European Journal of Orthodontics 28 (2006) 184–189
doi:10.1093/ejo/cji095
Advance Access publication 7 February 2006

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Sagittal airway dimensions following maxillary protraction: a pilot study

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SUMMARY The relationship between changes in the position of the maxillary structures caused by maxillary protraction therapy and airway dimensions have not been investigated as comprehensively as the accompanying skeletal changes. The purpose of this study was to examine the effects of rapid palatal expansion (RPE) used in conjunction with maxillary protraction headgear on the sagittal dimension of the airway.

The treatment sample consisted of 19 Class III patients (12 girls, 7 boys) with a mean age of 10.51 ± 1.15 years, presenting with maxillary retrognathism. A cap splint type rapid palatal expander that had hooks between the upper lateral and canine teeth was used intraorally, and a Petit type facemask device extraorally, for an average of 6.78 ± 0.93 months. Pre- and post-treatment cephalometric radiographs were evaluated.

The results of the study revealed that point A moved anteriorly. The palatal plane showed a counter-clockwise rotation matched by the clockwise rotation of the mandible and an accompanying decrease in SNB angle. The vertical parameters showed a statistically significant increase. The head was in a more extensive position in relation to the cervical vertebrae. The nasopharyngeal airway measurements (PNS–ad1, PNS–ad2) showed an increase of 2.71 ± 3.35 and 3.03 ± 2.37 mm, respectively. These results demonstrated that limited maxillary widening together with protraction of the maxilla, improve nasopharyngeal but not oropharyngeal airway dimensions in the short term.

Introduction

The skeletal and dentoalveolar effects of orthopaedic treatment in subjects with Class III malocclusions with maxillary retrognathia, have been well documented in the orthodontic literature. Maxillary skeletal protraction, forward movement of the maxillary dentition, counter-clockwise rotation of the palatal plane, labial tipping of the maxillary incisors, inhibition of anterior mandibular growth, augmentation of face height, clockwise rotation of the mandible and lingual tipping of the lower incisors have all been shown to take place when treating growing skeletal Class III patients with a facemask (Ishii *et al*., 1987; Mermigos *et al*., 1990; Delaire, 1997; Nartallo-Turley and Turley, 1998; Baccetti *et al*., 1998, 2000; da Silva Filho *et al*., 1998; Macdonald *et al*., 1999; Jäger *et al*., 2001; Turley, 2002).

Animal experiments have shown that the entire maxilla is displaced anteriorly, and not only point A. Furthermore, the significant effects of the facemask were seen as posteriorly as the zygomatico-temporal suture (Kambara, 1977; Nanda, 1978; Jackson *et al*., 1979). The use of rapid palatal expansion (RPE) is postulated to disarticulate the maxillary sutures and allow more efficient forward protraction of the maxilla (McNamara, 1987; Turley, 1988, 1996). The relationship between these extreme changes in the position of the maxillary structures and the airway dimensions has not been investigated as comprehensively as the skeletal changes. Severe maxillary hypoplasia seen in craniofacial anomalies has been suggested to constrict the upper airway, including the nasal cavity and velopharynx (Handler, 1985; Hui *et al*., 1998). The positive effect of midface distraction carried out to alleviate upper airway obstruction in midface hypoplasia seen with achondroplasia has recently been reported (Elwood *et al*., 2003). The change in respiratory function induced by RPE has also been documented (Basciftci *et al*., 2002; Doruk *et al*., 2004). The effects of a maxillary protraction appliance used in combination with a chin cap have been shown to alter the upper airway dimension during maxillary protraction (Hiyama *et al*., 2002). The purpose of this study was to examine the effect of RPE and maxillary protraction headgear on the sagittal dimensions of the upper airway.

Materials and methods

The material for this retrospective study consisted of 38 lateral cephalometric films obtained from 19 Class III patients with maxillary retrognathism from a university clinic. All the patients were between PP_2 and MP_3 cap developmental stages at the beginning of the treatment period. The mean ages for girls (n = 12) and boys (n = 7) were 10.50 ± 0.96 and 10.54 ± 1.51, respectively. The patients were included in the study based on the following criteria: (1) The presence of a skeletal Class III malocclusion

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with maxillary skeletal retrusion, (2) No other congenital anomalies or endocrine problems, (3) An anterior crossbite with a Class III molar relationship, and (4) No mandibular displacement.

