Original Article

Effect of rapid maxillary expansion on monosymptomatic primary nocturnal enuresis

Nameer Al-Taai[a]; Fakhri Alfatlawi[b]; Maria Ransjö[c]; Saad Fakhry[d]

ABSTRACT

Objective: To evaluate the effects of rapid maxillary expansion (RME) on nocturnal enuresis (NE) related to the nasal airway, nasal breathing, and plasma osmolality (as an indicator for antidiuretic hormone).

Materials and Methods: Nineteen patients with monosymptomatic primary NE, aged 6–15 years, were treated with RME for 10–15 days. To exclude a placebo effect of the RME appliance, seven patients were first treated with a passive appliance. Computed tomography of nasal cavity, rhinomanometric, and plasma osmolality measurements were made 2–3 days before and 2–3 months after the RME period. RME effects on NE were followed for three more years.

Results: Two to three months after the expansion there were significant improvements in the breathing function and a decrease in the plasma osmolality. NE decreased significantly in all patients after the RME period, and all patients showed full dryness after 3 years.

Conclusions: This study demonstrates that RME causes complete dryness in all patients, with significant effects on pathophysiological mechanisms related to NE. (*Angle Orthod.* 2015;85:102–108.)

KEY WORDS: Rapid maxillary expansion; Nocturnal enuresis; Antidiuretic hormone

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-05-15 via free access

INTRODUCTION

Rapid maxillary expansion (RME) increases the maxillary arch width by opening the midpalatal suture to achieve some degree of skeletal expansion. RME is commonly used as an orthopedic treatment for transverse maxillary deficiency and can improve breathing.[1–4] In addition, RME has been used to treat nocturnal enuresis (NE).[5–8]

For children older than 4–6 years of age, a NE diagnosis is confirmed if they wet their beds more than two nights per month. Several studies have reported 5% prevalence of NE in 10-year-olds and 10% prevalence in 6-year-olds. NE often causes severe psychological and social strain on children and their families.[9] NE is considered as monosymptomatic when the bedwetting is associated with normal urination during the day (ie, they have normal bladder function)[10] and as primary when the child does not have a period of dryness of more than 6 months.[11] NE is considered secondary when the child has a period of improvement and then relapses, for example, when under stress or for other psychological reasons. The antidiuretic hormone (ADH), which regulates the volume of urine, is secreted from the pituitary gland and contributes to the reabsorption of water in the kidney, thereby decreasing plasma osmolality. Secretion of ADH causes the body to produce a smaller and more concentrated amount of urine. Because children with NE often have reduced ADH secretions at night,[12,13] treatment of NE typically includes desmopressin (an analogue of arginine vasopressin) and an enuretic alarm, as psychological therapy.[13]

In addition, genetic predisposition, psychological disorders, and upper airway obstruction can cause NE.[11] Recently, several scientific reports[14–18] note that NE is a common symptom among children with breathing problems. Kunvari[19] suggested that improved circulation from the palate toward the pituitary gland is possible. Basal metabolism and glucose

[a] Former Orthodontic Resident, Department of Orthodontics, Department of Odontology, Umeå University, Umeå, Sweden.
[b] Professor, Department of Orthodontics, College of Dentistry, University of Baghdad, Baghdad, Iraq.
[c] Professor, Department of Orthodontics, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden.
[d] Assistant Professor, Department of Endocrinology and Metabolism, College of Medicine, University of Al-Nahrain, Baghdad, Iraq.
Corresponding author: Dr Nameer Al-Taai, Orthodontist, Department of Orthodontics, Department of Odontology, Umeå University, 901 87 Umeå, Sweden
(e-mail: nameeraltai@yahoo.com)

Accepted: May 2014. Submitted: March 2014.
Published Online: July 30, 2014
© 2015 by The EH Angle Education and Research Foundation, Inc.

 DOI: 10.2319/031014-172.1

tolerance were analyzed in 14 patients during orthodontic treatment of a palatal deformity; an unexpected benefit of orthodontic treatment was the cessation of NE.[20]

Previous studies[5–8] demonstrate that orthodontic RME is a good treatment option for children with NE, but the exact underlining mechanism and possible placebo effect of the RME appliance are not well understood.

To investigate possible mechanisms behind NE cessation as it relates to RME, this study evaluates the effects of RME on the nasal airway, nasal breathing, and plasma osmolality (as an indicator for ADH) with respect to NE. That is, this study evaluates RME as a treatment for NE. This study also evaluates the placebo effect of RME on the treatment of NE.

