Comparison of Skeletal and Airway Changes Between Subjects with Class II Malocclusion Treated with Functional Therapy in the Pre-Pubertal and Pubertal Phases

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DOI 10.23804/ejpd.2025.2544

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Abstract

Background Evaluate the skeletal and upper airway changes induced by the Twin Block device in patients with Class II malocclusion due to mandibular retrognathia using 2D imaging and compare the effects of prepubertal and pubertal treatment.
Methods Thirty patients (15 males and 15 females) with Class II malocclusion who were treated with the Twin Block device were selected. Latero-lateral teleradiographs were acquired at the beginning (T0) and end (T1) of treatment. The sample was divided into two groups (pre-pubertal and pubertal) according to cervical vertebral maturation (CVM). Patients wore the device 24 hours a day, except during meals and oral hygiene, and underwent monthly checkups. Images were analysed using DeltaDent software.
Results Cephalometric analysis revealed no statistically significant differences between the Pre-Pubertal and Pubertal groups, except for the H-C3A1 and Height (TH) variables.
Conclusions The Twin Block effectively improved mandibular position and dental occlusion, positively contributing to upper airway development with comparable effects in the two growth stages.

KEYWORDS Class II malocclusion, Twin Block appliance, skeletal maturation, cervical vertebral maturation, cephalometric analysis, airway development, mandibular advancement, functional orthopaedic treatment.

Introduction

Class II malocclusion is one of the most common and complex orthodontic conditions to manage in clinical practice. It poses a major diagnostic and therapeutic challenge [Capurro et al., 2024; P, 2024; Parisi et al., 2024; Strieder et al., 2024; Torchia et al., 2024]. It is characterised by an abnormal sagittal relationship between the maxillary bone bases [Bimalrag et al., 2024; Johnson et al., 2021; Madian and Elfouly, 2023; Mahamad et al., 2012; Mahony and Witzig, 1999]. The traditional classification system, developed by Edward H. Angle in the late 19th century, categorises Class II malocclusions into two types based on the inclination of the upper incisors and distinguishes between dentoalveolar, skeletal, and mixed forms of the condition [Lo Muzio et al., 2009; Lo Russo et al., 2019; Sabatucci et al., 2015; Termine et al., 2009]. Typical skeletal changes include mandibular retrusion and, less frequently, maxillary protrusion [Crincoli et al., 2016; Dioguardi et al., 2022, 2021; Favia et al., 2015; Lucchese et al., 2010]. These conditions are manifested by a convex facial profile and a functional discrepancy between the dental arches [Bambini et al., 2006; Memè et al., 2022b, 2023; Rossi et al., 2023]. This discrepancy can impair mastication, phonation, and facial aesthetics [Favero et al., 2024; Garrocho-Rangel et al., 2024; Ghilotti et al., 2024]. The aetiology of Class II malocclusion is multifactorial and complex, encompassing genetic, environmental, and functional factors [Capotosti et al., 2024; Lambert et al., 2024; Salerno et al., 2024]. Among these factors, flawed habits such as oral breathing, finger sucking, prolonged pacifier use, and lower lip interposition play a crucial role in the onset and maintenance of malocclusion [Duan et al., 2022; Dyer et al., 2001; Elfouly et al., 2024; Zhang et al., 2024; Zreaqat et al., 2022]. These parafunctional habits act on multiple levels [dental, skeletal, and muscular], negatively affecting the growth and morphology of the dental arches [Piombino et al., 2015; Sammartino et al., 2008, 2005b, 2005a]. Therefore, early recognition and correction of these habits are essential [Abanto et al., 2024; Sen Yavuz et al., 2024; Vasakova et al., 2024; Walia et al., 2024; Zerman, 2024a]. In the context of Class II malocclusion, it is crucial to consider the role of the upper airway [Adamo et al., 2021, 2022; Canfora et al., 2022; F. Inchingolo et al., 2024c; Inchingolo et al., 2025]. The upper airway, which includes the nasal cavities, pharynx, and larynx, plays a key role in proper nasal breathing [Bayrak et al., 2024; Cots et al., 2024; ElGhandour et al., 2024; Ilisulu et al., 2024]. This process is essential for filtering, warming, and humidifying air [Francesco Inchingolo et al., 2024c, 2024b, 2024a; Meme' et al., 2024; Minetti et al., 2024]. Oral breathing is often associated with Class II malocclusion and can lead to morphological and functional changes that result in airway narrowing and pharyngeal collapse, especially during sleep [Capotosti et al., 2024; Lambert et al., 2024; Salerno et al., 2024]. Obstructive sleep apnea syndrome (OSAS) is a clinically relevant condition characterised by intermittent partial or complete obstruction of the upper airway [Minervini et al., 2024, 2023; Nahidh et al., 2023; Uzunçıbuk et

