandible postured forward (Fränkel manoeuvre) of 100 Angle Class II individuals aged between 9 and 13 years were evaluated by six orthodontists (T0). Each examiner was asked whether the facial profile worsen or not with the manoeuvre after being trained by an expert orthodontist. The test was repeated after 2 weeks interval (T1). Intra-observer and inter-observer agreement were evaluated by computing the Cohen's *K*.

Results: The agreement (*K* values) between observations (T0 versus T1) for each examiner ranged from 0.49 to 0.72. The overall agreement was 0.65 [95% confidence interval (CI) = 0.54–0.75]. The agreement in the group with less clinical experience was 0.61 (95% CI = 0.46–0.76), while it was 0.68 (95% CI = 0.53–0.83) in the more experienced group. The amount of clinical experience did not affect intra-observer agreement ($P = 0.50$). The overall agreement between the examiners and the trainer was 0.74 (95% CI = 0.65–0.83) and 0.73 (95% CI = 0.64–0.83) at T0 and T1 respectively.

Conclusion: The assessment of the Fränkel manoeuvre is reproducible and it is not influenced by the amount of clinical experience.

This chapter is based on "Martina R, D'Antò V, Chiodini P, Casillo M, Galeotti A, Tagliaferri R, Michelotti A, Cioffi I. Reproducibility of the assessment of the Fränkel manoeuvre for the evaluation of sagittal skeletal discrepancies in Class II individuals. Eur J Orthod. 2015 Oct 3."

Background

Angle Class II is the most frequent malocclusion in growing individuals. Previous studies have shown that it is mostly associated to mandibular retrusion [1–4] and to a convex facial profile.

The diagnostic process for the evaluation of sagittal skeletal discrepancies in growing individuals includes both cephalometric and aesthetic assessments. The cephalometric analyses available for the evaluation of sagittal discrepancies still rely on angular and linear measurements. Nonetheless, a number of studies have questioned several of these indicators. For instance, the use of A point -Nasion -B point (ANB) angle has been criticized [5,6], since it is sensitive to the position of the anterior cranial base, and may vary according to the divergence of the jaws [7]. Similarly, the Wits appraisal is questionable [8,9], being also sensitive to a correct identification of the occlusal plane, and to its variations due to tooth eruption, and to the effect of orthodontic treatment. Linear measurements of the mandible and maxilla as well have limited significance because of the large individual variation and due to secular trends effect on norm cephalometric linear and angular measurements [10]. Hence, not surprisingly, cephalometric outcomes are only partly considered for a proper diagnosis of sagittal skeletal discrepancies in clinical setting [11].

The evaluation of the facial profile has increased the awareness of the limitations of cephalometric norms for the assessment of sagittal discrepancies. According to Arnett and Bergman [12], the aesthetic assessment of the facial profile is a good diagnostic indicator of sagittal skeletal discrepancies. Hence, they developed a soft-tissue cephalometric analysis. Nonetheless, this instrument uses norms from a limited sample of adult individuals and does not report measurements for growing patients.

To our knowledge, a set of soft-tissue cephalometric norms in growing individuals is lacking, probably because it could be awkward due to the well-known inter-individual differences in soft-tissue trait changes with growth [13].

Useful clinical information for the aesthetic evaluation of individuals with mandibular retrusion derives from the observation of the chin position and of the lip philtrum. In Class I individuals, the latter should exhibit a forward and downward slope when the patient assumes a natural head posture. Forward projection of the upper lip could be indicative of a protruding maxilla, while a backward projection of the lower lip may indicate a retruded mandible [14].

The Fränkel manoeuvre is a clinical procedure by which the lower jaw of individuals affected with Class II malocclusion is postured forward until molars and canines are in Class I relationship. Once the position is reached, the patient has to keep the lips in contact, without excessive contraction of the perioral muscles. The aesthetic evaluation of the manoeuvre provides additional information concerning the components determining the sagittal discrepancy [15]. According to the authors, a worsening of the profile with the Fränkel manoeuvre, with biprotruded appearance, could indicate a forward positioning of the upper jaw and that the mandible has adapted to this forward position. On the contrary, aesthetic improvement of the facial profile, with orthognatic appearance, may indicate a retruded mandible [15]. Although this tool is largely used in clinical practice, and partly for research purposes [16, 17], data concerning the reproducibility of its assessment are not available. Reproducibility refers to the variation in measurements made on a subject under changing conditions [18] and is an indicator of the quality of a diagnostic test. Testing the reproducibility of a diagnostic tool could increase the relevance of the interpretation of the clinical outcome.

Hence, the aim of this study was to evaluate the intra-observer and inter-observer reproducibility of the assessment of the manoeuvre and to assess whether the amount of clinical experience might influence its reproducibility. The null hypothesis to be tested was that the assessment of the manoeuvre presents a scarce intra-rater and inter-rater reproducibility.

Subjects and Methods

Study sample

Consecutive patients seeking for an orthodontic consultation were screened by two specialists in orthodontics (RM and AG) at two orthodontic divisions. Patients were considered eligible when they presented a full Class II molar relationship, overjet greater than 6mm, an age range of 10–13 years for boys and of 9–12 years for girls. The Fränkel manoeuvre [15] was used to evaluate the sagittal jaw discrepancy based on an aesthetic evaluation, as done in previous research reports [16, 17]. Patients were asked to posture the mandible forward until a Class I molar and canine relationship was achieved. The manoeuvre was then repeated at least three times while coaching the patients to keep the lips in contact without an excessive contraction of the perioral muscles. The following conditions were considered as exclusion criteria: lack of parent's willingness to sign an informed consent form, orofacial inflammatory conditions, tooth agenesis, congenital syndromes, facial asymmetries, and previous orthodontic treatment. The study protocol complied fully with the principles of the Helsinki Declaration and was approved by the Local Ethics Committee (reference number: 13704).

One hundred individuals (56 males, 44 females, mean age ± std deviation = 10.8±1.5) were recruited.

Two lateral photographs of the right facial profile of each patient were taken using a black background panel, in order to eliminate shadows, while in natural head position (NHP): one photo with the mandible in Class II relationship (centric occlusion) and another with the mandible positioned according to the Fränkel manoeuvre (Figure 1). Subjects were asked to keep their head and shoulders erect with both arms hanging free at their sides. A plumbline cable was photographed together with the patient to resemble the true vertical line. The camera was mounted at a distance of 2.5 m on an adjustable tripod. Cepahalometric sella -nasion -A point angle (SNA) and sella -nasion -B point angle (SNB) measurements were collected by a single operator over digitized lateral cephalograms using a software (Dolphin Imaging System 11.0, Chatsworth, CA). The method error was computed using the Dahlberg formula over repeated measurements collected over 30 lateral radiographs and was 0.4±1.2 for SNA and 0.2±0.6 for SNB.

Figure 2.1: Sample pictures of two individuals assessed for the study. Left: facial profile in centric occlusion; Right: facial profile with Fränkel manoeuvre. The manoeuvre causes an improvement of the facial profile in subject A, while a worsening of the facial profile with the manoeuvre is evident in case B (biprotruded appearance).

Examiners

Six orthodontists randomly selected among two groups of clinicians with different clinical experience (more than 10 years versus less than 5 years), each including 10 clinicians of the School of Orthodontics at the Section of Orthodontics, University of Naples, Italy, were invited to assess the outcome of the Fränkel manoeuvre for each recruited patient. Before the assessment, all the examiners were submitted to a training session lasting 1 hour, in which an operator (RM) expert in the usage of the manoeuvre trained all the examiners for a proper execution and evaluation of the manoeuvre. A set of clinical cases was shown during the presentation, and the interpretation of the Fränkel manoeuvre outcomes were critically discussed with all the examiners.

One hundred power-point slides (Microsoft, Redmond, WA), each including the previously described two facial profile photographs, were submitted to each examiner, who was invited to answer to the question ‘Does the facial profile worsen with the Fränkel manoeuvre?’, with a dichotomous response (yes/no). Each examiner was invited to assess the pictures in a quiet room, without time limit (time T0). After 15 days interval, all the examiners were invited to repeat the assessments with the same patients’ pictures placed in a different order (time T1).

Statistical analysis

A sample size of 96 subjects was required to estimate kappa, assuming a 95% CI, a margin of error of 0.2, a positive test in about 20%, and without assumption about the value of kappa.

Cohen’s kappa value and 95% CIs were calculated for single examiners and overall to evaluate the intra-rater agreement between observations (T0 versus T1 condition). The agreement between observations (T0 versus T1) was also computed for each group (experience less than 5 years versus experience more than 10 years). A test for equal kappa values among strata was also performed. The training was evaluated by computing the Cohen’s kappa between the examiners and the trainer (RM) at the different observations (T0 and T1).

The agreement between cephalometric diagnostic sagittal categories and the outcomes of the Fränkel manoeuvre were computed by calculating the Cohen's kappa between the trainer at T0 time and cephalometric categories of Class II discrepancies. Values outside cephalometric norms plus or minus a standard deviation for SNA and SNB were used for classifying the position of the jaws of the selected study sample. Subjects with SNA values increased of more than one deviation from the norm and with a SNB value within the normal range [19] were considered to have a forward position of the maxilla, and, therefore, the ones that should have been assessed as 'worsened' with the Fränkel manoeuvre. The statistical significance was set at $P < 0.05$. SAS version 9.2 (SAS Inc., Cary, North Carolina, USA) was used.

Results

The frequency and the distribution of the examiners' replies (outcomes of the Fränkel manoeuvre) are reported in Table 2.1. The agreement (*K* values) between observations (T0 versus T1) for each examiner ranged from 0.49 to 0.72. The overall agreement between the two observations was *K* = 0.65 [95% confidence interval (CI) = 0.54–0.75; Table 2.1]. The agreement in the group with less than 5 years clinical experience was *K* = 0.61 (95% CI = 0.46–0.76), while in the group greater than 10 years was 0.68 (95% CI = 0.53–0.83, Table 2.2). The amount of clinical experience did not affect the intra-observer agreement (*P* = 0.50, Table 2.2).

At T0, the agreement between the trainer and each examiner ranged between 0.59 and 0.71 (Table 2.3), while the agreement between the examiners and the trainer (T0 observation) sorted by experience (less than 5 years versus greater than 10 years) and controlled for examiner is reported in Table 2.4. No statistical differences were found between groups (*P* = 0.34).

Table 2.1: Frequencies of Fränkel manoeuvre outcomes (YES, NO, %) sorted by examiner at T0 and T1, and agreement (*K* values) between observations (T0 versus T1).

Examiner	NO		YES		*K* value*	95% Confidence interval
	T0	T1	T0	T1	T0 versus T1	
RC	90	91	10	9	0.71	0.47–0.95
GM	87	89	13	11	0.72	0.50–0.93
PF	92	94	8	6	0.54	0.21–0.86
AS	92	86	8	14	0.49	0.26–0.76
RV	91	96	9	4	0.59	0.28–0.91
AM	90	91	10	9	0.71 *P = 0.74*	0.47–0.95

*Overall agreement between observations (controlled for examiner) *K* = 0.65 (95% CI = 0.54–0.75).

At T_1, the agreement between the trainer and each examiner ranged between 0.55 and 0.83 (Table 2.3), while the agreement between the examiners and the trainer (T1 observation) sorted by experience (less than 5 years versus greater than 10 years) and controlled for examiner is reported in Table 2.4. No statistical differences were found between groups (*P* = 0.62). The agreement between the trainer (T0 observation) and the cephalometric assessment was *K* = 0.52. The disagreements regarded all patients with a maxillary protrusion (increased SNA and SNB within the norm [19]), but rated as ‘not worsened’ by the trainer.

