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A Cephalometric Comparison of Pharynx and Soft palate in Subjects treated with Rapid Maxillary Expansion

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To my parent, for their love, understanding and encouragement

and

to patients from whom I have learned so much

TABLE OF CONTENTS

1. INTRODUCTION

1.1. Background

Rapid Maxillary Expansion (RME) has been a clinically accepted treatment used by orthodontists for over 100 years. It is applicable for correcting posterior cross-bites (unilateral and bilateral), narrow maxillary arches, mandibular functional shift, and dental crowding. RME is performed in two phases. The first phase is an active expansion of the maxilla by means of midpalatal sutural expansion; the second phase of retention allows for calcification of the midpalatal suture. The primary goal of RME is to maximize the orthopedic movement of maxilla and minimize orthodontic movement of teeth. Expansion of the teeth occurs as a combination of bodily tooth movement and tipping.

This procedure was first introduced by Angell [5] in 1860, and since then, various appliances have been developed to expand the maxilla, ranging from the basic removable appliances with a midline screw attached to the banded or bonded expansion devices, to fixed appliances in order to achieve widening of the maxillary arch. The technique has been through periods of popularity and decline and was reintroduced during the 1960s by Haas [38-39].

Three treatment alternatives are available for this purpose: rapid maxillary expansion (RME), slow maxillary expansion (SME), and surgical-assisted RME (SARME) or a segmental Le Fort I-Type osteotomy with expansion (LFI-E) [11,60]. RME and SME are indicated for growing patients, whereas SARME is the alternative treatment selected for non-growing adolescents and young adult patients.

It has been noted that RME causes not only dentofacial changes but also craniofacial structural changes [39,40]. The effects of RME are not limited to the upper jaw because the maxilla is connected with many other bones [14]. RME separates the external walls of the nasal cavity laterally and causes lowering of the palatal vault and straightening of the nasal septum [39-40,48]. This remodeling decreases nasal resistance, increases internal capacity, and improves breathing[48,115].

1.2 Objectives of the Study

This study was designed for specific purposes:

1.2.1 To assess the cephalometric variables of nasopharynx, oropharynx and laryngopharynx including the soft palate among male and female subjects with different anteroposterior jaw relationships, orthognathic and retrognathic, treated with a rapid maxillary expander, a Hyrax-Type expansion appliance, in two dimensions.

1.2.2 To assess the cephalometric variables of the pharyngeal area in the control group.

1.2.3 To compare the variables of both groups in order to investigate the pharyngeal area.

1.3 Statement of the Problem

RME treats upper-jaw constriction or maxillary width deficiency. The question is whether RME treatment could improve:

1. Nasal respiration by increasing the upper airway compared with the control group and;
2. Oropharyngeal and laryngopharyngeal areas of orthognathic and retrognathic subjects in anteroposterior view.

3. Oropharyngeal and laryngopharyngeal areas which may be coincident with spontaneous anterior movement of the mandible in retrognathic subjects.

1.4 Significance of the Problem

RME of the midpalatal suture has been used for more than a century as a treatment for maxillary constriction. Although there is an abundance of publications on this subject in the dental literature, virtually all of it concerns reactions within the maxillary complex or nasopharyngeal area. At the present time, very little is mentioned about the response of oropharyngeal and laryngopharygeal areas to RME, even though these areas are regions of interest in sleep disordered breathing (SDB) patients or obstructive sleep apnea syndrome (OSAS) having characteristics typical of the retrognathic mandible and narrow oropharyngeal area.

1.5 Hypothesis (Null)

1.5.1 There is no difference in the effect on the pharyngeal area between pre- and post-treatment within subgroups, which was deduced from gender difference and then classified into orthognathic and retrognathic, treated with the Rapid Maxillary Expander, as a result of the Wilcoxon Signed Ranks Test.

1.5.2 There is no difference in the effect on the pharyngeal area of the control group between the first and second observation within subgroups of gender and facial type, as a result of the Wilcoxon Signed Ranks Test.

1.5.3 There is no difference in the effect on the pharyngeal area between subgroups of subjects treated with Rapid Maxillary Expander, as a result of the Mann-Whitney *U*-test.

1.5.4 There is no difference in the effect on the pharyngeal area between the different subgroups of the control group, as a result of the Mann-Whitney *U*-test.

1.5.5 There is no significant difference in the effect on the pharyngeal area between subjects treated with Rapid Maxillary Expander and control groups, as a result of the Mann-Whitney *U*-test.

1.6 Scope and Delimitation

The research is limited to:

1.6.1 Patients with skeletal maxillary constriction and no observable craniofacial abnormalities.

1.6.2 All patients that have never had previous orthopaedic treatment.

1.6.3 The cephalometric radiographs of pretreatment have distinguishable anatomical landmarks used for orthodontic diagnostic purpose and the second cephalograms are from the annual follow-up of the treatment.

1.6.4 The control group comprises patients seen in the orthodontic department of the Ludwig Maximilian University of Munich

1.6.5 All the lateral cephalometric radiographs are traced and measured by only one investigator.

1.7 Definition of Terms

Cephalometric radiograph (Cephalogram):

A radiograph of the head obtained under standardized conditions, introduced simultaneously in the United States and Germany (1931), by B.H. Broadbent and H. Hofrath, respectively [24].

Lateral cephalometric radiograph:

A radiograph of the head, taken with the x-ray beam perpendicular to the patient's sagittal plane. The beam most commonly enters on the patient's right side, with the film cassette adjacent to the patient's left side (so that the patient's head is oriented to the right on the radiograph), but the reverse convention is also used [24].

Orthognathic :

A facial type with normal anteroposterior relationships: the relationship of the maxilla and mandible in relation to each other and to the cranial base [24].

Rethognatic:

A term used to indicate the situation in which the mandible or the maxilla is retrusive (in the anteroposterior plane) in relation to other cranial or facial structures, due to smaller size and/or more posterior position. In the classification of facial types, the term is used to denote a retrognathic mandible [24].

Prognathic:

A term used to indicate the situation in which the mandible or the maxilla is protrusive (in the anteroposterior plane) in relation to other cranial or facial structures, due to its relatively larger size and/or more anterior position. In the classification of facial types, the term is used to denote a prognathic mandible [24].

Pharynx (pharynxes, pharynges):

The throat, specifically, a tubular structure about 13 cm long that extends from the base of the skull to the esophagus and is situated just in front of the cervical vertebrae. The pharynx serves as a passway for the respiratory and digestive tracts and changes shape to allow the formation of various vowel sounds. The pharynx is composed of muscle, lined with mucous membrane, and is divided into the nasopharynx the oropharynx and the laryngopharynx. It contains the opening of the right and the left auditory tubes, the openings of the two posterior nares, the fauces, the opening into the larynx, and the opening into the esophagus. It also contains the pharyngeal tonsils, the palatine tonsils, and the lingual tonsils [3].

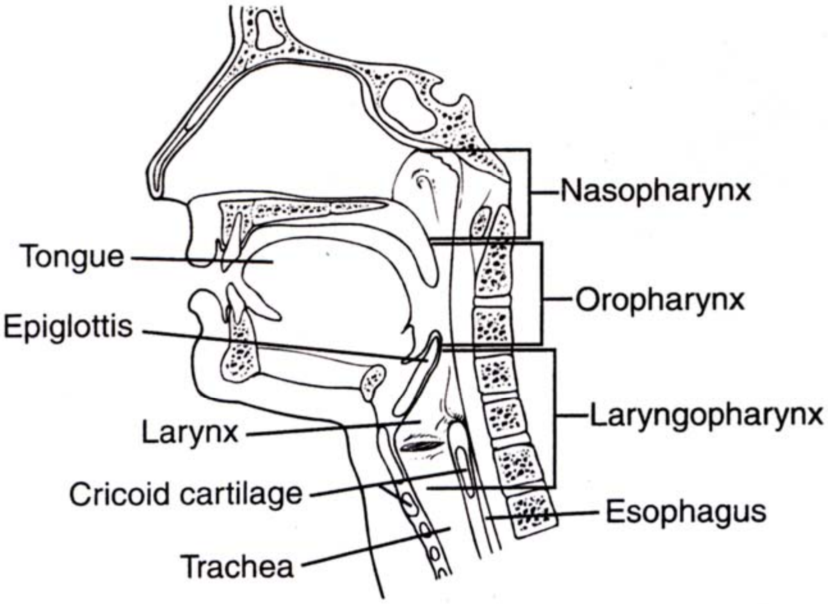


Fig.1. Pharynx, divided into the nasopharynx, oropharynx, and laryhgopharynx.
(From Anderson, DM Dorland's Illustrated Medical Dictionary)

Nasopharynx:

The uppermost of the three regions of throat, or pharynx, situated behind the nose and extending from the posterior wall of the nasopharynx; opposite the posterior nares, are the pharyngeal tonsils. Swollen or enlarged pharyngeal tonsils can fill the space behind the posterior nares and may completely block the passage of air from the nose into the throat [3].

Oropharynx:

One of the three anatomical divisions of the pharynx which extends behind the mouth from the soft palate above to the level of the hyoid bone below and contains the palatine tonsils and the lingual tonsils [3].

Laryngopharynx:

One of the three regions of the throat extending from the hyoid bone to the esophagus [3].

Adenoid:.

A glandular mass of lymphatic tissue, present in the nasopharyngeal area[3].

Adenoids:

Masses of lymphoid tissue in the nasopharynx which classically have been associated with airway obstruction and mouth breathing [24].

Adenoid facies:

A long-standing descriptive term implying a relationship between mouth breathing (due to enlarged adenoids) and the development of malocclusion through altered function. The classic description of “adenoid facies” consists of narrow nasal and alar width, hypotonic musculature, “dull” or vacant” facial expression and lips separated at rest [24].

Waldeyer’s throat ring (from Waldeyer-Heartz, German anatomist):

The palatine, pharyngeal, and lingual tonsils encircle the pharynx. They are also called the lymphoid ring, or the tonsillar ring [3].

2. LITERATURE REVIEW

2.1 Background to Maxillary Expansion

Buccolingual discrepancies or posterior crossbite is one of the most commonly occurring phenomena, noteworthy in transversal malocclusion, generally accompanied with upper dental arch crowding. Aetiological causes of this problem can be either genetic or environmental [97].

The concept of widening the maxillary dental arch by orthopedic force was first reported in the dental literature by Angell [5] in 1860. He described an expansion appliance which was activated by a central screw. The patient was instructed to turn the screw periodically. He stated that at the end of two weeks the maxillae were separated by development of a space between the maxillary central incisors. According to Derichsweiler [26], Eyssel —a German rhinologist from Kassel — raised the question at the Berlin Natural Philosophical Society meeting in 1886 whether it was possible to determinate the narrowing of the nasal cavity by the way of a jaw orthopedic treatment connectedly to palate narrowness and abnormal tooth position.

The rapid maxillary expansion (RME) was revisited by Goddard [34] in 1893 due to the assumed positive effects on nasal permeability [17,18,32,59,83,119]. In 1903, Brown [17] described cases which expanded the maxillary and improved in the cartilaginous portions of the nose. In 1909, he [18] investigated maxillary expansion in a cadaver and found that there was a separation of nasal bones through the points of attachment following orthodontic expansion of the maxillary arch, which resulted in an immediate increase of space within the nares. Wright [122] presented patients with nasal deformity with a dental irregularity. These patients enjoyed improved breathing and nasal structure after maxillary expansion. Meanwhile

Ketcham [56] reported that he had failed to open the maxillary midpalatal suture in living subjects and in a cadaver of a 5-year-old child.

In 1938, Brodie *et al.* [15] presented cephalometric analysis, described by Broadbent, which renewed interest in expansion of the maxilla and which has resulted in numerous studies since the 1960s. Brown [17-18], Derichsweiler [26-28], Sternbach *et al.* [99], Haas [38-41], Isaacson and Ingram [50], and Wertz [119-121] advocated splitting of the midpalatal suture to widen narrow maxillary arches.

In 1965, Cleall [21] studied the rapid expansion in Macacus rhesus monkeys and found that the final animal sacrifices three months out of the retention appliance after three months of expansion and three months of retention, showed the midpalatal suture to be well organized and essentially histological normal. The resultant bony defect was rapidly and completely healed with the restoration of the normally growing suture.

RME appliances showed the best examples of true orthopaedics (Figure 2, 3) in that changes were produced primarily in the underlying structures. The most frequent indications of RME treatment in the deciduous and mixed dentitions is that they have transversal discrepancies (Figure 4, 5) that result in either unilateral or bilateral posteriors which constricted skeletal (narrow upper dental arch or wide lower dental arch), dentition or induced both effects; sagittal discrepancies in construction of the maxilla related to the mandible in skeletal Class II or III malocclusions; and in cleft lip and palate with collapsed maxillae. However, RME is used much more frequently for other purposes, including the correct breathing mode [17-18,26], increasing available arch length as well as correcting the axis inclinations of the upper posterior teeth [1].

Fig.2. Maxillary occlusal view before treatment with RME

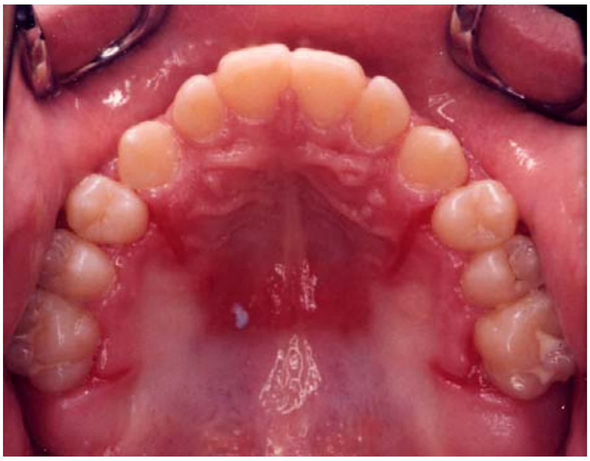


Fig.3. Maxillary occlusal view after retention period

Crowding of the dentition due to tooth size-arch length deficiency is the most common form of malocclusion treated by orthodontists [95]. Angle [6] advocated preserving the full complement of teeth; this became the dominant treatment philosophy for many years. In 1944, Tweed [110] presented his work and advocated positioning the mandibular incisors upright over basal bone and argued that expansion of dental units off basal bone led to instability; subsequently, the pendulum swung toward extraction during the 1950s. By the 1980s, the current trend in orthodontics had shifted towards the principles of dentofacial orthopaedics and non-extraction treatment modalities as orthodontists began using appliances and new technologies to increase arch length and width, making it easier to treat crowded dentitions without extractions. Adkins and co-workers [1] found that RME produced an increase in the maxillary arch perimeter at the rate of approximately 0.7 times the change in first premolar width. Whilst McNamara [82] stated that the maxillary arch with a transpalatal width of 36 to 39 mm could serve a dentition of average size without crowding or spacing. RME can also be used in the initial preparation of a patient for functional jaw orthopedics, facial mask therapy, or orthognathic surgery.

Fig.4. Frontal view before treatment with RME

Fig.5. Frontal view after retention period

RME treatments were reported to be clinically effective for expanding the maxillary arch [1,22,39-42,81,86,120]. Haas [42] evaluated the stability of RME treatment and demonstrated "totally stable 4 and 5 mm interchanging expansions in the lower arch and upper buckle teeth expanded 9 to 12 mm with the expansion remaining absolutely stable many years out of retention", while other clinical and histological studies reported relapse [47,69], root resorption [8,62-63,87-88], microtrauma of the temporomandibular joint, and microfractures at the midpalatal suture.