MATERIALS AND METHODS

Fifty-six patients (5 to 22 years old) suffering from NE attended the Endocrine Clinic in the Al-Kadhymia Teaching Hospital in Baghdad for 1 week. All patients underwent a detailed physical examination by an endocrinologist to exclude underling medical illness and by an ear-nose-throat (ENT) specialist to exclude major nasal obstruction requiring surgery. Laboratory investigations were performed, including fasting and random blood glucose to exclude diabetes mellitus and a complete blood count to exclude anemia (sickle cell anemia causes renal disorders) or underlining infections. Blood urea, creatinine, Ca^{++}, and K^{+} levels were measured to check renal function and electrolyte status. Urine analysis was performed to exclude urinary tract infection, and urine-specific gravity was measured to exclude patients with diabetes insipidus. Radiological examinations (lateral skull and chest X-rays) were completed to exclude skull lytic lesions, pituitary lesions, chest infections (pulmonary lesions), and heart disease. Patients below 6 years of age were excluded from the present study, as NE is only considered a disease in children above that age.[6] Patients older than 15 years were also excluded because maxillary expansion becomes difficult after that age.[21] Exclusion criteria were dryness lasting more than 6 months, urinary incontinence, serious illness, major nasal obstruction, and lack of any type of treatment for NE and/or daytime voids or dysuria. Inclusion criteria were a monosymtomatic primary NE (MPNE) treated with Minirin (ADH substitute) without sustained improvement. In addition, inclusion required the subjects to be healthy, other than the above diagnosis.

Nineteen patients (1 male and eight female patients aged 6–15 years) fulfilled the criteria of MPNE and were included in the study (see supplemental graphic).

Table 1. Information About the Patients

Patient	Age, y	Gender[a]	Frequency of Bedwetting per Night, No.
1	6	F	2
2	7	M	2
3	7	M	2
4	9	M	3
5	7	M	2
6	11	M	4
7	11	M	3
8	12	F	1
9	8	F	3
10	11	F	3
11	10	M	4
12	12	M	1
13	13	F	2
14	11	F	1
15	12	M	2
16	14	F	1
17	14	F	1
18	15	M	2
19	15	M	3
Mean	11		2.21

[a] M indicates male; F, female.

The study was approved by the Institutional Ethical Review Committee of the University of Baghdad.

According to the ethical criteria for clinical studies at the College of Dentistry, all patients and parents were informed of the purpose of the study and gave written consent to participate. The frequency of night wetting was obtained from the parents (Table 1). The orthodontic examination shows that most patients had mild to moderate crowding, and only two out of 19 patients had a cross bite. Study casts were taken before and after expansion to measure the maxillary arch width (intermolar distance). The numbers of patients who breathed through their mouths, who snored, and who slept deeply were recorded. Blood samples were taken during the early morning 2–3 days before the placement of the expansion appliance and 2–3 months after expansion was finished. Sodium, glucose, urea, and nitrogen were measured in order to calculate morning[22] so as to evaluate the ADH: Osmolality (mosmol/L) $= 2[\mathrm{Na}+]$ (meq/L) $+ 0.055[\mathrm{Glucose}]$ (mg/dL) $+ 0.36[\mathrm{BUN}]$ (mg/dL).[23]

Nasal airflow and nasal resistance were measured by anterior rhinomanometry (ATMOS® 300) 2–3 days before and 2–3 months after RME at the ENT department by the ENT specialist. A computed tomography (CT) scan (Somatom 64, Siemens, Forcheim, Germany) of the sinuses (coronal section) was performed 2–3 days before and 2–3 months after RME to evaluate the possible nasal obstruction and to measure the degree of expansion in the nasal cavity (horizontal plane). Measurements were made between

