Universidad Europea

GRADUATION PROJECT

Degree in Dentistry

PROFILE CHANGES IN PATIENTS TREATED WITH CLEAR ALIGNERS AND MANDIBULAR ADVANCEMENT

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RESUMEN

Introducción: La retrusión mandibular en pacientes en crecimiento origina maloclusión esquelética Clase II y un perfil facial convexo. El sistema Invisalign®, que incorpora componentes de avance mandibular, ha surgido como una alternativa mínimamente invasiva a los voluminosos aparatos funcionales tradicionales; **Objetivo:** Evaluar los cambios dentoesqueléticos y de perfil, así como la logística y duración del tratamiento, en pacientes Clase II tratados con Invisalign® y avance mandibular; **Materiales y Métodos*:*** Se analizaron retrospectivamente catorce pacientes en crecimiento (9-16 años). Las telerradiografías laterales pre-tratamiento y post-tratamiento se compararon para evaluar parámetros esqueléticos (SNA, SNB, ANB) y dentales (resalte incisivo, inclinación incisal). Se revisaron los registros clínicos relativos al número de alineadores, protocolos de uso y tiempo total de tratamiento; **Resultados:** Se observaron mejoras estadísticamente significativas en las relaciones anteroposteriores (aumento del SNB, disminución del ANB y reducción del resalte incisivo), lo que indica que el avance mandibular guiado produjo correcciones esqueléticas relevantes. La inclinación de los incisivos inferiores se mantuvo estable en la mayoría de los casos, indicando una protrusión mínima no deseada. La duración del tratamiento varió en función de la severidad inicial de la maloclusión y del momento de crecimiento, pero la mayoría de los pacientes completaron el tratamiento en un período de 12 a 36 meses; **Conclusión:** Invisalign® con avance mandibular mejora eficazmente la relación sagital maxilomandibular y el resalte incisivo sin inducir proclivación dentaria, ofreciendo una opción estética, cómoda y predecible para pacientes Clase II en crecimiento. Se precisan estudios prospectivos con mayores muestras para confirmar la estabilidad a largo plazo y optimizar los protocolos clínicos.

PALABRAS CLAVE

Odontología, Alineadores Transparentes, Avance Mandibular, Ala De Precisión, Maloclusión Clase II.

ABSTRACT

Introduction: Mandibular retrusion in growing patients produces skeletal Class II malocclusion and a convex facial profile. The Invisalign® system, incorporating mandibular advancement features, has emerged as a minimally invasive alternative to bulky functional appliances; **Objective:** Quantify dentoskeletal and profile changes, aligner logistics and overall duration in Class II growing patients treated with Invisalign® mandibular advancement; **Material and *Methods:*** Fourteen growing patients (aged 9–16 years) were retrospectively examined. Pre-treatment and post-treatment lateral cephalograms were compared to assess skeletal (e.g., SNA, SNB, ANB) and dental (overjet, incisor inclination) parameters. Treatment records detailing aligner count, wear protocols, and total treatment time were also analyzed; **Results:** Statistically significant improvements in anteroposterior jaw relationships (increased SNB, decreased ANB, and reduced overjet) were observed, suggesting that guided mandibular advancement yielded meaningful skeletal corrections. Lower incisor inclination remained stable in most cases, indicating minimal unwanted flaring. Treatment durations varied based on initial malocclusion severity and growth phase, but most patients completed care within 12–36 months; **Conclusion:** Invisalign® with mandibular advancement effectively improves sagittal jaw relationship and overjet while maintaining incisor control, offering an aesthetic, comfortable and predictable option for growing Class II patients. Larger, prospective cohorts are needed to confirm long-term stability and refine evidence-based protocols.

KEYWORDS

Dentistry, Clear Aligners, Mandibular advancement, precision wing, Class II malocclusion.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

1. INTRODUCTION

1.1. Definitions

1.1.1 Skeletal class II malocclusion

Skeletal Class II malocclusion, also called distocclusion, is characterized by the retrusion of the mandible. It is a common orthodontic condition that can significantly affect a patient's facial aesthetics and oral function(1). This relationship results in the upper teeth being positioned more forward than the lower teeth, leading to a convex facial profile.

This disharmony can manifest as both dental and skeletal discrepancies(2).The underlying etiology of Class II malocclusion is multifactorial, involving genetic predisposition, environmental influences, and functional habits. Edward Angle, considered the pioneer of modern orthodontics, created a classification system for malocclusions in the late 19th century, defining class II malocclusion by the mesiobuccal cusp of the upper first molar positioned anteriorly to the buccal groove of the lower first molar(3).

From a skeletal pattern, Class II malocclusion is often associated with a retrognathic mandible or a prognathic maxilla. It can result in a convex profile with a prominent upper lip. Patient shows an increased horizontal overlap of the upper front teeth over the lower anterior teeth, which is called overjet. Mandibular retrusion, a common skeletal contributor to Class II malocclusion, has a global prevalence estimated between 15% to 30% in children and adolescents, varying with ethnic and regional factors(4). This high prevalence underscores the need for early diagnosis and timely intervention during growth phases.

1.1.2 Mandibular growth pattern

The mandible plays a crucial role in facial aesthetics and oral function. The mandible, as the largest and most active bone in the craniofacial structure, undergoes considerable growth and remodeling during childhood and teenage years. These significant changes in size and position are essential for achieving an optimal occlusion and facial profile(5).

The mandibular growth pattern is a complex process influenced by genetic, environment and functional factors. The lower jaw grows downwards and forwards contributing to the overall lengthening and protrusion of the lower jaw. The mandible undergoes two types of ossification: the endochondral and the intramembranous(6). The key player in mandibular growth is the condyle, a bony structure at the back end of each ramus of the mandible. The condyle contains a cartilage growth center that allows bone formation and lengthening(7).