Table 2.2: Agreement (*K* values) between observations (T0 versus T1) for each group (experience <5 years versus experience >10 years, controlled for examiner).

Group	*K* value	95% Confidence interval
<5 years	0.61	0.46–0.76
>10 years	0.68 *P = 0.50*	0.53–0.83

Table 2.3: Agreement (*K* values) between examiners and trainer (T0 and T1 observations).

	T0		**T1**	
Examiner	***K* value**	**95% Confidence interval**	***K* value***	**95% Confidence interval**
RC	0.71	0.47–0.95	0.59	0.32–0.87
GM	0.69	0.47–0.92	0.84	0.66–1.00
PF	0.68	0.41–0.94	0.73	0.48–0.98
AS	0.68	0.41–0.94	0.62	0.39–0.86
RV	0.88	0.71–1.00	0.55	0.23–0.86
AM	0.59 *P = 0.50*	0.31–0.86	0.83*P = 0.36*	0.63–1.00

*Overall agreement between examiners and trainer at T0 *K* = 0.74 (95% CI = 0.65–0.83), at T1 *K* = 0.73 (95% CI = 0.64–0.83).

Table 2.4: Agreement (*K* values) between examiners and trainer (T0 and T1 observations) by experience (<5 years versus >10 years, controlled for examiner).

	T0		**T1**	
Group	***K* value**	**95% Confidence interval**	***K* value**	**95% Confidence interval**
<5 years	0.69	0.54–0.83	0.76	0.63–0.88
>10 years	0.78*P = 0.34*	0.65–0.90	0.71*P = 0.62*	0.57–0.85

Discussion

To the best of our knowledge, this is the first study that assessed the reproducibility of the Fränkel manoeuvre and the effect of clinical experience on this clinical diagnostic tool. According to the authors [15], the manoeuvre is completed while the patient is positioned in molar and canine Class I. A positive response to the question ‘does the facial profile worsen with the Fränkel manoeuvre?’ may be an indication of a biprotruded facial profile (while the manoeuvre is executed), suggesting that the subject has adapted the mandible to a forward position of the upper jaw. On the contrary a negative reply may indicate a more harmonious facial profile (while the manoeuvre is executed), pointing to a normal position of the upper jaw and a retruded position of the mandible (Figure 1).

In agreement with McNamara and Vasquez [1, 3], it was found that the facial profiles of the greater part of the study sample improved with the manoeuvre, thus suggesting the diagnosis of mandibular retrusion. This resembles the normal distribution of skeletal Class II phenotypes into the Caucasian population. Also, the results of the current study have revealed that, although the assessment of the manoeuvre may look very subjective at a first sight, it presents a substantial reproducibility [20, 21] which is not significantly influenced by the amount of clinical experience. This result makes the manoeuvre a useful diagnostic tool to be used by orthodontic practitioners for the sagittal evaluation of the facial profile in addition to the conventional diagnostic tools (i.e. cephalometric norms). Moreover, the agreement between the assessment of the manoeuvre and the cephalometric diagnosis was moderate and all the disagreements regarded patients with cephalometric diagnosis of maxilla protrusion, but considered ‘not worsened’ with the Fränkel manoeuvre. One of the disagreement was the case A of Figure 1, who presented a SNA = 94° and a SNB = 89°. This suggests that cepahlometric variables and the assessment of Fränkel manoeuvre could give in some cases different results. As a consequence of this, the manoeuvre should be considered an additional clinical test for evaluating sagittal Class II discrepancies, other than cephalometrics.

Although cephalometric analysis has still to be considered a keystone tool for treatment planning, more recently it has been shown to influence only partially the treatment approach [11, 22, 23]. At the same time, the aesthetic evaluation of soft tissues and facial profile seems nowadays to be crucial for an adequate treatment planning [12] which should consider a possible improvement of facial attractiveness. Hence, the manoeuvre can be considered a simple and useful tool, able to detect skeletal Class II due to mandibular retrusion, and to help the choice among different and rather opposite treatment modalities (i.e. functional therapy for obtaining a forward position of the mandible versus orthopedic control of the upper jaw). The question ‘does the facial profile worsen with the Fränkel manoeuvre?’ was constructed to interpret easily the outcome of the manoeuvre. Indeed, a worsening of the profile, mainly due to a biprotruded appearance, in most cases could indicate that the lower jaw should not be positioned forward with treatment. On the contrary, an improvement of the aesthetics of the profile with the manoeuvre would suggest that a mandibular advancement should be pursued to achieve a more harmonious facial profile.

It might be questioned whether all the examiners monitored properly the execution of the Fränkel manoeuvre and assessed it correctly. The substantial agreement found between the examiners and the clinical trainer, at both T0 and T1 time points, shows that the training of the examiner was good.

This study suffers of some limitations. First, it does not provide information about the validity of the manoeuvre. Indeed, validity refers to the degree in which a diagnostic tool is truly measuring what is intended to measure. However, since a gold standard for the evaluation of sagittal discrepancies is lacking, the validity cannot be tested. Instead, our data confirm that the examiners evaluated the outcome of the manoeuvre similarly. Second, the examiners were randomly selected among the staff of the same School of Orthodontics. As a consequence of this, they had similar orthodontic training, other than the training executed for the experiment. Third, it has been suggested that although NHP is highly reproducible [24], it may be sensitive to the type of malocclusion. Finally, no conclusion about the possibility of obtaining similar results between the outcome of the manoeuvre and treatment outcome can be drawn with this research design.

Conclusion

Orthodontic diagnosis is often a very difficult challenge. Different diagnostic tools should be considered in order to be more critical and tailored to the patient. The Fränkel manoeuvre is a diagnostic tool frequently used in clinical setting. This study has tested its reproducibility, which was shown to be moderate to high. This result could increase the relevance of the interpretation of the clinical outcome of the manoeuvre when evaluating sagittal skeletal discrepancies in Class II individuals.

In conclusion, this study has shown that the Fränkel manoeuvre is highly reproducible and can be used in addition to the cephalometric assessment for the evaluation of sagittal skeletal discrepancies.

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Chapter 3

Class II orthopaedic treatment: back or forth? - Part II Facial attractiveness of skeletal class I and class II malocclusion as perceived by layperson, patients and clinicians

Abstract

Aim: This study aimed to evaluate the influence of the sagittal jaw relationship, in Class I and Class II individuals, on the perception of facial attractiveness by people with different background.

Material and methods: A set of silhouettes was obtained by manipulation of a neutral facial profile, in order to simulate mandibular retrusion, maxillary protrusion, mandibular retrusion combined with maxillary protrusion, bimaxillary protrusion and severe bimaxillary protrusion. The attractiveness of the modified silhouettes and two copies of the neutral silhouette were assessed by five groups of people with different background, including orthodontists, maxillofacial surgeons, orthodontic patients and laypeople. Each examiner was asked to fill a Psychological General Well-Being (PGWB) questionnaire before starting the evaluation, to assess his/her psychological impairment. Examiners with an impaired PGWB were excluded. Data were analyzed with a mixed model.

Results: 106 valid questionnaires were filled by 23 expert orthodontists, 21 young orthodontists, 15 maxillofacial surgeons, 19 patients and 28 laypeople. Straight facial profiles received higher scores while convex profiles due to severe mandibular retrusion and mandibular retrusion combined with maxillary protrusion were rated worse ($p<0.05$). Convex profiles due to a slight retruded position of the mandible were rated worse by clinicians than by patients and laypeople ($p<0.05$).

Conclusions: Class II was considered unattractive as compared to class I. Laypeople and patients assessed facial profile aesthetics differently from clinicians and are less sensitive to profile than orthodontists when evaluating class II sagittal discrepancies.

Background

The appearance of individuals can influence our behaviour towards them. Several studies support the notion of a "beautiful is good" stereotype and suggest that facial appearance is used as a guide to infer a variety of characteristics, including attractiveness, personality, sociability, intellectual competence, mental health and personal achievement [1-2].

The face is thought to be one of the main features in determining physical attractiveness [3-4], and facial attractiveness may be related to lower facial appearance; that is why facial aesthetics is one of the main goals of orthodontic treatment. Particularly, the main effect on facial attractiveness of an orthodontic treatment is revealed in the facial profile [5]. Moreover, as patients are becoming more aesthetically educated and aware of their appearance, one of their primary motivations for seeking orthodontic treatment is to improve their looks [6].

The aesthetics of a facial profile is usually assessed by using normal or average patterns that may not correspond, necessarily, to the most attractive [7-8]. The ethnic background and culture [9], age and gender [10] of judges, socio-economical status and professional training [11] are all variables affecting personal opinion.

The overall appearance of a facial profile is defined by the relationship between the upper facial plane (from Glabella to Subnasale) and the lower facial plane (from Subnasale –SN- to Pogonion –Pg-). The angulation and inclination of these two lines define, respectively, the overall *contour* and the convexity or concavity of the facial profile. The contour angle is stated to be normally negative [9] but "straight" facial profiles, with soft tissue Pg on the vertical line passing through Nasion (Na) and Sn on or close to this line [13], has been long considered as most attractive [14-17]. More recent evidences support the idea that more convex profiles are favorable [6, 9, 18, 19], especially for females, and make the face look more youthful [18]. Instead, in men, a straight profile with prognathic maxilla is preferred [6, 20]. Slight mandibular retrusion (up to -4mm) or protrusion (up to +2mm) from the ideal position are essentially unnoticeable [11]. The perception of chin position is, in fact, influenced by lip position and prominence [19].

Lip prominence can be affected by orthodontic treatment or surgery [21] and is strongly influenced by ethnicity [8, 22] and age [23]. Linear measurements of the upper and lower lip to the E-line have significantly reduced with time, suggesting an increase in lip protrusion [24]: fuller lips are, nowadays, preferred [6, 15, 18, 19, 20, 24], both in the female and male genders [6], giving the face a more attractive and youthful appearance [18]. Greater lip protrusion is ideal when a discrepancy in normal chin or nose position is present [25]: when the chin is retruded a more forward position of the lip is preferred so that the lower lip may, to some extent, mask the severity of the Class II pattern [19]; at the same time, fuller lips may improve the profile appearance in a class III malocclusion [19, 25], likely fulfilling the concavity of the face.

Beauty and attractiveness is a complex issue and it is increasingly recognized that what is considered attractive by orthodontists and surgeons, based on their experience and training, may not be perceived as attractive by patients and laypeople [26].

Several studies have shown that the perception of facial attractiveness differs between patients, peers, and dental professionals [11, 27-29]. It has also been suggested that dental professionals may be more sensitive to certain aspects of the profile than laypersons and vice versa [27, 30, 31]. Patients, like, clinicians, demonstrate a greater sensitivity to noticeable differences in facial appearance from the ideal [11].

Some studies have reported that orthodontists have an enhanced and perhaps biased view, especially of the facial profile [31]. Orthodontists and oral surgeons, by nature of their training and work, may be sensitive to disharmonies in aesthetics.

Some authors, on the contrary, have reported laypersons as having more critical perceptions of profile aesthetics than professionals [32].