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-05-15 via free access

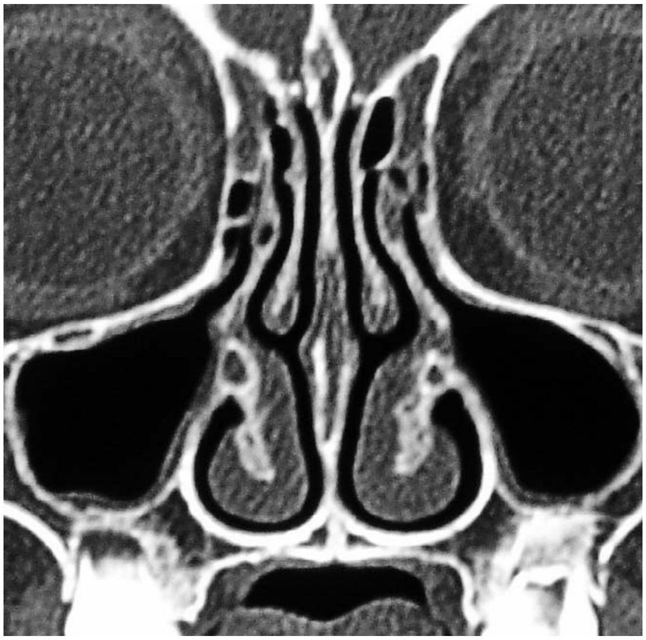

Figure 1. The degree of expansion in the nasal cavity (horizontal plane) measured between the medial ends of the inferior concha at the level of ostia of the maxillary sinus.

the medial ends of the inferior concha at the level of ostia of the maxillary sinus (Figure 1).

Orthodontic RME was performed with a fixed palatal appliance (Dentarum Hyrax screw, Dentaurum, Ispringen, Germany) soldered to Dentarum bands on permanent first molars and first premolars of patients or second primary molars of patients who had an unerupted first premolar (Figure 2). Activation started on the first day of insertion in 12 patients. To analyze the possible placebo effects of the appliance, a control group of seven patients wore the expansion appliance for 30 days without activation. Thereafter, the patients in the control group started activation of the Hyrax screw and were included in the study group. There were no particular differences between the patients in the study and the control groups. The RME appliance was activated by one of the patient's parents each morning and evening, with a total expansion of 0.45 mm/d. The activation continued until the palatal cusps of the upper posterior teeth were at the level of the buccal cusps of their lower counterparts. Activation continued for 10 to 15 days. After the expansion period, the RME appliance was left in the mouth without any activation for 1 month. Thereafter, the RME appliance was replaced with a Hawley retainer, which was used for 6 months. The patients did not use any other treatment during or after treatment with RME. A follow-up was made after 1 and 3 years by direct interviews or by telephone.

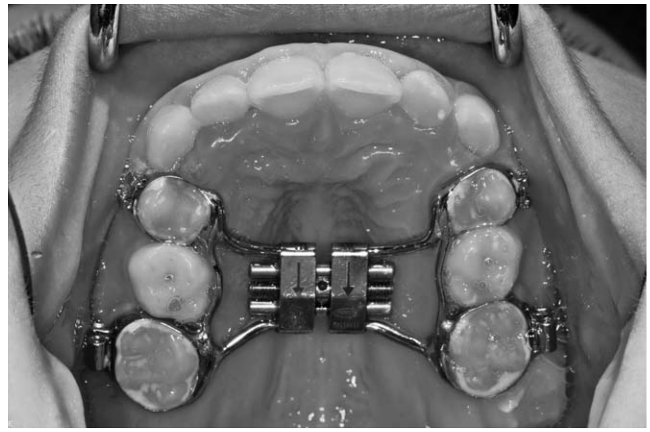

Figure 2. RME appliance (Hyrax screw).

Statistics

Results are expressed as mean ± standard deviation (SD). Statistical significances were analyzed using the paired *t*-test and McNemar's test. *P*-values of $<.05$ were considered significant. SPSS Statistics (IBM® SPSS® Statistics, Chicago, Ill) was used for the statistical analysis.

RESULTS

Thirty days after RME expansion, six patients exhibited complete dryness, and the rest exhibited an improvement of NE. In contrast, no significant effect on NE ($P > .05$) was obtained in the control group 30 days after insertion of RME appliance without activation (data not shown). The frequency of bedwetting varied from one to several times a night. The mean value before expansion was 2.21 wettings per night, and this decreased to 0.42 wettings per night 2–3 months after RME began (Table 2). There were significant improvements ($P < .005$) with respect to mouth breathing, snoring, and deep sleep 2–3 months after RME (Table 3). The patients experienced an improvement in their nasal breathing after RME, and according to the parents, most of the patients woke up by themselves after the RME. The intermolar distance increased significantly, with a mean difference of 4.6 mm ($P < .001$) after RME (Table 4). Cross bites were corrected for two of the patients. Five patients would not come to the hospital for a CT, rhinomonometry, and blood samples, so the CT, rhinomanometry, and plasma osmolality measurements after RME were not performed.