2.2 Rapid Maxillary Expander

Maxillary constriction can be corrected with slow maxillary expansion (SME), rapid maxillary expansion (RME), and surgically assisted rapid maxillary expansion (SARME). SME is indicated for very mild lateral discrepancies. Currently used SME devices are the acrylic plate (Figure 6) and the quad-helix appliance.

Fig. 6. Acrylic Maxillary Expander with Fan Type Screw

Two of the most popular palatal expanders, Haas and Hyrax types, are fixed appliances. The Haas type is the fixed split acrylic appliance, which is tissue-borne with bands on the first molars and premolars and manipulated by a jackscrew. This type was introduced by Derichsweiler [26] and advocated by Haas [39]. In 1961, Haas [39] stressed the importance of applying a more parallel expansion force on the maxillary halves by using a tissue-borne fixed split acrylic appliance, because most of the expansion force was exerted on the base of the bone and alveolar process rather than on the teeth. On the other hand, Alpern and Yurosko [2] found necrosis of palatal soft tissue due to tissue impingement between the palatal acrylic of this type of appliance and introduced the RME bite-plane or acrylic splint RME appliance (Figure 7). This appliance has the additional advantage for patients with steep mandibular plane angles, by acting as a posterior bite block to prevent the extrusion of posterior teeth [98].

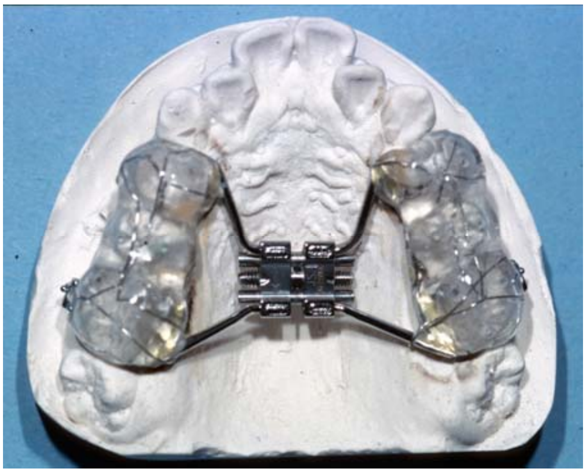


Fig. 7. An acrylic splint rapid maxillary expansion appliance. The occlusal coverage of acrylic produces a posterior bite block effect on the vertical dimension.

The Hyrax type (Figure 8), a tooth-borne device, consists of a metal framework that stands at a distance from the palate, the expansion screw that is located in the middle of the palatal region and in closed proximity to the palatal contour. Hyrax expanders are more popular because they are easy to clean and fabricate, and cause less speech interference.

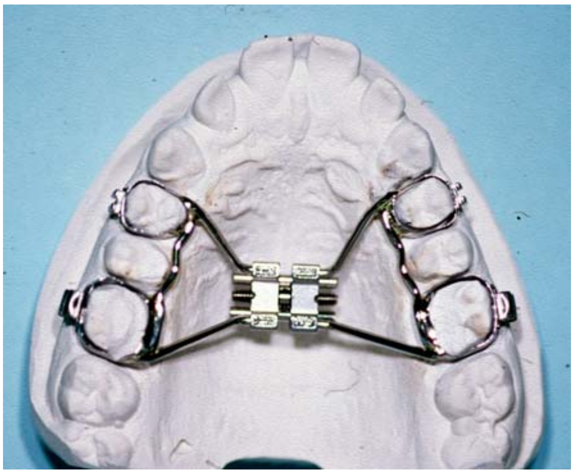


Fig. 8 Hyrax-Type expansion appliance

The Polyclinic for Orthodontics at Ludwig Maximilian University, Munich, normally used the Hyrax-type or modified Hyrax-type expander (Figure 8 and 9). Lamparski *et al.* [61] found that the 2-point appliance produced similar effects on the midpalatal suture and dentition, as did the 4-point appliance.

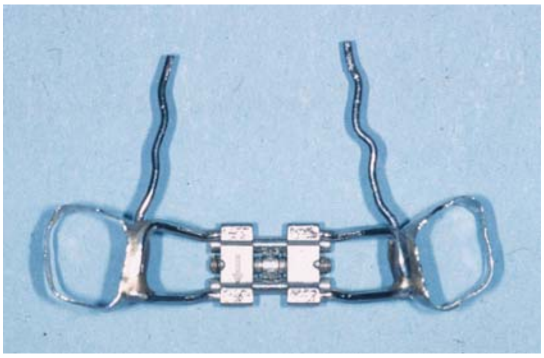


Fig. 9 Modified Hyrax-Type expansion appliance

2.3 Effects of RME on craniofacial structures.

Even though the prime objective of RME is to correct transverse deficiencies of the maxillary arch, its effects are not limited to the upper jaw. The maxilla is connected with 10 other bones of the craniofacial complex; therefore RME may directly or indirectly affect any one or more of these structures. These may include the mandible, nasal cavity, pharyngeal structures, temporomandibular joint, middle ear, zygomatic bones, and pterygoid process of the sphenoid bone [14,51]. (Figure 10.)

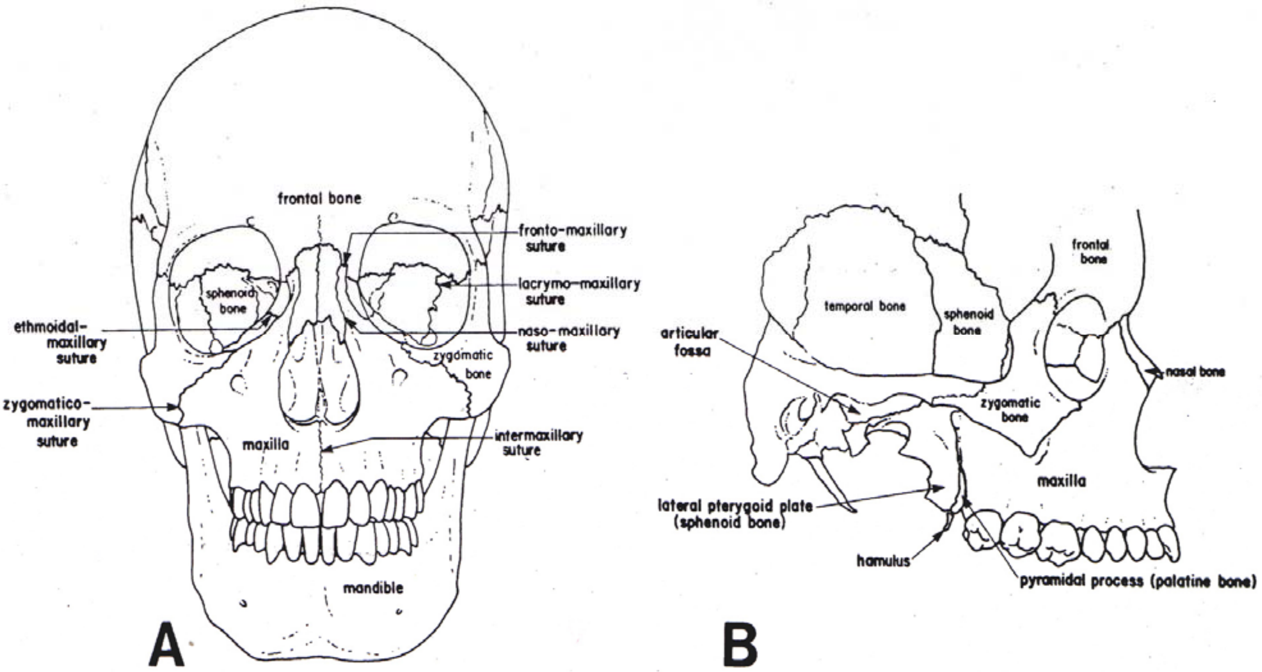


Fig. 10. The bony articulation of the maxillary. A, Frontal view. B, Lateral view
(From Bishara, SE. and Staley, RN. Am. J. Orthod. Dentofac. Orthop. 1987;91:6)

RME occurs when the appliance compresses the lateral force to the periodontal ligament, the posterior maxillary teeth and the alveolar process, and exceeds the limits needed for orthodontic tooth movement. It acts as an orthopedic force to separate the maxillary halves, tip the anchor teeth, and gradually open the midpalatal suture [39-40]. The force delivered by activation of the jackscrew surpasses the sutural resistance limit and splits not only the intermaxillary suture but also the circumzygomatic and circummaxillary suture systems. [51,91,99] Generally, RME appliances generate forces of 3 - 10 pounds by single turns of the jackscrew at the palate [50]. Zimring and Isaacson [123] reported that the residual loads on the appliance at the end of the expansion phase of treatment were shown to entirely dissipate during 5 - 7 weeks periods.

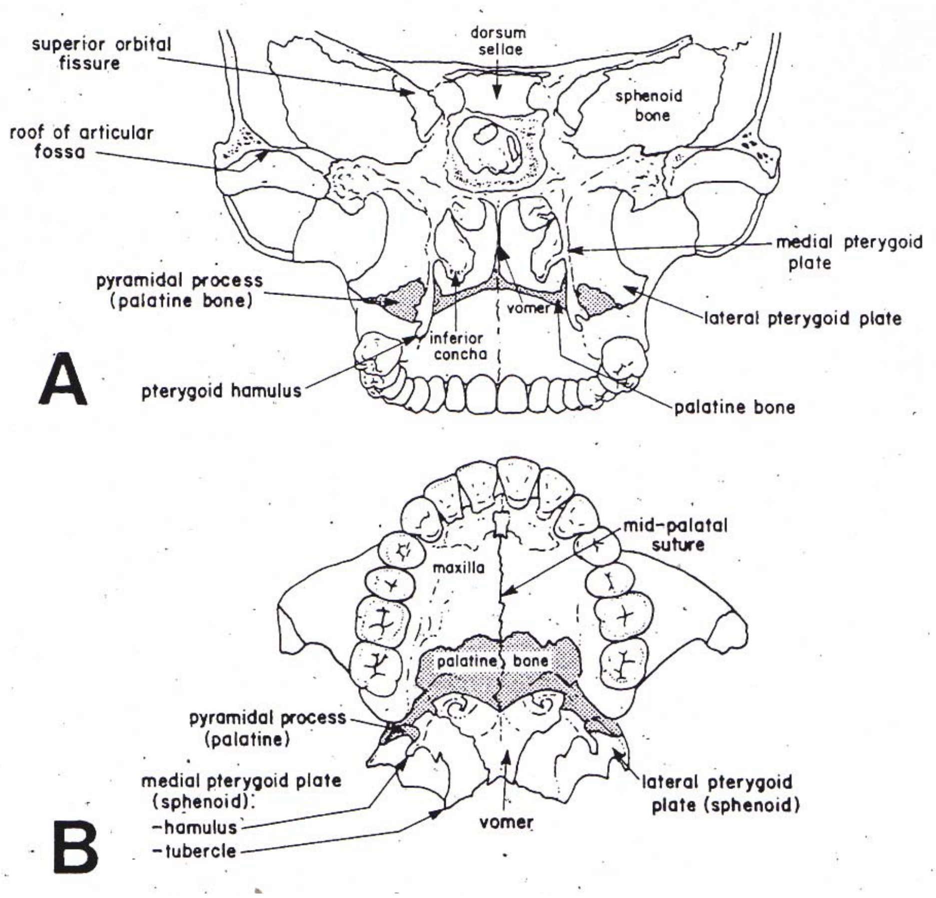


Fig. 11. Posterior (A) and inferior (B) view of the maxillae
(From Bishara, SE. and Staley, RN. Am. J. Orthod. Dentofac. Orthop. 1987;91:8)

Sagittal View: Through this sutural splitting, the maxilla was incited to displace itself downward and forward, with a rotation of the maxillary components in both the horizontal and frontal planes [20,25,39-41,120]. The downward displacement of the maxilla had a direct effect in the posterior rotation of the mandible when related to the anterior cranial base, due to the extrusion of the upper molars and the outward inclination of the upper alveolar process [25,120]. The mandible posterior rotation[20,40-41,120] induced other alterations such as opening of the bite, occlusal plane inclination, increase in the mandibular angle, and a downward and backward displacement of mandible. RME resulted in an increase in the vertical dimensions of the face because of the maxillary and mandibular downward and backward rotation. This increase was noticed in the:

(1) upper facial height (N-Sp') as a result of the downward displacement of the maxillae,

(2) lower facial height (Sp'-Gn) as a result of the mandibular rotation and downward displacement of both the maxilla and upper teeth,

(3) total anterior facial height (N-Gn) because of the rotation of both the maxilla and the mandible.

Occlusal View: The Wertz [120] study of three dry skulls, one adult and two in the mixed dentition phase also indicated that the shape of the anteroposterior palatal separation was nonparallel in all three skulls. An examination of occlusal films [119-120] showed that the opening of the midpalatal suture extends through the horizontal plates of the palatine bones. Sutural widening was greatest at Sn and tapered towards Pm.

Frontal View: the maxillary suture was found to separate vertically by inferior progression in a nonparallel manner [39-40,120]. The separation was pyramidal in shape and the greatest degree of widening was at the base of the oral side of the bone. The maxillary halves arced laterally, with the fulcrum located close to the maxillofrontal suture [120].

During the period following the active expansion of the appliance, a mesial tipping of the maxillary central and lateral incisors is usually observed [39-41]. In 1961, Haas[39] found that uprighting of the lower posterior teeth took place during the post-expansion period because of the redirection of occlusal force that confirmed by the results of Adkin and co-worker [1].

Haas [39] stated that half of his patients being treated with a RME appliance said that they felt the sensation of pressure in the region of the zygomaticomaxillary. Derichsweiler [26] and Haas [39] thought that displacement of the bones adjacent to the maxilla was limited. Haas believed that the reason the maxillae separated from each other in a tipping instead of parallel movement might be the buttressing effect of the zygomatic arches, the pterygoid and zygomatic process of the sphenoid bone, and the palatine bone. Haas [41] explained that the downward and forward movement of the maxilla during RME occurred because of the location of the maxillocranial sutures. Isaacson and Ingram [50], Zimring and Isaacson [123], Biederman and Chem [12], Melsen [84], Wertz [120-121], and Timms [107] stated that the feasibility of using RME decreases with the increasing age of the patient. RME is best and most often accomplished in adolescent patients.

Gardner and Kronman [33], in a study of RME in rhesus monkeys, found that the lambdoid, parietal and midsagittal sutures of the cranium showed evidence of disorientation, and in one animal these sutures split 1.5 mm. Therefore, it was inferred that RME could affect relatively remote structures and was not limited to the palate. Spheno-occipital synchondrosis opening might be a factor for the downward and forward movement of the maxilla. There was bone remodeling in the infratemporal region of the maxilla, the greater wing of the sphenoid, the zygomatic arch, the pterygoid plates, and the harmular process. In experiments on monkeys, the zygomaticotemporal, and midpalatal sutures, as well as all other maxillary articulations, were found to have an increased cellular activity when RME was used [33,99].