All results are, however, not fully comparable because of different methodologies or outcomes of the studies. Even if an overall agreement in preferences and general likelihood may exist [20], opinions differ in the perception of details, sensitivity to differences [11] and the recognition of slight modifications in the profile. Moreover, some studies use photographs instead of silhouettes, introducing many confounding factors (e.g., skin tone, hairstyle, facial expression, etc.) laypersons are particularly sensitive to [33].

Considering patients, it must be taken into account that their perception of attractiveness may be influenced by their own malocclusion and degree of skeletal discrepancy. It has been reported that orthognathic patients perceive facial profiles differently from laypersons [11, 34] and a comparative study of skeletal class II and III patients demonstrated that class III patients had stronger feelings regarding their profiles [35].

That is why facial attractiveness is a generic term that is subjective to the examiner’s

personality traits and personal background, and is very sensitive to information bias.
This study aimed to evaluate the influence of different types of sagittal skeletal discrepancies of Class I and Class II individuals on the perception of facial attractiveness, in order to determine which profile is perceived as unattractive.
The null hypothesis is that mandibular retrusion does not influence the perception of facial attractiveness and there is no difference in the perception of facial attractiveness among people with different backgrounds.

Materials and methods

A set of facial profile silhouettes was used to assess the attractiveness of facial profiles. A two-dimensional right facial profile silhouette was chosen randomly from a pool of 10 silhouettes, obtained by tracing the facial profile from a right lateral photograph of 10 adolescent patients with skeletal class I (as measured according to Steiner's cephalometric analysis), dental class I and an orthognathic profile.

The original facial profile silhouette was modified using software (Adobe Photoshop CS4-Adobe System Inc., San Jose, California, USA), to create six different silhouettes depicting a combination of different rates of mandibular and/or maxillary protrusion/retrusion.

The silhouette displayed a complete facial profile.

To produce the sagittal discrepancies, the middle and lower third of the face were advanced or retruded using 2-mm stepwise increments or decrements from the most retrusive to the most prognatic position. Smaller steps would have produced silhouettes without appreciable differences [11, 35].

Six different silhouettes were produced by manipulation (Figure 3.1) and each silhouette was randomly assigned a double letter code to identify it:

-mandibular retrusion (NF);

-maxillary protrusion (NB) ;

-mandibular retrusion combined to maxillary protrusion (NC);

-bimaxillary protrusion (NE);

-severe bimaxillary protrusion (ND);

-bimaxillary retrusion (NG).

The neutral orthognathic class I silhouette was assigned with the NA code. A duplicate of NA was inserted into the pool and named NH.

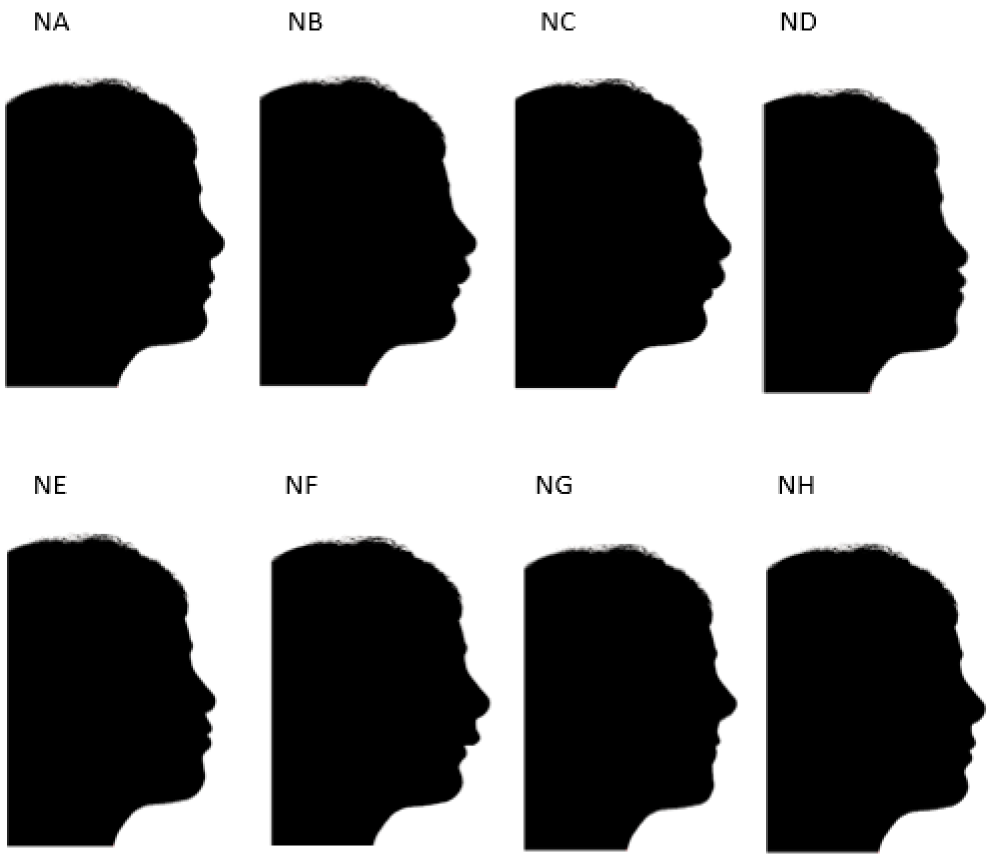

Figure 3.1: Silhouettes produced by manipulation.

Examiners

Five groups of people with different backgrounds were invited to assess the facial attractiveness of the seven silhouettes on a 7-points Likert scale.

The five groups included:

Orthodontic patients: patients (age >18 years) seeking an orthodontic treatment. Patients were recruited during an orthodontic first screening at the Department of Neuroscience, Section of Orthodontics at the University of Naples Federico II. Only patients with no prior facial surgical treatment, no history of facial trauma, no severe psychological issues and no body dysmorphic disorder were included.

Laypeople: people with no history of facial trauma, no severe psychological issues and no body dysmorphic disorders were included (age > 18 years).

Young Orthodontists (with less than 5 years of experience): the orthodontists earned their degrees less than 5 years ago. Only orthodontists with no history of facial trauma, no severe psychological issues, and no body dysmorphic disorder were included.

Expert Orthodontists (more than 5 years of experience): the orthodontists received their degrees more than 5 years ago; only orthodontists with no history of facial trauma, no severe psychological issues, and no body dysmorphic disorders were included.
Maxillofacial Surgeons: Maxillofacial surgeons and post-graduate students in maxillofacial surgery were recruited. Only surgeons with no history of facial trauma, no severe psychological issues, and no body dysmorphic disorders were included.

Each subject was provided with a questionnaire including information about age, gender, and occupation. Moreover, each examiner was asked if they had undergone a previous orthodontic treatment, if they were motivated to be treated with surgery to improve their profile and to rate their own facial profile attractiveness (Likert scale).
To test the examiners' psychological profile, we asked them to complete a Psychological General Well-Being (PGWB) questionnaire before starting the silhouette evaluation.
Examiners with an impaired PGWB (below the 20^{th} percentile of the score distribution) or wishing to improve their facial profile, because of a negative opinion about their own profile, were excluded.
In the second part of the questionnaire, the examiner was asked to rate the silhouettes on a 7–point Likert Scale. The questionnaire was in Italian.
Each silhouette was shown in a random sequence on a single sheet with the 7-point Likert Scale at the bottom. A duplicate of one image (orthognathic profile NH) was submitted to assess the intraexaminer's reliability. The identification code of each silhouette was not visible to the examiner during the evaluation.
It was strictly forbidden to look at two or more the silhouettes at the same time to avoid comparisons. No time limit was provided during the examination.
All data were collected by a single operator.

Statistical Analysis

Descriptive statistics for each facial profile were computed. A general mixed model was used to detect differences between groups in the facial profile attractiveness rated scores by evaluating the overall PGWB score. The distribution of previous orthodontic treatments and facial surgeries among groups was computed by a chi-squared test. Statistical significance was set at $p<0.05$.

Results

One hundred nine questionnaires were collected. Three questionnaires were excluded because they were incomplete. The data of the 106 questionnaires were analyzed.

Of the 106 examiners, 23 were expert orthodontists, 21 young orthodontists, 15 maxillofacial surgeons, 19 patients and 28 belonged to a panel of laypeople. The mean age of the participants was 36.6 ± 10.9 years, ranging from 18 to 61 years.

The mean ± standard deviation value of the scores for each profile examined are reported in table 3.2. Convex profiles had lower mean scores.

The lowest mean scores were given to more convex profiles: the lowest rank was given by the judges to NC and NF (table 3.1). NH, like NA, was ranked as the most attractive, with the mean highest score.

Table 3.1: Descriptive Statistics for overall facial attractiveness scores for each of the eight facial profiles examined. Significant differences at p<0.05 are indicated by using similar letters between different rows.

Facial Profile	N	Mean	SD	Significant comparisons	Rank
NA	106	5.52	1.19	A	1
NB	106	2.54	1.24	a b	3
NC	106	1.49	0.93	a b c	4
ND	106	3.12	1.38	a b c d	2
NE	106	3.54	1.47	a b c e	2
NF	106	1.58	0.89	a b d e f	4
NG	106	2.92	1.49	a c e f g	3
NH	106	5.57	1.21	c d e f g	1

Facial attractiveness scores for each of the eight facial profiles sorted by groups of examiners and between comparison groups are reported in Figure 3.2. NA was judged similarly by all the examiners. NB was considered more attractive by patients. Similar ratings among groups of examiners were collected for NC, ND, and NE (P>0.05). NF and NG were rated more attractive by patients and laypeople respectively. Lower scores for NH were provided by laypeople.

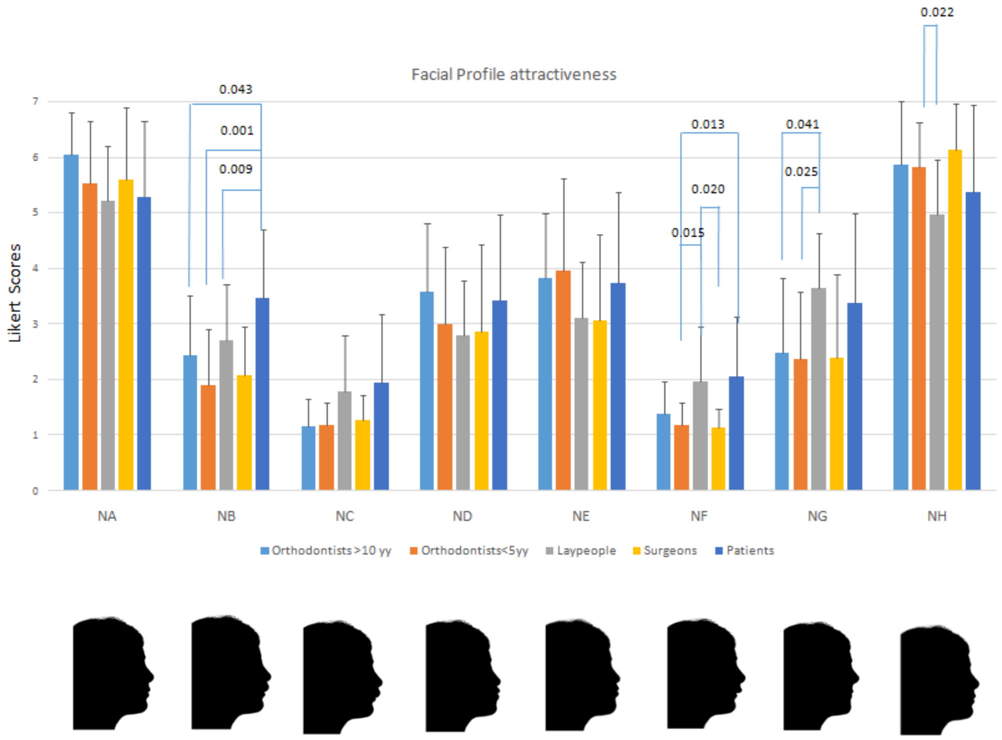

Figure 3.2: Facial attractiveness of the silhouettes as measured by different examiner groups. Means (columns) and standard deviations (bars) are reported. Statistically significant differences are reported between columns.

