ORIGINAL RESEARCH

Evaluation of the Oropharyngeal Airway Space in Class II Malocclusion Treated with Mandibular Activator: A Retrospective Study

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Abstract

Aim: The development of a class II malocclusion is usually related to a reduced oropharyngeal airway space. In order to prevent airway obstruction, functional appliances are commonly used for orthodontic therapy. The aim of the article is to verify if these appliances could positively influence oropharyngeal diameters preventing the onset of future respiratory disorders.

Materials and methods: A group of 10 patients treated at the Dental Clinic of San Gerardo Hospital in Monza with mandibular activator was selected. Ten similar untreated class II subjects with retrognathic mandible were used as control group. The cephalometric tracings were made on lateral teleradiographs of the skull before and after the active therapy with functional devices for the treated group and before and after growth peak for the control one. Descriptive statistical analysis was calculated for all the cephalometric values in both study cases and control group using Excel worksheet. The data distribution was evaluated with Shapiro–Wilk test and the in-between group discrepancies were evaluated with Mann–Whitney *U* test.

Results: At T1 period, both case and control groups showed a class II pattern. At T2 period, the study group shows an improvement in bones relationship with reduced ANB angles and OVJ measurements. The control group otherwise did not show any important changes in maxillo–mandibular discrepancies. The airway size increased in either group in most cases. No significant differences between the treated and control groups were detected for airway size neither in the upper, middle, nor lower level at the T1–T2 interval.

Conclusion: The upper airway values did not show any significant discrepancies between the two groups during the observation period.

Clinical significance: Functional devices were effective in solving class II relationships, but there is no evidence of successful breathing disorders prevention by using mandibular activators, probably due to the stability of airway tissues reached in pubertal age in both groups.

Keywords: Class II malocclusion, Mandibular activators, Occlusion, Oropharyngeal spaces, Obstructive sleep apnea syndrome, Sleep, Snoring, Temporomandibular joint, Upper airway resistance syndrome.

The Journal of Contemporary Dental Practice (2020): 10.5005/jp-journals-10024-2856

Introduction

The development of a class II malocclusion with retrognathic mandible is related to a reduced oropharyngeal airway dimension. In order to achieve a correct diagnosis, it is essential to trace cephalometric analysis and it is common in our practice to notice any relevant data not only about hard tissue but also about the soft tissue as the airways.[1]

The mandibular deficiency leads to a decrease of the airway space between mandibular bone and cervical column and this may induce a wrong and posterior posture of the tongue and soft palate. As long as this attitude remains unchanged, nocturnal respiratory problems such as snoring, upper airway resistance syndrome (UARS), and obstructive sleep apnea syndrome (OSAS) may occur.[2]

Functional appliances are a common orthodontic therapy for growing children in order to obtain a correction of mandibular retrognathism; furthermore, it is common to use similar devices in adults with breathing disorders, such as OSAS, to prevent airway obstruction during the sleeping time.

Orthodontic research and dental research are mostly oriented to find and test new treatment devices or to evaluate new radiographic analysis, but few are made to check variations in surrounding anatomical structures.[3–10]

Several long-term studies have shown the improvement of oropharyngeal diameters in patients treated with mandibular activators observed from childhood to adulthood; the correct use of these devices promotes numerous effects such as a mild mandibular growth, mandibular and maxillary reorientation, a repositioning of the tongue, and the soft palate and therefore can prevent the onset of future respiratory disorders.[11]

The specific observation period of our study, between almost 10 and 13 years of age, is associated with the simultaneous maturation of the oropharyngeal system and the regression of the surrounding lymphatic tissues with greater stability of these tissues.

The positive effects on the anatomy of the upper airways linked to the mandibular advancement devices should be masked if patients are evaluated in the infantile period when the adenoid hypertrophy combined with the mandibular retrognathism can

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How to cite this article: Cortese M, Pigato G, Casiraghi G, *et al.* Evaluation of the Oropharyngeal Airway Space in Class II Malocclusion Treated with Mandibular Activator: A Retrospective Study. J Contemp Dent Pract 2020;21(6):666–672.

Source of support: Nil

Conflict of interest: None

easily induce an obstructive phenomenon, resulting in the onset of sleep breathing disorders.