The peak of mandibular growth typically coincides with the pubertal growth spurt, which varies between individuals. During this period, the condyle experiences accelerated growth, leading to an increase in mandibular length and a downward and forward displacement of the mandible(8). However, variations in growth patterns can occur, leading to skeletal discrepancies such as mandibular retrognathia or prognathism. This natural growth pattern can be modified through orthodontic interventions.

1.2 The evolution of appliances

1.2.1 Functional appliances

Traditionally, the management of Class II malocclusion in growing patients has involved the use of functional appliances, which exert orthopedic forces to stimulate mandibular growth and correct jaw discrepancies. These devices, including Twin-Block, Herbst, Vanbeek Activator appliances, work by using the natural forces of the chewing muscles and the growth potential of the craniofacial complex to create positive changes in the position and shape of the mandible(9). Removable appliances, like Twin Block, are worn for a specified number of hours each day, while fixed appliances, such as the Herbst appliance, are cemented to the teeth and work continuously(10,11).

The mechanism of action of functional appliances involves a combination of factors. They alter the balance of forces from the lips, cheeks, and tongue on the teeth, potentially allowing for expansion of the dental arches. By positioning the mandible forward, they create an intermaxillary force. This forward positioning triggers neuromuscular adaptations and can stimulate additional mandibular growth at the condylar region, where new bone is formed via the cartilage growth center. As a result, the mandible is incrementally guided to match the maxilla more harmoniously(12).

However, these appliances are often bulky, it can lead to discomfort, they can cause also speech impairment and eating challenges(10).

1.2.2 Emergence of clear aligners with mandibular advancement

In a society more and more concerned with aesthetics, it is not unexpected that the method on how to straighten teeth has also changed. Today, a fresh wave of individuals who are mindful of how they look are opting for clear aligners, a patient-friendly alternative that prioritizes comfort and aesthetics(13,14). The impressive growth of clear aligners has been truly remarkable. From Invisalign® to various other brands, these new devices have increased treatment choices for patients and allowed them to manage their orthodontic process. This innovative method presents an attractive treatment option for Class II malocclusions patients by merging the visual appeal and comfort of clear aligners with the capability to enhance jaw growth.

Initially focusing on teeth alignment, improvements in clear aligners have broadened its application to fixing skeletal imbalances, especially in young patients. Utilizing precision wings Invisalign® is a great example of innovation for treating Class II malocclusions(15).

Clear aligners with mandibular advancement use strategically designed "wings" incorporated into the aligners to protrude the mandible forward. Precision wing aligners combine the ease of clear aligners with the orthopedic principles of functional appliances, representing a captivating development in orthodontic treatment(16). Clear aligners through features like precision wings, allow for controlled and gradual mandibular advancement. This controlled forced is likely more conducive to stimulating consistent bone growth compared to traditional appliances(17). It is important to use these specific aligners during period of active growth, the aligner's ability to stimulate condylar growth is maximized during these periods, leading to more significant and stable changes in mandibular position.

Figure 1 captures the patient's right side with both maxillary and mandibular aligners seated. The precision wings on the distal aspects of the premolar region are clearly visible; when the patient occludes, these wings interlock and posture the mandible forward. Full-arch coverage can be seen on both arches, and the incisors meet in an edge-to-edge position, typical of the advancement phase designed to stimulate sagittal mandibular growth.

Figure 1. Right-buccal intra-oral view during the mandibular-advancement stage of Invisalign® therapy.

The appeal of clear aligners with mandibular advancement extends beyond their aesthetic advantages. These appliances offer enhanced comfort, improved oral hygiene, and greater patient acceptance compared to traditional functional appliances. The fact that they are removable allow easier cleaning and maintenance, promoting better oral hygiene and reducing the risk of caries. Moreover, the discreet nature of clear aligners helps patient confidence and encourage better compliance, leading to more efficient and predictable treatment outcomes(13).

1.3 Facial profile

1.3.1 Importance of facial aesthetics in modern orthodontics

The facial profile is a key determinant of perceived beauty and attractiveness. It especially has great impact on how satisfied a patient is after undergoing orthodontic therapy(18). Whereas the earlier concept of orthodontics was about the positioning of teeth, the current concept is with the functional harmony of the teeth, the lips, the nose, the chin and the rest of the facial structures. Therefore, understanding and predicting profile changes associated with mandibular advancement is essential for successful treatment outcomes(19,20).

1.3.2 Key profile parameters influenced by mandibular advancement

There are a few key parameters that form the human profile, and their normal relationship may be altered by orthodontic treatment, especially the relationship with the protruded mandible(21). These include nasolabial angle, the facial convexity, the mentolabial angle. They are the measurable soft-tissue angles and linear distances that describe the sagittal outline of the face and are known to respond when the mandible is postured forward by a functional or aligner-based appliance.

1.3.3 Assessment method for profile analysis

We could assess these parameters by different methods, using cephalometric analysis, 3D facial scanning, facial photographs. Lateral cephalograms are useful in obtaining standardized radiographs of the skull that enable the measurement of skeletal and dento-alveolar relationships(22,23). Analyzed landmarks include nasion (N), subspinale (A), supramental (B), menton (Me), gonion (Go), incisal lower central incisor (IL1)(24). Trough these parameters, orthodontists are able to measure the nasolabial angle, facial convexity, and lower facial height respectively.

1.4 Justification

Growing patients with skeletal Class II malocclusion and mandibular deficiency often require early intervention to avoid long-term functional and esthetic complications. While traditional functional appliances can guide mandibular growth, their size and visibility frequently diminish patient compliance. Clear aligners with a mandibular advancement feature offer a more discreet alternative but require additional clinical evidence, especially regarding skeletal and dental changes during growth. By measuring pre- and post-treatment cephalometric parameters, this research directly addresses the need for objective data on aligner efficacy. Moreover, evaluating treatment outcomes in relation to individual growth patterns and the required number of aligners is essential for establishing evidence-based protocols. Ultimately, these findings will help orthodontists optimize treatment timing and methods for growing patients, promoting better facial balance, patient satisfaction, and long-term stability.