Comparisons between facial profile attractiveness within groups of examiners are reported in table 3.2.

The mean and standard deviations for PGWB scores are reported in table 3.3. The frequency of previous orthodontic treatments and facial surgeries were equally distributed between groups (table 4, all $p>0.05$).

Group	Facial Profile	Mena Score	SD	Significant Comparison within Groups
Orthodontists > 5yy n= 23	NA	6.04	0.77	a
	NB	2.43	1.08	ab
	NC	1.17	0.49	abc
	ND	3.57	1.24	abcd
	NE	3.83	1.15	abce
	NF	1.39	0.58	abdef
	NG	2.48	1.34	acdefg
	NH	5.87	1.14	bcdefg
Orthodontists < 5 yy n=21	NA	5.52	1.12	a
	NB	1.9A	1.00	ab
	NC	1.19	0.4	ac
	ND	3.00	1.38	abcd
	NE	3.95	1.66	abce
	NF	1.19	0.4	adef
	NG	2.38	1.2	aceg
	NH	5.81	0.81	bcdefg
Surgeons n= 15	NA	5.60	1.30	a
	NB	2.07	0.88	ab
	NC	1.27	0.46	ac
	ND	2.87	1.55	acd
	NE	3.07	1.53	ace
	NF	1.13	0.35	adef
	NG	2.40	1.5	ag
	NH	6.13	0.83	bcdefgh
Group	Facial Profile	Mena Score	SD	Significant Comparison within Groups
Laypeople n=28	NA	5.21	1.29	a
	NB	2.71	1.36	ab
	NC	1.79	1.23	ac
	ND	2.79	1.26	ad
	NE	3.11	1.34	ace
	NF	1.96	1.14	aef
	NG	3.64	1.42	acfg
	NH	4.96	1.20	bcdefgh
Patients n= 19	NA	5.28	1.36	A
	NB	3.47	1.22	ab
	NC	1.95	1.22	abc
	ND	3.42	1.54	acd
	NE	3.74	1.63	ace
	NF	2.05	1.08	abef
	NG	3.37	1.61	acg
	NH	5.37	1.57	bcdegh

Table 3.2: Descriptive Statistics for overall facial profiles examined, sorted by groups (p<0.05) are indicated by letters repeated by rows. No significant effect of the global PGWB score on main outcomes was found (data not shown).

Table 3.3: Descriptive statistics for PGWB total score.

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
						Lower Bound	Upper Bound		
PGWB Global Score	Ortho>5yy	23	57,45	4,044	0,862	55,66	59,25	51	64
	Ortho<5yy	21	57,76	3,632	0,793	56,11	59,42	52	65
	Lay	28	57,39	4,871	0,921	55,50	59,28	49	65
	Surgeons	15	57,40	3,158	0,815	55,65	59,15	51	61
	Patients	19	57,84	3,484	0,799	56,16	59,52	51	63
	Total	105	57,56	3,934	0,384	56,80	58,32	49	65

Table 3.4: Distribution of orthodontic treatments and facial surgeries among groups.

			ORTHODONTICS		Total	FACE SURGERY		Total
			NO	YES		NO	YES	
Panel	Ortho >5yy	n°	13	10	23	20	3	23
		%	56,5%	43,5%	100,0%	87,0%	13,0%	100,0%
	Ortho<5yy	n°	15	6	21	21	0	21
		%	71,4%	28,6%	100,0%	100,0%	0,0%	100,0%
	Lay	n	25	3	28	27	1	28
		%	89,3%	10,7%	100,0%	96,4%	3,6%	100,0%
	Surgeons	n°	10	5	15	14	1	15
		%	66,7%	33,3%	100,0%	93,3%	6,7%	100,0%
	Patients	n°	15	4	19	19	0	19
		%	78,9%	21,1%	100,0%	100,0%	0,0%	100,0%
	Total	n°	78	28	106	101	5	106
		%	73,6%	26,4%	100,0%	95,3%	4,7%	100,0%

Discussion

Facial harmony and facial beauty have a positive effect on personal success in almost all aspects of modern life, contributing to social power and interpersonal connections [6].

Class II is the most frequent malocclusion in Caucasian individuals [36] and it has been suggested that it determines a less attractive facial profile [14, 26, 37]. In this study, the potential change that may occur in the perception of profile silhouettes, simulating different Class II and Class I sagittal relationships, has been assessed. The silhouette displayed a complete facial profile. Cropping the neck would lead to changes in submental length [14, 34], while in the present study the submental length remained constant throughout all images. Using the entire profile created a more realistic image, particularly to non-clinical observers.

Furthermore, the choice to use silhouettes minimizes the possible confounding effects of eyes, hair, cheeks, and skin tone that may influence the attractiveness perception in photographs [38]. Furthermore, silhouettes provide anonymity for subjects [39].

It has been previously stated that the perception of facial aesthetics is a complex phenomenon influenced by psychosocial factors [40] and, especially on smile aesthetics [41], the evaluators' depressive state or impaired psychological well-being may have a strong influence [41]. In this study a psychological assessment, using PGWB, was conducted before the analyses of the silhouettes. This test is easy to perform and interpret and, moreover, describes psychology in all its items (anxiety, depression, vitality, general health, positive well-being and self-control) and with a total global score, provides outcomes about positive and negative emotions [42].

The results showed that the straight profile was preferred as the most attractive one among both the expert and non-expert groups. Similar findings have been reported in literature [10, 11, 19, 25, 35, 43], not only among Caucasians, but also for Western populations [44-46].

Generally, convex profiles received lower scores than straight ones, even if they were the result of a forward (bimaxillary protrusion) or retruded position (bimaxillary retrusion) of both the upper and lower jaws. This is in accordance with previous studies [10, 14, 34, 43].

Not surprisingly, the sagittal position of the chin strongly influenced the attractiveness of the profile [10]. Among the possible convex profiles presented, in fact, the ones with a retruded mandible (NC and NF) had the lowest scores. Moreover, the convex profile only affected by maxillary protrusion got better scores while the more convex the profile became, due to mandibular retrusion, the more its attractiveness decreased. These results highlight that, while examining convex profiles, maxillary protrusion is tolerated better than mandibular retrusion. This is likely related to the fact that an advanced position of the upper jaw reduces the anterior projection of the nose.

Following these considerations it could be argued that orthopedic therapy should be considered an elective treatment option in growing individuals with class II malocclusion and mandibular retrusion, in order to improve skeletal relationships and aesthetics [39].

Our study reveals that the examiners' background strongly influenced the ratings. This is possibly related to professional training [47].

While class I orthognathic profiles (NA) and biprotruded profiles (ND and NE) were similarly assessed by all the examiners, profiles affected by mandibular retrusion, maxillary protrusion or both were assessed differently, with the exception of the NC profile which was judged negatively by all the examiners.

Laypeople scored the NG profile (profile with a retrusive position of both mandible and maxilla) higher than the orthodontists. This result may beargued by the report by Burcal et al. [48], according to which, while examining profiles, clinicians focus more on the chin and laypeople on the lips while examining profiles. In the NG profile, in fact, the reciprocal relation between the upper and lower lips was maintained when compared to the NA, while the chin and maxillary positions in respect to cranial structure got worse. Also clinicians' mean scores for convex profiles (NB and NF) were lower than those of the laypeople.

Noticeably, a greater frequency of statistically significant differences between scores were observed in the groups of orthodontists, confirming their expertise in discriminating even small differences between facial profiles. A similar critical appraisal was not observed among surgeons nor laypeople.

In this study we preferred to distinguish laypersons from orthodontic patients. On the contrary, previously laypeople have been merged with patients [38]. A number of studies demonstrated that patients have a great sensitivity to notice differences in facial appearance from the ideal [11, 38], showing a critical appraisal similar to that of a clinician. While examining the NB profile, we found a statistically significant difference in ratings between laypeople and patients. This is probably influenced by the fact that patients are more sensitive to deviations from the norm because they have been progressively trained to a correct evaluation of facial aesthetics by previous orthodontic consultations. In our study the distribution of previous surgical and orthodontic treatments was not considered a factor influencing the ratings. Moreover, the perception of facial attractiveness does not change after an orthodontic or surgery treatment [43].

Conclusions

A straight profile is highly accepted and resulted the most attractive, for all examiner panels.

Convex facial profiles are judged less attractive and the more the convexity increases the more the rate of attractiveness reduces. In particular, among convex profiles, the mandibular retrusion profile received a lower score than the maxillary protrusion, and the maxillary protrusion combined with mandibular retrusion was rated as the least attractive.

This study has shown that laypeople and patients may assess facial profile aesthetics differently from clinicians. In particular, convex profiles due to a slight retruded position of the mandible are rated by clinicians worse than by patients and laypeople.

Clinicians and laypeople differ in their opinions about facial attractiveness, with laypeople giving generally lower scores to facial profiles and orthodontists being more critical in discerning profiles.

Patients, on the contrary, demonstrate a tendency to profile judgment more similar to that of the experts rather than the laypeople.

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Chapter 4

Class II orthopaedic treatment: evaluation of treatment outcomes - Part I
Morphologic predictors of mandibular changes induced by Sander's Bite Jumping Appliance.

Abstract

Aim: This study aimed to identify pretreatment cephalometric variables as possible predictors of the mandibular length increase in class II patients with mandibular retrusion, treated by means of the Bite Jumping Appliance (BJA).

Subjects and Methods: Forty-three subjects (22 males, 21 females) with class II malocclusion, treated with a BJA, were selected on the basis of the following inclusion criteria: full class II molar relationships, OVJ $\geq$ 6 mm and skeletal class II malocclusion with mandibular retrusion at the start of treatment (T0); cervical vertebral maturation stage 2 or 3 at T0. The following mandibular structural features were measured on lateral cephalograms: the width and height of the mandibular symphysis and its width/height ratio, the width and height of the mandibular ramus and its width/height ratio, the antegonial notch depth and the Co-Go-Me angle. Post-treatment changes were assessed by Pancherz's cephalometric analysis, evaluating the increases in mandibular length by measuring Pg/OLp+Co/OLp. A regression statistical model was used to test the association between morphologic variables and mandibular length changes.

Results: At T1, a significant increase in mandibular length (Pg/OLp+Co/Olp = 7.1±3.4 mm, $p < 0.001$) was measured as a result of increased Pg/OLp and increased Co/OLp. A significant association between the pretreatment Co-Go-Me angle and mandibular length change was found ($p < 0.0001$).

Conclusion: Individuals with smaller Co-Go-Me° respond better to the treatment with BJA.

Introduction

Nearly the 80% of Caucasian patients with skeletal class II malocclusion present mandibular retrusion [1, 2]. As a consequence, the main goal of the treatment in these patients should be mandibular advancement.