An acrylic cap splint type rapid palatal expander (A0620–09, Leone, Firenze, Italy), that had hooks between the upper lateral incisors and canines, was fabricated for each patient and cemented with fluoride releasing glass ionomer cement (Unitek Multi-Cure Glass Ionomer Band Cement, 3M-Unitek, Monrovia, California, USA) (Figure 1). Treatment started with one week of palatal expansion for the purpose of sutural disarticulation. The palatal screw was activated twice a day for seven days. At the end of day 7 protraction therapy was commenced. The facemask utilized in the study was a Petit type device (Ormco Corp., Glendora, California, USA) with bilateral forces set to 600–800 g. The direction of the elastics was approximately 30 degrees below the occlusal plane, as recommended in the literature (Itoh *et al*., 1985; Roberts and Subtelny, 1988; Ngan *et al*., 1996) (Figure 2). The patients were instructed to wear the appliance for at least 16 hours per day. The mean and standard deviation of treatment time was 6.78 ± 0.93 months.

Lateral cephalometric films, in natural head posture, were taken at the start and end of protraction. All the radiographs were taken with Trophy Ortho Slice 1000 C (Asahi Roentgen Ind. Co. Ltd, Kyoto, Japan) and were scanned at 300 dpi with an Epson Expression 1680 Pro scanner (Seiko Epson Corp., Nagano-Ken, Japan) into Dolphin Imaging Software 9.0 (Los Angeles, California, USA). The skeletal and dental parameters were calculated using the Dolphin Imaging software program, whereas head posture and sagittal airway measurements were traced, measured and registered by hand using conventional methods. The skeletal changes were assessed by SN–GoMe angle, ANSMe/NMe ratio, NP–A distance, maxillary depth angle, maxillary height angle, SNA angle, SNB angle and ANB angle. The dental changes were evaluated by U1–SN angle, L1–MP angle, SN–PP angle and SN–OP angle. The other parameters related to head posture and sagittal pharyngeal airway were NSL–OPT, NSL–CVT, NL–OPT, NL–CVT, and OPT–CVT angles, and PNS–ad1, PNS–ad2, OAW1, OAW2, OAW3, SPPS, MPS, and IPS distances, as defined by earlier research (Linder-Aronson and Henrikson, 1973; Solow and Tallgren, 1976; Hellsing, 1989; Figure 3).

Figure 1 Intraoral view of the appliance.

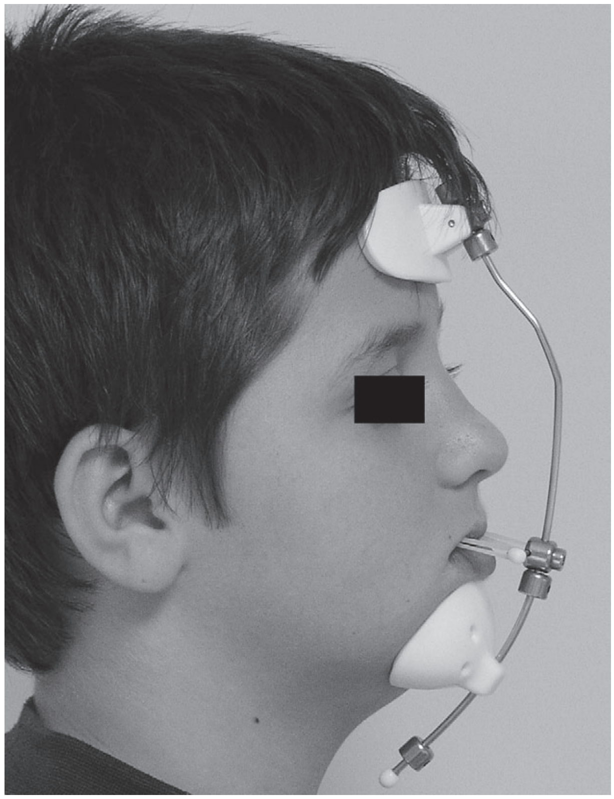

Figure 2 Profile view of a patient wearing facemask.

Statistical calculations were performed with GraphPad Prisma Version 3.0 software (San Diego, California, USA) for Windows. In addition to standard descriptive statistical calculations (mean and standard deviation), the non-parametric Wilcoxon signed rank test was utilized for the comparison of pre- and post-treatment changes (Table 1). The results were evaluated within a 95 per cent confidence interval. The statistical significance level was established at $P < 0.05$.

In order to assess the magnitude of the method error for each parameter, 20 randomly selected lateral cephalometric radiographs were retraced and remeasured by the same examiner (KS) with an interval of 20 days. Inter-rater correlation coefficients were found to be within 0.91 and 0.99.