1.5 Research question

Does treatment with the Invisalign® mandibular advancement device produce significant changes in skeletal and dental parameters in growing patients diagnosed with mandibular deficiency (skeletal Class II)? How do these changes vary according to individual growth patterns and the duration (in time and number of aligners) of treatment?

2. OBJECTIVE

2.1 Main objective

- To analyze the dentoskeletal changes of growing patient, with mandibular deficiency, treated with the mandibular advancement device of Invisalign® technique.

2.2 Secondary objectives

- To study the cephalometric changes, skeletal and dental, pre and post treatment of patients treated with the mandibular advancement device of Invisalign® technique.
- To analyze the efficacy of the treatment according to the growth pattern.
- To investigate the duration of the treatment in terms of time and amounts of aligners.

2.3 Hypotheses

Null Hypothesis (H_0): There is no difference in dentoskeletal profile changes among growing Class II patients treated with clear aligners incorporating mandibular advancement compared to those treated with conventional functional appliances.

3. MATERIAL AND METHODS

3.1 Material

3.1.1 Sample size

Fourteen patients (age range: 9–16 years; mean age: 12.5 years) who underwent orthodontic treatment with clear aligners and mandibular advancement were included. Sample taken from international cases gallery of Invisalign®. This population was chosen because growing patients are ideal candidates for mandibular advancement treatments, given their peak growth phase, which can enhance treatment outcomes. The final sample size of 14 patients was determined by the availability of eligible cases meeting the inclusion criteria.

3.1.2 Inclusion and exclusion criteria

3.1.2.1 Inclusion criteria

- Patients treated exclusively with clear aligners and mandibular advancement
- Availability of pre-treatment (T0) and post-treatment (T1) cephalometric radiographs
- No prior orthodontic treatment
- Cognitive capacity to understand the treatment

3.1.2.2 Exclusion Criteria

- Severe skeletal discrepancies requiring orthognathic surgery
- Missing or incomplete radiographic records
- Craniofacial syndromes

3.2 Methods

3.2.1 Methods of data collection

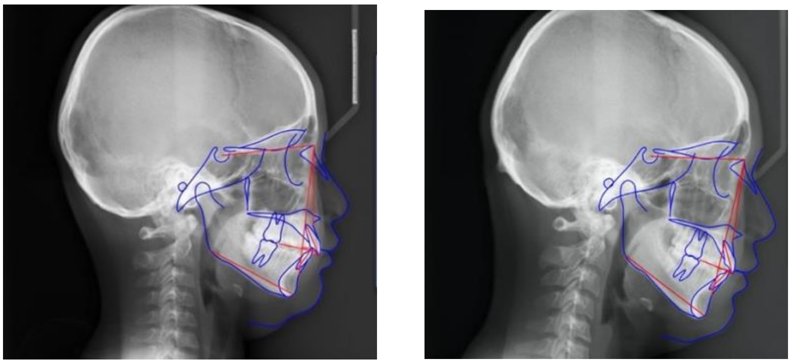
This is a retrospective observational study analyzing cephalometric radiographs obtained from patient records. The radiographs were taken at two time points:

- Pre-treatment (T0): Taken before initiating treatment.
- Post-treatment (T1): Taken immediately after completing treatment.

Cephalometric radiographs were uploaded into WebCeph software for standardized analysis. This software ensures consistent and precise measurement of the selected variables. Three standard cephalometric analyses were applied to assess the skeletal and dental relationships:

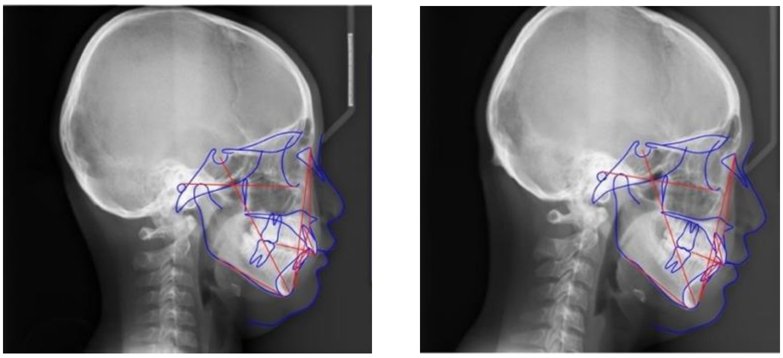
Ricketts, Downs, and Steiner. These analyses allowed evaluation of facial convexity, mandibular plane inclination, incisor angulation, and anteroposterior jaw discrepancies.

Figures 2A and 2B show the Steiner analysis, which provided key angular values such as SNA, SNB, and ANB for assessing sagittal skeletal relationships.



Figures 2A and 2B. Representative cephalometric analyses of patient 1C, using Steiner method performed in WebCeph, at T0 (left), at T1 (right).

Figures 3A and 3B present the Downs analysis, emphasizing vertical dimension and incisor inclination.



Figures 3A and 3B. Representative cephalometric of patient 1C, using Downs method performed in WebCeph, at T0 (left), at T1 (right).

Figures 4A and 4B show the Ricketts analysis applied to the patient's lateral cephalogram, which was useful for evaluating lower facial height and growth direction.

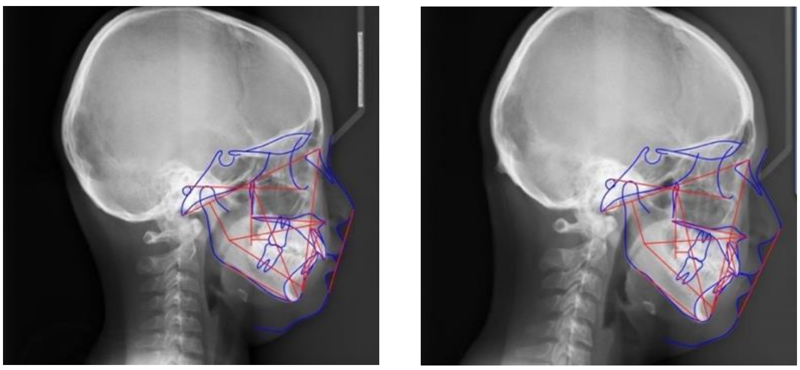


Figure 4A and 4B. Representative cephalometric analyses of patient 1C, using Ricketts method performed in WebCeph, at T0 (left), at T1 (right).