New bone was deposited in the area of expansion so that the integrity of the midpalatal suture was usually re-established after the palatal had been widened[38]. Korkhaus [59] and Ekström *et al.* [30] found that the mineral content within the suture rose rapidly during the first month after the completion of suture opening. In the bone, beside the suture, the mineral content decreased sharply during the first month, but returned to its initial level and the suture was very stable after retention for a period for 3 months. Ten Cate and co-worker [106] found that opening of the suture involved tissue injury followed by a proliferation of repair phenomena that ultimately led to regeneration of the suture.

Wertz [120] found that maxillary displacement during suture opening and recovery of displacement during the period of stabilization varied, so that only about 50 per cent of the cases demonstrated this post-treatment reaction when mandible displacement and subsequent recovery were usually noted. In 1977, he [121] stated that full recovery usually occurs during stabilization. Velázquez *et al.* [111] studied the effects of RME after three years of treatment and found skeletal changes resulting from RME that seemed to be compensated for, or corrected, in the course of orthodontic treatment. Nevertheless this compensation did not seem to be a major consequence or effect of treatment itself, but a function of it, which had allowed the growth to evolve normally, without great variations. The continuing changes would likely be a consequence of normal growth.

2.4 Relation between adenoids and nasopharynx

The pharynx is a muscular tube; it lies dorsal to the nasal cavity, the oral cavity, and the larynx. The nasopharyngeal area in humans is one of complexity, involving as it does structures concerned with the important functions of mastication, deglutition, respiration, olfaction, and speech. Each of these functions makes its own specific requirements and all of them must work synergistically at times. This area exhibits one of the widest ranges of various growth rate and function, whilst the maxilla must undergo around eighteen years for complete growth and development [102].

Adenoids are described as a hypertrophied state of the pharyngeal tonsils, which are located at the upper posterior wall of the nasopharynx and consist of the upper part of Waldeyer’s ring, which composes the pharyngeal (adenoid), palatine, and the lingual tonsils. Tonsils and adenoids are present at birth; they grow until the age of 5 and subsequently decrease in size to 10 years of age, whereas the size of the nasopharynx increases by age in children [71]. Hypertrophied adenoids are also associated with allergies that are quite common in children. There is the belief that an inflammatory response in the lymphoid tissue of the nasopharynx and oropharynx by the presence of Walderyer’s ring probably represents an important first line of defense in the fight against inhaled pathogenic agents. Children with, or for that matter without enlarged adenoids and tonsils, frequently develop airway infections, which will become manifest as recurrent or chronic sore throats, chronic sinusitis, and recurrent or persistent middle effusion.

The relationship between respiration function and craniofacial morphology has been interested and debated for more than a century [46,67,80,97]. The view among clinicians was that nasal airway impairment and nasal-oral breathing might lead to unfavorable facial growth and dental malocclusion [16,97].

Linder-Aronson [65] in a study of 162 children, consisting of 81 controls and 81 patients who were mouth breathers and who were diagnosed as requiring adenoidectomy, found that only 25% of them had adenoid facies or an adenoid type face while only 4% of a matched control group exhibited this phenomenon. He showed that children with nasopharyngeal obstruction, from hypertrophied adenoids more frequently present a deficiency in the upper arch, crossbite or a tendency to crossbite, retroclination of upper and lower incisors in relation to the base lines, a retrognathic mandible and longer total and lower anterior face height; they often hold the tongue low and have a tendency towards open bite compared to the control children. He stated that adenoids affected the mode of breathing, which then influences the individual’s dentition. The relationship between the size of the adenoids and that of the bony nasopharynx is important. Furthermore, due to nasal airway impairment which resulted in high nasal airflow resistance, the child was forced to switch to mouth breathing [65,68]. In 1979, Linder-Aronson [70] reported on a longitudinal study involving patients with nasal obstruction undergoing adenoidectomy who demonstrated a significant increase in nasal respiration, leading to a normalization of craniofacial changes.

On the other hand, there were several studies indicating that nasal airway obstruction had no predictable affect on dentofacial growth and that nasal-oral breathers tended to have the same incidence of malocclusion as nasal breathers[53]. In many samples, mouth breathing was self-correcting after puberty, through atrophy of hypertrophied pharyngeal and palatal lymphoid masses [79]. Concurrently, the rapid growth of the adolescent resulted in an increase in the size of the nasal and pharyngeal passages.

Contrary to the findings reported in the numerous studies noted above, there were opposing viewpoints that argued that the typical features described in the “long-face syndrome” and “adenoid facies” were the expression of an inherited factor, and that such entities could exist without the presence of inadequate airways. It was further suggested that nasal airway obstruction, and its associated mouth breathing, was secondary to, rather than being the primary cause of, a dentofacial deformity. Billing *et al.* [13] found that genetic factors had an influence on pharyngeal airway size and posterior pharyngeal wall thickness. In addition, it was pointed out that nasal resistance or impaired respiratory function and a variety of different facial patterns were found to be independent [57,117].

2.5 Relation between Rapid Maxillary Expansion and Upper Airway

The upper airway includes the nasal air passages, the nasopharynx and oropharynx, and the oral cavity and the laryngopharynx. Partial or complete obstruction of the nasal upper airway is a common complaint in young patients who usually present with excess restlessness at night and daytime sleepiness. These obstructions, increasing nasal resistance, may be due to the anatomical structure of bony nasal passages and conchae, as does septal deviation, polyps, pharyngeal tonsillar hypertrophy, and anatomical morphology as macroglossia, retrognathia, and micrognathia [96].

When the mouth is closed all air must flow through the nose. Similarly, when the nose is completely obstructed, all air flows through the mouth. However, there are many persons who combine nasal and oral breathing. The mode of oral or nasal breathing depends on the relative resistance of the nasal and oral airways. Although, the resistance of the oral and nasal passages depends on various factors, cross-sectional area of the nasal chamber and nasopharyngeal isthmus is the most important factor. This isthmus is bounded by the velum on its anterior side, the adenoid pad on its posterior side, and the lateral pharyngeal walls. Obviously, the size of the adenoid pad has the greatest effect on the cross-sectional size of the isthmus [114].

Warren *et al.* [116] studied the effect of age on nasal cross-sectional area and respiratory mode in 102 children between the ages of 6 and 15 years. He found that nasal airway size increased around 0.032 cm^2 each year. Mean nasal cross-sectional area increased from 0.21 ± 0.05 cm^2 at age 6 to 0.46 ± 0.15 cm^2 at age 14. The percentage of nasal breathing also increased with age.

In 1984, Warren *et al.* [114] demonstrated that in adults a nasal cross-sectional area of less than 0.4 cm^2 may represent an inadequate airway, and some oral breathing would be expected. This indicated that the size of adenoidal obstruction must be very large in order to affect airway resistance and probably cause predominant mouth breathing. If changes in facial morphology were to result from airway impairment, other factors such as large tonsils, long draping velum, and/or a large tongue were probably significant factors.

Controversy over the part of respiration in the cause of malocclusion had stimulated interest in the use of RME to enhance nasal respiration. The concept of maxillary expansion extended to decreased nasal resistance [29,44,48] was commonly held as the former studies suggested that nasal width and volume were obtained after maxillary expansion [17-18,28,39,41,59]. Wertz [119] concluded that there was advantage in using RME for the purpose of increasing nasal airway passage in patients with nasal airway obstruction where the stenosis positioned in the anterior-inferior portion of the nasal chambers and this was supported by Timms[108].

Hershey *et al.* [48], in his series of 17 patients treated by RME, found that RME corrected the crossbites of the subjects and concurrently provided an average reduction in nasal resistance of 45%. He concluded that RME was an effective method not only to expand the narrow maxilla but also to reduce nasal resistance from levels related to mouth breathing to levels compatible with normal nasal respiration. Furthermore, this study found that the reduction of nasal resistance accompanying maxillary expansion was substantial and was stable at least through the 3-month fixed-retention period. Hartgerink *et al.* [44] later reevaluated the patients after treatment with RME and found that the decrease in nasal resistance was stable one year after treatment.

Basciftci and co-worker [9] studied the effects of RME and SARME on nasopharyngeal area by using a digital planimeter on lateral cephalometric radiographs. Nasal cavity width was evaluated on postero-anterior radiographs. He found that there were no statistically significant differences between the groups. Following RME, there were increases in the width of the nasal floor near the midpalatal suture and nasal cavity. As the maxillary structures separated, the outer walls of the nasal cavity moved laterally resulting in an increase in internasal volume. Nasal resistance decreased whereas respiratory space increased in patients treated with RME.

Gray [36] reported that RME produced a change of over 80% from mouth to nose breathing and an improvement in respiratory infections, nasal allergy and asthma. Warren *et al.* [115] studied the effect of RME and SARME on nasal airway size and found that nasal cross-sectional area increased approximately 45% after the RME. Similarly, surgical expansion increased the minimal nasal cross-sectional area by approximately 55% postoperatively. However, nearly one third of the subjects in both groups did not improve enough to eliminate the possibility of essential mouth breathing. This finding suggested that maxillary expansion for airway purposes alone was not confirmed. Moreover Hartgerink *et al.* [44] in a group of 38 patients treated by RME and compared with a control group concluded that RME was not a predictable means of decreasing nasal resistance because of the highly variable individual response.

In 1989, Hartgerink and Vig [45] reported that no correlation was found between the amount of expansion and changes in nasal resistance and respiratory mode. Nasal resistance could only be determined with proper instrumentation and could not predict nasal airway impairment from a patient's face proportions and their lip posture at rest.

Numerous previous studies have attempted to investigate the problem by means of the rhinomanometric technique. Timms [108], using posterior rhinomanometry, recorded an average reduction of nasal resistance of 36.2% after palatal expansion, but he found that any significant correlation between resistance reductions and the delivered expansions was weak.

Buccheri [19] studied RME treatment in 24 children with mouth breathing and adenotonsillar hypertrophy (5-9 year of age) and found that there was an expansion of upper respiratory space that coincided with an improvement in nasal respiration. The increase in pharyngeal space and improvement in nasal breathing resulted from an enlargement of the pharyngeal space rather than a reduction in the size of the adenoid tissue.

2.6 Relation between RME, Retrognathic and OSAS or SDB

Obstructive sleep apnea syndrome (OSAS), which is one type of sleep disordered breathing (SDB) in patients, is a disorder characterized by repetitious partial and/or total obstruction of the upper airway during sleep. Certain anatomical and/or physiological factors contribute to OSA, including decreased upper airway dimensions, retrognathic position of both maxilla and mandible, increased lower facial height, and enlarged base of the tongue, decreased posterior airway space, elongated soft palate, and a low position of the hyoid bone [7,58,76-77,104]. Soft tissue factors can also predispose to OSA, for example tonsillar hyperthropy and obesity.

The main problem of OSA patients seems to be the narrowing of the airway space in the oropharynx area [103], as well as changes in the form of the tongue [73], but not of their naso- or hypopharyngeal airways, in the supine position compared with the upright position, while the oropharynx is narrower in the supine position [49].

Jonhston [54] found that the bony periphery of the nasopharynx remained stable during adulthood, whereas the anteroposterior depth of the nasopharyngeal space increased as a result of a reduction in thickness of posterior nasopharyngeal wall. The sagittal depth of the oropharynx posterior to the soft palate decreased with age. In addition, the soft palate length, its thickness and the vertical pharyngeal length increased. This indicated that the pharyngeal soft tissue still changed through adult life and with a tendency to increase to a longer and thicker soft palate and narrow oropharyngeal area.

Since 1980, there have been approximately 150 articles describing various oral devices used in the treatment of sleep disorders that have been published [112]. It is generally accepted that treatment of OSA with oral appliances is a variable option for some patients resulting in varying degrees of short- and long-term improvement and sometimes with side effects. Mandibular advancement devices also alter the position of the hyoid and increase the posterior airway space. Soft palate or uvula lifters reduce soft tissue vibrations that result in snoring. Surgical advancement of the maxillomandibular complex has also been proposed to treat certain OAS cases with retrognathic facial structures [112].

There has been a significant increase in the use of RME for transverse maxillary arch deficiencies especially for patients having respiratory problems. The previous studies found that widening the maxilla arch often led to a spontaneous forward posturing of the mandible to correct occlusion during the retention period [59, 81-82]. The spontaneous Class II correction during the 6 to 12 months of the retention period may be found in mild to moderate Class II patients [81], which was confirmed by Lima Filho and co-worker [64]. This phenomenon will automatically increase the sagittal depth of the oropharyngeal area and may improve facial type from retrognathic to orthognatic.

3. METHODOLOGY

3.1 Study design

This investigation is a retrospective study.

3.2 Study population

Seventy one lateral cephalometric radiographs were randomly selected from the record section of the department of Orthodontics of the Ludwig Maximilian University, Munich, according to the following criteria:

3.2.1 Patient with skeletal maxillary constriction
3.2.2 No observable craniofacial abnormalities
3.2.3 No previous orthopaedic treatment
3.2.4 First permanent molars, primary molars or premolars are in occlusion
3.2.5 Each lateral cephalometric radiograph is taken with teeth in centric occlusion

A total of 71 patients treated with a banded RME appliance were divided into male and female groups. Each group was divided into two subgroups according to skeletal relationship, namely, retrognathic and orthognathic. The control group was composed of 47 subjects, 22 females with 12 orthognathic and 10 retrognathic and 25 males with 13 orthognathic and 12 retrognathic. (Table 1).

Table 1. Subject population

Subject	***Female***	***Male***	***Total***
Control			
Orthognathic	***12***	***13***	***25***
Retrognathic	***10***	***12***	***22***
Total	***22***	***25***	***47***
RME			
Orthognathic	***12***	***18***	***30***
Retrognathic	***27***	***14***	***31***
Total	***39***	***32***	***71***

All the lateral cephalometric radiographs were taken using a standardized technique, with the tooth in centric occlusion, with the lips relaxed. The subjects stood with the sagittal plane parallel to the film and the bilateral ear rods gently inserted into the external auditory meatus to stabilize the head position during exposure. The head was adjusted so that the Frankfurt horizontal plane was parallel to the floor.

Cephalometric radiographs were taken using a Siemens Orthopos machine (Sirona Dental Systems GmbH, Federal Republic of Germany. 90 kV/12 mA), by means of a standardized technique and a fixed anode-midsagittal plane distance. The films used were Kodak Ortho-G 24x30 (Eastman Kodak Company, Rochester, US). The peak voltage was adjusted to optimize the contrast of both hard and soft tissues. All films were processed under standardized conditions.

Distances between the anode, the midsagittal plane and the film are set at 150 centimeters and 15 centimeters respectively, giving a magnification factor of 10 percent linear enlargement at the median plane. Measurements were not corrected for radiographic enlargement.

Two lateral cephalometric radiographs for each patient were taken for each patient before and after the maxillary expansion treatment.

3.3 Methods

3.3.1 Orthodontic treatment

The midpalatal suture expansion was obtained using a Hyrax-type rapid maxillary expander, which was cemented to the first molars and first deciduous molar or first premolar or canine. These patients were asked to turn the screw two or three quarter-turns per day (0.25 mm per quarter). After adequate expansion was achieved, the appliance was left in place for approximately 6 months as a retention device, then removed, and the necessary orthodontic treatment completed.