Results

The changes which occurred during facemask therapy are shown in Table 1. Parameters regarding the sagittal maxillary position (NPer–A distance, maxillary depth angle, SNA angle) demonstrated that point A moved anteriorly. The palatal plane demonstrated a counter-clockwise rotation parallel

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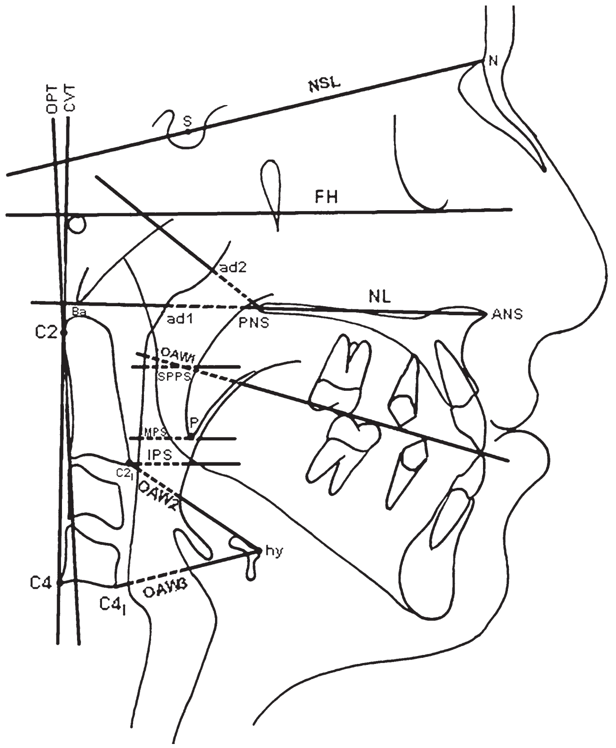

Figure 3 Diagrammatic representation of cephalometric head posture and airway variables. ad1, the point where posterior nasal spine (PNS)–basion (Ba) line intersects the posterior pharyngeal wall; ad2, the point where a line perpendicular to sella (S)–Ba plane passing through PNS intersects the posterior pharyngeal wall; OAW1, the distance between the points where the functional occlusal plane intersects the anterior and posterior pharyngeal walls; OAW2, the distance between points where a line passing through hyoid (hy) and $C2_i$ intersects the anterior and posterior pharyngeal walls; OAW3, the distance between the points where a line passing through hy and $C4_i$ intersects the anterior and posterior pharyngeal walls; SPPS, anteroposterior width of the pharynx measured between the posterior pharyngeal wall and the dorsum of the soft palate on a line parallel to the Frankfort horizontal (FH) plane that runs through the middle of a line from PNS to pogonion (P); MPS, anteroposterior width of the pharynx measured between the posterior pharyngeal wall and the dorsum of the tongue on a line parallel to the FH plane that runs through P; IPS, anteroposterior width of the pharynx measured between the posterior pharyngeal wall and the dorsum of the tongue on a line parallel to the FH plane that runs through $C2_i$.

to the clockwise rotation of the mandible, revealed by the decrease in SNB angle. The vertical parameters (SN–GoMe, ANSMe/NMe) showed a statistically significant increase.

The upper incisors tipped labially, a mean of 1.37 degrees with respect to the anterior cranial base, and the lower incisors tipped lingually. The amount of mean overjet increase was 8.06 mm.

The head was in a more extended position in relation to the cervical vertebrae, confirmed by the 2.38 degrees increase in NSL–CVT angle. NL–OPT and NL–CVT angles also showed an increase, slightly more than the NSL–CVT angle, supporting the counter-clockwise rotation of the maxillary complex. The mean increases in nasopharyngeal airway measurements (PNS–ad1 and PNS–ad2) were 2.71 and 3.03 mm, respectively.

Discussion

The present investigation analysed the treatment changes after orthopaedic therapy of Class III malocclusions by means of a bonded RPE used in conjunction with a facemask. An acrylic cap splint-type RPE was used as the anchorage appliance for the protraction therapy in order to obtain greater stability and skeletal effects (Kim *et al.*, 1999; Turley, 1988, 1996).

A control group could not be established in the present study. There are studies in the literature where Class I control groups have been used; however, the dentoalveolar and skeletal growth trends in subjects with a Class III malocclusion may differ from those of normal subjects. The need to use a Class III adequately matched control sample to make valid comparisons is therefore essential. Furthermore, there are examples which show that Class I control groups are not suitable for comparing with Class III treatment groups (Tindlund, 1989; Takada *et al.*, 1993; Shanker *et al.*, 1996). As for airway measurements, Özbek *et al.* (1998) showed that only negligible changes occurred in the upper airway during their 1.8 year observation period. Another limitation of the present study is the two-dimensional airway measurements, meaning that the results for these parameters are for the sagittal section only, and should be interpreted with caution taking this fact into consideration.