All radiographic analyses were analyzed by an operator and verified independently by one orthodontist to minimize measurement errors.

Table 1 presents cephalometric variables that were measured to assess skeletal and soft-tissue changes.

Table 1. Cephalometric variables.

Variables	**Definitions**
SNA	Formed by Sella-Nasion-Point A; Anteroposterior position of the maxilla relative to the cranial base(25).
SNB	Formed by Sella-Nasion-Point B; Anteroposterior position of the mandible relative to the cranial base(25).
ANB	Anteroposterior relationship between the maxilla and the mandible(26).
Overjet	Horizontal distance between the incisal edges of the upper incisors and the incisal edges of the lower incisors when the teeth are in occlusion(27).
NAPog	Formed by Nasion-Point A-Pogonion; Helps assess the overall facial convexity(28).
Nasolabial	Formed by the columella, the subnasal and the labrale superius; It can suggest maxillary protrusion or mandibular retrusion, leading to a convex profile(28).
IMPA	Long axis of the lower central incisor and the mandibular plane(29).
Mandibular plane angle	Formed by Sella-Nasion line and Gonion-Menton line; Vertical inclination or growth pattern of the mandible(30)

All cephalometric measurements were recorded initially in Microsoft Excel (Version 16.16.27 (201012)) to facilitate data entry and organization. Each row in the Excel spreadsheet corresponded to one patient, with columns for T0 and T1 values of the relevant variables (Tables 4 and 5 in Annexes).

The Wilcoxon signed-rank test have been used, a non-parametric test ideal for comparing two related samples, to assess whether there was a significant change in the different variables analyzed between T0 (pre-treatment) and T1 (post-treatment) for the 14 patients. The test was conducted using StatsKingdom Wilcoxon Signed Ranks Test. A p-value < 0.05 was considered statistically significant.

3.2.2 Information sources

A review of relevant literature was conducted using PubMed and Google Scholar to contextualize and support the cephalometric findings. Key search terms included “clear aligners,” “mandibular advancement,” “cephalometric analysis,” and “profile changes.”

3.3 Approvals required

The study was approved by Align Technology, and all participants provided informed consent for participation as well as for the use of their radiographic data for research purposes. On the 12th of November 2024, the Research Ethic Committee of the European University also approved this study (Código CI: 2024-964; Código Departamento: OD. 034/2223).

4. RESULTS

A total of 14 growing patients (mean age 12.5 years, range 9–16) with Class II malocclusions were evaluated before (T0) and after (T1) treatment with clear aligners featuring a mandibular advancement component. The sample included nine females and five males. A total of approximately 80 aligners (range: 50–100) was prescribed for the maxillary arch, and around 75 aligners (range: 48–96) for the mandibular arch, reflecting the individualized requirements of each case. Most patients changed aligners every week, although some followed a 10-day cycle based on the specific prescription and tooth movement needs. The mean overall treatment time was about 22 ± 5.6 months (range: 12–36 months). Younger patients (9–10 years old) sometimes required refinements due to ongoing growth, resulting in additional aligners and longer durations.

Table 2 details each patient's age, sex, number of aligners prescribed for the maxilla and mandible, as well as the wear intervals.

Table 2. Description of the 14 patients.

Case	Age	Sex	Max. Aligners	Mand. Aligners	Wear Interval	Treatment (months)
1C	12	M	96	80	1 week	24
2C	12	F	95	95	1 week	26
3C	11	M	66	66	1 week	17
4C	9	F	48	48	1 week	12
5C	13	M	82	82	1 week	22
6C	14	M	100	76	10 days	36
7C	13	F	99	87	10 days	30
8C	10	F	74	74	1 week	22
9C	11	M	58	58	7–14 days	29
10C	16	M	73	73	1 week	21
11C	16	F	96	96	1 week	N
12C	14	F	98	94	1 week	24
13C	12	F	81	79	1 week	23
14C	12	F	51	51	10 days	22

(M: Male; F: Female, Max: Maxillary, Mand: Mandibular; N: Not none)

Cephalometric comparisons examined both skeletal (SNA, SNB, ANB, Mandibular Plane Angle, NAPog) and dental/soft-tissue (Overjet, IMPA, Nasolabial Angle) parameters.

Table 3 presents the mean changes in key cephalometric measurements, comparing T0 with T1. For each parameter, both the pre- and posttreatment mean (± standard deviation) and the mean difference (Delta) are reported, along with p-values.

Table 3. Mean of cephalometric measurements of patients pre and post-treatment.

Measure	Unit	T0 (Mean ± SD)	T1 (Mean ± SD)	Delta	p-value
SNA	degrees	84 ± 4,65	81,45 ± 3,37	-2,76	0,7148
SNB	degrees	76,30 ± 2,83	77,66 ± 2,79	1,36	0,0039*
ANB	degrees	4,98 ± 1,21	3,80 ± 1,33	-1,18	0,0067*
NAPog	degrees	8,44 ± 3,09	5,72 ± 3,81	-2,72	0,0067*
Overjet	mm	6,97 ± 1,94	3,69 ± 0,58	-3,28	0,0002*
IMPA	degrees	99,52 ± 5,84	99,65 ± 3,83	0,13	0,9515
Nasolabial	degrees	96,05 ± 11,23	95,90 ± 13,31	-0,15	1
Mandibular plane angle	degrees	21,11 ± 4,73	22,40 ± 6,37	1,29	0,1937

(: statistically significant)*

The most pronounced finding in the group emerged in Overjet, which decreased from a mean of 6.97 ± 1.94 mm at T0 to 3.69 ± 0.58 mm at T1 ($p < 0.001$). The decrease of 3.28 mm indicates that the use of aligner-supported mandibular advancement was successful in decreasing the excessive horizontal overlap that is typical of Class II malocclusions in a growing population. This reduction was both clinically and statistically significant ($p < 0.001$), highlighting the effectiveness of aligner therapy coupled with mandibular advancement in addressing excessive horizontal overlap.