3.3.2 Radiologic evaluation

All the lateral cephalometric radiographs were hand-traced using 0.35 mm lead 2H pencil on 0.003 mm matte acetate tracing paper (Dentaurum, Federal Republic of Germany) in a darkened room with extraneous light from the viewing box (Maier, GmbH, Federal Republic of Germany) blocked out. All tracings were performed by one investigator and were measured with a digital caliper (Mitutoyo (U.K.) Ltd. Model CD-15D) calibrated to 0.01 mm (Figure 12).

Fig.12. Lateral cephalometric radiograph, acetate paper, three angle ruler, digital calliper, Tracing-template 3M®, pencil and rubber

3.3.3 Cephalometric reference points

Lateral skull radiographs were traced on acetate paper and 16 hard and soft tissue cephalometric points were registered (Figure 13) yielding 10 linear measurements (Figure 14).

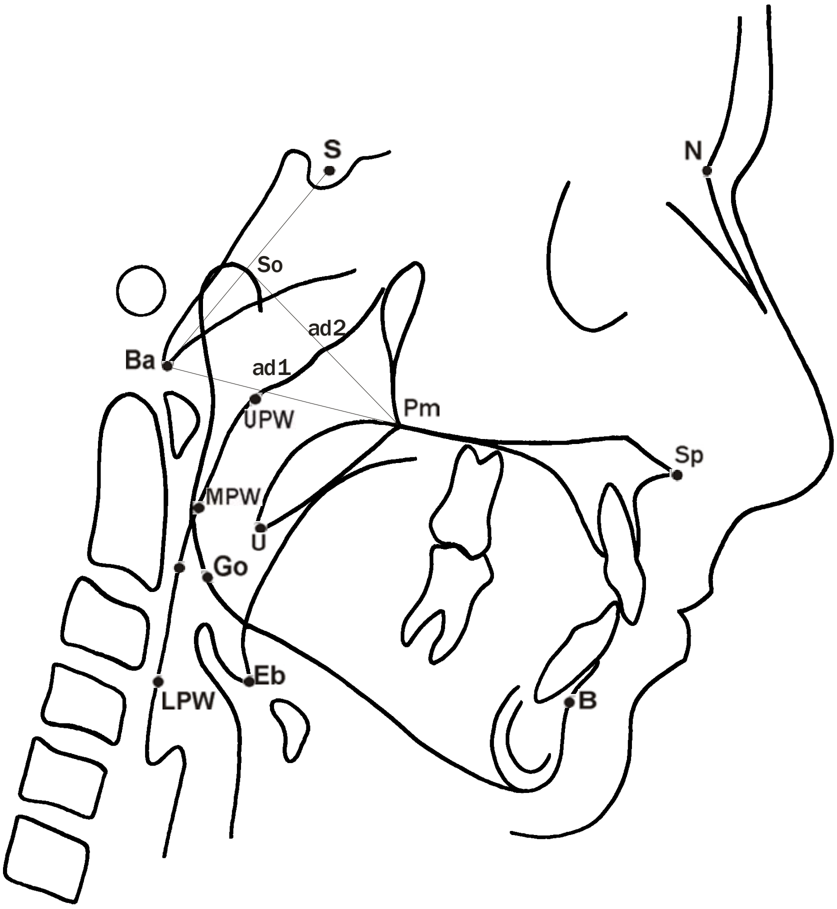


Fig.13. Diagrammatic representation of anatomic points

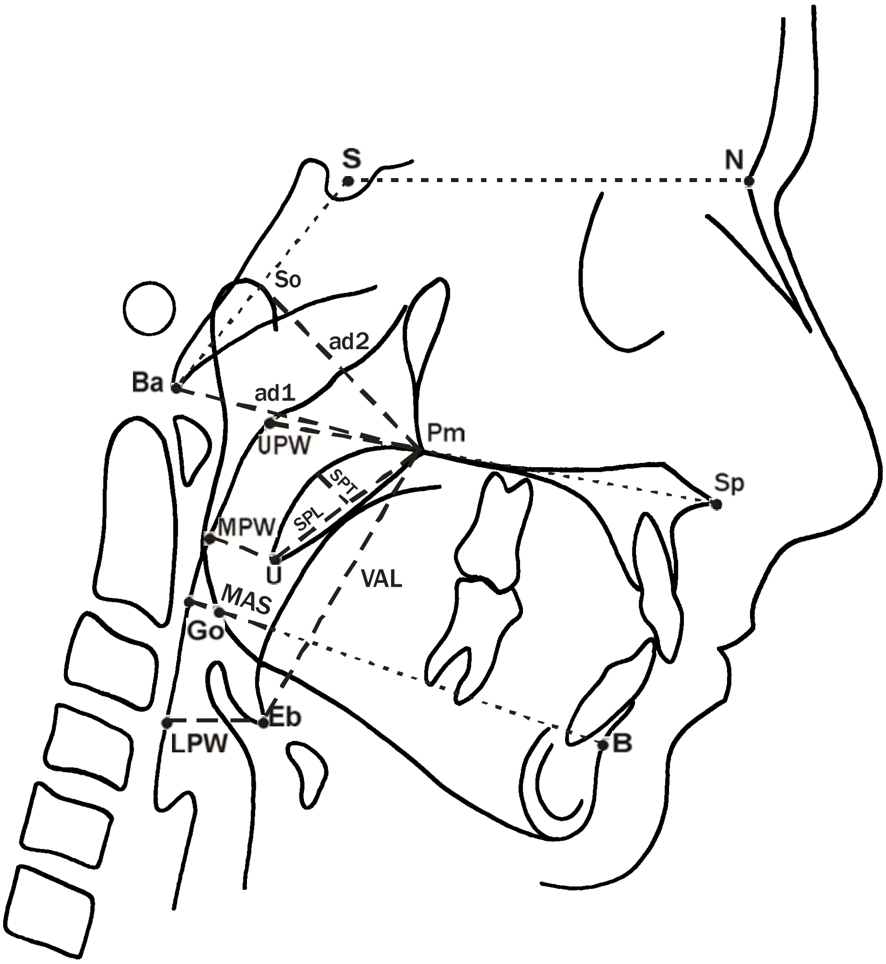


Fig.14. Diagrammatic representation of landmarks and reference lines

3.3.3.1 Craniofacial skeletal reference points used in the study

The definitions of the cephalometric landmarks, lines or planes, and measurements used in the study are as follows:

S = Sella:
The geometric center of the pituitary fossa (Sella turcica), determined by inspection - a constructed point in the midsagittal plane.

N = Nasion:
The intersection of the internasal and frontonasal sutures, in the midsagittal plane.
(the most anterior point of the frontonasal suture)

Ba = Basion:
The most anterior inferior point on the margin of the foramen magnum, in the midsagittal plane. It can be located by following the image of the slope of the occipital bone to its posterior limit, superior to the dens of the axis.

Sp = Anterior nasal spine:
The tip of the bony anterior nasal spine at the inferior margin of the piriform aperture, in the midsagittal plane. It corresponds to the anthropological point acanthion and is often used to define the anterior end of the palatal plane (nasal floor).

Pm = Pterygomaxillary or Posterior nasal spine (PNS):
The most posterior point on the bony hard palate in the midsagittal plane; the meeting point between the inferior and the superior surfaces of the bony hard palate (nasal floor) at its posterior aspect. It can be located be extending the anterior wall of the pterygopalatine fossa inferiorly, until it intersects the floor of the nose.

So = Mid-point of distance sella-basion

B-point = Point B, Supramentale, sm:
The deepest (most posterior) midline point on the bony curvature of the anterior mandible, between the infradentale and pogonion.

Go = Gonion:
The most posterior inferior point on the outline of the angle of the mandible. It may be determined by inspection, or it can be constructed by bisecting the angle formed by the intersection of the mandibular plane and the ramal plane and by extending the bisector through the mandibular border.

3.3.3.2 Pharyngeal reference points used in the study

UPW = ***Upper pharyngeal wall:***
A point on the posterior pharyngeal wall identified by an extension of the palatal (Sp-Pm) plane; presenting the width of the oropharynx at level of Pm

MPW = ***Middle pharyngeal wall:***
A point on the posterior pharyngeal wall identified by drawing a line from U to the posterior pharyngeal wall parallel to Go-B line

LPW = ***Lower pharyngeal wall:***
A point on the posterior pharyngeal wall identified by an extension of a line through Eb drawn parallel to the SN plane

U = ***Tip of Uvula:***
The most postero-inferior point of the uvula

Eb = ***Base of Epiglottis:***
The deepest point of the epiglottis

ad1 = Intersection of the line Pm-Ba and the posterior nasopharyngeal wall

ad2 = Intersection of the line Pm-So and the posterior nasopharyngeal wall

3.3.3.3 Reference lines used in the study

NSL = ***Sella - Nasion line.***
A line joining points S and N, representing the anterior cranial base

NL = ***Nasal line, palatal plane, nasal floor, spinal plane***:
The line between the anterior nasal spine (Sp) and the pterygomxillary (Pm), representing the maxillary plane

Clivus-line = ***Sella-Basion line***
A line joining points S and N

3.3.4 Linear measurements used in the study (mm)

Twelve linear measurements are obtained from the cephalometric tracings by hand with the aid of a digital caliper. These parameters are used to compare the craniofacial morphology between treated subjects and the control group.

Nasopharyngeal parameters (mm): (Figure15 – 16)
Pm-ad2, ad2-So, Pm-ad1, ad1-Ba, Pm-Ba

Oropharyngeal parameters (mm): (Figure 17 – 21)
Pm-UPW, U-MPW, MAS, Eb-LMW, VAL

Soft palate parameters (mm): (Figure 22 – 23)
SPL, SPT

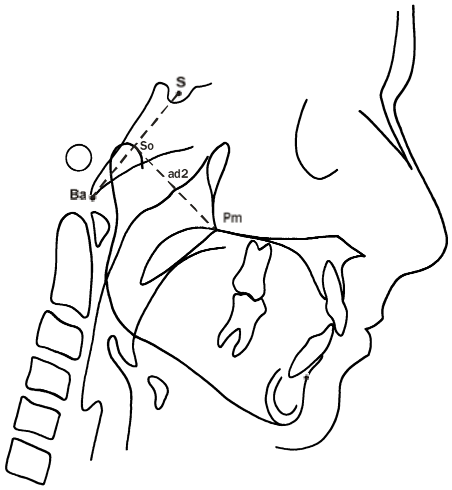


Fig.15. Pm-ad2, ad2-So

Pm-ad2 = **superior nasopharyngeal depth** upper sagittal depth of the nasophalyngeal airway; representing the upper nasopharyngeal airway space

ad2-So = thickness of the soft tissue on the superior nasopharynx;

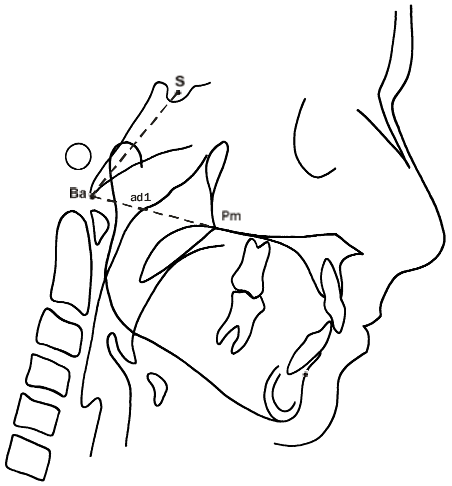


Fig.16. Pm-ad1, ad1-Ba, Pm-Ba

Pm-ad1 = **inferior nasopharyngeal depth** lower sagittal depth of the nasophalyngeal airway; representing the lower nasopharyngeal airway space

ad1-Ba = thickness of the soft tissue on the posterior nasopharyngeal wall;

Pm-Ba = sagittal depth of the bony nasopharynx, representing the horizontal position of Pm to Ba.

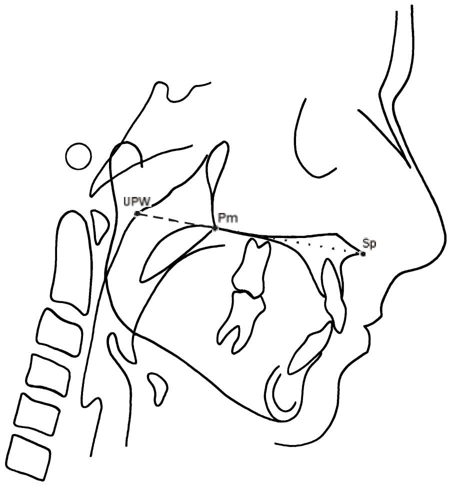
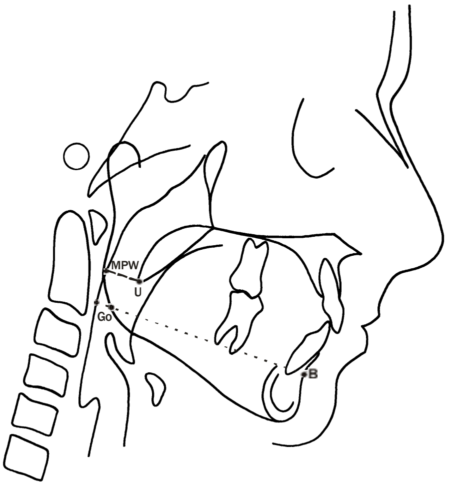


Fig.17. Pm-UPW

Pm-UPW = nasopharyngeal space



U-MPW = **Retropalatal airway space**

The width of airway along parallel line to Go-B line through U, representing the width of the oropharynx at the tip of the uvula

Fig.18. U-MPW

MAS = Middle airway space.