The purpose of the following retrospective study involves the analysis of cephalometric tracings of patients with class II malocclusion undergoing therapy with mandibular activators, compared with the traces of a nontreated group affected by the same malocclusion, belonging to a historical archive of the American Association of Orthodontists Foundation Craniofacial Growth Legacy Collection (http://www.aaoflegacycollection.org) in order to clarify if mandibular activators really expand oropharyngeal spaces when lymphatic tissues are almost stabilized.

Materials and Methods

The following study was conducted at the Dental Clinic of San Gerardo Hospital in Monza and since it is a retrospective radiographic study, formal consent is not required.

The treated group was divided into a study group of 10 subjects who presented a class II malocclusion undergoing therapy with mandibular activators and a control group of 10 subjects with untreated retrognathic mandible, both evaluated in the interval between the beginning and end of the growth peak.

The selection of treated subjects in the Dental Clinic of San Gerardo Hospital in Monza included patients at the end of interceptive therapy with mandibular activator such as Andresen monoblock appliance and Clark's twin block. The cephalometric tracings were detected on lateral teleradiographs of the skull before and after the active treatment with functional devices at a T1 period – before growth peak – and at a T2 period – at the end of growth peak. Similarly, the historical control group contains untreated class II subjects with retrognathic mandible observed between periods T1 and T2, respectively, before the beginning and after the end of growth peak.

The cephalometric survey conducted by a single operator allowed to evaluate the main dento-skeletal values according to Steiner analysis together with specific parameters of the upper airway size. The cephalograms were traced between the beginning and the end of the growth peak both in treated and in control groups, in order to find out any dento-skeletal variations in airway size between the two groups. By the comparison between a treated group of patients and an untreated one, it was possible to discriminate any successful cephalometric variations or significant parameters from the physiological growth of subjects obtained at the end of the growth peak. The timing evaluation was carried out with CVM method (cervical vertebral maturation) considering a prepeak stage – cervical stage 3 – and a postpeak stage – cervical stage 4/5.[12]

Cephalometric parameters regarding jaw relationship with bone bases and upper airway values were compared in the two groups with the use of Mann–Whitney nonparametric test, revealing the effectiveness of treatment with functional devices in solving dento-skeletal malocclusion and the low significance in changing airway size. The aim of this retrospective study is to identify the change in airway dimensions detectable by pre- and posttreatment cephalometric evaluation of patients subjected to orthodontic treatment with mandibular activators, compared with a nontreatment historical control group.

The selection criteria used were the following: ANB angle > 4°, OVJ > 4 mm, class II malocclusion division 1, patterns of skeletal class II malocclusion with retrognathic mandible, and observation period from the beginning to the end of growth peak.

Otherwise the exclusion criteria were skeletal class II hyperdivergent patients proposed for orthognathic surgery, class II malocclusion division 2, congenital craniofacial anomalies, adenoidectomy, mandibular growth peak overcoming, and abnormalities of the mandibular condyle in the temporomandibular joint (TMJ).

The selected subjects were 10 treated patients – 7 males, 3 females – and 10 control subjects – 5 males, 5 females – both observed between the beginning and the end of the growth peak. The average age of the study group was 10.9 years at T1 period (standard deviation ± 1.2 years) and 12.7 years at T2 period (standard deviation ±1.1 years); the control group mean age was 10.1 years at T1 (standard deviation ± 0.9 years) and 13.5 years at T2 period (standard deviation ± 1 years).

Treatment Protocol

The study group treatment protocol consisted of a functional therapy with Andresen monoblock for ipo- or normodivergent patients and Clark's twin block for patients with an hyperdivergent tendency; by a careful unloading of occlusal bite blocks indeed, it is possible to take control of vertical dimension in order to prevent the open bite onset.

Functional therapy to be successful needs a rigorous compliance by using the devices for almost 14–16 hours per day, especially at night when growth hormone level is higher; during the monthly checks were detected molar relationship, occlusal bite contacts, and patients collaboration. The mandibular activator therapy is performed as long as the growth peak can be exploited. Clinically, the CS5 stage of CVM method is a good indicator of the end of the growth peak (Figs 1 and 2).

Cephalometric Analysis

Lateral cephalograms of both case and control groups at T1 and T2 periods were manually traced by a single operator using an orthodontic protractor; landmarks and value parameters were verified by a second one. Three angular and seven linear variables were generated for each radiograph:

- SNA angle: Sella-Nasion to point A angle.
- SNB angle: Sella-Nasion to point B angle.
- ANB angle: A point to B point angle.
- Overjet (OVJ): the overlap of the teeth in the horizontal dimension.