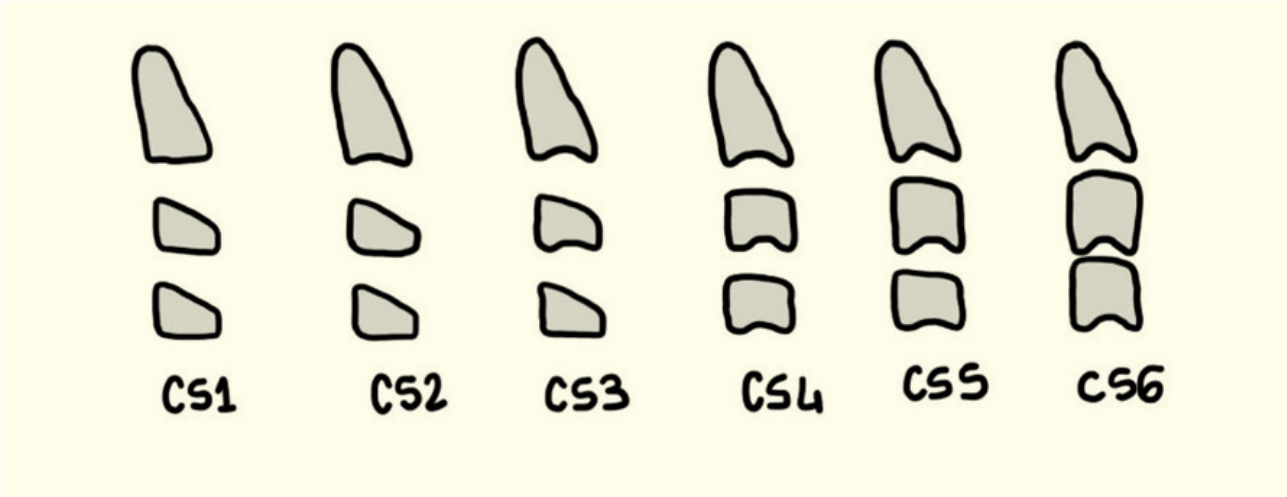

FIG 1. Graphic representation of cervical vertebrae and stages of growth.