Regarding skeletal parameters, SNB demonstrated a statistically significant mean increase of +1.36° (from 76.30 ± 2.83° at T0 to 77.66 ± 2.79° at T1, $p < 0.05$), indicating the forward movement of the mandible. ANB angle reduced by approximately 1.18°, from 4.98 ± 1.21° to 3.80 ± 1.33° (p = 0,0067). Such parallel improvements, an elevated SNB and a lowered ANB, highlight a significant skeletal adaptation that is most likely the result of improved mandibular positioning in relation to the maxilla. This result correlates with the postulated mechanism for mandibular advancement, in which the mandible is guided into a more forward position to permit condylar growth to accommodate the new anteroposterior relationship. In contrast, SNA is not significant (p= 0,7148), indicating no repositioning of the maxilla at the group level.

Facial convexity, measured by NAPog, also improved. NAPog decreased by an average of 2.72° (from 8.44 ± 3.09° to 5.72 ± 3.81°, $p < 0.05$), pointing to a reduced facial convexity and an enhanced chin projection. Such improvements may be especially relevant in a growing adolescent study concerned with balancing facial proportions.

Soft-tissue and incisor inclination parameters remained relatively stable. The nasolabial angle changed only by $-0.15°$ ($p = 1$), from $96.05 \pm 11.23°$ at T0 to $95.90 \pm 13.31°$ at T1. This stability meant that the position of the upper lip relative to the subnasale was nearly unchanged, an outcome appreciated by most patients as major repositioning of the lips can be undesirable. Lower incisor inclination remained essentially stable, changing from $99.52 \pm 5.84°$ at T0 to $99.65 \pm 3.83°$ at T1, with a delta of $+0.13°$ and $p >> 0.05$. This stability is clinically reassuring, given the usual concerns that skeletal Class II corrections can sometimes induce unwanted incisor flaring. Both IMPA and the Nasolabial Angle exhibited no statistically significant differences, suggesting that lower incisor inclination and upper lip posture did not undergo substantial alterations during treatment. Although, the Mandibular Plane Angle showed an increase of approximately 1.29° (from $21.11 \pm 4.73°$ at T0 to $22.40 \pm 6.37°$ at T1, $p \approx 0.1937$), which means that there was a generally non-significant vertical alteration in the sample. There were some patients who exhibited small increments in vertical facial growth, while others remained relatively stable. Vertically high-angle patients might need monitoring so that the anterior positioning of the mandible will not exacerbate vertical tendencies.

5. DISCUSION

5.1. Skeletal and profile adaptations

The results indicate that growing Class II patients treated with clear aligners incorporating a mandibular advancement feature experienced significant improvements in anteroposterior jaw relationships (increased SNB, decreased ANB) and marked reductions in overjet, whereas minimal or non-significant alterations occurred in SNA, IMPA, and the nasolabial angle.

The cephalometric changes observed in this study are broadly consistent with those reported in prior research on Class II correction using clear aligner mandibular advancement. For instance, *Sabouni et al.* (2022) documented significant improvements in skeletal and dental parameters, including reductions in ANB angle, increased mandibular length, and decreased facial convexity, following Invisalign® with mandibular advancement in growing patients(16). These findings mirror our results, which showed a favorable shift toward Class I jaw relationship and a flatter facial profile. *Caruso et al.* (2021) similarly found that both clear aligners with mandibular advancement and Twin-Block appliances produced Class II improvements such as ANB reduction and overjet correction(17). This suggests that our treatment outcomes, improved jaw relationship and overjet, are comparable in nature to those achieved with traditional functional appliances.

Despite these similarities, some differences emerge when comparing magnitudes of change. *Caruso et al.* (2021) noted that Twin-Block therapy induced a greater increase in mandibular dimensions than did the aligner-based advancement, indicating a more pronounced skeletal effect with the traditional appliance(17). Our findings align with this trend, as the skeletal changes achieved were modest.

5.2 Dental effects and incisor control

Dental changes, such as incisor positioning, were well-controlled by the aligners. Overjet reduction in our patients occurred with minimal change in incisor inclination or nasolabial angle. Notably, previous studies report that clear aligners with precision wings tend to avoid the significant upper incisor retroclination seen in Twin-Block treatment. We also observed this in this retrospective study, minimal change in upper incisor inclination, which matches the controlled incisor movement described by *Sabouni et al.* (2022) (16). Additionally, our results confirm a key point highlighted in the literature: clear aligner mandibular advancement maintains excellent control over the lower incisor position. Both *Wu et al.* (2023) and *Sabouni* *et al.* (2022) observed negligible proclination of the lower incisors with aligners, whereas conventional devices like Herbst and Twin-Block tend to cause the lower incisors to tip forward as a side effect(16,31).

Gurgel et al. (2023) evaluated skeletal and dental changes in growing Class II patients treated exclusively with Invisalign® mandibular advancement, demonstrating that aligner-based forward positioning utilizes remaining growth potential to correct Class II discrepancies while preserving lower incisor inclination(32). These findings closely match our own, which showed minimal incisor flaring (ΔIMPA of +0.13°), highlighting the capacity of aligners to exert well-controlled forces and prevent undesirable incisor proclination, an advantage for both periodontal health and smile esthetics. However, *Gurgel et al.* (2023) also noted slightly larger SNB gains in certain cases, attributing this variation to the timing of intervention (particularly if initiated at the peak of the pubertal growth spurt) and the individualized nature of virtual planning used to target specific skeletal outcomes(32).