A wide range of functional appliances aimed to stimulate mandibular growth by forward posturing of the mandible is available to correct class II malocclusion [3]. However, the efficacy of the functional orthopedic treatment and the effects determined by the functional appliances are some of the most debated topics in the orthodontic literature, with the most controversial results [4]. It has been observed that treatment success with functional appliances depends on a great number of confounding variables: patient compliance (for removable appliances), skeletal maturity, and severity of the baseline conditions [5].

Ahlgren found that poor cooperation was one of the main reasons for treatment failure [6]. Bondevik attempted to identify the factors that influence the success of functional appliance treatment outcomes and found that good cooperation was the only variable associated with a satisfactory result [7]. Regarding skeletal maturity, it has been proposed that a greater increase in mandibular growth occurs when the functional jaw orthopedics treatment is performed during a growth spurt [3]. Despite good compliance and adequate treatment timing, some individuals with skeletal class II malocclusion may present an unfavorable growth trend, considered a consequence of a clockwise rotation growth pattern [8]. Since an increased overbite may be an indicator of an inherent pattern of upward and forward growth rotation of the mandible, Caldwell and Cook investigated the relation between the pretreatment overbite (ovb) and the reduction of the overjet (ovj), and showed that the ovb is the variable most strongly related to the reduction of the overjet in growing patients treated with twin block appliance [9]. Furthermore, it has been proposed that pretreatment ovb and the vertical height of the mandibular ramus were associated with a good prognosis for functional jaw orthopedics outcomes [10]. Franchi and Baccetti found that a class II patient with a pretreatment Co-Go-Me° smaller than 125.5° is expected to be a “good responder” to functional jaw orthopedics [11]. On the other hand, Ruf and Pancherz found no statistical differences for either dental or skeletal parameters between hypodivergent and hyperdivergent subjects treated with the Herbst appliance [12]. Enhanced skeletal reaction in hyperdivergent cases has also been reported by Windmiller using an acrylic-splint Herbst appliance [13].

Despite the contrasting results of the aforementioned studies, there is still a common belief in a good response to class II treatment in forward growth rotation patients rather than in backward ones. Bjork drew attention to the possibility of predicting mandibular growth patterns by looking at specific anatomic mandibular structures. He suggested seven structural signs, seen on lateral cephalograms, for the identification of the mandibular growth rotation: condylar head inclination, curvature of the mandible canal, shape of the lower border of the mandible, inclination of the symphysis, interincisal angle, interpremolar and intermolar angles and anterior lower face height [14]. Not all of them will be found in each individual, but the greater the number present, the more reliable the prediction should be [14]. Aki et al. evaluated the morphology of mandibular symphysis as a predictor of the direction of mandibular growth [15]. A mandible with an anterior growth direction was associated with a small height, large depth, small ratio, and large angle of the symphysis. Conversely, a posterior growth direction was associated with a large height, small depth, large ratio, and small angle of the symphysis. Singer et al. detected significant differences in mandibular growth between deep antegonial notch and shallow antegonial notch subjects [16]. Kolodziej et al. found a statistically (but not clinically) significant negative relationship between antegonial notch depth and subsequent horizontal growth of the maxilla and mandible in untreated growing patients [17].

A recent randomized clinical trial has shown that Sander's BJA is effective in determining a significant short term increase of mandibular growth in class II individuals as compared to untreated controls [18]. Hence, the purpose of our investigation was to determine whether some pretreatment mandibular structural signs, measured on lateral cephalograms, may be associated with higher increases of mandibular length in individuals treated with the BJA.

Subjects and methods

Forty-three patients (22 males, 21 females), with an average age of 11.13 ± 1.64, were included in the study.

The patients were selected on the basis of the following inclusion criteria: full class II molar relationships, OVJ ≥ 6 mm and skeletal class II malocclusion with mandibular retrusion assessed by Fraenkel maneuver (aesthetic evaluation); cervical vertebral maturation stage (CVMS) 2 or 3; an age range of 10–13 years for boys and of 9–12 years for girls. The following conditions were considered as further exclusion criteria: lack of parent's willingness to sign an informed consent form; OSAS or night snoring; sella-nasion to mandibular plane (Me-Go) angle equal to or greater than the normal value plus a standard deviation; periodontal diseases; orofacial inflammatory conditions; tooth agenesis; congenital syndromes and previous orthodontic treatment. All the subjects were treated, by using a standard Sander Bite Jumping Appliance with an acrylic cover of lower anterior teeth, at the Department of Neuroscience, Section of Orthodontics, of the University of Naples "Federico II" and at the Division of Dentistry of the Pediatric Hospital "Bambino Gesù" in Rome. The posttreatment cephalograms were taken when a Class I molar relationship was achieved.

The following mandibular structural features were measured on lateral cephalograms: the width (x) and height (y) of the mandibular symphysis and their ratio, the width (l) and height (h) of the mandibular ramus and their ratio, the antegonial notch depth and the Co-Go-Me angle.

Symphysis height was calculated as follows (Figure 4.1): A line tangent to pogonion and perpendicular to Go-Me was used as the long axis of the symphysis and a grid was formed with the lines of the grid parallel and perpendicular to the constructed tangent line. The superior limit of the symphysis was set at the lower incisor labial gingival border (cement-enamel junction), the inferior at the most inferior point of the symphysis, the anterior at the most anterior point of the bony chin, and the posterior at the most inner point on the lingual border of the symphysis. The width of the symphysis was calculated as the distance from the anterior to the posterior limit on the grid.

Figure 4.1: Mandibular symphysis

Mandibular ramus width was calculated as the distance from R-1 (the deepest point on the anterior border of the ramus, located halfway between the superior and the inferior curves) to R-2 (located on the posterior border of the ramus, opposite R-1). Mandibular ramus height was calculated as the distance from R-3 (the deepest point of the sigmoid notch, halfway between the anterior and the posterior curves) to R-4 (opposite R-3 on the inferior border of the mandible) (Figure 4.2).

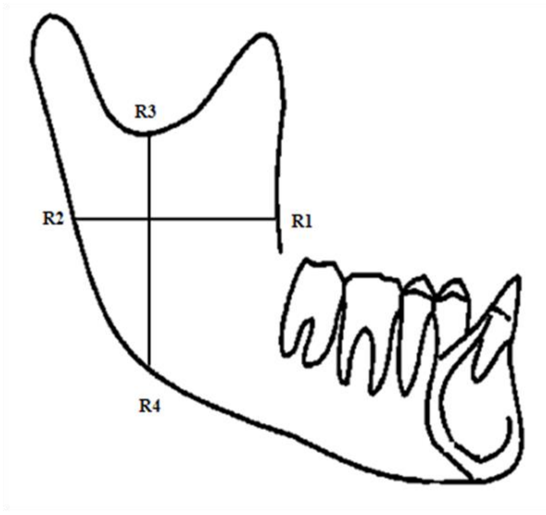

Figure 4.2: Mandibular ramus

Antegonial notch depth was calculated as the distance between the deepest part of notch concavity and a line passing through the two points of greatest convexity (ACP

= anterior convex point; PCP = posterior convex point) on the inferior border of the mandible (Figure 4.3).

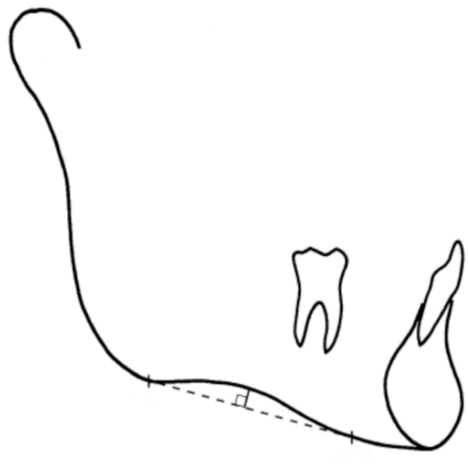

Figure 4.3: Antegonial notch.

All of these measurements were collected by a single operator on digitized cephalograms using a digital caliper (Screen Caliper version 4.0). Cephalometric analysis was performed by the same operator, who had been extensively training in electronic cephalomethic analysis, using Dolphin Imaging 11.0 software (Chatsworth, CA, USA). Dentoalveolar, skeletal and vertical changes with treatment were evaluated using the cephalometric landmarks and lines shown in Fig. 4 following Pancherz's method [20].

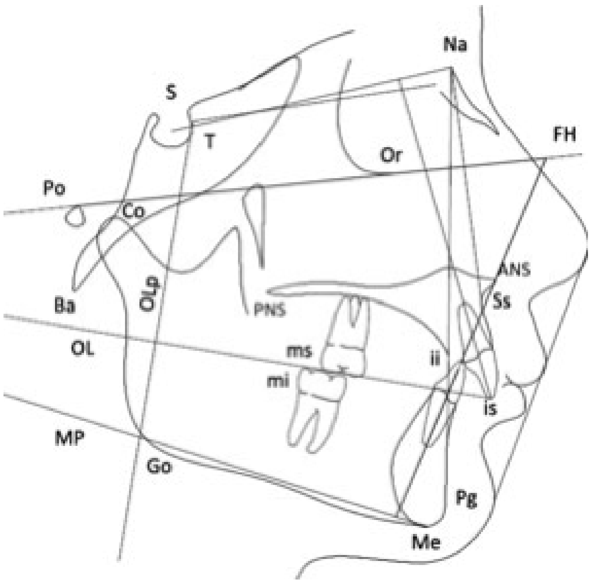

Figure 4.4: Cephalometric analysis. ***Landmarks:*** *ANS (anterior nasal spine), the tip of the anterior nasal spine; Ba (basion), the midsagittal point of the anterior margin of the*

foramen magnum; Co (condyle), most superoposterior point on the curvature of the condylar head; where there was a double projection to two points, the midpoint was used; ii (incision inferius), incisal tip of the most prominent mandibular central incisor; is (incision superius), incisal tip of the most prominent maxillary central incisor; mi (molar inferius), distal contact point of the mandibular permanent first molar determined by a tangent perpendicular to the occlusal line (OL) – where there was a double projection to two points, the midpoint was used; ms (molar superius), distal contact point of the maxillary permanent first molar determined by a tangent perpendicular to OL – where there was a double projection to two points, the midpoint was used; Pg (pogonion), most anterior point on the bony chin determined by a tangent perpendicular to the OL; Ss (subspinale), deepest point on the anterior contour of the maxillary alveolar projection; Sella (S), center of the hypophyseal fossa; N (Nasion), most anterior point of the junction of the nasal and frontal bone (frontonasal suture); Or (Orbitale), lowest point of the inferior margin of the orbit; Po (Porion), most superior point on the anatomical external auditory meatus; Go (Gonion), midpoint of the curvature of the angle of the mandible; Me (Menton), most inferior point of the mandibular symphisis; PNS (posterior nasal spine): the tip of the posterior nasal spine; T (T point), most superior point of the anterior wall of the sella turcica at the junction with tuberculum sella. ***Reference lines:*** *FH (Frankfurt horizontal), line connecting the Po point to the Or point; MP (mandibular plane), line connecting the Me point to the Go point; SN (sella nasion line), line through S and N; OL (occlusal line), line through the is point and the distobuccal cusp of the maxillary permanent first molar; OLp (occlusal line perpendicular), line perpendicular to the OL through the T; PP (palatal plane), line connecting ANS and PNS.* ***Linear distances/skeletal landmarks:*** *Ss/OLp, position of the maxillary base; Pg/OLp, position of the mandibular base; Co/OLp, position of the condylar head; Pg/OLp + Co/OLp, sagittal mandibular length. Linear distances/dental landmarks: is/OLp position of the maxillary central incisor; ii/OLp, position of the mandibular central incisor; ms/OLp, position of the maxillary permanent first molar; mi/OLp, position of the mandibular permanent first molar.*

Variables for dental changes within the maxilla and within the mandible were calculated as follows: is/OLp minus Ss/OLp, change in position of the maxillary central incisor within the maxilla; Ii/OLp minus Pg/OLp, change in position of the mandibular central incisor within the mandible; Ms/OLp minus SS/OLp, change in position of the maxillary permanent first molar within the maxilla; Mi/OLp minus Pg/OLp, change in position of the mandibular permanent first molar within the mandible. For all of the linear measurements, the OL and the OLp of the initial radiograph were used as a reference grid. The grid was then transferred from the pretreatment radiograph to the post treatment one by superimposing on the nasion-T point line, with the T point as the registering point. All of the measurements were made parallel to the OL. Differences in T1-T0 linear measurements were recorded according to Pancherz's method [20].

