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A Cephalometric Evaluation of Oropharyngeal Airway Changes Duing Twin-Block Appliance Treatment

Research Article

M. J. Trenouth[1*], S. R. Desmond[2]

[1] Consultant Orthodontist (Retired), Royal Preston Hospital, Sharoe Green Lane, Preston, England.
[2] Formerly Hospital Practitioner in Orthodontics.

Abstract

Introduction: The research hypothesis under test was that functional orthopaedic treatment with the Twin-block appliance increases the oropharyngeal airway as well as correcting the jaw relationships in class II division 1 patients.
Method: 20 cases, 10 male, 10 female. Age range: 11-18 years, average treatment time 9.4 months were randomly selected from the records of a previously completed prospective trial. Cephalometric radiographs taken before and after treatment were analysed. p, the shortest distance between the soft palate and posterior pharyngeal wall and t, the shortest distance between the tongue and the posterior pharyngeal wall were measured.
Results: There was a statistically significant increase in both p and t after Twin-block appliance treatment (p=0.000). A control group selected from normative data matched individually for age and sex and treatment time showed no change over the same growth period.
Conclusions: In Class II division 1 malocclusion, the oropharyngeal airway is already reduced compared to Class I and Class II. Treatment involving premolar extraction and incisor retraction further reduces the airway as does headgear and is contraindicated. Functional appliance treatment is the method of choice as it enlarges the oropharyngeal airway reducing the potential for obstructive sleep apnoea.

Keywords: Twin-Block Treatment; Oropharyngeal Airway; Obstructive Sleep Apnoea; Cephalometric Analysis; Class II Division 1.

Introduction

In 1902 Pierre Robin invented the monobloc to treat mandibular hypoplasia and glossoptosis [1, 2]. The retracted lower jaw and tongue gave rise to airway obstruction which was relieved using the monobloc to restore normal jaw relationships. Glossoptosis caused children to be pigeon chested, fail to thrive and be backward at school [3].

An increase in oropharyngeal airway size after functional appliance treatment was first demonstrated by Grim [4] on a series of six cases using measurements from lateral cephalometric radiographs. Ozbek *et al* [5] studied 26 patients treated with the Harvold activator and 15 controls. The treated cases showed a statistically significant increase in linear dimensions of the oropharynx taken from lateral cephalometric radiographs compared to no change in the control subjects. Similar studies have been reported by a number of authors using a variety of functional appliances (Table 1). All found a significant improvement in oropharyngeal airway dimensions as a result of functional appliance treatment except for three. Restrepo *et al* [12] did not report the skeletal changes in their study. Kinzinger *et al* [13] and Lin *et al* [14] demonstrated only small skeletal improvements which could well account for the lack of improvement in the oropharyngeal airway. Jena *et al* [9] found that the Twin-block appliance produced a greater change in the oropharyngeal dimensions than the MPA-IV and this was also reflected by a greater skeletal change.

Whilst Singh *et al* [15], Yassaei *et al* [6] Schütz *et al* [8] all failed to use a control group; the dimensions of the oropharyngeal airway do not appear to change with age. Mislik *et al* [16] analysed lateral cephalometric radiographs from 880 patients (412F, 468M) aged 6-17 years. They found neither age-related changes nor sexual dimorphism for p, the shortest distance between the soft palate

***Corresponding Author**:
M. J Trenouth B.Sc., M.D.S., Ph.D., F.D.S., D.Orth., D.D.O,
Consultant Orthodontist (Retired), Royal Preston Hospital, Sharoe Green Lane, Preston, PR2 9HT, England.
Tel: (+44/1772) 717016
E-mail: michaeltrenouth@hotmail.co.uk

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and the posterior pharyngeal wall and t, the shortest distance between the tongue and the posterior pharyngeal wall. These findings are consistent with those in the control groups of the studies by Ozbek *et al* [5], Hänggi *et al* [7], Jena *et al* [9], Ghodke *et al* [10], Iwasaki *et al* [11].

Although a wide variety of different linear measurements of the oropharynx have been used, most studies have included one or both of the following. P, the shortest distance between the soft palate and the posterior pharyngeal wall and t, the shortest distance between the tongue and the posterior pharyngeal wall. Since being introduced by McNamara [17] distances p and t have been used extensively in airway studies [18-21]. Such airway dimensions have been found to be highly reproducible [22].