al., 2024]. This leads to repeated nocturnal awakenings, hypoxia, and alterations in sleep architecture [Beretta et al., 2024; Izzetti et al., 2024; Memè et al., 2024]. OSAS is associated with general risk factors, such as obesity, male sex, and advanced age, as well as local anatomical factors, such as mandibular retrognathia, adenotonsillar hypertrophy, and nasal deviations [Almeida et al., 2023; Langaliya et al., 2023; Minervini et al., 2024, 2023; Ramalingam et al., 2024]. Diagnosis is based on thorough patient history, physical examination, and instrumental tests such as polysomnography and cephalometric evaluations [Dipalma et al., 2023, 2025a; AM Inchingolo et al., 2023b; F. Inchingolo et al., 2023; Malcangi et al., 2023b]. These evaluations allow identification of patients at increased risk and planning of targeted treatment [Zhao et al., 2024; Radwan et al., 2022; Xu et al., 2024; Ong et al., 2024; Pattipati et al., 2022]. Functional therapy is an established and proven approach for correcting Class II skeletal malocclusions [Cenzato et al., 2024a; Cianetti et al., 2024; Remy et al., 2024; Ronsivalle et al., 2024; Salvati et al., 2024]. It originated in the late 19th century with the introduction of the first removable appliances designed to adjust the position of the mandible and stimulate bone growth [Quinzi et al., 2021.; S et al., 2021; Saccomanno et al., 2021b, 2022, n.d.]. Pioneers of this field include Kingsley, Robin, and Andreasen [Avvanzo et al., 2009; Crincoli et al., 2021; Tepedino et al., 2018; Troiano et al., 2018]. Their contributions led to the development of the "Norwegian System," a theoretical framework that remains relevant today [Al-Saleh et al., 2015; Golfeshan et al., 2018; Khoja et al., 2016; Yildirim et al., 2014]. Functional appliances, such as the Twin Block, Fränkel, Andreasen monoblock, and Bionator, work by altering the mandible's posture through forces transmitted to the dental and skeletal structures [Adamo et al., 2024, 2020; Adamo and Spagnuolo, 2022; Mignogna et al., 2009, 2008]. This stimulates bone and cartilage remodeling processes [AD Inchingolo et al., 2022; AM. Inchingolo et al., 2023a; Malcangi et al., 2023a; Montenegro et al., 2021; Patano et al., 2023]. The optimal time to intervene is during mixed dentition, specifically during the Pubertal of pubertal growth, which can be identified by analysing the maturational stages of the cervical vertebrae (CS3) [Dipalma et al., 2025b; F. Inchingolo et al., 2022; Laudadio et al., 2021; Rapone et al., 2022; Santacroce et al., 2021]. This is a time when the response to treatment is maximised (Figure 1) [Campobasso et al., 2021; Cazzolla et al., 2018; Ciavarella et al., 2012, 2011; Laino et al., 2015]. The Twin Block has established itself as one of the most widely used functional appliances for Class II skeletal correction [Baccaglione et al., 2020; Burhan and Nawaya, 2015; Buyukcavus and Kale, 2021; Gandedkar et al., 2019; Yıldırım and Karaçay, 2021]. It uses inclined planes that guide the mandible forward and downward, promoting steady mandibular advancement and stimulating mandibular branch and symphysis growth [Aktaş and Atabek, 2024; Bhatia et al., 2024; Scribante et al., 2024; Spinas et al., 2024c]. Twin Block therapy consists of an active phase, aimed at mandibular repositioning and control of tooth eruption, and a maintenance phase, to consolidate the new position [Cafiero et al., 2019; Grippaudo et al., 2014; Muraglie et al., 2020]. The total duration of treatment is about 18 months, including an overnight retention phase [Hatia et al., 2024; Laganà et al., 2015, 2013; Vinjolli et al., 2023]. The efficacy of the device is manifested by an increase in mandibular length, moderate inhibition of maxillary growth, favorable dental changes such as retroclination of upper incisors, proclination of lower incisors, and distalisation of upper molars, and improvements in facial aesthetics, with reduced convexity and greater definition of the mandibular profile [Ajami et al., 2019; Alsilq and Youssef, 2025; Baheti et al., 2022; Çoban Büyükbayraktar and Camcı, 2023; Lombardo et al., 2024]. Functionally, the Twin Block also contributes to improved breathing by increasing the volume of the upper airway, an effect achieved by anterior traction of the tongue and soft palate with consequent widening of the pharyngeal lumen [Brescia et al., 2024; Spinas et al., 2024b, 2024a; Zerman et al., 2024]. This results in a potential benefit in reducing the severity and frequency of nocturnal obstructive events, with a positive impact on sleep quality and the patient's overall condition [Bambini et al., 2005b, 2005a, 2004; Memè et al., 2022a; Strappa et al., 2022]. Class II malocclusion and its respiratory comorbidities require a multidisciplinary approach that integrates clinical, radiologic, and functional assessments to define an individualised treatment plan [Campanella et al., 2020; Dinoi et al., 2016; Marchetti et al., 2017; Pasini et al., 2020; Quinzi et al., 2020]. Functional therapy with appliances such as the Twin Block, appropriately timed and followed, is an effective and predictable treatment for the correction of skeletal and dental discrepancies, with positive effects on aesthetics, masticatory and respiratory function, and overall improvement in the patient's quality of life [Batra and Shetty, 2022; Kalha, 2014; Kaur et al., 2022; Khan et al., 2022; Varrela, 1998].