Statistical analysis

Mean, standard deviations, and minimum and maximum values were computed for all cephalometric parameters and morphological variables considered as predictors for mandibular growth in the current study. The method error for measurements of morphological features of the mandible was computed in 16 individuals using the Dahlberg Formula by collecting duplicate measurements at one week intervals. It was on average 0.23 +/- 0.20 mm, and ranged from 0.007 mm for the width/height ratio of the mandibular symphysis to 0.58 mm for the measurement of the width of the mandibular ramus. A T-test was used to assess cephalometric changes with treatment. Correlations between morphologic variables (width, height, width/height of mandibular symphysis; width, height, width/height of mandibular ramus, antegonial notch depth and Co-Go-Me°) were computed. A regression statistical model was used to test the association between morphologic variables and mandibular length changes with treatment (Pg/OLp+Co/Olp). Only the morphological variables not showing intercorrelations were used in the model. SPSS (IBM) software, V22.0, was used. The statistical significance was set at <0.05.

Sample size calculation

A sample size of 43 achieves 80% power to detect an R-Squared of 0.24 attributed to 4 independent variable(s) using an F-Test with a significance level (alpha) of 0.05.

Results

Skeletal and dental measurements at T_0 and T_1 and their changes with treatment are reported in table 4.1. Mandibular length showed a significant increase during treatment (Pg/OLp+Co/Olp = 7.1±3.4 mm, p<0.001) as a result of increased Pg/OLp and increased Co/OLp. Vertical jaw relationships did not change significantly during treatment (MP-FH° = 0.2±2, p=0.145; SN-MP = -0.5±2.6, p=0.467). The appliance determined an improvement of sagittal dental relationships by producing a significant overjet reduction (-4.6±2.6 mm, p<0.001), a molar relation improvement (-4.9±2.6, p<0.001) with a small proclination of the lower incisors (4.8±5.4, p<0.001) and a retroclination of the maxillary incisors (-4.3±6.2, p<0.001). Table 4.2 shows morphologic measurements of the mandibles at T0 and the estimate of their effect on mandibular length (Pg/OLp+Co/OLp). No significant association was found between the increment of mandibular length and the variables used in the regression analysis (width/height of mandibular symphysis; width/height of mandibular ramus and antegonial notch depth) with the exception of Co-Go-Me° (p<0.0001). The smaller the Co-Go-Me angle, the more the mandibular length increases (Figure 4.5).

Table 4.1: **Cephalometric measurement before (T0) and at the end (T1) of treatment periods.**

Measurement		*T0 (mean ± SD)*	*T1 (mean ± SD)*	*T1–T0 (mean ± SD) -15 months -*	*P value*
Overjet (is/OLp – ii/OLp)		7.9±1.91	3.6±1.5	-4.6±2.6	**<0.001**
Molar relation (ms/OLp − mi/OLp)		2.2±1.8	-2.6±2.3	-4.9±2.6	**<0.001**
Maxillary Base (Ss point to OLp)		67.5±5.3	70.5±5.2	2.9±3.1	**<0.001**
Mandibular base (Pg/OLp)		67.3±6.1	73.1±7.2	5.9±3.4	**<0.001**
Condylar head (Co/OLp)		13.4±3.2	14.9±3.8	1.2±2.9	0.019
Mandibular lenght (Pg/OLp + Co/OLp)		92.3±12.8	100.5±15.4	7.1±3.4	**<0.001**
Mandibular length (Co − Pg)		97.8±8.2	105.7±8.8	7.9±4.0	**<0.001**
Mandibular height (Co − Go)		50.6±5.2	54.5±6.4	3.8±3.1	**<0.001**
Maxillary incisor (is/OLp − Ss/OLp)		8.5±2.7	7.6±2.9	-1.0±2.0	**<0.001**
Mandibular incisor (ii/OLp − Pg/OLp)		0.3±2.8	0.6±3.6	0.3±2.3	**0.310**
Maxillary molar (ms/Olp − Ss/OLp)		-35.2±9.6	-37.6±10.2	-2.4±2.8	**<0.001**
Mandibular molar (mi/OLp − Pg/OLp)		-37.2±10.2	-37.7±10.6	-0.4±2.4	0.800
SN-MP (°)		30.0±5.6	30.0±5.8	0.2±2.5	0.467
MP-FH (°)		22.6±4.6	22.0±4.7	-0.5±2.6	0.145
U1/SN (°)		108.6±6.1	104.6±6.6	-4.3±6.2	**<0.001**
IMPA (°)		96.8±7.04	101.3±5.8	4.8±5.4	**<0.001**
L1_FH (°)		60.7±5.4	56.6±5.7	-4.5±5.3	**<0.001**
PP-MP (°)		24.2±4.7	23.8±5.1	-0.3±2.4	0.859

Descriptive statistics for the variables examined. Absolute cephalometric changes (T1-T0) are converted to relative changes over a 15-month period (see statistical methods). Linear measurements are in mm. Significance level was set at $p < 0.05$. Bold type: statistically significant.

Table 4.2: Morphologic measurements of the mandibles and estimate of their effect on mandibular length (Pg/OLp + Co/OLp) changes with treatment.

Measurement		*mean±SD*	*minimum*	*maximum*	*p*
Width of mandibular symphysis		15.1±2.3	10.8	24.1	**-**
Height of mandibular symphysis		28.0±3.1	21.9	35.0	**-**
Width/Height mandibular symphysis		0.5±0.1	0.4	0.7	0.563
Width of Mandibular ramus		29.6±3.9	22.7	43.0	-
Height of Mandibular ramus		40.2±6.0	28.3	61.6	-
Width/Height of Mandibular Ramus		0.7±0.1	0.5	0.9	0.274
Depth of the antegonial mandibular notch		1.2±0.9	0.0	2.9	0.118
Co-Go-Me°		121.8±6.0	108.8	131.8	**<0.0001**

NOTE: Due to significant correlations between morphologic variables, only a number of variables was retained in the final regression model**.**

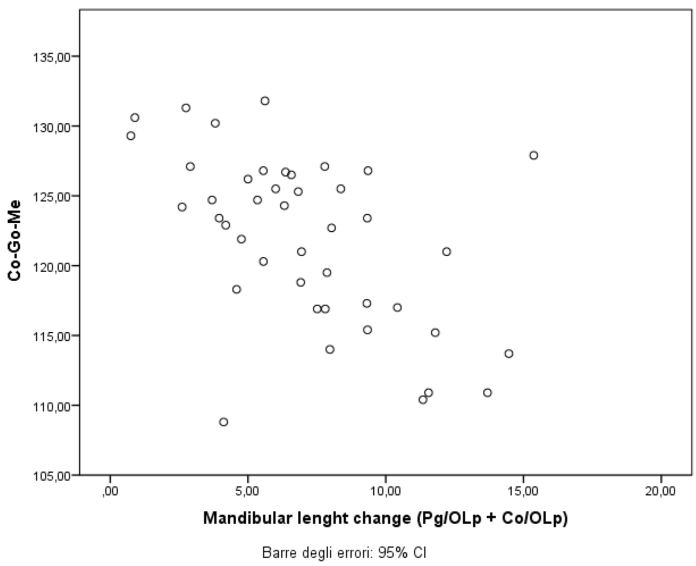

Figure 4.5: Scatter plot depicting the correlation between the Co-Go-Me angle and mandibular length change with treatment (r2=0.27).

Discussion

The results of the present investigation revealed that, among mandibular morphologic variables examined, the Co-Go-Me angle was the only one showing a positive correlation with mandibular changes (Pg/OLp+Co/OLp) in class II subjects treated with BJA. This result is in agreement with a previous study by Franchi and Baccetti [11] who found that each new class II patient at CS3 with a pretreatment value for Co-Go-Me smaller than 125.5° is expected to respond favorably to treatment including functional jaw orthopedics in terms of supplementary mandibular elongation. Instead, each new class II patient at CS3 with a pretreatment value for Co-Go-Me greater than 125.5° is expected to respond poorly. Despite the same results, Franchi and Baccetti used a sample made of subjects treated with different kinds of functional orthopedic appliances (twin block, stainless steel crown Herbst and acrylic splint Herbst) while our sample included only subjects treated by Sander's Bite Jumping Appliance. The Co-Go-Me angle expresses the inclination of the condyle in relation to the mandibular base and, probably, this variable is more intimately linked to a forward/backward rotation pattern of the mandible and could, therefore, have a great influence on therapy. Ruf and Pancherz, instead, focused on the correlation between the mandibular plane angle and class II correction by means of the Herbst appliance [12]. The authors analyzed and compared the sagittal dental and skeletal effects contributing to class II correction in subjects with small (ML/NSL≤26°) or large (ML/NLS>39°) pretreatment mandibular plane angles in a treatment period of seven months. No statistically significant differences for either dental and skeletal parameters was found between hypodivergent and hyperdivergent ones. Surprisingly, mandibular length (Pg/OLp) was, on average, advanced 1.1 mm more in the high angles than in the low angles even if the difference was not statistically significative. Our investigation was carried out considering the whole orthopedic treatment phase (15 months) and the sample did not include severe hyperdivergent subjects who usually are not undergoing BJA in our clinical practice. Moreover, we focused on morphologic mandibular features instead of the mandibular plane angle because this angle expresses the position of the mandible in relation to other craniofacial structures and maybe should not play a significant role in predicting individual responsiveness to functional jaw orthopedics.

The other mandibular morphologic variables examined (the ratio between width and height of the mandibular symphysis, the ratio between the width and height of the mandibular ramus and the antegonial notch depth) did not show any statistically correlation with mandibular length changes (Pg/OLp+Co/OLp). Aki et al. evaluated the morphology of mandibular symphysis as a predictor of the direction of mandibular growth in a cross-sectional study [15]. They considered B point as the upper limit of the symphysis instead of lower incisor labial gingival border. We preferred the latter to have the entire vertical dimension of mandibular symphysis even if it depends largely by the amount of lower incisors eruption. Moreover, they found a correlation between symphysis morphology and the direction of the mandibular growth, especially in male subjects. However, this assessment relied heavily on cross-sectional adult data without any orthopedic intervention. Our study, instead, investigated a sample of growing class II malocclusion treated with functional jaw orthopedics.