Clearly a two-dimensional representation of a three-dimensional structure has its limitations [23, 24, 19]. Ideally three dimensional imaging such as computerised tomography or magnetic resonance imaging are needed for volumetric assessment [23, 18]. However, the smallest cross-sectional area is of greatest relevance clinically because the conductance of respiratory gases is dictated by its narrowest part. Linear two dimensional cephalometric measurements relate well to three dimensional magnetic resonance imaging measurements [20]. Riley and Powell [25] reported a high correlation (r=0.92) between posterior airway space on cephalometric radiographs and the volume of the pharyngeal airway on CT scans. Hakan and Palomo [26] used three – dimensional cone beam computed tomography to study 101 patients of differing skeletal classifications. They found that the cross-sectional area at the most constricted region of the tongue base showed the best correlation with oropharyngeal volume ($r=0.73$ $p<0.001$). In a three-dimensional cone beam computed tomography study comparing OSA and non-OSA patients, Ogawa *et al* [27] found that the smallest cross-sectional airway area was the only significant difference between the groups. Systematic reviews have shown lateral cephalometric radiographs to be a reliable screening tool for upper airway obstruction [28, 29]. Iwasaki *et al* [11] used three-dimensional cone beam computed tomography before and after Herbst appliance treatment to measure changes in pharyngeal airway. The increase in oropharyngeal airway volume in the Herbst group (24 patients 11M, 13F) was significantly greater than the control group (20 patients 9M, 11F). They also computed cross-sectional linear distances of the airway. Change in oropharyngeal depth measurements reached the same level of significance ($p=0.004$) as total airway volume and greater than oropharyngeal volume ($p=0.015$).

Li *et al* [30] used cone beam computed tomography to measure volume and cross-sectional area of the oropharyngeal airway before and after Twin-block treatment. Compared to untreated Class II patients the oropharynx and hypopharynx showed significant enlargement. Only two previous studies have evaluated oropharyngeal airway changes in the Twin-block appliance using linear dimensions from lateral cephalometric radiographs [9, 10]. These studies only measured distance p but not t and were orientated to measuring the thickness and inclination of the soft palate. The design of the present study was to use p and t to measure the change in oropharyngeal airway size before and after Twin-block appliance treatment.

The hypothesis under test was that functional orthopaedic treatment with the Twin-block appliance increases the oropharyngeal airway as well as correcting the jaw relationships in Class II division 1 patients.

Methods

Subjects

A consecutive series of patients requiring functional appliance treatment for Class II division 1 malocclusion were selected from a previous prospective study [31]. Records from 20 cases were analysed, 10 males and 10 females, average age 14 years with an age range of 11 to 18 years. The average treatment time was 9.4 months.

A control group was derived from published normative data where this was available. For oropharyngeal dimensions the study of Mislik *et al* [16] was used. For cephalometric measurements, the normative data published by Bhatia and Leighton [32] derived from London School Children, was chosen because of its nearest geographic proximity. For each set of pre-treatment and post-treatment cephalometric measurements taken from the patient, an equivalent set was derived from normative data tables controlled for age and sex according to the method of Valant and Sinclair [33].

Selection criteria

The following inclusion criteria were applied: -

- Class II division 1 malocclusion
- Age range 9-20 years
- Overjet greater than 6mm
- ANB angle greater than 4°

The following exclusion criteria were applied: -

- Patients with congenital syndromes
- Obvious asymmetry
- Prior appliance therapy
- Crowing requiring extractions

The setting was the Orthodontic department, Royal Preston Hospital District General Hospital, Preston U.K.

Interventions

The subjects were all treated by the standardised technique described by Trenouth [34]. This involved first, prefunctional semi-rapid maxillary expansion after Mew [35] and alignment of the upper arch. Second, Class II correction using a modification of the Twin-block functional appliance introduced by Clark [36, 37] but with steeper bite blocks and excluding the extra oral

Table 1. Effect of functional appliance treatment on airway dimensions.