5.3 Influence of growth patterns and treatment logistics

5.3.1 Timing of intervention

These results contribute a clearer understanding of how aligner-based mandibular advancement can harmonize the occlusion and facial profile in a growing population, thereby substantiating existing hypotheses for the optimization of skeletal alteration during the pubertal growth spurt. *Ravera et al.* (2021) prospectively followed adolescents treated with the Invisalign® mandibular-advancement feature and reported that subjects who entered treatment at cervical-vertebral maturation (CVM) stages 3, during pubertal growth, achieved a predominantly skeletal correction, whereas those treated at CVM2 (during pre-pubertal growth) exhibited mainly dento-alveolar change. Their data support timing mandibular advancement to the pubertal growth spurt(33). Our series echoes this pattern: adolescents treated close to the peak growth spurt displayed a more pronounced mandibular advancement, while the 9- to 10-year-olds achieved the same occlusal end-point chiefly through dental movements and required later refinements.

5.3.2 Aligners count, refinements and final duration

Several studies show that the number of trays and the time needed to finish mandibular-advancement aligner therapy depend strongly on the child's growth stage at the moment treatment begins. A three-dimensional analysis by *Gurgel et al.* (2023) reported that an 11 years old patient needed 61 aligners in Mandibular-Advancement phase and 14 extra aligners for the refinement(32). A large North-American audit by *Meade and Weir* (2024) echoed those findings, noting that many early patients ran out of trays before their jaw relationship was fully corrected, unless additional aligners were ordered(34). Our results sit between these published figures: on average our patients used seventy-five to eighty trays and finished in about twenty-two months. These parallels and differences together reinforce a practical takeaway: starting aligner-based mandibular advancement close to the adolescent growth peak usually means fewer trays and a shorter schedule, whereas very early intervention is feasible but almost always demands extra refinement aligners to keep up with ongoing growth.

5.4 Limitations of this study

This study has several limitations that must be acknowledged. First, the sample size is relatively small, which limits the generalizability of our findings. A larger sample would provide more statistical power and could capture a wider range of growth patterns and treatment responses. Without a control or comparison group treated with an alternative method, it is difficult to distinguish how much of the observed changes are due to the treatment itself versus normal growth or other factors. The lack of a concurrent control (for example, a Twin-Block group or an untreated Class II group) means we relied on comparisons to historical controls from the literature, which is a weaker form of evidence. The long-term stability of Class II correction achieved with clear aligners and mandibular advancement is an important consideration, particularly given the relatively recent introduction of this technique. While our study demonstrates positive short-term changes, we must consider how these results hold up as patient complete growth and move into retention.

5.5 Clinical implications and future recommendations

From a clinical perspective, the stability of lower incisor inclination (IMPA) and nasolabial angle is particularly encouraging for orthodontists seeking to avoid adverse esthetic or dental side effects. For practitioners, this study demonstrates that growth modulation using aligners can be applied to a broader range of patients who might be reluctant to wear bulkier functional appliances thus extending accessibility to orthodontic treatments that promote both function and esthetics. Moreover, the improved anteroposterior correction observed here corresponds well with the secondary objectives of studying treatment efficacy according to growth patterns and analyzing alignment duration, as the observed changes were achieved within typical aligner treatment times and standard aligner counts.

Further research should replicate this design in a larger, prospective cohort to validate the observed skeletal and dental changes and explore how treatment outcomes vary by growth pattern. Direct comparison investigations of aligner-based mandibular advancement versus conventional functional appliances in randomized, controlled settings would yield additional data on efficacy, compliance, and long-term stability. Lastly, it may be useful to include standardized protocols for evaluation of growth and gather information on patient-centered outcomes to further allow evidence-based recommendations for the utilization of mandibular advancement in clear aligner treatment.

6. CONCLUSIONS

1. The use of Invisalign® with mandibular advancement in growing patients with skeletal Class II malocclusion resulted in measurable improvements in anteroposterior jaw relationships (evidenced by changes such as increased SNB), indicating effective forward repositioning of the mandible during active growth.
2. Cephalometric analysis showed significant changes in SNB, ANB, Overjet, and NAPog, indicating forward mandibular positioning and reduced horizontal overlap. Lower incisor inclination (IMPA) remained stable, suggesting minimal unwanted dental effects.
3. The treatment's effectiveness was influenced by each patient's growth trajectory, with individuals closer to their pubertal growth spurt often exhibiting more pronounced skeletal changes.
4. Treatment times spanned 12-36 months, with the quantity of aligners determined by the patient's initial malocclusion severity and adherence to the protocol, highlighting how growth potential and consistent wear are crucial for finishing on schedule.

7. SUSTAINABILITY

From an environmental perspective, aligner therapy offers both challenges and opportunities. Although single-use aligners are fabricated from plastics, the shift toward digital workflows, particularly intraoral scanning, significantly reduces the consumption of impression materials and the need for repeated plaster models. This consolidation of resources lowers waste generation and storage requirements. In addition, fewer chair visits further diminish patient-related travel emissions.

Social sustainability is likewise enhanced. Growing adolescents with Class II malocclusions can benefit greatly from the aesthetic appeal of clear aligners. Clear transparent aligners confer superior aesthetics and comfort relative to conventional functional appliances, aligners can support self-esteem and psychosocial integration during a sensitive developmental phase. Patients and their families also benefit from digital monitoring options that reduce the frequency of office visits, easing temporal and transport constraints.

Economically, aligner therapy with mandibular advancement can yield benefits for both patients and healthcare systems. While the initial outlay for digital scanning technology may be higher than traditional methods, reduced chairside time and improved treatment efficiency often offset these expenses over the long term. Moreover, effective correction of mandibular discrepancies during growth reduces the probability of later orthognathic surgery or extensive restorative intervention, offering both cost savings and better overall outcomes.