The aim of the present study was to investigate the effects of

MEASURE	DEFINITION
NOSEPHARYNX	
S-PNS	Distance from the saddle (S) to the posterior nasal spine (PNS).
AD1-PNS	Distance from AD1 to posterior nasal spine (PNS). AD1 is the point of intersection of the posterior pharyngeal wall with the line joining posterior nasal spine (PNS) and basion (Ba).
AD2-PNS	Distance from AD2 to the posterior nasal spine (PNS). AD2 is the point of intersection of the posterior pharyngeal wall with the line from the midpoint of the line from the saddle (S) to the basion (Ba) to the posterior nasal spine (PNS).
OROPHARYNX	
AA-PNS	Distance from the most anterior point of the atlas (AA) to the posterior nasal spine (PNS).
VE-PVE	Distance from the soft palate point closest to the posterior pharyngeal wall (velum palatinum, VE) to the corresponding horizontal point on the posterior pharyngeal wall (PVE).
P-PP	Distance from the tip of the soft palate (P) to the corresponding horizontal point on the wall posterior pharyngeal (PP).
PAS	Distance from the points of intersection on the anterior and posterior pharyngeal wall to the line joining the supramental (B) to the gonion (Go).
PH-PPH	Distance of the corresponding horizontal points on the anterior and posterior pharyngeal wall at level of the oropharynx in its 'narrowest area.
SOFT PALATE	
ANS-PNS-P	Angle from anterior nasal spine (ANS) to posterior nasal spine (PNS) to palatal point (P).
PNS-P	Distance from the posterior nasal spine (PNS) to the tip of the soft palate (P).
SP1-SP2	Cross section of the thickest part of the soft palate.
HYPOPHARYNX	
EB-PEB	Distance from the vallecula of the epiglottis (EB) to the corresponding horizontal point on the posterior pharyngeal wall (PEB).
MAXILLA	
SNA	Angle from saddle (S) to nasion (N) to subspinal (A).
ANS-PNS	Palatal plane length from anterior nasal spine (ANS) to posterior nasal spine (PNS).
JAW	
SNB	Angle from saddle (S) to nasion (N) to supramental (B).
ANB	Angle from subspinal (A) to nasion (N) to supramental (B).
NS-MP	Angle from nasion (N) to saddle (S) to mandibular plane (MP). The mandibular plane is the line joining the point of the mandibular base (MBP) to the chin (ME).
CO-GN	Mandibular length. The length from the most posterior and superior point of the head condylar (CO) to the most anterior and inferior point of the mandibular symphysis (GN).
C3AI-HPT-RGN	Sum of two distances: (1) the perpendicular distance between the most anterior and lowest point of the body of the third cervical vertebra (C3AI) and HPT. HPT is the vertical line from the most anterior and superior point of the hyoid bone perpendicular to the line from the nasion (N) to the saddle (S) with an upward correction of 7°. (2) The distance from the most posterior point of the mandibular symphysis (retrognation, RGN) perpendicular to HPT.
FACIAL HEIGHTS	
N-ME	Distance from nasion (N) to chin (ME).
ANS-ME	Distance from anterior nasal spine (ANS) to chin (ME).
TONGUE	
LENGTH (TT-EB)	Tongue length. The distance from the anterior point of the tip of the tongue (TT) to the base of the epiglottis (EB).
HEIGHT (TH)	Tongue height. The perpendicular distance from the highest point of the tongue (TH) located below the posterior nasal spine (PNS) to the line joining the tip of the tongue (TT) to the point of intersection of the tongue and mandibular border (TG).
HYOID BONE	
H-H'	Distance from the most anterior and superior point of the hyoid bone (H) perpendicular to the plane mandibular (MP).
H-C3AI1	Hyoid (H). The perpendicular distance from the most anterior and superior point of the bone hyoid to the perpendicular line joining C3AI to HPT.

TABLE 1 Points, planes and angles of reference.

functional Twin Block device treatment on skeletal parameters and upper airway dimensions in subjects with Class II malocclusion due to mandibular retrusion [Ballini et al., 2020; A. M. Inchingolo et al., 2022; Angelo Michele Inchingolo et al., 2024a; Laforgia et al., 2025; Mancini et al., 2024]. Specifically, we aimed to analyse, by means of two-dimensional imaging, the pre- and post-treatment morphological evolution, comparing the effectiveness of the intervention at two different stages of pubertal development, distinguishing patients according to their skeletal maturity assessed by the cervical vertebral maturation method (CVM).

Materials and Methods

Ethical Considerations

The study was conducted in compliance with the ethical principles outlined in the Declaration of Helsinki. All clinical data collected, including those deriving from cephalometric analyses, were obtained and processed in a compliant manner. Approval of the research protocol was obtained from the Ethics Committee "clinical study reference number 7593" to Prof. F. Inchingolo U.O. of Odontostomatology Prot. n°0015257|15/02/2023 AOUCPG23 COMET|P.

Sample and Study Design

The present study involved the analysis of latero-lateral teleradiographs obtained at two time points: at the beginning of orthodontic treatment (T0) and at the end of orthodontic treatment (T1). Thirty patients (15 male and 15 female) with Class II malocclusion and undergoing functional therapy using Twin Block device were selected. The subjects were divided into two study