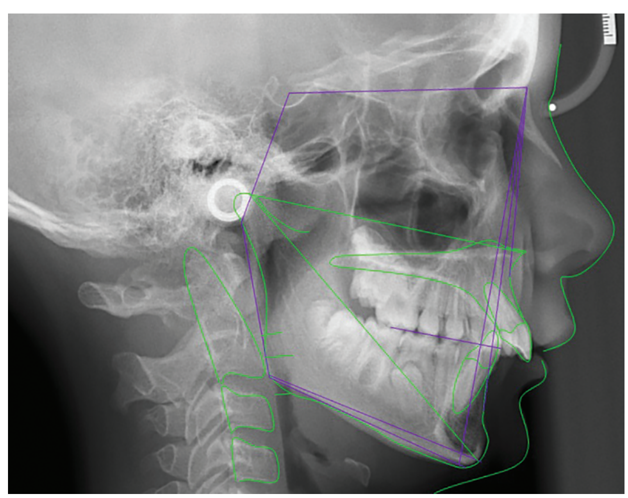

Fig. 1: T1 patient cephalogram from the case group

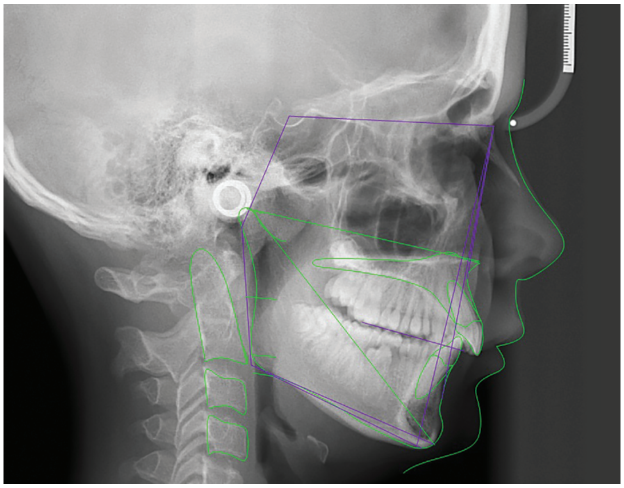

Fig. 2: T2 patient cephalogram from the case group

- Cd-ANS: the distance between the most superior point of the condyle and the ANS; the maxillary unit length (MxUL).
- Cd-Pg: the distance between the extreme superior point of the condyle and the Pg; the mandibular unit length (MdUL).
- ULD: the unitary length discrepancy; ULD = MxUL-MdUL.
- SPAS: superior–posterior airway space; smallest distance between the posterior border of the soft palate and the posterior pharyngeal wall.
- MAS: middle airway space; smallest distance between the posterior border of the tongue and the posterior pharyngeal wall through the tip of the soft palate.
- IAS: inferior airway space; smallest distance between the posterior border of the tongue and the posterior pharyngeal wall at the mandibular angle.

Statistical Analysis

Descriptive statistical analysis was calculated for all the cephalometric values at T1, T2, and T2-T1 in both case and control groups using Excel worksheet. The data distribution was not normal as Shapiro–Wilk test established, so the between-group discrepancies were evaluated with Mann–Whitney *U* test ("Social Science Statistics," 2019), a nonparametric test that allows two groups to be compared without making the assumption that values are normally distributed (Shapiro and Wilk, 1965).

Results

Cephalometric records in both groups were detected at a T1 period, corresponding to the beginning of the functional therapy for the case group and the beginning of the growth peak for the control group. The correct timing was established adopting the CVM method (cervical vertebral maturation), setting the start of the growth peak approximately at CS3 stage and the end of the peak at CS4/5 stage.

At T1, both case and control groups showed a class II malocclusion with reduced SNB angle and augmented ANB angle; also interdental relationship indicate a class II malocclusion through OVJ values (Tables 1 and 2).