		p			t		
Author	Date	Before Treatment Mean (SD)	After Treatment Mean (SD)	Treatment Change Mean (SD)	Before Treatment Mean (SD)	After Treatment Mean (SD)	Treatment Change Mean (SD)
Ozbex *et al* [5]	1998	9.4 (0.6)	-	2.3 (0.6)	8.6 (0.8)	-	1.9 (0.7)
Yassaei *et al* [6]	2007	-	-	-	10.8 (2.4)	12.3 (2.5)	1.5 (0.6)
Hänggi *et al* [7]	2008	8.3 (2.4)	9.0 (2.3)	0.7 (2.8)	8.5 (2.6)	9.8 (2.9)	1.3 (3.0)
Schütz *et al* [8]	2011	-	-	-	10.1 (3.2)	13.3 (3.6)	3.2 (3.6)
Jena *et al* [9]	2013	7.3 (2.0)	9.4 (2.7)	2.1 (1.8)	-	-	-
Ghodke *et al* [10]	2014	9.2 (2.0)	10.7 (2.5)	-	-	-	-
Iwasaki *et al* [11]	2014	10.1 (2.6)	13.8 (3.0)	3.7 (2.6)	10.6 (3.6)	14.8 (3.6)	4.2 (3.6)
Mean		8.9 (1.9)	10.7 (2.6)	2.2 (2.0)	9.7 (2.5)	12.6 (3.2)	2.4 (2.3)

Table 2. Method Error.

Cephalometric Measurement	Mean Difference (degrees)	95% CI of Difference	Maximum Error (degrees)
t	0.08	-0.22 to +0.39	2.25
p	0.15	-0.17 to +0.47	2.38
C_3 – Hy	-0.08	-0.50 to +0.33	3.02
C_3 – Me	-0.25	-0.75 to +0.25	3.73
C_3 – Go	-0.5	-1.14 to +0.14	4.84
Hy – Go	0.07	-0.49 to +0.62	4.05
Hy – Me	0.13	-0.43 to +0.70	4.12
Go – Me	-0.17	-0.65 to +0.32	3.54
SNA	-0.17	-0.43 to +0.01	1.96
SNB	0.01	-0.15 to +0.28	1.60
ANB	-0.17	-0.39 to +0.01	1.68

Table 3. Cephalometric measurements for Twin-block patients before and after treatment.

	Before Treatment				After Treatment					
Cephalometric measurement	Mean	SD	95%	CI	Mean	SD	95%	CI	t	P
t	7.2	2.4	6.1	8.3	11.2	2.5	10	12.4	-5.2	0
p	7.4	1.8	6.6	8.3	10.7	2	9.7	11.6	-5.4	0
C_3 – Hy	28.7	3.2	27.2	30.2	34	4.2	32.1	36	-4.54	0
C_3 – Me	68.4	7	65.2	71.7	73.3	10.1	68.6	78.1	-1.77	0.042
C_3 – Go	22.6	5.6	20	25.2	23.8	7.2	20.5	27.2	-0.61	0.273
Hy – Go	30.9	6.6	27.8	34	28.7	5.1	27.8	34	1.17	0.25
Hy – Me	40	5.2	37.6	42.4	39.9	6.5	36.9	42.9	0.051	0.479
Go – Me	60.4	4.5	58.2	62.5	64.6	4	62.8	66.5	-3.157	0
SNA	82.1	2.1	81.1	83	81.7	2	80.8	82.6	2.33	0.031
SNB	74.9	2.6	73.7	76.2	77.5	2.4	76.3	78.6	-10.64	0
ANB	7.1	1.3	6.5	7.7	4.3	1.4	3.6	4.9	15.68	0

Table 4. Cephalometric measurements for normative data before and after treatment.

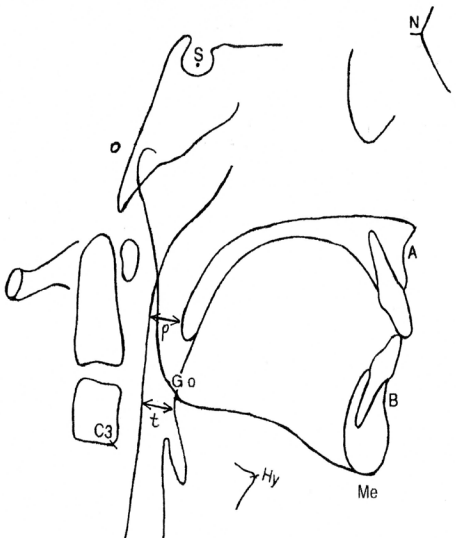
	Before Treatment				After Treatment					
Cephalometric measurement	Mean	SD	95%	CI	Mean	SD	95%	CI	t	P
t	10.1	0.6	9.8	10.4	10.3	0.5	10	10.5	-0.97	0.339
p	8.8	0.3	8.7	9	9	0.2	8.9	9.1	-1.2	0.236
Go – Me	68.1	2.1	67.1	69	68.8	1.9	68	69.7	-1.25	0.217
SNA	80.3	0.2	80.2	80.4	80.4	0.2	80.3	80.5	-1.11	0.273
SNB	77.8	0.5	77.6	78	77.9	0.4	77.7	78.1	-1.18	0.247
ANB	2.7	0.3	2.5	2.8	2.6	0.3	2.4	2.7	1.3	0.201

Table 5. Change in cephalometric measurements during treatment.