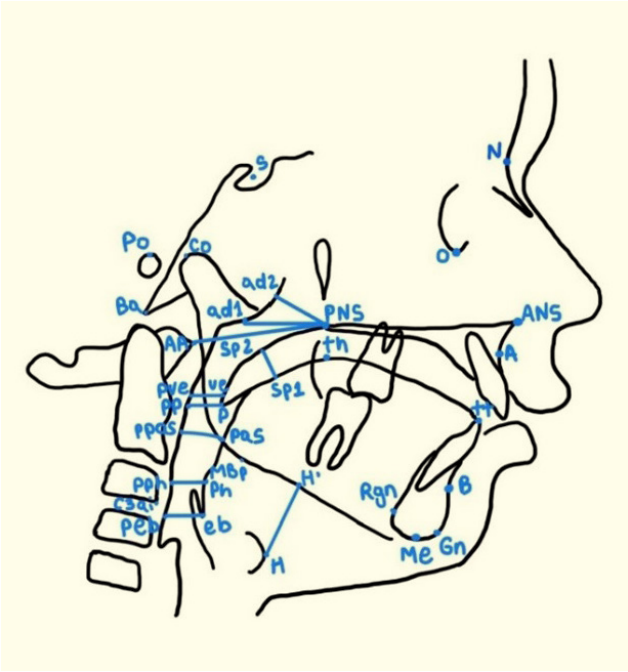

FIG 2 Graphical representation of points, planes and reference angles.

groups, each consisting of 15 individuals, according to the degree of skeletal maturation determined at time T0 by the cervical vertebral maturation method (CVM). Morphological analysis of cervical vertebrae C2, C3 and C4, particularly the assessment of the concavity of the lower margin and the morphology of the vertebral body, allowed us to distinguish a group in the pre-pubertal stage (stages CS1-CS2) and a group in the pubertal peak stage (stage CS3). All treatments were performed by two orthodontists with established clinical experience, following standardised treatment protocols in the use of the Twin Block device.

Treatment Protocol

The treatment protocol involved the use of a Twin Block designed according to Clark. Patients were instructed to wear the appliance 24 hours a day, except during meals and oral hygiene, and were revisited every 4 weeks. During each appointment, the antero-posterior relationship of the dental arch with and without the functional appliance was assessed. Active treatment was considered completed when canine and molar class I was archived with fully interccuspidation at the molar area. Next, the Twin Block was replaced with an upper plate equipped with an advancement segment in the anterior palatal area in order to promote mandibular protrusion and the proper eruption of the first and second premolars. Treatment was completed when a Class I canine-to-molar and fully intercupsidation ratio was achieved.

Cephalometric analysis

To assess the effects of Twin block on upper airway dimensions, latero-lateral radiological images at T0 (before treatment) and T1 (at the end of treatment) were plotted using cephalometric software (DeltaDent). Measurements were taken by a single operator. The reference points used are defined in Table 1 and presented in Figure 2 (Table 1) (Figures 2). Lines parallel to the Frankfurt horizontal plane (Po-O) were used in determining the counterpart landmarks of VE, P, PH, and EB on the posterior pharyngeal wall.

Statistical Analysis

Data were analysed using IBM SPSS Statistics version 20, M-DEAP version 2, and Microsoft Excel 365. A t-test was used to determine whether there was a significant difference in the cephalometric tracings among subjects. Changes were considered statistically significant when the P value was less than 0.05, indicating a low probability that the observed differences occurred by chance.

Results

This study revealed significant changes in several cephalometric measurements after Twin Block treatment (Table 2). In particular, statistically significant differences ($p < 0.05$) emerged between T0 and T1 related to SPNS, P-PP, SNB, CO-GN, Overjet, Overbite, N-ME, ANS-ME, Length (TT-EB) and Height (TH). These results suggest that Twin Block treatment positively affects mandibular position and dentition relationships, as evidenced by CO-GN, Overjet, and Overbite, as well as promotes increased upper airway size, as evidenced by S-PNS and other related measurements.

Table 3-4 shows the mean changes (AVERAGE T1-T0) and standard deviations (DEV STANDARD) of cephalometric measurements in the Pre-Pubertal group and the Pubertal group (Table 4). In the later group, with more advanced cervical vertebral maturation, significant changes compared with the Pre-Pubertal group were observed in several variables.

- Nasopharynx: Measurements such as S-PNS and AD1-PNS show more pronounced increases in the Pubertal group than in the Pre-Pubertal group, with mean values of 3.64 (P-value = 0.56) and 2.97 (P-value = 0.96) respectively. In contrast, no significant differences were observed between the two groups for AD2-PNS.
- Oropharynx: In the Pubertal group, there was an average increase of 0.82 mm (standard deviation 2.55) for P-PP, suggesting improvements in the oropharyngeal relationship after treatment.
- Soft Palate and Hypopharynx: ANS^PNS^P in the soft palate and EB-PEB in the hypopharynx showed improvements in the Pubertal group, with values of 0.56 (P-value = 0.33) and 1.5 (P-value = 0.55), while PNS-P showed a non-significant decrease of -0.3 (P-value = 0.14). In the Pubertal group, an average increase of 1.63 mm (standard deviation 1.93) in SP1-SP2 was also observed, indicative of adequate post-treatment soft palate development.
- Maxilla: A mean increase of 1.36 degrees (standard deviation 1.92) was recorded for SNA in the Pre-Pubertal group, which was slightly higher than the value shown in the Pubertal group 0.76 (standard deviation 1.32).
- Mandible: Measurements such as SNB and CO-GN indicate improvements in both groups no differences in this campionsample, with values of 2.09 (P-value = 0.86) and 8.91 (P-value = 0.91), in mandibular augmentation.
- Facial Heights and Dental Values: Measurements such as N-ME and ANS-ME show more pronounced increases in the Pubertal group, with values of 8.3 (P-value = 0.81) and 4.9 (P-value = 0.94).
- Tongue and Hyoid Bone: In the Pubertal group, an average increase of 2.7 mm (standard deviation 1.56) per Height (TH) was observed (P-value = 0.02), suggesting improvements in tongue position and size after treatment; while Hyoid Bone Height (H-C3A1) demonstrates a displacement of the bone itself, with a significant decrease