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9. ANNEXES

9.1 Cephalometries of the 14 patients pre and post-treatment.

Figure 5. Cephalometry of patient 1C, at T0.

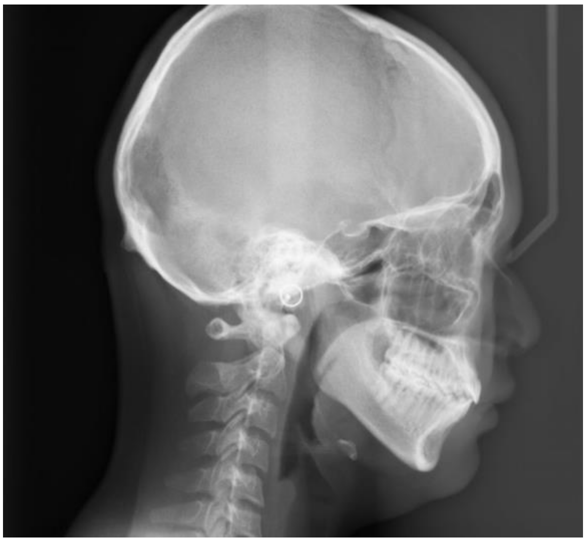

Figure 6. cephalometry of patient 1C, at T1.

Figure 7. Cephalometry of patient 2C, at T0.


Figure 8. Cephalometry of patient 2C, at T1.


Figure 9. Cephalometry of patient 3C, at T0.

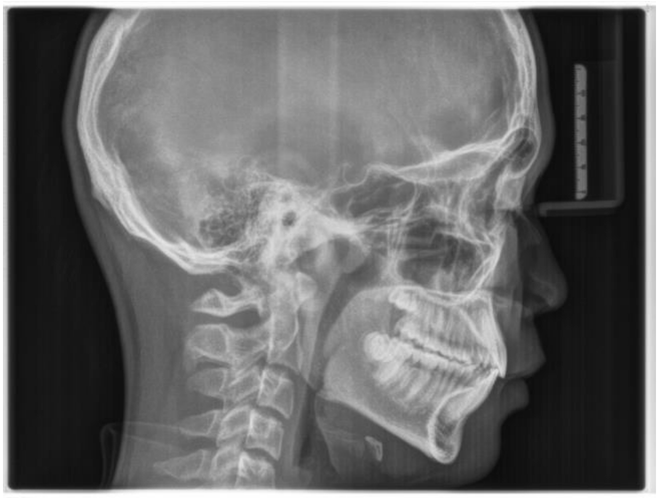
Figure 10. Cephalometry of patient 3C, at T1.

Figure 11. Cephalometry of patient 4C, at T0.

Figure 12. Cephalometry of patient 4C, at T1.

Figure 13. Cephalometry of patient 5C, at T0

Figure 14. Cephalometry of patient 5C, at T1.

Figure 15. Cephalometry of patient 6C, at T0.

Figure 16. Cephalometry of patient 6C, at T1.

Figure 17. Cephalometry of patient 7C, at T0.

Figure 18. Cephalometry of patient 7C, at T1.

Figure 19. Cephalometry of patient 8C, at T0.

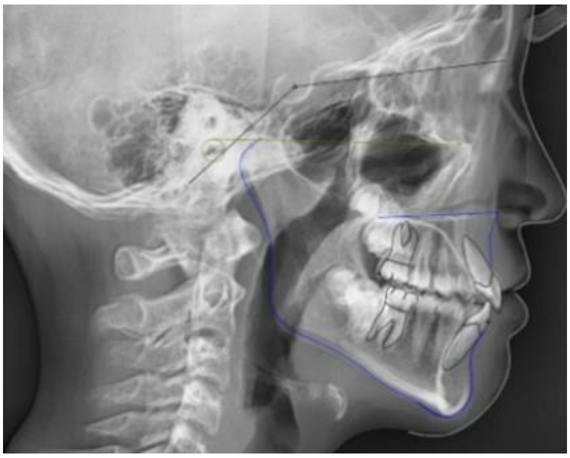

Figure 20. Cephalometry of patient 8C, at T1.

Figure 21. Cephalometry of patient 9C, at T0.

Figure 22. *Cephalometry of patient 9C, at T1.*


Figure 23. Cephalometry of patient 10C, at T0.


Figure 24. Cephalometry of patient 10C, at T1.

Figure 25. Cephalometry of patient 11C, at T0.

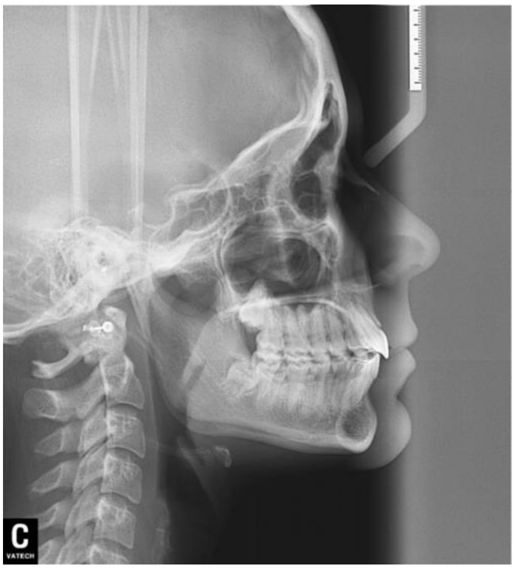

Figure 26. Cephalometry of patient 11C, at T1.