CT scans show that the nasal cavity width increased significantly ($P < .001$) at the level of the inferior concha following RME. The mean value for interinferior chonchal distance before expansion was 1.41 cm, and the value after after expansion was 1.59 cm (Table 4),

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-05-15 via free access

Table 2. Frequency of Bedwetting (FBW) per Night Before and After Rapid Maxillary Expansion (RME)

Patient	FBW Before RME	FBW 2–3 Months After RME	FBW 1 Year After RME	FBW 3 Years After RME
1	2.00	0.80	0.14	0.0
2	2.00	0.80	0.00	0.0
3	2.00	0.80	0.10	0.0
4	3.00	0.00	0.00	0.0
5	2.00	1.00	0.14	0.0
6	4.00	0.60	0.00	0.0
7	3.00	0.00	0.00	0.0
8	1.00	0.14	0.00	0.0
9	3.00	0.14	0.00	0.0
10	3.00	1.00	0.00	0.0
11	4.00	0.14	0.00	0.0
12	1.00	0.00	0.00	0.0
13	2.00	0.28	0.00	0.0
14	1.00	1.00	0.00	0.0
15	2.00	0.00	0.28	0.0
16	1.00	0.00	0.00	0.0
17	1.00	0.00	0.00	0.0
18	2.00	0.70	0.28	0.0
19	3.00	0.70	0.14	0.0
Mean	2.21	0.42	0.06	0.0
Standard deviation	0.98	0.40	0.10	0.0

with a mean difference of 1.8 mm. The CT scan examination revealed that most of the patients were suffering from mild to moderate nasal obstruction before the expansion. This finding contradicts the ENT clinical examination: that is, most of the patients had a normal nasal airway before RME. CT scan examination by a radiologist showed notable improvement in nasal obstruction after RME in most of the patients. Rhinomanometry demonstrated that nasal airflow increased significantly ($P < .001$). The mean value for nasal airflow before expansion was 405.05 cm^3/s, and this value rose to 584.86 cm^3/s after expansion (Table 4). Nasal airway resistance significantly decreased ($P < .001$): the mean value for the nasal resistance before expansion was 0.44 pa/cm^3/s, and the value dropped to 0.24 pa/cm^3/s after expansion (Table 4). Morning plasma osmolality measurements were higher than the normal limit (280–296 mosmol/L)[24]; however, after RME, plasma osmolality significantly decreased ($P < .05$), from a mean of 302 to 295 mosmol/L (Table 4), which is within the normal limit. After 1 year, seven patients were interviewed in person, and the others were interviewed by telephone. At the time of the interviews, two patients wet their beds about two times per week, four wet their beds about once a week, and 13 reported complete dryness. After 3 years, patients could be reached only by telephone, and all patients reported complete dryness (Table 2).

Table 3. Results from Interview and Orthodontic Examination Before and 2–3 Months After Rapid Maxillary Expansion (RME)

	Mouth Breathing		Snoring		Deep Sleep		Cross Bite	
Patient	Before	After	Before	After	Before	After	Before	After
1	+	−	−	−	+	+	−	−
2	+	−	+	−	+	−	−	−
3	−	−	−	−	−	−	−	−
4	+	−	+	−	+	−	−	−
5	−	−	−	−	+	+	−	−
6	+	−	+	−	+	−	−	−
7	+	−	+	−	+	−	−	−
8	+	−	+	−	+	−	+	−
9	+	−	+	−	+	−	−	−
10	+	−	+	−	+	−	−	−
11	+	−	+	−	+	−	+	−
12	−	−	−	−	−	−	−	−
13	+	−	−	−	+	−	−	−
14	−	−	−	−	+	−	−	−
15	+	−	+	−	+	+	−	−
16	−	−	−	−	+	−	−	−
17	−	−	−	−	+	−	−	−
18	−	−	−	−	+	+	−	−
19	+	+	+	+	+	+	−	−

+ means yes, − means no.