The parameters regarding the sagittal maxillary position (NP–A distance, maxillary depth angle, SNA angle) show that point A moved anteriorly. These results are similar to previously published reports as far as the amount and nature of the protraction effects. Most other studies (Nanda, 1980; Mermigos *et al.*, 1990; Gallagher *et al.*, 1998) reported between 1 and 3 mm of maxillary protraction, in line with the current study. This skeletal movement was accomplished by a force below the centre of resistance of the maxilla and directed downward and forward, lowering the posterior maxilla more than the anterior. The amount of skeletal movement of the maxilla was limited by the amount of dental movement, because the patients were generally treated until a positive overjet was achieved (Gallagher *et al.*, 1998). However, there is also a large range of responses reported in the literature, from significant maxillary advancement to minimal or no change with treatment (Turley, 2002). This inconsistency in response might be due to variations in treatment protocol including the design of appliances, the force level used, the number of hours worn per day, and the overall treatment time.

Maxillary height did not show any significant changes in the present study. Shanker *et al.* (1996) reported a 0.3 mm downward movement of the vertical position of point A in the treatment group, compared with a 1.0 mm downward movement in the control group. Those authors concluded that treatment appeared to inhibit normal downward movement of

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Table 1 Comparison of intra-group changes (Wilcoxon sign rank test).

	Pre-treatment				Post-treatment				Difference				
	Mean	SD	Median	Range	Mean	SD	Median	Range	Mean	SD	Median	Range	*P*
Skeletal													
Sn–GoMe (°)	38.11	6.14	39.10	17.50	40.43	6.51	40.60	19.50	2.33	1.28	2.50	6.10	***
NPer–A (mm)	−4.43	2.93	−5.20	9.70	−2.12	3.61	−2.20	14.50	2.31	2.05	2.00	6.50	**
Maxillary height (°)	61.77	3.32	61.60	11.10	61.53	3.29	61.20	11.50	−0.24	1.65	−0.60	6.50	
Maxillary depth (°)	85.88	3.24	84.90	11.20	87.76	3.24	88.00	13.70	1.88	2.38	2.10	9.30	**
SNA (°)	76.99	4.17	77.10	16.20	79.59	4.61	79.40	19.00	2.59	1.59	2.30	5.50	***
SNB (°)	78.90	3.24	80.00	10.40	76.79	3.30	77.40	10.30	−2.11	1.01	−2.10	4.70	***
ANB (°)	−1.88	2.22	−1.40	8.50	2.78	2.45	3.00	9.20	4.52	1.59	4.20	6.20	***
SN–PP(°)	10.17	2.92	10.20	10.70	8.32	3.18	8.40	10.00	−1.85	1.60	−2.10	6.90	***
ANS–Me/NMe (%)	54.46	2.60	54.90	8.60	56.27	2.60	57.00	9.20	1.81	1.26	2.00	5.20	***
Dental													
SN–OP (°)	19.98	4.85	20.20	15.80	19.59	5.00	19.30	2.30	−0.39	2.40	−0.20	7.40	
U1–SN (°)	101.86	5.38	102.30	17.30	103.23	5.50	104.00	17.70	1.37	2.92	1.20	10.60	*
L1–MP (°)	82.72	7.55	82.30	26.50	80.17	7.20	79.70	25.90	−2.55	2.71	−1.70	9.70	***
Overjet (mm)	−1.75	2.02	−2.00	8.90	6.31	3.35	6.10	12.50	−2.47	6.60	7.30	11.40	***
Overbite (mm)	1.42	2.25	1.90		1.04	2.11	0.60		3.95	2.41	−0.10		
Head posture													
NSL–CVT (°)	101.75	8.43	100.90	35.60	104.13	9.07	102.20	37.70	2.38	4.67	2.40	18.00	*
NSL–OPT (°)	100.26	7.07	100.00	33.00	101.37	9.54	101.00	36.00	1.05	5.17	0.50	18.00	
NL–CVT (°)	91.89	9.18	90.00	37.00	95.79	10.09	93.50	42.00	3.89	5.01	4.50	19.00	*
NL–OPT (°)	89.47	8.75	88.50	41.50	92.79	10.22	89.50	44.00	3.32	5.06	3.00	19.00	**
OPT–CVT (°)	2.71	2.08	2.00	8.50	3.29	2.04	3.00	8.50	0.58	1.90	0.50	8.00	
Airway													
PNS–ad1 (mm)	15.16	4.37	14.50	17.00	17.87	4.05	18.00	13.00	2.71	3.35	2.00	11.00	**
PNS–ad2 (mm)	11.05	2.99	11.50	11.50	14.08	3.47	14.00	12.50	3.03	2.37	2.50	9.00	***
OAW1 (mm)	17.92	5.38	18.00	20.00	17.74	4.38	19.00	16.50	−0.18	3.21	−0.50	12.00	
OAW2 (mm)	10.92	3.96	11.00	18.00	10.66	3.16	11.00	13.00	0.26	3.24	0.00	11.00	
OAW3 (mm)	11.95	2.44	11.00	10.50	12.84	2.36	12.00	10.50	0.89	1.71	1.50	6.50	
SPPS (mm)	10.34	2.59	10.00	9.00	10.76	2.01	10.50	7.00	0.42	3.10	1.00	14.00	
MPS (mm)	13.84	3.45	13.00	15.50	14.50	3.10	14.50	10.50	0.66	2.49	1.00	10.50	
IPS (mm)	10.03	2.56	90.50	10.00	10.55	2.27	10.00	8.00	0.53	2.52	1.00	8.50	