	T0	T1	T1-T0	P-Value (T0;T1)
NOSEPHARYNX				
S-PNS	44,83	48,01	3,19	0,02
AD1-PNS	22,16	25,08	2,92	0,07
AD2-PNS	18,18	19,73	1,55	0,24
OROPHARYNX				
AA-PNS	33,20	34,74	1,54	0,25
VE-PVE	9,51	10,11	0,61	0,48
P-PP	9,28	10,77	1,49	0,05
PAS	12,87	13,68	0,81	0,37
PH-PPH	9,15	9,70	0,55	0,55
SOFT PALATE				
ANS^PNS^P	135,92	134,96	-0,97	0,61
PNS-P	31,24	32,36	1,13	0,42
SP1-SP2	6,86	8,46	1,61	0,03
HYPOPHARYNX				
EB-PEB	12,01	14,16	2,14	0,08
MAXILLA				
SNA	81,96	83,02	1,06	0,41
ANS-PNS	50,26	52,74	2,49	0,08
JAW				
SNB	75,76	77,92	2,16	0,04
ANB	6,20	5,09	-1,11	0,14
NS-MP	33,40	32,06	-1,34	0,48
CO-GN	99,77	108,88	9,11	0,00
C3AI-HPT-RGN	61,01	65,77	4,76	0,07
DENTAL VALUES				
Overjet	8,97	4,66	-4,31	0,00
Overbite	4,68	3,14	-1,55	0,00
FACIAL HEIGHTS				
N-ME	103,94	111,83	7,89	0,00
ANS-ME	58,47	63,46	4,99	0,00
TONGUE				
Length (TT-EB)	69,24	74,57	5,33	0,02
Height (TH)	17,39	21,37	3,98	0,00
HYOID BONE				
H-C3A1	-6,47	-7,7	-1,24	0,57
H-H'	15,05	16	0,96	0,54

TABLE 3 The table shows the averages of cephalometric values at T0 (before treatment) and T1 (after treatment) for Twin Block-treated patients, along with the differences (T1 - T0) and relative p-values for each measurement. Significant measurements ($p < 0.05$) are highlighted in bold.

of -3.7 (P-value = 0.03) [Jena et al., 2013; Ali et al., 2015; Elfeky and Fayed, 2015; Chand et al., 2017].

The results, therefore, show clear differences between the pre-treatment group and the post-treatment group in several cephalometric measurements.

Discussion

It is becoming increasingly evident how crucial the role of clinicians is in the management of airway development and craniofacial formation, despite the continuing controversy over