DISCUSSION

All patients decreased the frequency of their bedwetting after 1 year, and all patients showed complete dryness after 3 years. The treatment effect of RME in this study is better than that in other reported studies.[5–8] This difference could be due to this study's diagnostic criteria and the careful selection of enuretic patients included in the study. The orthodontist conducting the expansion also followed the patients through all examinations and follow-up visits. The patient's sense of being given high priority and receiving optimum care is a factor that may have contributed to the high success rate.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-05-15 via free access

Table 4. Measurements of Intermolar Distance (IMD), Interchonchal Distance (ICD), Nasal Airflow (NAF), Nasal Airway Resistance (NAR), and Plasma Osmolality (POSM) Before and 2–3 Months After Rapid Maxillary Expansion (RME)

	IMD, mm		ICD, cm		NAF, cm³/s		NAR, pa/cm³/s		POSM, mosmol/L	
Patient	Before	After	Before	After	Before	After	Before	After	Before	After
1	30.60	36.50	1.10	–	464.00	–	0.32	–	297.70	–
2	34.90	39.90	1.60	1.70	456.00	808.00	0.32	0.18	315.40	296.60
3	31.40	36.50	1.20	–	620.00	–	0.24	–	293.60	–
4	39.40	44.20	1.70	1.90	216.00	704.00	0.69	0.21	295.10	288.30
5	37.40	41.00	1.00	1.20	596.00	832.00	0.25	0.18	325.90	303.00
6	35.50	41.70	1.00	1.20	320.00	432.00	0.46	0.34	318.70	301.00
7	33.30	37.70	1.80	2.00	0.00	528.00	0.85	0.28	294.90	285.00
8	32.80	36.40	1.20	1.30	192.00	688.00	0.78	0.21	289.80	287.40
9	35.70	39.70	1.40	–	272.00	–	0.55	–	305.30	–
10	35.00	39.50	1.50	1.60	376.00	708.00	0.39	0.21	291.10	301.10
11	31.00	37.50	1.40	1.60	196.00	564.00	0.76	0.26	296.80	292.40
12	36.60	41.00	1.70	2.00	516.00	548.00	0.29	0.27	315.40	309.90
13	27.70	31.60	1.00	1.10	416.00	624.00	0.36	0.24	290.20	290.60
14	33.60	36.70	1.80	–	752.00	–	0.19	–	297.30	–
15	34.70	39.70	1.30	1.60	312.00	344.00	0.48	0.43	314.40	297.70
16	34.10	37.30	1.70	1.90	648.00	652.00	0.23	0.23	287.40	288.00
17	34.50	40.00	1.30	1.60	544.00	568.00	0.27	0.26	322.30	298.20
18	37.60	42.10	1.80	–	800.00	–	0.18	–	303.40	–
19	37.50	41.10	1.30	1.50	0.00	188.00	0.79	0.08	290.20	291.00
Mean	34.38	38.95	1.41	1.59	405.05	584.86	0.44	0.24	302.36	295.01
Standard deviation	2.85	2.84	0.29	0.30	228.92	175.65	0.22	0.08	12.43	7.20

We found that there was no placebo effect on NE with use of the RME appliance. Seven NE patients had a passive appliance for 30 days without any improvement and felt disappointed. In contrast, 20–30 days after active RME, all of the study patients had reduced emissions and less frequent bedwetting episodes. Although a possible placebo effect of the RME appliance was ruled out, the fact that there was no control group without a RME appliance could be a limitation of our study.

Nasal Obstruction and Sleep Patterns

The increase in the maxillary arch width (3–5 mm) seen in this study is similar to the results reported by most RME studies.[2,4,25] The effect of RME on the nasal airways was investigated in this study because of the possible relationship between breathing patterns and nasal airway obstruction and NE. Assessment of the nasal airway on the basis of conventional radiographs has limitations due to superimposition and lack of soft tissue detail. Therefore, before and after RME, and in addition to clinical ENT examinations, this study used CT scans to assess nasal obstruction. Many researchers[2–4] have reported that the nasal cavity width increases immediately following the RME. In this study, CT scans show an increase in the nasal cavity width after RME, at the level of the inferior concha. The increase in the width of the nose increases nasal capacity, as predicted by Poiseuille's Law: in every small duct, the flow varies by the fourth power of the radius.[26] Our CT scans showed notable improvement in patients suffering from mild to moderate nasal obstruction after RME. Many investigators[3,5,6,26] have reported that RME reduces nasal airway resistance and improves nasal breathing. The patients reported that their nasal breathing was improved and that there was a significant reduction in mouth breathing and snoring after RME.