The width of airway behind the tongue along line to the Go-B line to the posterior pharyngeal wall; representing the middle airway space

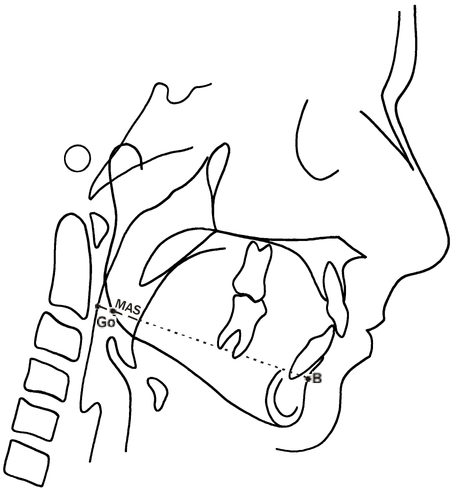
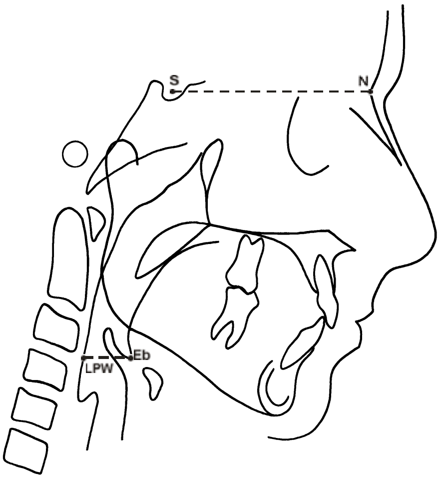


Fig.19. MAS



Eb-LPW = **hypopharyngeal space**

the distance from Eb to LPW, representing the laryngo-pharyngeal airway space

Fig.20. EB-LPW

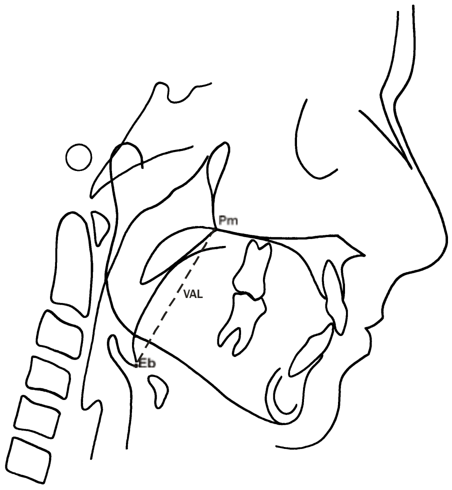


Fig.21. VAL

VAL = Vertical airway length:
distance between Pm and Eb

Fig.22. SPL

SPL = Soft palate length:
the distance from the uvula tip (U) to Pm

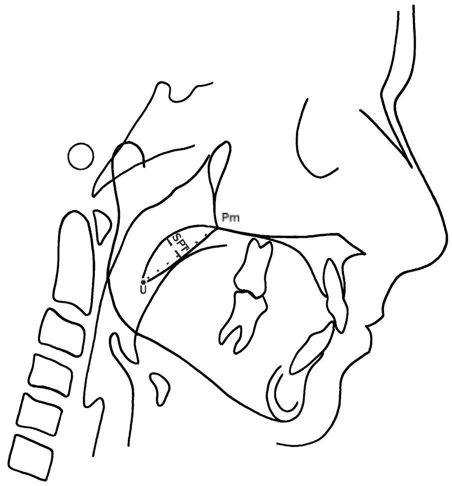


Fig.23. SPT

SPT = Soft palate thickness:
maximum thickness of soft palate measured on the line perpendicular to Pm-U line

3.4 Statistics

3.4.1 Method error

For the error measurements, 20 randomly selected cephalometric radiographs were traced and remeasured after a 2 week period by the same investigator. The method error was carried out using Dahlberg's formula [23],

$$\text{Error} = \sqrt{\frac{\sum d^2}{2N}}$$

where d represents the difference between the first and the second tracing measurements, and N denotes sample size, (the number of double measurements).

3.4.2 Statistical analysis

The results were calculated using SPSS® statistical software (version 11.0 for windows, SPSS Inc., Chicago, Illinois, USA)

Descriptive statistics including the mean, standard deviation and ranges for each group were computed.

The statistical analyses were performed to analyze and compare the changes in the cephalometric variables before and after treatment with rapid maxillary expansion using Wilcox Signed Ranks tests, with a significance level of $P < 0.05$.

The differences in cephalometric variables before and after treatment were compared to determine whether significant differences existed between the groups according to gender and facial type. A Mann-Whitney *U*-test with a significance level of $P < 0.05$ was performed to evaluate the significance of the following comparisons:

4. RESULTS

The patients were divided into two groups. The first group (control group) included 47 individuals, 22 females and 25 males. The females ranged in age from 7 years 1 month to 16 years 2 months at T1 and 8 years 8 months to 17 years 2 months at T2, The males ranged in age from 6 years 7 months to 14 years 1 month at T1 and 8 years 1 month to 16 years 2 months at T2. (Table 2) The second group (RME group) included 71 patients, 39 females and 32 males. The females ranged in age from 6 years 4 months to 15 years 6 months at pre-treatment (T1) and 7 years 9 months to 17 years 2 months at post-treatment (T2), and the males from 7 years to 15 years 9 months at T1 and 8 years 6 months to 17 years 2 months at T2.

Table 2: Shows the distribution, minimum age, maximum age, average ages, and the standard deviation of the female and male control and RME groups.

	N	Minimum (Year)	Maximum (Year)	Mean (Year)	Std. Deviation
Control - Female					
First Observation (T1)	22	7.08	16.17	9.75	1.97
Second Observation (T2)	22	8.67	17.17	11.48	1.91
Control - Male					
First Observation (T1)	25	6.42	14.08	10.11	2.25
Second Observation (T2)	25	8.08	16.17	11.59	2.29
RME - Female					
Pre-Treatment (T1)	39	6.33	15.50	9.88	2.21
Post-Treatment (T2)	39	7.75	17.17	11.31	2.16
RME - Male					
Pre-Treatment (T1)	32	7.00	15.75	10.49	2.21
Post-Treatment (T2)	32	8.50	17.17	11.99	2.20

The mean observation duration of the control group was 9.94 ± 2.11 years at T1 and 11.54 ± 2.10 at T2 while the mean observation duration of the RME group was 10.15 ± 2.22 years at T1 and 11.62 ± 2.19 years at T2. (Table 3)

Table 3: Shows the distribution, minimum age, maximum age, average ages, and standard deviation of the control and RME groups.

	N	**Minimum** (Year)	**Maximum** (Year)	**Mean** (Year)	**Std. Deviation**
Control					
First Observation (T1)	47	6.42	16.17	9.94	2.11
Second Observation (T2)	47	8.08	17.17	11.54	2.10
RME					
Pre-Treatment (T1)	71	6.33	15.75	10.15	2.22
Post-Treatment (T2)	71	7.75	17.17	11.62	2.19

The data was analyzed with SPSS® statistical software (version 11.0 for windows) for a between-case and within-case design. Descriptive statistics, including mean, standard deviation, minimum and maximum values were calculated for each of the cephalometric sets of measurements. The Wilcoxon Signed Ranks Test was used to analyze whether the changes in the cephalometric variables between pre- and post- treatment of the patients with RME and the first and second observations of the control group shown in Tables 5 to 12. Statistical significance was tested at *P* < .05. To compare the changes observed in both groups, a Mann-Whitney *U*-test was performed, as shown in Tables 13 to 24. Comparisons of the changes before and after (post-treatment – pretreatment), over time, between the orthognathic and retrognathic group were also accomplished by way of independent tests. This present study used a non-parametric test because the studied variables were not normally distributed.

4.1 Method error

The method error of the measurement was calculated using Dahlberg's method error formula. The results for errors for all the variables are shown in Table 4.

Table 4: Method error from 20 subjects calculating from Dahlberg's formula.

Variable	**N**	**Error** (mm)	**Error** (mm)
		Pre-treatment	***Post-treatment***
Nasopharyngeal airway			
Pm-ad2	20	0.19	0.17
ad2-So	20	0.17	0.28
Pm-ad1	20	0.20	0.18
ad1-Ba	20	0.23	0.23
Pm-Ba	20	0.23	0.24
Oropharyngeal airway			
Pm-UPW	20	0.22	0.23
U-MPW	20	0.18	0.18
MAS	20	0.17	0.17
Eb-LPW	20	0.21	0.21
VAL	20	0.15	0.20
Soft palate			
SPT	20	0.22	0.20
SPL	20	0.20	0.18

The range of error between the two registrations was 0.15 mm to 0.28 mm for linear measurements. Dahlberg's method does not take into account the size of the error in relation to the magnitude of the variable itself; however, the errors of the magnitude in this study are considered to be relatively low [10]. Clinically, 0.15 - 0.28 mm is not considered significant.

4.2 Growth effect on the control group

Table 5: Comparison of the first and second observation values (T2-T1) between and within the control in orthognathic females.

Variable	Control-Female-Orthognathic *n* =12						
	1^{st} Observation (T1) (mm)		2^{nd} Observation (T2) (mm)		Change with growth (T2-T1) (mm)		Wilcoxon Signed Ranks Test
	Mean	SD	Mean	SD	Mean	SD	
Nasopharyngeal airway							
Pm-ad2	14.7275	2.27332	16.2175	3.55968	1.4900	2.73670	.136
ad2-So	26.7083	2.11687	26.8517	2.63707	0.1433	3.02502	.695
Pm-ad1	19.5642	4.43930	20.3333	6.08850	0.7692	3.72774	.433
ad1-Ba	27.2767	3.34066	27.5783	4.47120	0.3017	4.33769	.875
Pm-Ba	46.8950	2.60373	48.0233	3.06040	1.1283	1.41608	.019*
Oropharyngeal airway							
Pm-UPW	22.5267	4.75174	22.6250	5.79300	0.0983	4.19604	.754
U-MPW	12.6133	2.15162	12.3808	3.27386	-0.2325	2.21866	.814
MAS	14.5017	3.62904	13.3117	3.55912	-1.1900	3.25179	.060
Eb-LPW	16.7508	1.88751	16.6650	2.44583	-0.0867	3.00801	.754
VAL	59.1100	3.70584	63.1725	5.62212	4.0625	3.62444	.006*
Soft palate							
SPT	9.5742	0.93548	9.8917	1.58864	0.3175	0.96622	.308
SPL	29.8567	3.46422	30.5783	4.24797	0.7217	1.24656	.055

SD, standard deviation.
* Significant values (*P*< .05).

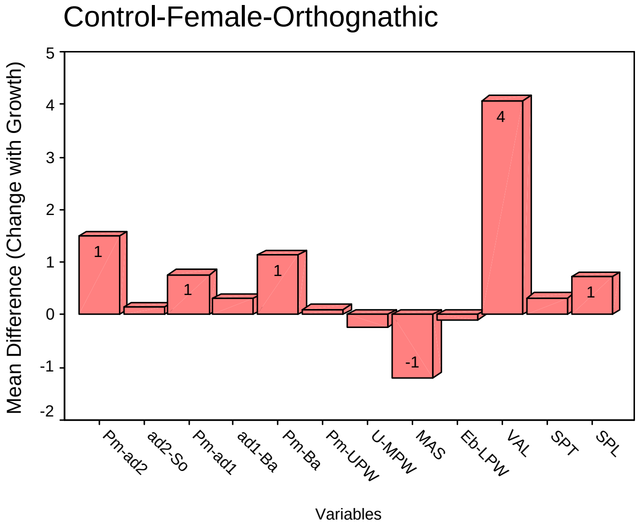


Fig.24. Mean difference change with growth in orthognathic females

<u>Results</u> Table 5, and Figure 24 show the comparison for each cephalometric measurement in consideration of the first and second observation in the control group and the Pm-Ba (nasopharynx) and the induced VAL (oropharynx) variable of statistically significant difference (*P* < 0.05).

Table 6: Comparison of the first and second observation values (T2-T1) between and within the control in retrognathic females.

	Control-Female-Retrognathic *n =10*						
Variable	***1st Observation (T1)*** *(mm)*		***2nd Observation (T2)*** *(mm)*		***Change with growth (T2-T1)*** *(mm)*		***Wilcoxon Signed Ranks Test***
	Mean	***SD***	***Mean***	***SD***	***Mean***	***SD***	
Nasopharyngeal airway							
Pm-ad2	16.9350	2.46244	17.8430	2.23887	0.9090	1.56281	.139
ad2-So	23.2550	2.11975	23.5010	2.22887	0.2460	1.39612	.575
Pm-ad1	23.8330	3.54481	23.4160	3.49637	-0.4170	2.36447	.508
ad1-Ba	23.0500	3.38744	24.3650	3.24769	1.3150	1.94502	.139
Pm-Ba	46.9400	2.93718	47.8470	2.91721	0.9070	1.11010	.028*
Oropharyngeal airway							
Pm-UPW	26.2580	3.34336	26.4200	2.50992	0.1620	2.33682	.959
U-MPW	10.0375	3.09786	10.7460	2.24030	0.7080	1.55046	.241
MAS	12.5170	4.03325	11.2690	3.86691	-1.2480	1.92235	.092
Eb-LPW	15.1290	4.25500	16.3170	3.10938	1.1880	3.39025	.575
VAL	59.8490	7.58221	62.8510	8.32032	3.0020	3.50630	.074
Soft palate							
SPT	8.9080	0.53304	9.2080	1.15129	0.3000	1.53512	.646
SPL	31.5910	2.21492	32.1320	2.47550	0.5410	2.03489	.241

SD, standard deviation.
* Significant values (*P*< .05).

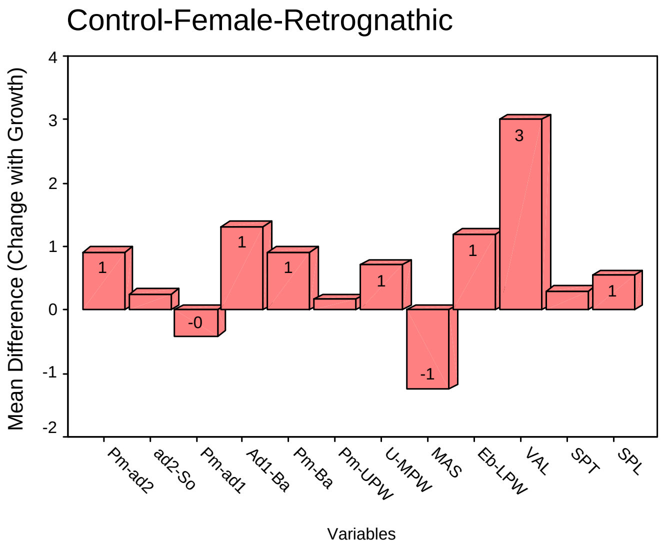


Fig.25. Mean difference change with growth in retrognathic females

Results In the female retrognathic group, the present study found changes that were of statistical significant difference (*P* < 0.05) only in the nasopharyngeal area (Pm-Ba). (Table 6 and Figure 25).

Table 7: Comparison of the first and second observation values (T2-T1) between and within the control in orthognathic males.

Variable	**Control-Male Orthognathic *n =13***						
	***1st Observation (T1)** (mm)*		***2nd Observation (T2)** (mm)*		***Change with growth (T2-T1)** (mm)*		***Wilcoxon Signed Ranks Test***
	Mean	***SD***	***Mean***	***SD***	***Mean***	***SD***	
Nasopharyngeal airway							
Pm-ad2	17.7500	2.92865	18.9138	3.15648	1.1638	1.74054	.043*
ad2-So	25.3892	3.46299	25.2062	3.41369	-0.1831	1.58032	.753
Pm-ad1	23.1938	4.35564	23.9646	5.06596	0.7708	2.41647	.249
ad1-Ba	24.4046	4.77391	24.7677	4.79309	0.3631	2.90379	1.000
Pm-Ba	47.6446	4.36847	48.7515	3.45337	1.0377	1.67676	.023*
Oropharyngeal airway							
Pm-UPW	24.2246	4.48314	24.6969	5.37882	0.4723	2.48266	.382
U-MPW	11.4077	2.48837	10.9277	2.58736	-0.4800	2.26039	.600
MAS	11.1062	3.03284	10.6569	2.90991	-0.4492	2.07716	.701
Eb-LPW	15.4923	2.93175	16.3354	3.13593	0.8431	2.48812	.152
VAL	59.7738	5.17838	62.5354	7.34027	2.7615	3.32936	.006*
Soft palate							
SPT	10.2562	1.91538	10.2723	1.97363	0.0162	1.36399	1.000
SPL	32.2923	4.36158	32.6562	4.68737	0.3638	1.36360	.402

SD, standard deviation.
* Significant values (*P*< .05).