	Twin-block group				Control group					
Cephalometric measurement	Mean	SD	95%	CI	Mean	SD	95%	CI	t	P
t	4	2.1	3.1	5	0.17	0.4	0	0.4	-5.2	0
p	3.2	2.2	2.2	4.2	0.09	0.2	0.01	0.2	-5.4	0
C_3 – Hy	5.4	4	3.5	7.2	-	-	-	-	-	-
C_3 – Me	4.9	8	1.1	8.6	-	-	-	-	-	-
C_3 – Go	1.2	5.1	-1.2	3.6	-	-	-	-	-	-
Hy – Go	-1.9	5.4	-4.5	0.6	-	-	-	-	-	-
Hy – Me	-0.1	6.9	-3.3	3.1	-	-	-	-	-	-
Go – Me	4.3	3.2	2.8	5.7	0.7	0.6	0.4	1	4.95	0
SNA	-0.4	0.7	-0.7	0	0.07	0.01	0	0.1	-2.83	0.011
SNB	2.5	1.1	2	3	0.2	0.1	0.1	0.22	9.82	0
ANB	-2.9	0.8	-2.5	-3.2	-0.1	0.1	0	-0.2	-15.6	0

No control normative data available

Figure 1. Cephalometric points, lines and angles.



traction and intermaxillary elastics. Third, retention using an upper removable appliance with a very steep anterior facing bite plane.

Outcomes

The treatment outcome was measured from lateral cephalometric radiographs taken before and after functional appliance treatment. All radiographs were taken on the same equipment, with the teeth in centric occlusion and the Frankfort plane in true horizontal. It was important to standardise head position because Hellsing [38] has shown that variation in head position can alter the oropharyngeal airway dimension. Also taking the records in centric occlusion was important because changing from open to closed jaw position alters the volume of the oropharynx [39]. All subjects were instructed to relax, breath out and not to swallow during radiographic exposure.

The radiographic enlargement was indicated by a millimetre scale incorporated into the machine. The pre and post-treatment radiographs were manually traced by the same operator with a sharp pencil using acetate paper on an illuminated light box.

The following points were located; (Figure 1):

N-Nasion, the most anterior point on the frontonasal suture.

S-Sella, the centre of the sella turcica.

A-Subspinale, the deepest point on the concave outline of the upper labial alveolar process extending from the anterior nasal spine to prosthion.

B-Supramentale, the deepest point on the bony curvature between the infradentale and pogonion.

Go-Gonion – the midpoint at the angle of the mandible.

Me-Menton, the lowest point on the lower border of the mandibular symphysis.

Hy-Hyoidale, the most superior and anterior point on the body of the hyoid bone.

C_3 - the most anteroinferior point on the third cervical vertebra.

The following distances were measured and corrected for radiographic magnification:

p, the shortest distance between the soft palate and the posterior pharyngeal wall.

t, the shortest distance between the tongue and the posterior pharyngeal wall.

C_3 - Hy, C_3 - Me, C_3 - Go, Hy -Go, Hy -Me, Go- Me.

The following angles were measured:

SNA, SNB and ANB by subtraction of SNB from SNA.

Statistics

Statistical analysis was carried using Power Analysis Statistical System PASS, and Number Cruncher statistical system, NCSS, UT, USA.

An a priori sample size calculation found that 20 cases were required to detect a 2.5mm difference in primary outcome measure t with a standard deviation of 2.3mm (average of previous studies Table 1) with an 80% power and statistical significance of $p<0.01$.

The data was found to be normally distributed and a paired t-test used to detect significant differences between the various cephalometric measurements before and after treatment. Statistical significance was set at $p<0.01$ with non-overlap of confidence limits.

Correlation was also performed between the airway measurements and the other cephalometric measurements that changed during treatment.

Error Analysis

An error assessment was performed by retracing 30 of the original 40 cephalometric radiographs selected using random number tables.