Several reports[14–18] mention NE as a common symptom among children with breathing problems and sleep apnea. Improvement in NE is linked to improvement in breathing capacity and better oxygen saturation of blood. This may have a beneficial effect in restoration of normal sleep patterns and may cause the patient to wake up more easily.[5,6] Therefore, we can conclude that an improvement in the breathing caused by RME may lead to improvement in the sleep patterns of enuretic patients. This is confirmed in the present study, as significant improvements were found for deep sleep patients.

Antidiuretic Hormone

ADH can be assessed indirectly by measuring plasma osmolality or directly by measuring plasma ADH.[27] Problems associated with the study of plasma ADH are the pulsatile secretion of the hormone[10] and the fact that most immunoassays are unable to quantitate the low levels of ADH (0.35–1.94 ng/L) with certainty.[27] For the best interpretation of results, plasma ADH values should be correlated with plasma

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-05-15 via free access

osmolality.[27] It is well known that ADH secretion depends on plasma osmolality,[28] and ADH secretion is a function of plasma osmolality.[29] In the present study, plasma osmolality was measured in the patients before RME and levels were higher than the normal limit (280–296 mosmol/L).[24] After RME, plasma osmolality decreased nearly to the normal limit. These results are similar to the results seen in a study by Tomasi et al.,[22] which used imipramine on NE patients. They report a decrease in the morning plasma osmolality from 298.5 to 294.9 mosmol/kg with an increase in nocturnal ADH excretion. This significant decrease in plasma osmolality after RME is due to increased plasma ADH, since ADH secretion leads to water reabsorption in the renal collecting ducts, lowering plasma osmolality and decreasing urine production.[30]

A reduction in nighttime ADH secretion in the enuretic patients, as compared to nonenuretic children, has been reported[12,13,22] and is the reason why vasopressin is used for NE treatment.[13,31,32] Effects on the pituitary gland after orthodontic treatment have been reported. When patients with palatal deformity were treated, an unexpected benefit was the cessation of NE, so effects on the antidiuretic function of the pituitary gland should not be excluded from possible explanations.[20] Kunvari[19] concluded that improved circulation from the palate to the pituitary gland could be a possible mechanism. This supports the hypothesis in the present study that an increase in ADH secretion from the pituitary gland following RME causes a significant decrease in plasma osmolality. Therefore, it can be suggested that improvement in NE may also be a result of an increase in the ADH secretion following RME. Further studies are needed to determine the effect of RME on other hormones secreted from the pituitary gland.

CONCLUSIONS

- Following RME, a significant number of the enuretic patients showed complete dryness, and the rest had significant improvement with respect to NE after 2–3 months.
- Complete dryness was revealed in all patients after 3 years. The present study shows that RME has significant effects on pathophysiological mechanisms related to NE, which is probably related to an improvement in breathing and an increase in ADH.
- RME is a simple treatment for NE, as compared to other treatments, but effective use of RME as a treatment for NE requires correct diagnosis of MPNE.

ACKNOWLEDGMENTS

Sincere gratitude is extended to Dr Mazin Abbas Shubber, Prof Dr Ghassan Al-Shamaa, Dr Fawaz Rasam, Prof Dr Khalid Abdullah, and Dr Ahmed Hashim for their unlimited scientific advice, guidance, and teaching efforts along the way.