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.
SD, standard deviation.

point A, which may be the result of the reported counter-clockwise rotation of the maxilla with protraction forces (Linder-Aronson and Henrikson, 1973; Ishii *et al*., 1987; Tindlund, 1989; Shanker *et al*., 1996). The palatal plane in this study showed a counter-clockwise rotation, resulting in a backward and downward displacement of the mandible. These findings are similar to the results of da Silva *et al*. (1998) and Ishii *et al*. (1987), where the ratio between maxillary anterior displacement and mandibular retroposition was almost 1:1.

The accompanying decrease in SNB angle is not a reflection of a change in dimension (da Silva *et al*., 1998), but of a change in position, revealed by the vertical parameters (SN–GoMe, ANSMe/NMe) which showed a statistically significant increase. This downward and backward mandibular rotation results in point B moving backward, which then allows an increase in facial convexity and improvement in the profile.

Post-treatment, the head was in a more extended position in relation to the cervical vertebrae demonstrated, by a mean increase of 2.38 degrees in NSL–CVT angle. NL–OPT and NL–CVT angles also showed an increase, slightly more than that of NSL–CVT angle, supporting the counter-clockwise rotation of the maxillary complex.

Upper airway dimension and head posture were found to be strongly correlated with previous research (Spann and Hyatt, 1971; Thach and Stark, 1979; Hiyama *et al*., 2002). Nasopharyngeal airway measurements (PNS–ad1 and PNS–ad2) showed a mean increase of 2.71 and 3.03 mm, respectively in this study. The other airway parameters measured demonstrated no statistically significant differences. There are studies regarding the influence of functional appliances or RPE devices on the upper airway. In a recent review, oral devices were shown to be effective in approximately 50–70 per cent of patients with obstructive sleep apnoea (OSA; Verse *et al*., 2003). Mandibular distraction osteogenesis may also be of help in OSA in patients with mandibular hypoplasia and severe

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upper airway obstruction (Elwood *et al*., 2003; Mandell *et al*., 2004). Considering that mandibular growth has a definite influence on the upper airway dimension, it can be speculated that maxillary growth could also have beneficial effects on the upper airway (Hiyama *et al.*, 2002).

Even though no significant changes between pre- and post-treatment airway parameters were found by Hiyama *et al*. (2002), they carried out a multiple regression analysis which revealed that greater forward maxillary growth was associated with a greater increase in the superior upper airway dimension. A possible explanation as to why Hiyama *et al*. (2002) could not find any differences in the between the pre- and post-treatment airway parameters may be the lack of related parameters in their study. The upper airway measurements used (SPPS, MPS, IPS) were mainly at the back of the tongue and very minimally related to maxillary structures. The backward rotation of the mandible, although implicitly restricting the related sagittal airway dimensions, did not appear to cause any change.

Conclusions

This study evaluated the effect of using maxillary disarticulation and protraction on the sagittal dimension of the naso- and oropharyngeal airways in 19 growing patients with a skeletal Class III relationship. The results, however, should be interpreted with caution because of the small sample size and the lack of a control group. The findings showed:

1. Point A moved anteriorly, the palatal plane showed a counter-clockwise rotation matching the clockwise rotation of the mandible as revealed by the decrease in SNB angle, and the vertical parameters showed a statistically significant increase.
2. The head was in a more extended position in relation to the cervical vertebrae. Nasopharyngeal airway measurements (PNS–ad1, PNS–ad2) showed a mean increase of 2.71 and 3.03 mm, respectively.
3. Maxillary disarticulation and protraction improved naso- but not oropharyngeal airways.

Further research may be needed to evaluate the functional status of the airway after maxillary protraction.

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