No correlation was found between antegonial notch depth and mandibular growth. Conversely, Singer et al. found a strong correlation between them [16]. He based the results of his study on Bjork's implant studies [14] reporting that mandibles with a forward growth tendency exhibit a surface of apposition below the symphysis and surface of resorption under the mandible angle. The opposite pattern occurred in the subjects with backward mandibular growth tendencies leading to concavity on the lower border of the mandible known as the antegonial notch. However, the sample used by Singer consisted of fifty growing subjects with extreme morphologic patterns (notch depths>3.0 mm or <1 mm) while the sample of our investigation was a non-extreme population (notch depth mean: 1.2±0.9). Kolodziej et al. found a statistically (but not clinically) significant correlation ($0.40 \leq r \leq 0.47$; $p \leq .05$) between antegonial notch depth and horizontal growth of the maxilla and mandible from adolescence to adulthood in an untreated group of adolescents without the bias to extremeness [17], but, due to the lack of clinical significance, the authors did not suggest the use of antegonial notch depth as a predictor of mandibular growth.

Conclusions

- The Co-Go-Me angle shows an inverse correlation with mandibular growth changes (Co/OLp+Po/OLp): A class II subject with a smaller Co-Go-Me° is expected to have a better response to Sander Bite Jumping Appliance treatment. Conversely, a class II subject with a bigger Co-Go-Me° is expected to have a poor response.

- The width/height ratio of the mandibular symphysis, the width/height ratio of the mandibular ramus, and antegonial notch depth do not show any correlation with mandibular growth changes and they should not be used as growth predictors.

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Chapter 5

Class II orthopaedic treatment: evaluation of treatment outcomes - Part II

Evaluation of Sander II Bite Jumping Appliance effects on the anatomy of pharyngeal airway passage in class II malocclusion subjects.

Abstract

Aim: To study the effects of Sander II Bite Jumping appliance treatment on upper airway structures of growing subjects with Class II division 1 malocclusion.

Subjects and Methods: Thirty-four class II malocclusion subjects with mandibular retrusion, were treated by means of BJA. The control group consisted of thirty-four class II malocclusion untreated. The effect of BJA appliance were evaluated from lateral cephalograms recorded prior-to and after the correction of the malocclusion in the treatment group subjects and the changes were compared with the changes in the control group subjects. Student's t-test Mann-Whitney U test were used for statistical analysis; P-value of 0.05 was considered a statistically significant level.

Results: The depth of the oropharynx was increased significantly in the treatment group subjects (P= 0.001), but not as compared to the control group subjects (P = 0.077). The depth of the hypopharynx increased in both control and treatment group, but without a statistically significant difference between them. The tongue height (th) increased significantly (p<0,05) in subjects who underwent BJA treatment (P < 0.001) compared both to pretreatment values and control group (P = 0.038).

Conclusions: the pharyngeal dimensions increased both in treated and untreated subjects. Correction of mandibular retrusion by Sander BJA appliance in class II malocclusion subjects determined a slightly higher and not statistically significant increase of depth of the oropharynx respect to control group.

Introduction

Many studies in the last years investigated the morphology and the measurement of pharyngeal air way passage (PAP) in subjects with sleep-disordered breathing and OSAS and demonstrated that its narrowing is an important feature in patients with breathing problems [1-3].

It is a general belief that patients with Class II division 1 malocclusion are characterized by narrower oropharingeal and hypopharyngeal spaces related to Class I patients [3-5], even if several studies failed to demonstrate it [6,7].

Hakan and Palomo [5] measured airway comparing skeletal discrepancies but they took in account the sagittal position with mandible and maxilla with regard to the cranial base. In this study, the authors observed that Class II malocclusion subjects with mandibular retrusion had the most narrow oropharyngel and nasopharyngeal airway volume. The greater difference was observed between these subjects related to the class III malocclusion with mandibular protrusion ones.

Functional appliances, used in young patients, are able to correct skelatal Class II malocclusion characterized by a retrognathic mandible [8], altough theirs effects are controversial and depend on a great number of confunding variables [9].

Different studies demonstrated that oral appliances which determinate mandibular protrusion may be able to increase PAP dimensions in children [10-15].

Recently, a randomized clinical trial has shown that Sander's Bite Jumping appliance is effective in determining a significant short term increase of mandibular growth in class II individuals as compared to untreated controls [16].

Therefore, the aim of this study is to evaluate the changes that Sander's BJA treatment may determine on pharyngeal airways.

Subjects and Methods

Subjects

Thirty-four subjects (21 males, 13 females) with skeletal class II malocclusion associated with mandibular retrusion were selected for this prospective longitudinal study. The patients were selected on the basis of the following inclusion criteria: full class II molar relationships, OVJ $\geq$ 6 mm and skeletal class II malocclusion with mandibular retrusion assessed by Fraenkel maneuver (aesthetic evaluation); cervical vertebral maturation stage (CVMS) 2 or 3; an age range of 10–13 years for boys and of 9–12 years for girls. The following conditions were considered as further exclusion criteria: lack of parent's willingness to sign an informed consent form; OSAS or night snoring; sella-nasion to mandibular plane (Me-Go) angle equal to or greater than the normal value plus a standard deviation; periodontal diseases; orofacial inflammatory conditions; tooth agenesis; congenital syndromes and previous orthodontic treatment. All the subjects were treated, by using a standard Sander Bite Jumping Appliance (BJA group) with an acrylic cover of lower anterior teeth, at the Department of Neuroscience, Section of Orthodontics, of the University of Naples "Federico II" and at the Division of Dentistry of the Pediatric Hospital "Bambino Gesù" in Rome. The posttreatment cephalograms (T1) were taken when a Class I molar relationship was achieved (mean treatment time 14.8 ± 5.8 months). The BJA group was compared with a control group (CTR group) of thirty-four subjects (25 males, 9 females) with the same baseline characteristics of the treated group, followed for 13.9 ± 5 months. The mean age of the subjects at the beginning of the study was 11.1 ± 1.2 years for the BJA and 10.4 ± 1.2 years CTR.

Methods

The linear measurements and angles were calculated using Deltadent (Piolla, Milan, Italy). The used landmarks are defined in Table 5.1 and presented in Figure 1.

The technical errors of measurement were calculated from 14 randomly selected participants. All the measurements were reassessed by one examiner after a memory washout period of at least 8 weeks. The method error for the 27 measurements was calculated using Dahlberg's formula [16]. Systematic differences between duplicated measurements were tested using a paired Student's t-test with the type I error set at <0.1 [17].

Table 5.1: Cephalometric measurements and their definition.

Measure	Definition
Nasopharynx	
S-PNS	The distance of sella (S) to posterior nasal spine (PNS)
ad1-PNS	The distance of ad1 to posterior nasal spine (PNS). Ad1 is the intersection point of posterior pharyngeal wall and the line from posterior nasal spine (PNS) to basion (Ba)
ad2-PNS	The distance of ad2 to posterior nasal spine (PNS). Ad2 is the intersection point of posterior pharyngeal wall and the line from the midpoint of the line from sella (S) to basion (Ba) to posterior nasal spine (PNS)
Oropharynx	
AA-PNS	The distance of the most anterior point of atlas vertebra (AA) to posterior nasal spine (PNS)
ve-pve	The distance of the closest point of soft palate to the posterior pharyngeal wall (velum palatinum, ve) to the horizontal counterpoint on the posterior pharyngeal wall (pve)
p-pp	The distance of the tip of soft palate (p) to horizontal counterpoint on posterior pharyngeal wall (pp)
Pas	The distance of the intersection points on anterior and posterior pharyngeal wall of the line from supramentale (B) to gonion (Go)
ph-pph	The distance of horizontal counterpoints on anterior and posterior pharyngeal wall in oropharynx at its narrow-est area
Soft palate	
ANS-PNS-p	The angle anterior nasal spine (ANS) to posterior nasal spine (PNS) to palate point (p)
PNS-p	The distance of posterior nasal spine (PNS) to tip of soft palate (p)
sp1-sp2	The thickest cross section of the soft palate
Hypopharynx	
eb-peb	The distance from vallecula of epiglottis (eb) to horizontal counterpoint on the posterior pharyngeal wall (peb)
Maxilla	
SNA	The angle sella (S) to nasion (N) to subspinale (A)
ANS-PNS	The length of the palatal plane from anterior nasal spine (ANS) to posterior nasal spine (PNS)
Mandible	
SNB	The angle sella (S) to nasion (N) to supramentale (B)
ANB	The angle subspinale (A) to nasion (N) to supramentale (B)
NS-MP	The angle nasion (N) to sella (S) to mandibular plane (MP). Mandibular plane is the line from mandibular base point (MBP) to menton (Me)
Co-Gn	Mandibular length. The length from the most posterior and superior point on the condylar head (Co) to the most anterior and inferior point on the mandibular symphysis (Gn)
C3ai-HPT-Rgn	Sum of two distances: (1) the perpendicular distance between the most anterior and inferior point on the cor-pus of the third cervical vertebra (C3ai) and HPT. HPT is the vertical line from the most anterior and superi-or point of hyoid bone perpendicular to nasion (N) to sella (S) line with 7° upward correction. (2) The dis-tance from most dorsal point of mandibular symphysis (retrognation, Rgn) perpendicular to HPT
Facial heights	
N-Me	The distance from nasion (N) to menton (Me)
ANS-Me	The distance from anterior nasal spine (ANS) to menton (Me)
Tongue	
Length (tt-eb)	Tongue length. The distance from anterior point of tip of tongue (tt) to the base of epiglottis (eb)
Height (th)	Tongue height. The perpendicular distance of superior point of tongue (th) bellow posterior nasal spine (PNS) to line from the tongue tip (tt) to the intersection point of tongue and mandibular border (tg)
Hyoid bone	
H-H′	The distance from the most anterior and superior point of hyoid bone (H) perpendicular to mandibular plane (MP)
H-C3ai	Hyoidale (H). The perpendicular distance from the most anterior and superior point of hyoid bone to perpen-dicular line from C3ai to HPT

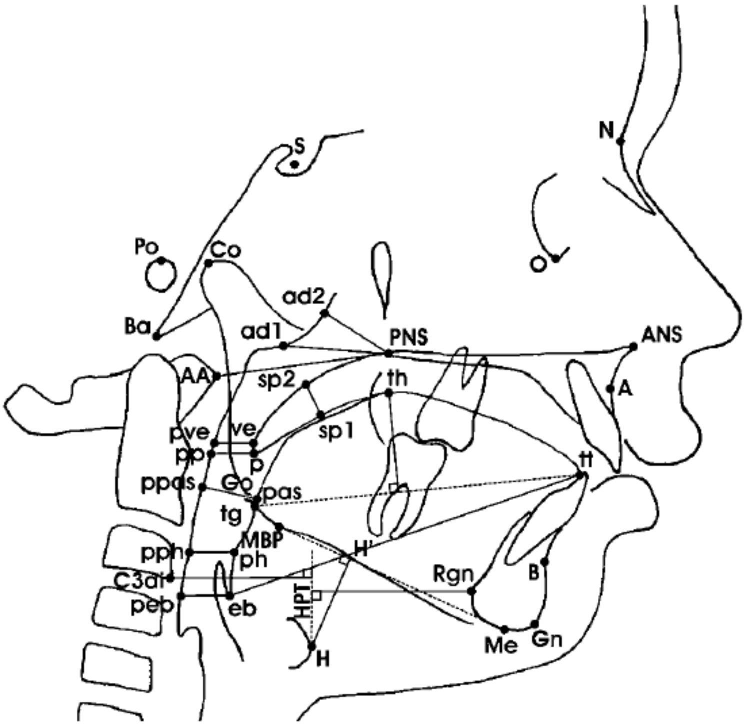

Figura 5.1: Cephalometric analysis and landmarks.