At T2, the study group shows an improvement in bones relationship with reduced ANB angle and OVJ measurement (Table 3); the control group otherwise did not show any important changes in solving maxillo–mandibular discrepancies (Table 4). The airway

Table 1: Case group T1 period

Case group T1	*SNA (°)*	*SNB (°)*	*ANB (°)*	*OVJ (mm)*	*Cd-ANS (mm)*	*Cd-Pog (mm)*	*ULD (mm)*	*SPAS (mm)*	*MAS (mm)*	*IAS (mm)*
C.R.	80	74	6	5	95	108	13	9	13	8
C.L.	82	78	4	8	93	100	3	6	8	12
C.L.	84	79	5	8	93	105	12	5	5	5
D.A.V.	79	75	4	5	85	105	20	8	11	10
L.F.	78	73	5	6	100	116	16	12	10	11
M.D.S.	83	77	6	8	94	110	16	7	10	10
M.M.	87	80	7	13	92	102	10	10	12	10
P.G.	80	72	8	6	101	110	9	9	13	13
R.G.	82	77	5	1.5	85	103	18	11	15	15
T.M.	78	73	5	6	86	106	20	10	12	13
Mean	81.3	75.8	5.5	6.65	92.4	106.5	13.7	8.7	10.9	10.7
Standard deviation	2.9	2.8	1.3	2.96	5.8	4.7	5.4	2.2	2.85	2.83

Table 2: Control group T1 period

Control group code T1	*SNA (°)*	*SNB (°)*	*ANB (°)*	*OVJ (mm)*	*Cd-ANS (mm)*	*Cd-Pg (mm)*	*ULD (mm)*	*SPAS (mm)*	*MAS (mm)*	*IAS (mm)*
Pt1	80	75	5	4	72	93	21	9	11	15
Pt2	83	78	5	5	76	95	19	10	12	11
Pt3	81	75	6	6	72	92	20	12	9	18
Pt4	82	77	5	2	68	81	13	9	9	7
Pt5	79	72	7	5	63	80	17	6	6	3
Pt6	82	74	8	4	71	87	16	9	8	5
Pt7	81	76	5	4	69	83	14	10	11	9
Pt8	85	78	7	5	66	81	15	11	13	9
Pt9	80	72	8	5	67	80	13	5	8	6
Pt10	82	74	8	4	69	79	10	7	10	8
Mean	81.5	75.1	6.4	4.4	69.3	85.1	15.8	8.8	9.7	9.1
Standard deviation	1.7	2.2	1.35	1.07	3.65	6.14	3.5	2.2	2.1	4.5

Table 3: Case group T2 period

Case group T2	*SNA (°)*	*SNB (°)*	*ANB (°)*	*OVJ (mm)*	*Cd-ANS (mm)*	*Cd-Pg (mm)*	*ULD (mm)*	*SPAS (mm)*	*MAS (mm)*	*IAS (mm)*
C.R.	81	75	6	2	94	111	17	9	16	10
C.L.	78	76	2	3	97	106	9	7	8	17
C.L.	82	79	3	5	90	101	11	9	8	7
D.A.V.	83	80	3	4	79	100	21	15	14	17
L.F.	74	70	4	6	91	117	26	17	19	17
M.D.S.	78	73	5	3	88	105	17	7	10	10
M.M.	83	81	2	8	94	115	21	11	16	13
P.G.	79	74	5	4	108	125	17	7	12	10
R.G.	83	79	4	2	87	104	17	8	9	6
T.M.	75	73	2	4	91	113	22	11	12	10
Mean	79.6	76	3.6	4.1	91.9	109.7	17.8	10.1	12.4	11.7
Standard deviation	3.34	3.6	1.4	1.85	7.5	7.9	5.1	3.5	3.8	4.1

size increased in either groups in most cases. By the comparison of the values detected after the active treatment with functional appliances and then at the end of the growth peak for the control group, the study group showed a significant decrease in SNA angle (p value < 0.05), a decrease in ANB angle (p value < 0.01), and in OVJ values (p value < 0.05). No significant differences between the treated and control were detected for airway size neither in the upper, middle, nor lower level in the T1-T2 interval (Table 5).

Discussion

This retrospective case control short-term study focuses on the effectiveness of functional appliances in solving malocclusion problems and preventing the onset of any nocturnal breathing disorders. Over the years, functional appliances were widely used in the orthopedic treatment of growing children with hypotrophic or retrognathic mandible.[13] Many previous studies have shown a possible relationship among pharyngeal airway and skeletal structures, soft tissues, and musculature.[14,15] McNamara stated that 60% of the skeletal class II malocclusions are a consequence of mandibular retrognathism.[15]

However, few studies examined the class II oropharyngeal development during an active treatment with mandibular activators and generally they deal with long-term observation period, from childhood to adulthood. The present analysis on the contrary included patients near the adolescent growth peak, which promotes maturation of secondary sexual characters, the shift from the mixed dentition to the permanent one, massive facial growth, and finally a differential development of the two jaws.