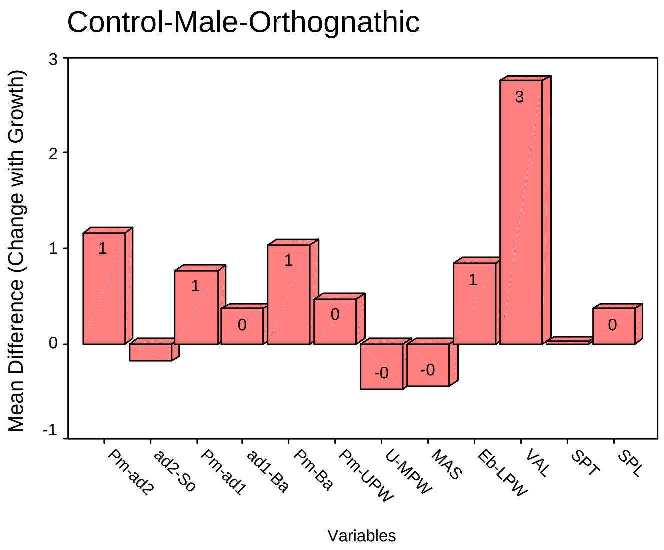


Fig.26. Mean difference change with growth in orthognathic males

Results In the male orthognathic group, the study found changes that were of statistically significant difference ($P < 0.05$) in the nasopharyngeal area (Pm-ad2 and Pm-Ba), and the oropharyngeal area (VAL), whereas there was no change in the soft palate data. (Table 7 and Figure 26)

Table 8: Comparison of the first and second observation values (T2-T1) between and within the control in retrognathic males.

Variable	**Control-Male Retrognathie *n =12***						
	***1st Observation (T1)** (mm)*		***2nd Observation (T2)** (mm)*		***Change with growth (T2-T1)** (mm)*		***Wilcoxon Signed Ranks Test***
	Mean	***SD***	***Mean***	***SD***	***Mean***	***SD***	
Nasopharyngeal airway							
Pm-ad2	16.6042	3.66038	18.0883	2.37896	1.4842	2.01359	.028*
ad2-So	24.0192	4.03951	23.6550	3.39372	-0.3642	2.20136	.814
Pm-ad1	21.8558	5.19003	23.0975	3.38831	1.2417	4.52913	.084
ad1-Ba	23.9775	5.67414	23.7692	4.40247	-0.2083	4.16194	.784
Pm-Ba	45.9533	3.50744	46.9300	3.61877	0.9767	1.30567	.023*
Oropharyngeal airway							
Pm-UPW	23.2383	5.06947	24.7417	3.89474	1.5033	3.89445	.136
U-MPW	11.3300	4.43566	11.1992	3.40263	-0.9642	3.67715	.754
MAS	13.4483	5.51506	13.3383	4.57332	-0.1017	3.36806	.814
Eb-LPW	15.6108	1.99278	15.5675	2.67596	-0.0433	2.15839	.814
VAL	57.2250	6.15250	59.3167	7.19089	2.0917	4.09397	.130
Soft palate							
SPT	9.7208	1.01895	9.3200	1.04079	-0.4008	1.17348	.388
SPL	31.0683	3.51680	31.3942	3.31948	0.3258	1.95269	.530

SD, standard deviation. * Significant values (*P*< .05).

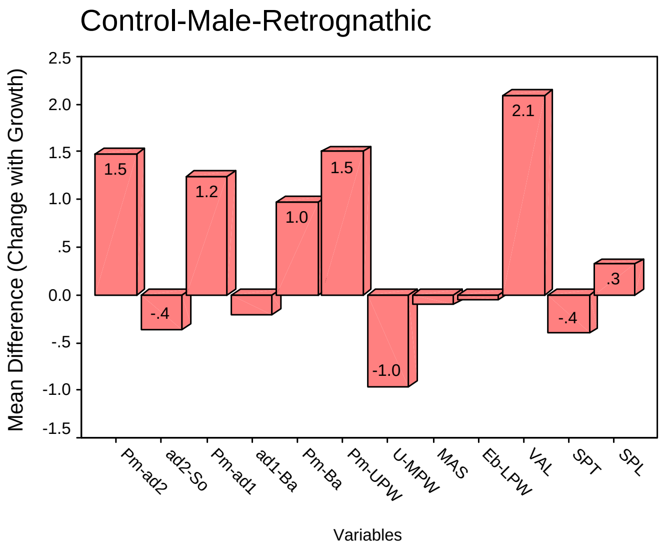


Fig.27. Mean difference change with growth in retrognathic males

Results The statistically significant differences (*P* < .05) changes are found only in the nasopharynx (Pm-ad2 and Pm-Ba) (Table 8 and Figure 27).

4.3 Effect of RME on the treatment group

Table 9: Comparison of pre- and post-treatment values (T2-T1) within the RME in orthognathic females.

Variable	**RME-Female-Orthognathic *n =12***						
	***Pre-treatment (T1)** (mm)*		***Post-treatment (T2)** (mm)*		***Change with Treatment (T2-T1)** (mm)*		***Wilcoxon Signed Ranks Test***
	Mean	***SD***	***Mean***	***SD***	***Mean***	***SD***	
Nasopharyngeal airway							
Pm-ad2	16.3142	3.54815	17.7683	3.41907	1.6358	1.81583	.034*
ad2-So	23.1958	3.06687	23.3250	3.64860	0.1458	2.13699	.969
Pm-ad1	21.8550	5.86507	22.9858	4.68198	1.1308	2.50516	.050*
ad1-Ba	21.4617	3.23204	21.5692	3.89529	0.1075	2.40765	.814
Pm-Ba	43.8242	4.66445	45.0417	4.08835	1.2175	1.53526	.023*
Oropharyngeal airway							
Pm-UPW	22.9508	5.24598	24.4292	4.92098	1.4783	2.64342	.117
U-MPW	9.7783	2.79306	9.7167	2.64270	-0.0617	1.28448	.638
MAS	12.5967	3.65267	11.9642	2.34604	-0.6325	2.52287	.480
Eb-LPW	16.2500	2.31625	17.2883	2.78006	1.0383	1.58722	.034*
VAL	61.4917	6.84063	63.1792	6.02519	1.6875	4.77783	.117
Soft palate							
SPT	9.6092	0.87894	9.1500	1.23934	-0.2925	1.07982	.170
SPL	31.6850	5.37243	32.7300	4.78208	1.0433	2.72472	.099

SD, standard deviation.
* Significant values (*P*< .05).

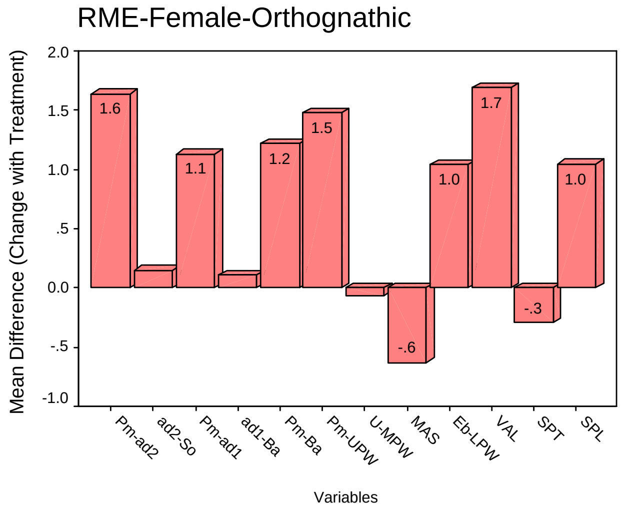


Fig.28. Mean difference change with RME in orthognathic females.

Results The comparison for each cephalometric measurement consideration pre- and post-treatment in orthognathic females treated with RME indicates Nasopharynx changes that are statistically significant at Pm-ad2, Pm-ad1, and Pm-Ba, while the oropharynx changed at Eb-LPW and there was no change for the soft palate. (Table 9 and Figure 28)

Table 10: Comparison of pre- and post-treatment values (T2-T1) between and within the RME in retrognathic females

Variable	**RME-Female-Retrognathic *n =27***						
	***Pre-treatment (T1)** (mm)*		***Post-treatment (T2)** (mm)*		***Change with Treatment (T2-T1)** (mm)*		***Wilcoxon Signed Ranks Test***
	Mean	***SD***	***Mean***	***SD***	***Mean***	***SD***	
Nasopharyngeal airway							
Pm-ad2	15.0448	4.71987	16.4489	5.33091	1.4307	3.05568	.014*
ad2-So	24.5167	4.28729	24.1563	4.56273	-0.3570	3.00889	.414
Pm-ad1	19.2252	6.50729	19.8444	6.51190	0.6193	3.29976	.259
ad1-Ba	25.4219	6.32482	25.6185	6.09031	0.2041	3.20566	.792
Pm-Ba	44.6959	3.05203	45.5089	3.56747	0.8130	1.73178	.040*
Oropharyngeal airway							
Pm-UPW	21.5426	6.58044	22.8585	6.02350	1.2967	4.15088	.118
U-MPW	10.4289	2.72149	10.2811	3.10871	-0.1478	2.40276	.589
MAS	12.5515	2.63863	12.7111	3.49280	0.1591	3.26887	.614
Eb-LPW	16.1548	2.87315	16.8759	4.02493	0.7211	4.23475	.792
VAL	58.2367	5.27984	60.5033	5.92126	2.2741	3.56408	.006*
Soft palate							
SPT	8.7896	1.45739	8.8533	1.15151	0.0637	0.88176	.428
SPL	31.7537	3.12269	32.0904	3.37209	0.3367	1.55348	.239

SD, standard deviation. * Significant values (*P*< .05).

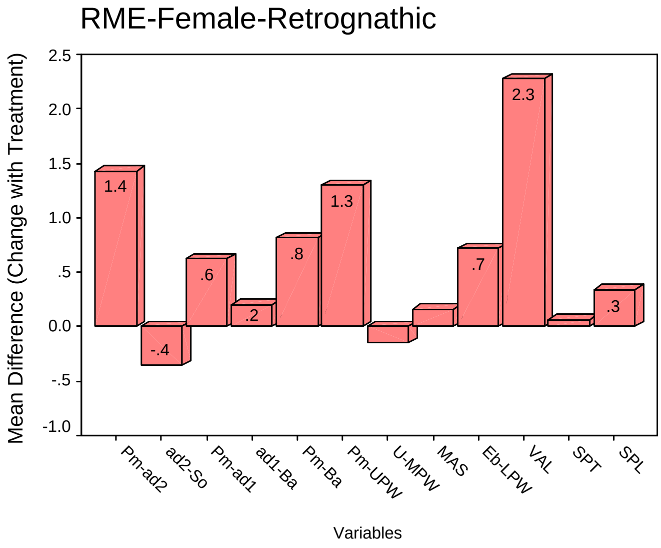


Fig.29. Mean difference change with RME in retrognathic females

Results In retrognathic females, the present study found changes in nasopharyngeal area (Pm-ad2 and Pm-Ba), and oropharyngeal area (VAL), whereas there is no change in soft palate. (Table 10 and Figure 29)

Table 11: Comparison of pre- and post-treatment values (T2-T1) between and within the RME in orthognathic males.

Variable	**RME- Male-Orthognathic *n =18***						
	***Pre-treatment (T1)** (mm)*		***Post-treatment (T2)** (mm)*		***Change with Treatment (T2-T1)** (mm)*		***Wilcoxon Signed Ranks Test***
	Mean	***SD***	***Mean***	***SD***	***Mean***	***SD***	
Nasopharyngeal airway							
Pm-ad2	17.1594	4.72945	17.9867	5.30738	0.8272	2.21949	.122
ad2-So	25.4228	3.89763	26.1039	3.04755	0.6811	1.83138	.215
Pm-ad1	21.8361	5.52574	22.7667	5.93349	0.9306	1.62949	.031*
ad1-Ba	25.1567	4.07453	25.5200	4.04567	0.3633	1.50494	.248
Pm-Ba	47.1217	3.67781	48.3383	4.15321	1.2167	1.14003	.002*
Oropharyngeal airway							
Pm-UPW	23.9961	4.77836	25.3428	5.77650	1.3467	2.87252	.053
U-PMW	10.3144	3.80506	10.4339	3.69389	0.1194	3.17010	.983
MAS	11.8767	2.48265	12.1967	3.25182	0.3200	2.15420	.711
Eb-LPW	15.6267	3.24073	16.0278	3.40202	0.4011	2.03870	.500
VAL	60.6933	7.15996	63.2156	8.51111	2.5222	3.66627	.020*
Soft palate							
SPT	9.6033	1.05511	10.1972	1.31542	0.5939	1.09292	.025*
SPL	32.2033	4.97052	33.0322	4.81765	0.8289	1.44796	.033*

SD, standard deviation. * Significant values (*P*< .05).

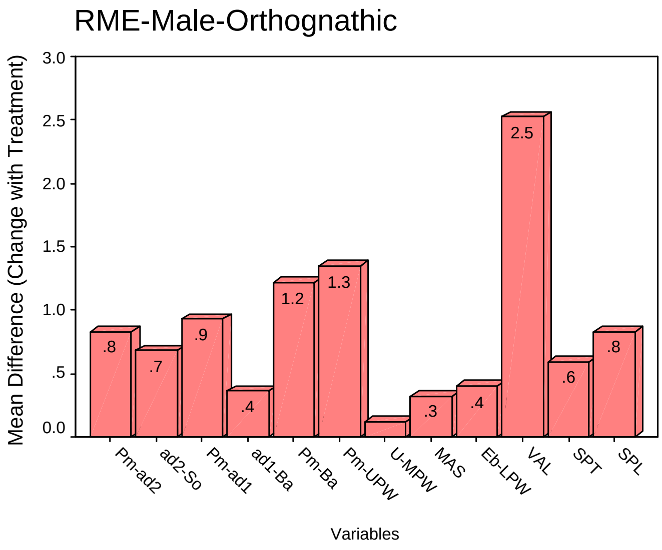


Fig.30. Mean difference changes with RME in orthognathic males

Results Table 11 and Figure 30 shows the comparison for each cephalometric measurement consideration pre- and post-treatment with RME in orthognathic males. There were statistically significant differences (*P* < 0.05) in nasopharynx (Pm-ad1 and Pm-Ba), oropharynx (VAL) and soft palate (SPT and SPL).

Table 12: Comparison of pre- and post-treatment values (T2-T1) between and within the RME in retrognathic males.

Variable	**RME-Male-Retrognathic *n =14***						
	Pre-treatment (T1) *(mm)*		***Post-treatment (T2)*** *(mm)*		***Change with Treatment (T2-T1)*** *(mm)*		***Wilcoxon Signed Ranks Test***
	Mean	***SD***	***Mean***	***SD***	***Mean***	***SD***	
Nasopharyngeal airway							
Pm-ad2	14.6843	3.43457	17.1664	4.47606	2.4821	2.80792	.016*
ad2-So	26.2514	2.23862	25.1750	3.09744	-1.0764	2.33463	.109
Pm-ad1	20.0079	5.79847	22.5886	6.52939	2.5807	3.55118	.019*
ad1-Ba	25.5357	5.47765	23.8814	6.10381	-1.6543	3.43030	.061
Pm-Ba	45.6600	2.73802	46.6100	2.92667	0.9500	1.76613	.084
Oropharyngeal airway							
Pm-UPW	21.9486	6.02636	24.7879	6.06754	2.8393	4.20720	.016*
U-MPW	11.4350	2.24980	12.0300	3.48309	0.5950	3.44137	.875
MAS	13.2579	2.28905	13.7500	3.61264	0.4921	3.65966	.826
Eb-LPW	16.9629	2.40119	17.4471	3.64987	0.4843	3.37505	.683
VAL	63.1043	7.00385	67.1243	9.74533	3.1886	5.36512	.009*
Soft palate							
SPT	9.7107	1.43328	10.0900	1.21185	0.3650	1.00736	.198
SPL	33.8629	3.79869	34.5164	3.90233	0.6536	1.85624	.177

SD, standard deviation. * Significant values (*P*< .05).