The systematic error was determined by calculating the mean of the differences between the first and second tracings (MD) [40]. The 95% confidence intervals were also calculated. This contained zero indicating any systematic bias was not statistically significant (Table 2).

The maximum error (ME) was calculated from the intra-subject standard deviation [40]. When the standard deviations for each subject were plotted against their mean values for each of the eleven variables, no significant relationships were found, nor was there any systematic bias. This indicated that the measurement error did not increase with the measurements increasing magnitude. The mean difference between repeat readings (MD) was less than the maximum error (ME) in all cases indicating an acceptable level of random error (Table 2).

Results

For both t and p there was a highly statistically significant increase with non-overlap of confidence intervals for the Twin-block patients during treatment (Table 3). The control group data showed a non-significant difference for the same time period (Table 4).

In the case of t, the mean increase was 4.0mm compared to 3.2mm for p, which indicates considerable widening of the oropharyngeal airway during treatment. The control data only showed an increase of 0.17mm for t and 0.09mm for p over the same time period. The differences between the change in the Twin-block group and control data was statistically highly significant for both t and p (Table 5).

The distances C_3–Hy and Go-Me also increased during treatment to a degree that was statistically significant with non-overlap of

confidence intervals (Table 3). There was no control data available for C_3–Hy but that for Go-Me showed a non-significant difference (Table 4). C_3–Hy distance increased on average by 5.4mm indicating forward movement of the hyoid bone away from the cervical spine as the oropharyngeal airway increased. There was no control data available. Go-Me increased on average by 4.3mm indicating that the mandible lengthened during treatment. The control data changed only by 0.7mm over the same period of time. The difference between the change in the Twin-block group and control data was highly significant for Go-Me (Table 5).

Whilst the distance C_3–Me showed a statistically significant increase the confidence intervals overlapped probably due to a large degree of variation (SD) inferring a borderline difference (Table 3). No control data was available for C_3–Me. However, the mean increase of 4.9mm was large indicating a forwards movement of the mandible relative to the cervical spine (Table 5).

For the distances C_3–Go, Hy–Go and Hy–Me there were small but statistically non-significant changes with overlap of confidence intervals (Table 3). It would seem that the hyoid bone maintained a constant relationship with the mandible.

For angle SNA there was a statistically non-significant change with overlap of confidence intervals (Table 3). The control data showed a non-significant difference (Table 4). The change in SNA in the Twin-block group during treatment was -0.4°. This was statistically non-significant with overlap of confidence intervals when compared to control data (Table 5). Thus the position of the maxilla relative to the cranial base does not appear to change during treatment.

Both angle SNB and ANB showed a very highly statistically significant change during treatment (Table 3), whilst the control data showed a non-significant change (Table 4). Angle SNB showed a mean increase of 2.5° whilst angle ANB decreased by 2.9°. Both were statistically significant with non-overlap of confidence intervals, when compared to the control data (Table 5). Thus the skeletal reduction in Class II relationship was achieved largely by forward positioning of the mandible during treatment.

Discussion

The results for the distances t and p before and after treatment (Table 3) were comparable to previous studies (Table 1). For the control group normative data (Table 4) there was no significant change in distances t or p during the equivalent treatment period. This was consistent with the findings of previous workers that there was no significant change in the oropharyngeal dimensions during the growth period under study (11 to 18 years). [16, 5, 7, 9-11]. The present study would appear to support the research hypothesis that the dimensions of the oropharyngeal airway t and p were significantly increased by Twin-block functional appliance therapy.

In the present study the distance t showed positive correlation with Go-Me (r = 0.5), C3-Hy (r = 0.3), C_3 – Me (r = 0.4) and to a lesser extent SNB (r = 0.2). Trenouth and Timms [41] in a cross-sectional study of 70 subjects aged 10 to 13 years found a similar correlation of t (OPA) with Go-Me (r = 0.3) and C_3-Hy (r = 0.3). Similar results were obtained by Hakan and Palmo [26] who found the minimal cross sectional area of the oropharynx correlated with Go-Gn (r = 0.39) to a greater extent than SNB (r = 0.22). Thus increase in the oropharyngeal airway was mainly related to lengthening of the mandible (Go-Me) rather than its position relative to the cranial base (SNB). The hyoid bone tends to follow the mandible as the airway increases. A significant correlation has been found between jaw relation, hyoid position and width of the pharyngeal cavity [42].