A class II malocclusion tends to remain unchanged when untreated as the literature investigations stated and, even if historical controls evaluated in a reduced time may be a limitation, they are a good representation of what happens to a growing subjects without interceptive orthodontic treatment.[16]

Functional devices by acting on the condylar cartilage and soft tissues that bring insertion on mandibular ramus and body stimulate growth and orientation of the mandible.[17] Similarly, the maxilla undergoes the effect of reaction forces of the upper soft tissues stretched by the mandibular advancement, causing a reduced anterior growth of the bone itself.[18] Accordingly to these statements in our study group, the SNA angle, which represents the maxillary relationship with the skull base, in treated patients is significantly reduced (mean –1.7, standard deviation 2.9), probably as a result of fibers stretching during active use of mandibular activator; ANB angle appears significantly reduced as well in the case group (mean – 1.9, standard deviation 1.4), showing the achievement of a better relationship between the two jaws. Finally as previously stated by Wieslander, the decreased overjet represents a dental positive effect of the functional therapy (mean – 2.55, standard deviation 2.03 in our case group).[19] By the way SNB angle and mandibular unit length (MdUL) seem to be similar both for cases and controls, according to the literature reviews, which support the opinion that a supplementary growth of the mandible is not always detectable as the CS3 stage sets the beginning of growth peak in clinical activity but may result in a variability of 1 or 2 years.[12–15,20]

Different authors reported that there was a significant increase in sectional pharyngeal levels and total airway volume in treated cases after the functional therapy. These findings match with those observed by Haskell in his study on the effects of mandibular advancement devices (MAD) on airway dimensions. They reported an average oropharyngeal volume increase of approximately

Table 4: Control group T2 period

Control group code T2	*SNA (°)*	*SNB (°)*	*ANB (°)*	*OVJ (mm)*	*Cd-ANS (mm)*	*Cd-Pg (mm)*	*ULD (mm)*	*SPAS (mm)*	*MAS (mm)*	*IAS (mm)*
Pt1	82	77	5	5	75	92	17	13	12	13
Pt2	82	77	5	4	75	95	20	8	15	14
Pt3	82	77	5	4	75	91	16	9	8	10
Pt4	82	77	5	3	69	83	14	10	9	8
Pt5	81	74	7	5	75	97	22	5	10	6
Pt6	85	76	9	5	70	88	18	8	7	7
Pt7	82	77	5	4	72	87	15	8	9	9
Pt8	82	76	6	5	62	78	16	11	13	8
Pt9	80	73	7	5	68	84	15	5	6	5
Pt10	84	75	9	4	70	83	13	6	10	8
Mean	82.2	75.9	6.3	4.4	71.1	87.8	16.6	8.3	9.9	8.8
Standard deviation	1.4	1.45	1.64	0.7	4.23	5.98	2.76	2.6	2.8	2.86

Table 5: T2-T1 nonparametric Mann-Whitney analysis

	Case group		Control group				
T2-T1 Period	*Mean*	*Standard deviation*	*Mean*	*Standard deviation*	*p value*	*U value*	
SNA	−1.7	2.907844	0.7	1.766981	0.0394	23	*
SNB	0.2	2.65832	0.8	1.398412	0.4483	40.5	NS
ANB	−1.9	1.449138	−0.1	0.737865	0.0028	11.5	**
OVJ	−2.55	2.033743	0	0.942809	0.0038	14	**
Cd-SNA	−0.1	5.300943	−0.1	5.3009433	0.6687	45.5	NS
Cd-Pg	3.7	6.700746	2.7	5.5787294	0.7541	44.5	NS
ULD	4.2	4.315347	0.8	2.820559	0.1767	32	NS
SPAS	1.3	3.020302	−0.5	1.95789	0.1157	29	NS
MAS	1	4.027682	0.2	1.9888579	0.2954	43	NS
IAS	1.1	4.931757	−0.3	3.198958	0.4682	37.5	NS

*p value <0.05; **p value <0.01, NS, not significant

2800 mm^3 with MAD therapy. In the same way, previous other authors have suggested improvement in volume in the oropharynx with MAD.[21–24]

Nevertheless for what concern the jaws development and the oropharyngeal complex, it is important to remind the different patterns and time of growth they show. In fact, according to Scammon curve of growth, different tissues evolve at different speeds. Nervous tissue ultimates its growth around 6–7 years of age; muscle and bone tissues slow down during childhood and recover during puberty; lymphatic tissues proliferate profusely in late childhood and undergo a significant reduction during pubertal development.[25]