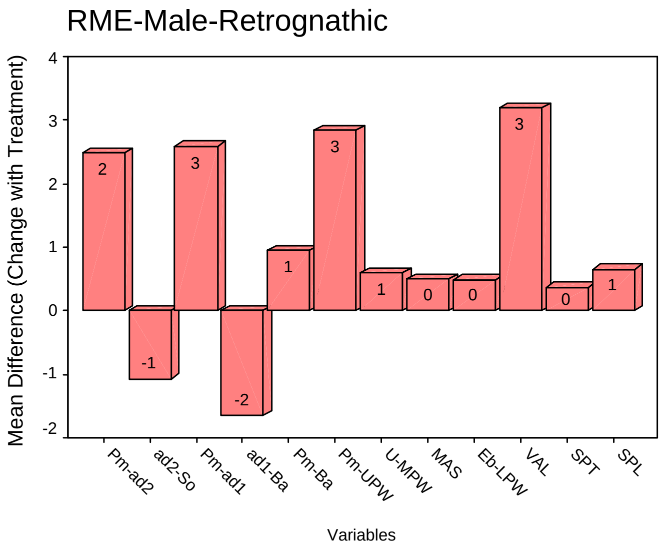


Fig.31. Mean difference change with RME in retrognathic males.

<u>Results</u> In retrognathic males, the current study found statistically significant difference changes (*P* < 0.05) in the nasopharyngeal area (Pm-ad2 and Pm-ad1), and oropharyngeal area (Pm-UPW and VAL), whereas there is no change in the soft palate data. (Table 12 and Figure 31)

4.4 Comparison between the groups of control group

None of the standard cephalometric parameters showed any significant differenced within control groups. (Table 17 – 20)

Table 13: Comparison of mean different values for cephalometric variables between orthognathic and retrognathic data in female control group. (measurement value with the **second** minus the **first** observation)

Variable	**Control - Female**				
	Orthognathic n =12		***Retrognathic n = 10***		**Group Difference**
	***Difference** (mm)*		***Difference** (mm)*		**Mann Whitney**
	Mean	***SD***	***Mean***	***SD***	**U-test**
Nasopharyngeal airway					
Pm-ad2	1.4900	2.73670	0.9090	1.56281	.346
ad2-So	0.1433	3.02502	0.2460	1.39612	.381
Pm-ad1	0.7692	3.72774	-0.4170	2.36447	.283
ad1-Ba	0.3017	4.33769	1.3150	1.94502	.456
Pm-Ba	1.1283	1.41608	0.9070	1.11010	.872
Oropharyngeal airway					
Pm-UPW	0.0983	4.19604	0.1620	2.33682	.923
U-MPW	-0.2325	2.21866	0.7080	1.55046	.722
MAS	-1.1900	3.25179	-1.2480	1.92235	.771
Eb-LPW	-0.0867	3.00801	1.1880	3.39025	.456
VAL	4.0625	3.62444	3.0020	3.50630	.497
Soft palate					
SPT	0.3175	0.96622	0.3000	1.53512	.497
SPL	0.7217	1.24656	0.5410	2.03489	.456

SD, standard deviation.
* Significant values (*P*< .05).

Results There was no statistically significant difference (*P* < .05) for any of the cephalometric variables. There was homogeneity between orthognathic and retrognathic groups of the female control data. (Table 13)

Table 14: Comparison of mean different values for cephalometric variables between orthognathic and retrognathic in the male control group. (measurement value with the **second** minus the **first** observation)

Variable	**Control – Male**				
	Orthognathic ***n =13***		***Retrognathic*** ***n = 12***		**Group Difference**
	Difference *(mm)*		***Difference*** *(mm)*		**Mann Whitney**
	Mean	***SD***	***Mean***	***SD***	**U-Test**
Nasopharyngeal airway					
Pm-ad2	1.1638	1.74054	1.4842	2.01359	.611
ad2-So	-0.1831	1.58032	-0.3642	2.20136	.810
Pm-ad1	0.7708	2.41647	1.2417	4.52913	.728
ad1-Ba	0.3631	2.90379	-0.2083	4.16194	.894
Pm-Ba	1.0377	1.67676	0.9767	1.30567	.728
Oropharyngeal airway					
Pm-UPW	0.4723	2.48266	1.5033	3.89445	.611
U-MPW	-0.4800	2.26039	-0.9642	3.67715	.538
MAS	-0.4492	2.07716	-0.1017	3.36806	.728
Eb-LPW	0.8431	2.48812	-0.0433	2.15839	.503
VAL	2.7615	3.32936	2.0917	4.09397	.852
Soft palate					
SPT	0.0162	1.36399	-0.4008	1.17348	.437
SPL	0.3638	1.36360	0.3258	1.95269	.936

SD, standard deviation.
* Significant values (*P*< .05).

Results There was no statistically significant difference (*P* < .05) between the orthognathic and retrognathic data in the control male group. (Table 14)

Table 15: Comparison of mean different values for cephalometric variables between female and male orthognathic control groups. (measurement value with the **second** minus the **first** observation)

Variable	**Control - Orthognathic**				
	Female *Orthognathic* *n =12*		**Male *Orthognathic*** *n = 13*		**Group Difference**
	***Difference** (mm)*		***Difference** (mm)*		**Mann Whitney**
	Mean	***SD***	***Mean***	***SD***	**U-test**
Nasopharyngeal airway					
Pm-ad2	1.4900	2.73670	1.1638	1.74054	.406
ad2-So	0.1433	3.02502	-0.1831	1.58032	.894
Pm-ad1	0.7692	3.72774	0.7708	2.41647	1.000
ad1-Ba	0.3017	4.33769	0.3631	2.90379	.894
Pm-Ba	1.1283	1.41608	1.0377	1.67676	.936
Oropharyngeal airway					
Pm-UPW	0.0983	4.19604	0.4723	2.48266	.894
U-MPW	-0.2325	2.21866	-0.4800	2.26039	.611
MAS	-1.1900	3.25179	-0.4492	2.07716	.186
Eb-LPW	-0.0867	3.00801	0.8431	2.48812	.347
VAL	4.0625	3.62444	2.7615	3.32936	.270
Soft palate					
SPT	0.3175	0.96622	0.0162	1.36399	.470
SPL	0.7217	1.24656	0.3638	1.36360	.347

SD, standard deviation
* Significant values (*P*< .05).

Result There was no statistically significant difference between sexes in control orthognathic group. (Table 15)

Table 16: Comparison of mean different values for cephalometric variables between female and male in retrognathic controls. (measurement value with the **second** minus the **first** observation)

Variable	**Control –Retrognathic**				
	Female *Retrognathic* ***n =10***		**Male *Retrognathic*** ***n = 12***		**Group Difference**
	***Difference** (mm)*		***Difference** (mm)*		**Mann Whitney**
	Mean	***SD***	***Mean***	***SD***	**U-Test**
Nasopharyngeal airway					
Pm-ad2	0.9090	1.56281	1.4842	2.01359	.346
ad2-So	0.2460	1.39612	-0.3642	2.20136	.974
Pm-ad1	-0.4170	2.36447	1.2417	4.52913	.107
ad1-Ba	1.3150	1.94502	-0.2083	4.16194	.159
Pm-Ba	0.9070	1.11010	0.9767	1.30567	.974
Oropharyngeal airway					
Pm-UPW	0.1620	2.33682	1.5033	3.89445	.456
U-MPW	0.7080	1.55046	-0.9642	3.67715	.123
MAS	-1.2480	1.92235	-0.1017	3.36806	.140
Eb-LPW	1.1880	3.39025	-0.0433	2.15839	.722
VAL	3.0020	3.50630	2.0917	4.09397	.674
Soft palate					
SPT	0.3000	1.53512	-0.4008	1.17348	.628
SPL	0.5410	2.03489	0.3258	1.95269	.722

SD, standard deviation
* Significant values (*P*< .05).

Results Table 16 shows a comparison between the mean differences of retrognathic control group in both sexes. No statistically significant difference was found.

4.5 Comparison between the groups of RME group

A Mann-Whitney U-test (*P* < .05) was performed to evaluate the significance of the comparison between groups.

Table 17: Comparison of mean different values for cephalometric variables between orthognathic and retrognathic in RME female subjects. (measurement value with **post-** minus **pre-** treatment with RME)

Variable	**RME – Female**				
	Orthognathic ***n =12***		***Retrognathic*** ***n = 27***		**Group Difference Mann Whitney U-Test**
	Difference *(mm)*		***Difference*** *(mm)*		
	Mean	***SD***	***Mean***	***SD***	
Nasopharyngeal airway					
Pm-ad2	1.6358	1.81583	1.4307	3.05568	.578
ad2-So	0.1458	2.13699	-0.3570	3.00889	.461
Pm-ad1	1.1308	2.50516	0.6193	3.29976	.461
ad1-Ba	0.1075	2.40765	0.2041	3.20566	.685
Pm-Ba	1.2175	1.53526	0.8130	1.73178	.343
Oropharyngeal airway					
Pm-UPW	1.4783	2.64342	1.2967	4.15088	.663
U-MPW	-0.0617	1.28448	-0.1478	2.40276	.869
MAS	-0.6325	2.52287	0.1591	3.26887	.538
Eb-LPW	1.0383	1.58722	0.7211	4.23475	.199
VAL	1.6875	4.77783	2.2741	3.56408	.988
Soft palate					
SPT	-0.2925	1.07982	0.0637	0.88176	.391
SPL	1.0433	2.72472	0.3367	1.55348	.118

SD, standard deviation.
* Significant values (*P*< .05).

Results There were no statistically significant differences for any of the cephalometric variables. There was homogeneity of the data comparing orthognathic and female retrognathic groups treated with RME. (Table 17)

Table 18: Comparison of mean different values for cephalometric variables between male orthognathic and retrognathic subjects in RME. (measurement value with **post-** minus **pre-** treatment with RME)

	RME – Male				
	Orthognathic		***Retrognathic***		**Group**
Variable	***n =18***		***n = 14***		**Difference**
	***Difference** (mm)*		***Difference** (mm)*		**Mann Whitney**
	Mean	***SD***	***Mean***	***SD***	**U-Test**
Nasopharyngeal airway					
Pm-ad2	0.8272	2.21949	2.4821	2.80792	.084
ad2-So	0.6811	1.83138	-1.0764	2.33463	.028*
Pm-ad1	0.9306	1.62949	2.5807	3.55118	.180
ad1-Ba	0.3633	1.50494	-1.6543	3.43030	.022*
Pm-Ba	1.2167	1.14003	0.9500	1.76613	.488
Oropharyngeal airway					
Pm-UPW	1.3467	2.87252	2.8393	4.20720	.301
U-MPW	0.1194	3.17010	0.5950	3.44137	.750
MAS	0.3200	2.15420	0.4921	3.65966	.896
Eb-LPW	0.4011	2.03870	0.4843	3.37505	.837
VAL	2.5222	3.66627	3.1886	5.36512	.694
Soft palate					
SPT	0.5939	1.09292	0.3650	1.00736	.464
SPL	0.8289	1.44796	0.6536	1.85624	.925

SD, standard deviation.
* Significant values (*P*< .05).

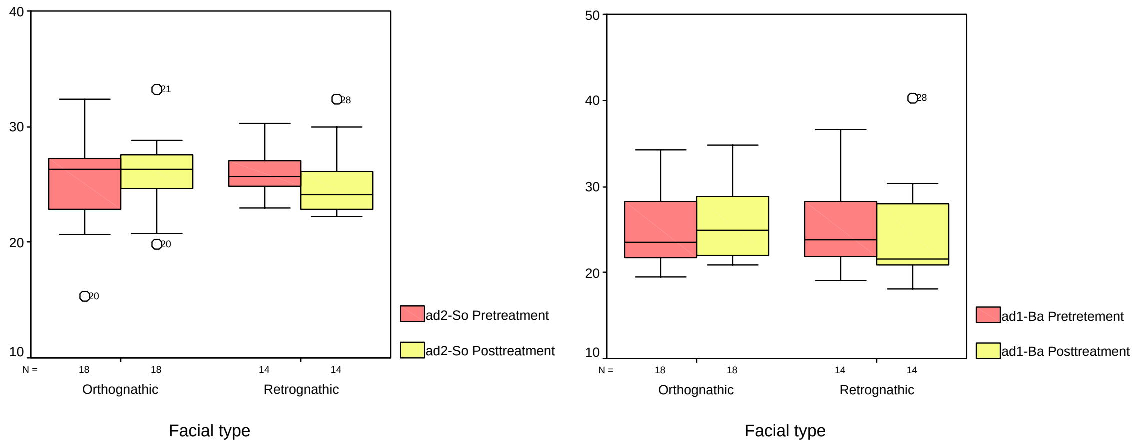


Fig.32. – 33. Mean difference change with RME in orthognathic and retrognathic males in ad2-So and ad1-Ba variables

Results The statistically significant differences (*P* < .05) were found only in the nasopharynx data (ad2-So and ad1-Ba) (Table 18 and Figure 32 - 33).

Table 19: Comparison of mean different values for cephalometric variables between orthognathic male and female subjects. (measurement value with **post-** minus **pre-** treatment with RME)

	RME – Orthognathic				
Variable	**Female *Orthognathic*** ***n = 12*** ***Difference*** *(mm)*		**Male *Orthognathic*** ***n =18*** ***Difference*** *(mm)*		**Group Difference Mann Whitney U-Test**
	Mean	***SD***	***Mean***	***SD***	
Nasopharyngeal airway					
Pm-ad2	1.6358	1.81583	0.8272	2.21949	.511
ad2-So	0.1458	2.13699	0.6811	1.83138	.817
Pm-ad1	1.1308	2.50516	0.9306	1.62949	.631
ad1-Ba	0.1075	2.40765	0.3633	1.50494	.736
Pm-Ba	1.2175	1.53526	1.2167	1.14003	.763
Oropharyngeal airway					
Pm-UPW	1.4783	2.64342	1.3467	2.87252	.873
U-MPW	-0.0617	1.28448	0.1194	3.17010	.736
MAS	-0.6325	2.52287	0.3200	2.15420	.363
Eb-LPW	1.0383	1.58722	0.4011	2.03870	.403
VAL	1.6875	4.77783	2.5222	3.66627	.958
Soft palate					
SPT	-0.2925	1.07982	0.5939	1.09292	.008*
SPL	1.0433	2.72472	0.8289	1.44796	.534

SD, standard deviation.
* Significant values (*P*< .05).