their interrelationship with breathing and malocclusions [Paglia et al., 2024; Rosa et al., 2024; Signoriello et al., 2025; Starkhammar Johansson et al., 2024]. During growth and development, the airway, breathing pattern, and craniofacial formation are closely interrelated, significantly influencing each other [Ghodke et al., 2014; O'Brien et al., 2003; Xie et al., 2021; Zreaqat et al., 2025, 2023]. It is well documented that form can follow function and vice versa, making it imperative to normalise form and function as soon as possible to optimize long-term function [Feres et al., 2015; Jeha and Haddad, 2024; Jena et al., 2006; Taloumtzi et al., 2020; Wigal et al., 2011]. This implies an active role by clinicians in the management of craniofacial and airway development in growing children, underscoring the importance of early intervention to prevent or correct abnormalities that could compromise long-term health [Baccetti et al., 2000; Koretsi et al., 2015; Zymperdikas et al., 2016]. Orthodontists, in particular, are taking an increasingly central role in the care and airway management of patients of all ages, especially those with sleep-disordered breathing disorders [Khalil et al., 2024; Meazzini et al., 2024; Moscati et al., 2024]. These disorders are commonly associated with serious vascular complications such as hypertension, coronary artery disease, and strokes [Oliva et al., 2018; Pelo et al., 2011; Vozza et al., 2021]. This further reinforces the need for early and careful management of respiratory conditions in children to prevent future complications [Cenzato et al., 2024b; Farronato et al., 2024; F. Inchingolo et al., 2024b; Pesaressi et al., 2024]. Characteristics of chronic oral breathing and respiratory obstruction syndrome include breathing through the mouth even at rest, increased tonsils and adenoids in volume, open bite, cross-bite malocclusion, and excessive anterior facial height [González Espinosa et al., 2020; Li et al., 2023; Lu et al., 2025; Mao et al., 2023; Sawant et al., 2024]. These signs indicate an important relationship between nasal resistance and various orthodontic problems such as increased overjet, open bite, and tooth malposition [Saccomanno et al., 2014; Sabina Saccomanno et al., 2018a; S. Saccomanno et al., 2018; Saccomanno et al., 2021a]. These conditions need to be identified early to intervene effectively and promote proper craniofacial growth and orthodontic stability [Grippaudo et al., 2014, 2010; Sabina Saccomanno et al., 2018b]. Other studies have further shown that nasal airway obstruction can lead subjects to breathe predominantly through the mouth, affecting lower jaw positioning and altering facial appearance and tooth alignment compared with control animals [Baka and Fidanboy, 2021; Batista et al., 2018; Frilund et al., 2023; Thiruvenkatachari et al., 2013; Veitz-Keenan and Liu, 2019]. Therefore, it is critical to recognise and prevent this nasal incompetence in children through early intervention, as this can significantly affect orthodontic stability and proper craniofacial growth [D'oria et al., 2024; Giuca, 2024; Shetty et al., 2024; Zerman, 2024b]. In this study we initially set out to evaluate the positive impact of Twin Block treatment on upper airway dimensions as a primary objective, and once the positive results were confirmed at both mandibular and airway levels, a more specific evaluation was implemented on different study groups. There were many measurements that showed statistically significant differences ($p < 0.05$) between T0 and T1, confirming that Twin Block treatment positively affects both mandibular position and upper airway dimensions. Based on these results, cephalometric measurements of patients distinguished according to their cervical vertebral maturation (CVM) were then compared according to the method originally developed by Lamparski and later implemented by O'Reilly and Yanniello GJ. This made it possible to evaluate the effectiveness of treatment timing especially when performed before or during pubertal growth. In the present study, analysis of changes in oropharyngeal and hypopharyngeal parameters, although not all statistically significant, still suggested trends of improvement at the upper airway level, reducing respiratory resistance associated with conditions such as obstructive sleep apnea.

- Nasopharynx: Measurements such as S-PNS and AD1-PNS show more pronounced increases in the Pubertal group than in the Pre-Pubertal group, showing how much the distance between the posterior nasal spine and posterior surface of the pharynx can increase. In contrast, no significant differences were observed between the two groups for AD2-PNS.
- Oropharynx: looking at the measurements in detail showed how much each individual value increased, regardless of the stage of cervical vertebral maturation, leading to improvements in the oro-pharyngeal relationship after Twin block treatment.
- Soft palate and hypopharynx: ANS^PNS^P in the soft palate and EB-PEB in the hypopharynx showed improvements in the Pubertal group, with mean values of 0.56 and 1.5 respectively. A mean increase of 1.63 in SP1-SP2 was also observed in the Pubertal group, indicative of adequate post-treatment soft palate development.
- Mandible: Again, regardless of the stage of cervical vertebral maturation, values showed a significant increase in both the Pubertal and Pre-Pubertal groups.
- Facial Heights and Dental Values: Overbite and Overjet show a medine decrease in the two groups, suggesting a similar correction of values in the two groups; measurements of facial heights such as N-ME show, however, more pronounced increases in the Pubertal group.
- Tongue and Hyoid Bone: Height (TH) value shows an average increase in the Pubertal group, indicating a possible correction of tongue and hyoid bone positions. as well as enhanced respiratory function, as suggested by findings reported in other studies.

It is important to consider some limitations of the study, including the sample size and the retrospective nature of the study design. In addition, the heterogeneity of patients in terms of age and degree of skeletal development could influence the results.