Whilst functional appliance therapy increases the oropharyngeal airway dimensions, treatment involving extraction of premolars and incisor retraction has been found to cause a reduction in the airway dimensions [43-45, 47-49]. Similarly the use of headgear has been shown to reduce the oropharyngeal airway [50-52]. In fact a recent review on the link between sleep disordered breathing and Class II malocclusion urged caution when premolar extraction was followed by incisor retraction. They recommended accepting residual overjet to avoid compromising the airway [53].

Oropharyngeal airway size has also been shown to be related to skeletal pattern being greater in Class III than Class II and intermediate in Class I [42, 54-58, 26, 59, 60, 46, 61, 62]. Also Class I and Class II subjects with vertical growth patterns have significantly narrower upper pharyngeal airways [63] Class II malocclusion is known to be associated with oral breathing especially where there is mandibular retrusion and increased lower face height [64].

Changes in oropharyngeal airway size with orthognathic surgery have been well documented. Significant reductions occur with mandibular set back osteotomies [65-73]. Mandibular setback combined with maxillary advancement surgery results in a lesser decrease in the oropharyngeal airway with an increase in the nasopharyngeal region [74-78].

The reduction in oropharyngeal airway after mandibular surgery may be compensated for by cervical hyperflexion and so may not show up as suggested by Timms [79] and demonstrated by a number of studies [80, 81, 68, 82, 83]. Upper airway reduction can lead to extension of the cranio-cervical angle to relieve the obstruction [84]. Cranio-cervical angle was found to be on average 10 degrees larger in patients with obstructive sleep apnoea [85].

Patients with obstructive sleep apnoea have been shown to have reduced dimensions of the oropharyngeal airway [86-98, 24]. Gokce *et al* [10] found that sagittal distances, cross-sectional area and volume measurements of the oropharyngeal airway all had negative correlation with the apnoea-hypopnea index and positive correlation with sleep efficiency and mean oxygen saturation. Obstructive sleep apnoea syndrome is characterised by signs and symptoms related to arterial oxygen desaturation cessation of breathing resulting in arousal and sleep fragmentation caused by pharyngeal obstruction during sleep.

Obstructive sleep apnoea can result in serious morbidity and mortality mainly as a result of cardiovascular disease and road traffic accidents [99-109]. Children with obstructive sleep apnoea are more prone to having poor learning skills, behavioural problems, attention deficit hyperactivity disorder and depression [110-114].

The site of airway obstruction during episodes of apnoea is

usually located in the oropharyngeal region involving the soft palate, dorsum of the tongue and posterior pharyngeal wall. The most constricted area of the airway has an inverse relation to the resistance to air flow. Poiseuille's law demonstrates that even a modest decrease in the radius of the airway will result in a disproportionate increase in airway resistance (halving the radius results in a 16 times increase in resistance). There have even been reports of cases where mandibular setback surgery actually led to obstructive sleep apnoea [115, 116, 67]. Alternatively Class II correction using functional appliances has been found not only to enlarge the oropharyngeal airway but to improve nocturnal breathing. Maxillary expansion followed by Herbst appliance treatment has been found to decrease the number of respiratory effort-related arousals and respiratory disturbance index [8].

In conclusion it would seem that Class II patients already have a reduced oropharyngeal airway. Treatment involving extraction of premolars and retraction of incisor segments would further reduce the airway as would headgear. Therefore such an approach would be contra-indicated. Conversely functional appliance treatment would increase the airway dimensions obviating any potential airway problems.

Conclusions

1. Simple linear dimensions p, the shortest distance between the soft palate and the posterior pharyngeal wall and t, the shortest distance between the tongue and the posterior pharyngeal wall, correlate highly with three-dimensional volumetric and two-dimensional area measurements and are valid methods of airway assessment.

2. Twin-block appliance treatment increases the oropharyngeal airway as demonstrated by a statistically significant increase in both p and t. These findings are supported by previous similar studies published in the literature.

3. In Class II division 1 malocclusion the oropharyngeal airway is already reduced compared to Class I and III. Treatment involving premolar extraction and incisor retraction further reduces the airway as does headgear and is contraindicated. Functional appliance treatment is the method of choice as it enlarges the oropharyngeal airway reducing the potential for obstructive sleep apnoea.

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Special Issue on

"Long-term effects of orthodontic treatment"

Theme Edited by:

Saeed M Banabilh, Qassim University,
Saudi Arabia.
E-mail: banabilh23@gmail.com
Yanqi Yang, University of HongKong,
Hong Kong
E-mail: yangyanq@hku.hk