The upper airways follow a progressive development during childhood, with a pharyngeal tissue increase, due to an augmented functional demand; the accelerated growth of these districts also involves lymphatic tissues such as the palatine tonsils and the adenoids, which play a role of first defense against the microorganisms present in the upper aerial tract. As a result, a huge and persistent inflammatory response may generate an obstruction, which is the main cause of sleep disorders in children.[26]

During adolescence, at a hypothalamic level, the "releasing factors" stimulate an increase in sex hormones that may induce a physiological differential growth of the various tissue districts, with an acceleration of general musculoskeletal growth and a reduction of lymphoid tissue.[27] Therefore, both in the treated group and in the untreated one, we can expect that the maxillary and mandibular unit lengths, respectively, Cd-ANS and Cd-Pg, undergo an increase, while their difference remains almost unchanged (ULD), as it is shown from the absence of a statistically significant difference in the two groups.

The oropharyngeal development has been investigated in many studies adopting different imaging instruments such as MRI and lateral teleradiography. Arens et al. by MRI analysis concluded that the middle and lower thirds of the face continue to grow linearly along the sagittal and axial planes during childhood and, at the same time, the soft tissues that define the upper airways, including tonsils and adenoids, evolve in constant proportion to bone structures in order to maintain airway patency.[28]

In Fujioka et al. study, by tracing lateral teleradiography, the AN ratio between adenoids and nasopharynx remain unchanged from the neonatal period to puberty; as well as Jeans et al. by the examination of lateral cephalogram, defines the linear development of the entire surface of nasopharynx in males and females aged between 3 years and 11 years, with a decrease of this area between 3 and 5 years, parallel to a moderate acceleration of soft tissue growth.[29] From 5/6 years onward, there is a linear growth up to 11 years, without further increase of the nasopharyngeal soft tissue area; this condition is associated with adenoids spread, which occurs in growing patients, causing a reduction in upper airways patency.[30] The Vogler et al. MRI examinations, moreover, proved an increase in adenoid thickness during the first decade of life, reaching the maximum values between 7 and 10 years of age, and then there is a continuous regression up to the age of 60.[31] By considering the developmental stages of both maxillofacial complex and oropharynx, the strict period of observation plays an important role regarding the results obtained: the mean age of our study group is 10.9 years at T1 period and 12.7 years at T2 period, while at T1, the mean age of the control group is 10.7 years and 13.5 years at T2 period.

The pharyngeal diameter augmentation is therefore associated mainly with adenoids and Waldeyer lymphatic ring regression after childhood, rather than a huge airways development; the latter in fact develop coherently and simultaneously with the other facial districts.

The unique limitations for mandibular activator therapy is dolichofacial pattern of growth because the posterior bite blocks may lead to an open bite caused by mandibular post-rotation. Relating to any collateral effects, some studies evidence the possibility of articular disorders occurred after active treatment but they are mild and short-term conditions. Furthermore, the importance of solving a class II malocclusion is more important in order to prevent an excessive retrusion of the condyle and the development of articular damages.

It is opportune to highlight the prevalence of male treated patients in this study, which reaches almost two years later the growth peak compared to female patients despite an important variability among subjects.[12]

Eventually, a stabilization period concerns the nighttime use of the devices as far as the second step of dental alignment is planned.

Conclusion

The cephalometric records in this retrospective study showed the effectiveness of mandibular activators in solving a class II maxillary relationship, as long as the correct treatment timing is identified. The SNA and ANB angles, together with the overjet values, are significantly decreased within the treated group, while there are not appreciable changes in the SNB angle, which enhancement seems to be clinically questionable in the literature too. The upper airway values (SPAS, MAS, and IAS) did not show any significant discrepancies between the two groups during the observation period at the growth peak. So there is no evidence of successful breathing disorders prevention by using mandibular activator in class II retrognathic patients.

Clinical Significance

The airways diameters were similar in treated and untreated subjects because they follow a physiological and constant growth. However, there are several positive results on the development of the maxillofacial complex promoted by the mandibular activator, such as, a more harmonious and coordinated development of the dental arches, as rebalancing of the muscular forces acting on the stomatognathic system, and a postural re-education of the jaw that can prevent joint disorders in adulthood. Therefore according to our results, the treatment of choice for pediatric patients suffering from sleep disorders such as snoring, UARS, and OSAS seems to remain adenoidectomy, which removes the mechanical obstruction to upper airways patency.

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