REFERENCES

1. Montgomery WM, Vig PS, Staab EV, Matteson SR. Computed tomography: a three-dimensional study of the nasal airway. *Am J Orthod*. 1979;76:363–375.
2. Haas AJ. Palatal expansion: just the beginning of dentofacial orthopedics. *Am J Orthod*. 1970;57:219–255.
3. Wertz RA. Skeletal and dental changes accompanying rapid midpalatal suture opening. *Am J Orthod*. 1970;58:41–66.
4. Haas AJ. Rapid expansion of maxillary dental arch and nasal cavity by opening the mid palatal suture. *Angle Orthod*. 1961;31:73–90.
5. Kurol J, Modin H, Bjerkhoel A. Orthodontic maxillary expansion and its effect on nocturnal enuresis. *Angle Orthod*. 1998;68:225–232.
6. Timms DJ. Rapid maxillary expansion in the treatment of nocturnal enuresis. *Angle Orthod*. 1990;60:229–233.
7. Schutz-Fransson U, Kurol J. Rapid maxillary expansion effects on nocturnal enuresis in children: a follow-up study. *Angle Orthod*. 2008;78:201–208.
8. Usumez S, Iseri H, Orhan M, Basciftci FA. Effect of rapid maxillary expansion on nocturnal enuresis. *Angle Orthod*. 2003;73:532–538.
9. Neveus T, Lackgren G, Tuvemo T, Hetta J, Hjalmas K, Stenberg A. Enuresis—background and treatment. *Scand J Urol Nephrol Suppl*. 2000:1–44.
10. Lackgren G, Neveus T, Stenberg A. Diurnal plasma vasopressin and urinary output in adolescents with monosymptomatic nocturnal enuresis. *Acta Paediatr*. 1997;86:385–390.
11. Tietjen DN, Husmann DA. Nocturnal enuresis: a guide to evaluation and treatment. *Mayo Clin Proc*. 1996;71:857–862.
12. Aikawa T, Kasahara T, Uchiyama M. The arginine-vasopressin secretion profile of children with primary nocturnal enuresis. *Eur Urol*. 1998;33(suppl 3):41–44.
13. Elder JS. Voiding dysfunction. In: Behrman RE, Kliegman R, Jenson HB, eds. *Nelson Textbook of Pediatrics*. Philadelphia, Pa: Saunders; 2000:1642–1643.
14. Clubb RW. Nasal obstruction and its effects upon the fields of medicine and dentistry. *J Pedod*. 1990;14:76–83.
15. Guilleminault C, Stoohs R. Obstructive sleep apnea syndrome in children. *Pediatrician*. 1990;17:46–51.
16. Laurikainen E, Aitasalo K, Erkinjuntti M, Wanne O. Sleep apnea syndrome in children—secondary to adenotonsillar hypertrophy? *Acta Otolaryngol Suppl*. 1992;492:38–41.
17. Weider DJ, Hauri PJ. Nocturnal enuresis in children with upper airway obstruction. *Int J Pediatr Otorhinolaryngol*. 1985;9:173–182.
18. Weider DJ, Sateia MJ, West RP. Nocturnal enuresis in children with upper airway obstruction. *Otolaryngol Head Neck Surg*. 1991;105:427–432.
19. Kunvari B. Morphologic aspect of the palate as a sensitive sign of pituitary gland dysfunction. *Rep Congr Eur Orthod Soc*. 1964;40:66–82.
20. Sheary CB. Possible influence of orthodontics on pituitary gland function and learning ability. *J Clin Orthod*. 1985;19:889–890.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-05-15 via free access

21. Handelman CS, Wang L, BeGole EA, Haas AJ. Nonsurgical rapid maxillary expansion in adults: report on 47 cases using the Haas expander. *Angle Orthod*. 2000;70:129–144.
22. Tomasi PA, Siracusano S, Monni AM, Mela G, Delitala G. Decreased nocturnal urinary antidiuretic hormone excretion in enuresis is increased by imipramine. *BJU Int*. 2001;88:932–937.
23. Barrett KE, Boitano S, Barman Susan M, Brooks Heddwen L. *Ganong's Review of Medical Physiology*. 2010.
24. BloodBank.com. Blood test results—normal ranges. Available at: http://www.bloodbook.com/ranges.html. Accessed July 22, 2011.
25. Timms DJ. A study of basal movement with rapid maxillary expansion. *Am J Orthod*. 1980;77:500–507.
26. Timms DJ. The effect of rapid maxillary expansion on nasal airway resistance. *Br J Orthod*. 1986;13:221–228.
27. Whitley RJ, Meikle AW, Watts NB. Hormones from the posterior lobe of the pituitary gland (neurohypophyseal hormones). In: Burtis CA, Ashwood ER, eds. *Tietz Textbook of Clinical Chemistry*. Philadelphia, Pa: WB Saunders Company; 1994:1685–1697.
28. Thompson CJ, Bland J, Burd J, Baylis PH. The osmotic thresholds for thirst and vasopressin release are similar in healthy man. *Clin Sci (Lond)*. 1986;71:651–656.
29. Eggert P. What's new in enuresis? *Acta Paediatr Taiwan*. 2002;43:6–9.
30. Robertson GL. Physiology of ADH secretion. *Kidney Int Suppl*. 1987;21:S20–S26.
31. Robson WL. Current management of nocturnal enuresis. *Curr Opin Urol*. 2008;18:425–430.
32. Norgaard JP, van Gool JD, Hjalmas K, Djurhuus JC, Hellstrom AL. Standardization and definitions in lower urinary tract dysfunction in children. International Children's Continence Society. *Br J Urol*. 1998;81(suppl 3):1–16.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-05-15 via free access