Conclusions

Regarding the treatment of Class II malocclusion, the use of the Twin Block appliance has been shown to be effective not only in improving tooth and mandibular position but also in positively influencing the upper airway. This is particularly relevant for patients with respiratory problems associated with malocclusions and craniofacial dysfunction. The results indicate that the initiation of treatment with removable functional appliances, such as the Twin Block, should be delayed until puberty if the goal is to stimulate mandibular growth, chin advancement and a better respiration. The significant changes observed in cephalometric measurements and upper airway dimensions underscore the clinical effectiveness of the Twin Block in improving respiratory function in addition to orthodontic correction. However, further research is needed to confirm these results and to better understand the underlying mechanisms that contribute to these improvements. This approach not only optimises clinical outcomes, but also takes into account individual patient needs, ensuring individualised and targeted treatment to improve both aesthetics and function of the craniofacial system.

	PRE-PUBERTAL GROUP		PUBERTAL GROUP		
	Average T1-T0	STANDARD DEV	Average T1-T0	STANDARD DEV	P VALUE
NOSEPHARYNX					
S-PNS	2,73	1,39	3,64	4,60	0,56
AD1-PNS	2,87	3,72	2,97	4,86	0,96
AD2-PNS	1,83	2,44	1,26	4,62	0,73
OROPHARYNX					
AA-PNS	1,91	2,10	1,17	3,67	0,59
VE-PVE	0,01	2,58	1,2	3,29	0,38
P-PP	2,16	1,66	0,82	2,55	0,18
PAS	1,16	3,53	0,45	3,19	0,64
PH-PPH	-0,2	3,79	1,3	2,82	0,33
SOFT PALATE					
ANS^PNS^P	-2,49	6,14	0,56	7,31	0,33
PNS-P	2,55	1,99	-0,3	5,54	0,14
SP1-SP2	1,58	4,20	1,63	1,93	0,97
HYPOPHARYNX					
EB-PEB	2,78	5,66	1,5	3,35	0,55
MAXILLA					
SNA	1,36	1,92	0,76	1,32	0,43
ANS-PNS	2,64	3,85	2,33	4,51	0,87
JAW					
SNB	2,22	1,74	2,09	1,43	0,86
ANB	-0,84	1,28	-1,37	1,96	0,48
NS-MP	-1,64	2,20	-1,03	1,82	0,51
CO-GN	9,31	5,15	8,91	9,91	0,91
C3AI-HPT-RGN	6,14	10,04	3,37	8,90	0,52
DENTAL VALUES					
Overjet	-3,65	1,69	-4,96	2,07	0,14
Overbite	-1,13	1,94	-1,96	1,73	0,33
FACIAL HEIGHTS					
N-ME	7,47	3,51	8,3	10,12	0,81
ANS-ME	5,07	2,58	4,9	6,25	0,94
TONGUE					
Length (TT-EB)	7,65	6,96	3	8,18	0,19
Height (TH)	5,26	2,86	2,7	1,56	0,02
HYOID BONE					
H-C3A1	1,25	4,86	-3,7	4,24	0,03
H-H'	1,54	5,02	0,37	3,99	0,57

TABLE 4 Results of cephalometric measurements between Pre-Pubertal and Pubertal groups after orthodontic treatment with Twin Block. Values represent the mean difference (T1-T0) between pre-treatment (T0) and post-treatment (T1) measurements, with standard deviation and P-value to compare differences between groups. P-values highlight statistically significant differences between groups, indicating a differential effect of orthodontic treatment according to the degree of cervical vertebral maturation.

Author Contributions

Conceptualisation, A.D.I. and A.M.I.; methodology, P.B., G.M. and F.V.; software, A.P. and P.B.; validation, R.L., F.I. and P.B.; formal analysis, A.D.I., G.M. and G.D.; investigation, F.I., R.L. and F.V.; resources, G.D., R.L. and P.B.; data curation, F.I. and A.P.; writing—original draft preparation, G.D., R.L. and F.V.; writing—review and editing, G.D., A.P. and A.M.I.; visualisation, A.D.I. and A.P.; supervision, A.M.I. and G.M.; project administration, A.M.I. and G.M.; funding acquisition, A.D.I. and F.I. All authors have read and agreed to the published version of the manuscript.

Funding
This research received no external funding.

Institutional Review Board Statement
Not applicable.
Data Availability Statement
Not applicable.

Conflicts of Interest
The authors declare no conflicts of interest.

Abbreviation	Definition
ANS	Anterior nasal spine
Ba	Basion
CO	Condylar
CVM	Cervical vertebral maturation
EB	Epiglottis
Go	Gonion
H	Hyoid bone
MBP	Point of the mandibular base
MP	Plane mandibular
N	Nasion
OSAS	Obstructive sleep apnea syndrome
PNS	Posterior nasal spine
PP	Posterior Pharyngeal
PVE	Posterior pharyngeal wall
RGN	Retrognation
S	Saddle
TH	Height Tongue
VE	Velum Palatinum

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