Sample size calculation

The sample size was calculated considering ph_pph**.** Group sample sizes of 26 and 26 achieve 81% power to detect a differenz -0.8 between the null hypothesis that the mean of the group 2 is 0.8 with estimated group standard deviations of 1.0 and 1.0 and with a significance level (alpha) of 0.05 using a two-sided two-sample t-test.

Statistical analysis

A single operator who was blinded to patient allocation (i.e. the allocation was masked to him in the dataset) performed the statistical analysis. Data were analysed by conventional descriptive statistics. Absolute cephalometric changes were converted to relative changes over a 15-month period.

A Shapiro-Wilk test to evaluate if the samples were normally distributed was performed. Between-group differences were compared by means of parametric unpaired samples t-test and non-parametric statistic Mann-Whitney U test. Intra-group differences were compared by means of parametric paired t-test of non-parametric statistic Wilcoxon signed-rank test. If the analysed variables had a Gaussian distribution the p-value of the parametric tests were considered, if the distribution was asymmetric the p-value of non-parametric tests were considered. Statistical significance was set at $P<0.05$. Analysis were performed with SPSS version 20.0 (SPSS IBM, New York, NY).

Results

The method of errors were very low, ranging for linear measurements from 0.1 to 1.1 mm and for angular measurements from 0.4 and 0.8°. There was no systematic error for any of the 27 measurements (Student's t-test; P<0.1).

Differences within group

The BJA group showed a statistically significant increase in the airways dimensions for the nasopharynx (S_Pns=0.9±2; P=0.007) and oropharynx (ph_pph=1.8±3.2; P=0.001). Moreover, other statistically significant changes were showed by the soft palate (Ans_Pns_P=-3.8±7.8; P=0.007); the length of the palatal plane (Ans-Pns=1.9±3.7; P=0.007); the sagittal position of the mandible (SNB=1.3±1.9; P=0.001; ANB=-1.8±2.7; P=0.001; C3ai_HPT_RGn= 4±7.3; P=0.005) and the length of the mandible (Co_Gn=7.2±3.7; P<0.001); and the length and the height of the tongue (Length(tt_eb)=3.6±4.4; P<0.001; Height (th)=2.8±3.7; P<0.001). Finally, the BJA group showed also a decrease in the Overjet (-4.8±2.9; P<0.001) and an increase in the total facial height (N_Me=5.6±5; P<0.001) and lower facial height (Ans_Me=3.4±3.9; P<0.001).

The CTR group a statistically significant increase in the airways dimensions for the nasopharynx (S_Pns=0.9±2; P=0.007; ad2_Pns=1.6±3; P=0.002) and hypopharynx (eb_peb=1.8±4.5; P=0.020). Moreover, other statistically significant changes were showed by the length of the mandible (Co_Gn=3.9±1.9; P<0.001); and an increase in the total facial height (N_Me=3.1±3.4; P<0.001) and lower facial height (Ans_Me=1.3±2.5; P=0.005).

Differences between groups

The BJA group showed a statistically significant higher increase in the length of the palatal plane (Ans-Pns, P=0.035) and in the height of the tongue (Height (th), P=0.038) respect to the CTR group. Moreover, the BJA group revealed an effect of the appliance on the mandible parameters (SNB, P=0.046; Co_Gn, P<0.001), on the overjet (P<0.001) and on the lower facial height (Ans_Me, P=0.010). Finally, the BJA group had a greater decrease of the Ans_Pns_P angle (P=0.026) than the CTR group.

Table 5.2:

	Treated vs Control subjects	T0 (mean ± SD)	T1 (mean ± SD)	T1–T0 (mean ± SD) -15 months-	P-Value within group differences	P-Value between groups differences
S_Pns	treated	44.3±2.9	45.2±3.1	0.9±2	0.007	0.035
	control	42.9±3.3	44.2±3.3	2.2±4	<0.001	
ad1_Pns	treated	21.4±3.8	22.2±3.9	0.7±4.5	0.288	0.512
	control	20.2±3.7	21.4±3.5	1.5±5.4	0.120	
ad2_Pns	treated	15.6±2.7	16.3±3.7	0.7±2.6	0.111	0.200
	control	13.7±2.6	15.1±2.9	1.6±3	0.002	
AA_Pns	treated	31.4±3.4	31.4±3.8	0.3±3.7	0.916	0.360
	control	31.8±2.9	32±3.4	0.5±4	0.738	
ve_pve	treated	8.8±2.6	9.3±2.5	0.4±2.9	0.397	0.564
	control	9.1±3.6	8.9±3.1	-0.2±5.4	0.844	
p_pp	treated	9±2.4	9.4±2.7	0.2±3.5	0.383	0.849
	control	8.9±2.4	9.1±2.8	0.4±2.9	0.522	
PAS	treated	10.4±4	11.5±3.7	1.2±4.5	0.129	0.650
	control	11.5±2.7	12±3.8	0.6±5.7	0.606	
ph_pph	treated	8.4±2.4	10.2±3.1	1.8±3.2	0.001	0.077
	control	9.1±2.3	9.7±3.1	0.73±4.0	0.314	
Ans_Pns_P	treated	138.1±7.6	134.7±6.4	-3.8±7.8	0.007	0.026
	control	138.2±5.6	137.9±7.2	-0.1±5.4	0.705	
Pns_P	treated	29.8±3.1	29.9±4	0.2±4.8	0.813	0.864
	control	29.5±2.9	30±3.5	0.7±4.2	0.387	
sp1_sp2	treated	7±1.4	7.3±1.3	0.3±1.8	0.360	0.559
	control	6.8±1.1	6.9±1	0.1±1.2	0.692	
eb_peb	treated	13.2±2.1	14.2±3.1	1.1±3.8	0.090	0.501
	control	12.7±2.6	14.3±3.3	1.8±4.5	0.020	
SNA	treated	81.1±3.2	80.7±3.3	-0.5±2.4	0.371	0.920
	control	82.1±3.2	81.8±3.7	-0.4±3.3	0.451	
Ans_Pns	treated	51.3±4.5	53±4.3	1.9±3.7	0.007	0.035
	control	52.3±3.4	52.4±3.8	-0.1±4	0.853	
SNB	treated	75.5±2.7	76.6±3.1	1.3±1.9	0.001	0.046
	control	75.1±3.4	75.5±3.4	0.4±1.7	0.154	
ANB	treated	5.6±2.3	4.1±2.4	-1.8±2.7	0.001	0.159
	control	7±1.8	6.3±2.2	-0.8±2.8	0.082	
NS_MP	treated	32.3±5.1	32.7±5.9	0.5±3.3	0.469	0.307
	control	33.0±5.2	32.7±5.1	-0.3±3.2	0.498	
Co_Gn	treated	99.8±5.7	106.6±5.3	7.2±3.7	<0.001	<0.001
	control	98.3±5	101.9±5	3.9±1.9	<0.001	
C3ai_HPT_RGn	treated	62.4±7.2	66±7.5	4±7.3	0.005	0.457
	control	62.4±7.3	64.1±8.4	2.5±8.6	0.153	
Overjet	treated	8.8±2.1	4.4±1.6	-4.8±2.9	<0.001	<0.001
	control	8.1±1.7	7.9±1.9	0±2	0.075	
N_Me	treated	105.6±6.4	110.8±7.1	5.6±5	<0.001	0.022
	control	104±5.5	106.9±5.5	3.1±3.4	<0.001	
Ans_Me	treated	59.9±4.3	63±5.3	3.4±3.9	<0.001	0.010
	control	60.1±4	61.3±4.2	1.3±2.5	0.005	
Length(tt_eb	treated	67.5±5.3	70.9±5.2	3.6±4.4	<0.001	0.185
	control	66.8±5.5	68.3±6.2	1.8±6.1	0.106	
Height (th)	treated	18.9±3	21.3±2.8	2.8±3.7	<0.001	0.038
	control	18.6±2.8	19.1±3.1	0.6±4.7	0.461	
H_C3a1	treated	-5.6±4.8	-5.9±5.9	0±5.4	0.681	0.577
	control	-4.8±4.7	-5.5±4.9	-0.8±5.6	0.366	
H_H'	treated	12.5±4.6	12.9±5.2	0.2±4.5	0.610	0.365
	control	12.3±5.3	13.2±4.7	1.3±5.1	0.118	

Discussion

Several studies suggested the association between airway volume and the mandibular position [5, 18]. Forward mandibular repositioning appliances are often used in the treatment of mild to moderate obstructive sleep apnoea in adults; the success of this treatment depends on the ability of this tool to prevent upper aiway collapse during sleep [20].

Nevertheless, contrasting evidence are available in the relevant literature on the hypothesis that class II patients with retrognathic mandible present a reduction of oropharyngeal airway volume. This statement is supported by several studies [19, 20], but not by other ones [6,7].

Sander's BJA is a well-accepted tool for the correction of class II division 1 malocclusion with mandibular retrusion. The present study confirms the effectiveness of Sanders's BJA to improve mandibular growth in treated patients, as published in a recent RCT [21]. In fact Co-Gn and C3ai-HPT-Rgn dimension increases are statistically significant in the treated group in comparison with the control group.

Skeletal and airway dimensions were measured on lateral cephalograms which are 2 dimensional images of a 3 dimensional anatomical complex. Although their use is not ideal, it is an established tool with an highly accurate reproducibility which provide precise information in estimating tongue and pharynx volumes [22-24].

In this study we tested the hypothesis that forward mandibular growth induced by Sander's BJA may increase OA volume and A-P airway dimensions.

Nasopharynx changes between two groups were limited to S-PNS distance which increased more in treated patients. Previous studies report results in contrast about nasopharynx. Restrepo et al [14] reported an increase in the nasopharyngeal airway in Class II patients treated with activator. Other studies [2, 12] found that functional appliances do not influence nasopharynx dimension.

Mandibular advancement by Sander's BJA induced forward relocation of hyoid bone and tongue causing an increase of oropharyngeal airway. Although there was no statistically significance between treated and untreated groups, patients who underwent treatment with Sander's BJA presented a statistically significant increase of oropharyngeal airway related to the values at the beginning of observation period. Many authors reported similar findings induced by various functional appliances [12, 24, 25]

The effect on the tongue were similar to those reported in a previous study [2] with an increase of tongue height. Tongue length changes are not statistically significant although treatment with Sander's BJA causes a repositioning of tongue due both to functional re-education and to mandibular advancement.

The palatal plane dimension ANS-PNS increased in treated group even if the headgear effect of BJA. Thus is in accord with findings of Kirjavainen and Kirjavainen [2] who supposed that headgear effect was limited to maxillary alveolar process resulting in an forward growth of anterior nasal spine. The Ans-Pns-P angle decrease significantly in patients who underwent treatment with Sander's BJA.

Conclusions

The pharyngeal dimensions increased both in treated and untreated subjects. Correction of mandibular retrusion by Sander BJA appliance in class II malocclusion subjects determined a slightly higher and not statistically significant increase of depth of the oropharynx respect to control group.

The tongue height (th) increased significantly in subjects who underwent BJA treatment compared both to pretreatment values and control group.

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