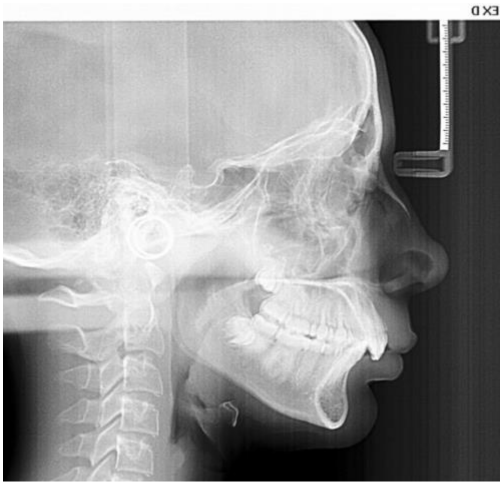
Figure 27. Cephalometry of patient 12C, at T0.

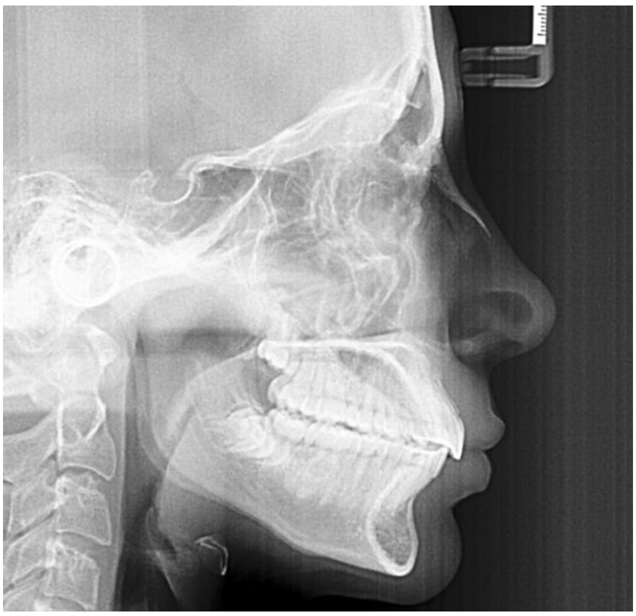
Figure 28. Cephalometry of patient 12C, at T1.

Figure 29. Cephalometry of patient 13C, at T0.

Figure 30. Cephalometry of patient 13C, at T1.


Figure 31. Cephalometry of patient 14C, at T0.


Figure 32. Cephalometry of patient 14C, at T1.

9.2 Tables of all cephalometric measurements pre and post-treatment, made through Excel.

Table 4. Cephalometric measurements of 14 patients pre and post-treatment.

Case	SNA_T0	SNA_T1	SNB_T0	SNB_T1	ANB_T0	ANB_T1	NAPog_T0	NAPog_T1
1C	82.84	83.78	76.95	78.56	5.90	5.22	13.87	11.71
2C	79.86	79.73	74.10	77.18	5.76	2.68	7.81	-0.48
3C	83.25	79.58	77.59	77.33	5.66	2.25	10.40	3.83
4C	82.24	80.96	76.97	77.37	5.27	3.59	8.61	4.86
5C	84.47	82.15	79.63	79.25	4.84	2.90	6.08	3.16
6C	80.71	80.11	75.71	77.36	5.00	2.75	8.79	2.76
7C	85.10	86.57	80.28	81.62	4.82	4.95	8.89	9.89
8C	75.29	77.44	72.48	75.91	2.81	1.53	4.32	-0.29
9C	85.16	87.38	79.15	82.63	6.01	4.75	10.65	8.28
10C	83.69	83.48	77.44	77.13	6.25	6.35	11.48	10.96
11C	80.68	80.85	75.57	76.69	5.11	4.11	8.07	6.96
12C	80.63	80.59	74.38	75.72	6.25	4.87	11.54	7.98
13C	80.99	83.17	77.87	79.63	3.12	3.54	4.48	5.70
14C	72.99	74.57	70.11	70.93	2.88	3.64	3.16	4.82

(T0: pre-treatment; T1: post-treatment)

Table 5. Cephalometric measurements of 14 patients pre and post-treatment.

Case	Overjet_T0	Overjet_T1	IMPA_T0	IMPA_T1	Nasolabial_T0	Nasolabial_T1	Mandibular Plane_T0	Mandibular Plane_T1
1C	6.00	3.30	98.00	96.89	91.50	98.60	27.98	29.94
2C	8.31	3.00	104.56	101.54	96.73	94.96	16.32	15.99
3C	8.28	3.45	104.01	97.86	85.82	86.83	18.28	20.38
4C	7.34	4.44	89.33	99.32	89.57	80.58	26.55	27.90
5C	11.10	4.01	96.73	101.89	92.87	99.74	16.86	13.66
6C	5.44	3.00	95.73	101.97	94.66	82.16	19.55	16.47
7C	7.86	3.80	103.46	103.96	85.05	89.27	16.94	20.42
8C	4.94	3.24	100.75	93.64	78.83	75.82	28.09	29.22
9C	8.88	3.30	110.72	105.47	102.19	97.28	17.07	15.46
10C	3.33	3.67	89.91	94.67	120.01	120.96	23.82	23.16
11C	6.44	3.32	102.30	104.95	110.46	117.89	14.26	16.55
12C	5.88	4.90	103.14	96.52	110.26	110.26	22.98	32.74
13C	7.80	4.49	96.07	95.97	91.82	95.20	21.06	22.82
14C	6.00	3.68	98.54	100.43	94.86	92.97	25.83	28.85

(T0: pre-treatment; T1: post-treatment)

9.3 Approval of Align Technology

align

2 de febrero de 2023

Align Technology acepta que con domicilio de investigación en la Facultad de Odontología de la Universidad Europea de Madrid, C. Tajo, s/n, 28670 Villaviciosa de Odón, Madrid pueda utilizar los casos de la Galería Internacional Invisalign para su investigación al ser un contenido público.
El uso de esta información para dicho propósito deberá ser obtenida a través de la cuenta del doctor certificado.
El uso de la información publicada en la Galería Internacional Invisalign, debe hacer mención a Align Technology como fuente de origen referenciada.

Atentamente,

Align Technology