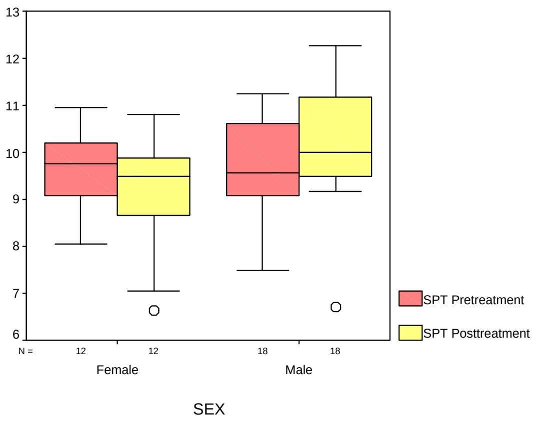


Fig.34. Mean different change with RME in orthognathic data for the SPT variable

Results There was a statistically significant difference (*P* < .05) for the cephalometric variable only for the soft palate (SPT). (Table 19 and Figure 34)

Table 20: Comparison of mean different values for cephalometric variables between retrognathic male and female subjects. (measurement value with **post-** minus **pre-** treatment with RME)

Variable	**RME - Retrognathic**				
	Female *Retrognathic* ***n =27*** ***Difference** (mm)*		**Male *Retrognathic*** ***n = 14*** ***Difference** (mm)*		**Group Difference Mann Whitney U-Test**
	Mean	***SD***	***Mean***	***SD***	
Nasopharyngeal airway					
Pm-ad2	1.4307	3.05568	2.4821	2.80792	.362
ad2-So	-0.3570	3.00889	-1.0764	2.33463	.406
Pm-ad1	0.6193	3.29976	2.5807	3.55118	.143
ad1-Ba	0.2041	3.20566	-1.6543	3.43030	.063
Pm-Ba	0.8130	1.73178	0.9500	1.76613	.968
Oropharyngeal airway					
Pm-UPW	1.2967	4.15088	2.8393	4.20720	.235
U-MPW	-0.1478	2.40276	0.5950	3.44137	.654
MAS	0.1591	3.26887	0.4921	3.65966	.860
Eb-LPW	0.7211	4.23475	0.4843	3.37505	.924
VAL	2.2741	3.56408	3.1886	5.36512	.674
Soft palate					
SPT	0.0637	0.88176	0.3650	1.00736	.376
SPL	0.3367	1.55348	0.6536	1.85624	.523

SD, standard deviation.
* Significant values (*P*< .05).

Results Table 20 shows a comparison between the mean differences of treated RME in retrognathic data of both genders. No statistically significant difference (*P* < .05) was found, although several mean differences of clinically significant size were apparent.

4.6 Comparison of the RME and control groups

Pharyngeal changes were present after treatment in all subgroups of RME and with growth in all control groups. There were statistically significant differences in comparison to subgroups treated with RME, whereas there were statistically insignificant changes in the control groups.

Table 21 – 24 shows a comparison between the cephalometric values for the control group and the treated RME group. There was no statistically significant difference in any variable between the RME and control in each of the subgroups, although several mean differences of a clinically significant value are found in the RME group.

Table 21: Comparison of mean different values for cephalometric variables between RME and control in orthognathic female subjects.

Variable	**RME & Control- Female Orthognathic**				
	RME *Orthognathic*		**Control *Orthognathic***		**Group**
	n =12		***n = 12***		**Difference**
	Difference *(mm)*		***Difference*** *(mm)*		**Mann Whitney**
	Mean	***SD***	***Mean***	***SD***	**U-Test**
Nasopharyngeal airway					
Pm-ad2	1.6358	1.81583	1.4900	2.73670	0.755
ad2-So	0.1458	2.13699	0.1433	3.02502	0.671
Pm-ad1	1.1308	2.50516	0.7692	3.72774	1.000
ad1-Ba	0.1075	2.40765	0.3017	4.33769	1.000
Pm-Ba	1.2175	1.53526	1.1283	1.41608	0.799
Oropharyngeal airway					
Pm-UPW	1.4783	2.64342	0.0983	4.19604	0.590
U-MPW	-0.0617	1.28448	-0.2325	2.21866	0.590
MAS	-0.6325	2.52287	-1.1900	3.25179	0.514
Eb-LPW	1.0383	1.58722	-0.0867	3.00801	0.160
VAL	1.6875	4.77783	4.0625	3.62444	0.198
Soft palate					
SPT	-0.2925	1.07982	0.3175	0.96622	0.266
SPL	1.0433	2.72472	0.7217	1.24656	0.551

SD, standard deviation
* Significant values (*P*< .05).

<u>Results</u> Table 21 shows a comparison between the mean differences of RME and the control group in orthognathic female groups. No statistically significant difference (*P*< .05) was found.

Table 22: Comparison of mean different values for cephalometric variables between RME and control in retrognathic female subjects.

Variable	RME & Control - Female - Retrognathic				
	RME *Retrognathic* *n =27*		Control *Retrognathic* *n = 10*		Group Difference
	Difference *(mm)*		***Difference*** *(mm)*		Mann Whitney
	Mean	***SD***	***Mean***	***SD***	U-Test
Nasopharyngeal airway					
Pm-ad2	1.4307	3.05568	0.9090	1.56281	.489
ad2-So	-0.3570	3.00889	0.2460	1.39612	.302
Pm-ad1	0.6193	3.29976	-0.4170	2.36447	.302
ad1-Ba	0.2041	3.20566	1.3150	1.94502	.335
Pm-Ba	0.8130	1.73178	0.9070	1.11010	.724
Oropharyngeal airway					
Pm-UPW	1.2967	4.15088	0.1620	2.33682	.448
U-MPW	-0.1478	2.40276	0.7080	1.55046	.229
MAS	0.1591	3.26887	-1.2480	1.92235	.286
Eb-LPW	0.7211	4.23475	1.1880	3.39025	.428
VAL	2.2741	3.56408	3.0020	3.50630	.674
Soft palate					
SPT	0.0637	0.88176	0.3000	1.53512	.801
SPL	0.3367	1.55348	0.5410	2.03489	.724

SD, standard deviation
* Significant values (*P*< .05).

Results Table 22 shows a comparison between the mean differences of RME and the control groups in retrognathic female groups. No statistically significant difference (*P*< .05) was found.

Table 23: Comparison of mean different values for cephalometric variables between RME and control in orthognathic male subjects.

Variable	**RME & Control- Male – Orthognathic**				
	RME *Orthognathic* ***n =18*** ***Difference** (mm)*		**Control *Orthognathic*** ***n = 13*** ***Difference** (mm)*		**Group Difference Mann Whitney U-Test**
	Mean	***SD***	***Mean***	***SD***	
Nasopharyngeal airway					
Pm-ad2	0.8272	2.21949	1.1638	1.74054	.890
ad2-So	0.6811	1.83138	-0.1831	1.58032	.183
Pm-ad1	0.9306	1.62949	0.7708	2.41647	.890
ad1-Ba	0.3633	1.50494	0.3631	2.90379	.540
Pm-Ba	1.2167	1.14003	1.0377	1.67676	.622
Oropharyngeal airway					
Pm-UPW	1.3467	2.87252	0.4723	2.48266	.373
U-MPW	0.1194	3.17010	-0.4800	2.26039	.708
MAS	0.3200	2.15420	-0.4492	2.07716	.650
Eb-LPW	0.4011	2.03870	0.8431	2.48812	.395
VAL	2.5222	3.66627	2.7615	3.32936	.984
Soft palate					
SPT	0.5939	1.09292	0.0162	1.36399	.115
SPL	0.8289	1.44796	0.3638	1.36360	.441

SD, standard deviation
* Significant values (*P*< .05).

Results Table 23 shows a comparison between the mean difference of RME and control in orthognathic male groups. No statistically significant difference (*P*< .05) was found.

Table 24: Comparison of mean different values for cephalometric variables between RME and control in retrognathic male subjects.

Variable	**RME & Control Male - Retrognathic**				
	RME *Retrognathic* ***n =14*** ***Difference** (mm)*		**Control *Retrognathic*** ***n = 12*** ***Difference** (mm)*		**Group Difference Mann Whitney U-Test**
	Mean	***SD***	***Mean***	***SD***	
Nasopharyngeal airway					
Pm-ad2	2.4821	2.80792	1.4842	2.01359	.374
ad2-So	-1.0764	2.33463	-0.3642	2.20136	.527
Pm-ad1	2.5807	3.55118	1.2417	4.52913	.403
ad1-Ba	-1.6543	3.43030	-0.2083	4.16194	.131
Pm-Ba	0.9500	1.76613	0.9767	1.30567	1.000
Oropharyngeal airway					
Pm-UPW	2.8393	4.20720	1.5033	3.89445	.212
U-MPW	0.5950	3.44137	-0.9642	3.67715	.274
MAS	0.4921	3.65966	-0.1017	3.36806	.940
Eb-LPW	0.4843	3.37505	-0.0433	2.15839	.781
VAL	3.1886	5.36512	2.0917	4.09397	.667
Soft palate					
SPT	0.3650	1.00736	-0.4008	1.17348	.160
SPL	0.6536	1.85624	0.3258	1.95269	.631

SD, standard deviation
* Significant values (*P*< .05).

Results Table 24 shows a comparison between the mean difference of RME of the control group and the retrognathic male group. No statistically significant difference (*P*< .05) was found.

5. DISCUSSION

This study has compared the results of rapid maxillary expansion treatment and the consequent growth change in a group who were selected according to craniofacial skeletal type and gender with a control group. A total of 71 patients who had undergone RME treatment and 47 control subjects were divided into female and male groups and then classified into orthognathic and retrognathic facial subtypes. All 12 linear variables used in the study have been investigated for each of the subgroup used in the present study.

5.1 Limitation of the study

This retrospective clinical investigation of consecutively treated patients was aimed at describing the effect of the RME treatment on the skeletal and pharyngeal area. Within the limitations of this study, the cephalometric radiographs of each treatment group were obtained from an annual follow-up of the treatment, while the prospective research was designed in conjunction with the study in order to determine the effects of RME treatment**.** This included the effect of RME and growth in the treated group occurring together, due to the mean duration from pretreatment (T1) to post-treatment (T2), which was 1.46 ± 0.55 years (Table 25) However, the final appearance of patients after a course of normal orthodontic treatment was a consequence of the combination of growth and functional treatment from any given appliance. The mean value of the observation period was 1.62 ± 0.63 years for the control group.

Table 25: Shows the distribution, minimum age, maximum age, average ages, and standard deviation of the duration of observation in both groups.

	N	**Mean** (Year)	**Std. Deviation**
Control	47	1.62	0.63
RME	71	1.46	0.55

5.2 Comparison of the first and second observation of control group

5.2.1 Nasopharyngeal measurements

In the female control group, the overall changes in the craniofacial complex due to growth during the observation period were characterized by an increase in all variables except the inferior nasopharyngeal depth (Pm-ad1) in retrognathic females. In the male control group there was reduced thickness of soft tissue on the superior nasopharynx (ad2-So) in orthognatic patients and in the thickness of soft tissue on the superior nasopharynx (ad2-So) and the posterior nasopharyngeal wall (ad1-Ba) in retrognathic patients. (Table 5 – 8)

There were statistically significant different increases in:

- Sagittal depth of the bony nasopharynx (Pm-Ba) in orthognathic and retrognathic female patients.
- Sagittal depth of the bony nasopharynx (Pm-Ba) and superior nasopharyngeal depth (Pm-ad2) in orthognathic and retrognathic males.

The size of the soft tissue pharyngeal wall and the adenoids relating to the volume of the bony pharynx determines the space of the airway and mode of breathing [71]. The developmental growth of adenoid tissue is very quick and may take up one-half of the nasopharyngeal space by 2-3 years of age [101]. The thickness of the soft tissue on the posterior wall is at a maximum at five years of age and successively reduces up to the age of ten [71] and is sometimes as late as 14-15 years of age [101]. Linder-Aronson [71] found that there was a slight increase between 10 and 11 years of age and subsequently a continuous decrease due to the influence of the sex hormones on reaching the pubertal period. That implies that the sagittal nasopharyngeal airway was narrowest at five years of age before becoming wider and increasing further between 5 and 10 and then 11 years of age. Hypertrophy of the lymphoid tissue on the posterior nasopharyngeal wall causes problem in breathing especially during the preschool period and during early school years. In 1988, Billing and co-worker [13] stated that genetic factors had a notable influence on the dimensions of pharyngeal space, the thickness of the posterior pharyngeal wall and the nasopharyngeal airway.

As the head and facial structures grow, the hard palate movement parallels away from the cranial base. The lowering of the palate from the sphenoid bone increases the vertical dimension of the nasopharynx and coincides with an enlargement in the nasopharyngeal area. The vertical dimension of the nasopharynx will normally enlarge until the maxilla completes its growth at about 17-18 years of age [101].

The process of displacement [31] causes the maxillary complex to move anteriorly and inferiorly from the cranium by expansion and growth of the soft tissues in the midfacial area and increase in size of the bones comprising the middle cranial fossa. From the remodeling growth concept of Enlow [31], the palate grew downward by periosteal resorption on the nasal side and deposition on the oral side. This growth and remodeling process helps enlargement of the nasal chambers and development of the vertical enlargement of the nasal region. The Pterygomaxillary (Pm) moved forward and this increased the distance from Pm to Ba. Linder-Aronson [71] found that the thickness of the posterior nasopharyngeal wall (ad1-Ba) was less than the inferior nasopharyngeal depth (Pm-ad1) due to Ba movement more sagittally than did Pm during the period of growth in his observations.

These findings describe the annualized forward growth of the control group during the mean duration of 1.62 years. A possible explanation for this increase in growth could be the displacement and remodeling process of the nasomaxillary complex in relation to the bony and soft tissue nasopharynx due to the statistically significant different increase in sagittal depth of the bony nasopharynx (Pm-Ba) in both genders and only the superior nasopharyngeal depth (Pm-ad2) in the male patients. It may possible explain this on the basis that the male group had soft tissue on the posterior wall in this area which was thicker than in the female group. Alternatively the difference could arise in growth in the nasopharynx between the female and male patients because the basic difference in size after puberty due to male growth taking place for a longer period and to a larger size than for females at comparable ages [31]. Handelman and Osborne investigated the growth of the nasopharynx and adenoid development at the age of 18 and found that there were different growth patterns for females and males [43].

Linder-Aronson and Henrikson [66] state that a clinical record of the breathing mode could be complemented with data from cephalometric radiographs of the anteroposterior size of the nasopharyngeal airway when the orthodontic treatment plan allowed.

5.2.2 Oropharyngeal measurements

The oropharyngral area is the only collapsible segment of the upper airway because its walls are not sufficiently rigid for giving protection against negative transmural pressure [75]. Without bony or cartilaginous structures, the wall of oropharynx is composed of soft palate, tongue, and pharyngeal muscles.

During the observation period, overall changes in the oropharyngeal area took place due to growth. There were increases in the measurements for all variables except the following variables, which were statistically insignificant decreases in the measurements (Table 5 – 8):

- Retropalatal airway space (U-MPW), middle airway space (MAS) and hypopharyngeal space (Eb-LPW) in female orthognathic and male retrognathic groups.
- Middle airway space (MAS) in female retrognathic.
- Retropalatal airway space (U-MPW) and middle airway space (MAS) in male orthognathic.

Taylor and co-worker [105] studied the soft tissue growth of the oropharyngeal area at 6, 9, 12, 15, and 18 years of age. He found that the hyoid bone moved downward and slightly forward up to age 18 while two soft tissue measurements, retropalatal airway space (Pm-UPW) and posterior soft palate to pharyngeal wall, increased. Normally, the pharyngeal soft tissues were identified for two periods of accelerated change (6 - 9 years and 12 - 15 years) and two periods of quiescence (9 - 12 years and 15 - 18 years). Furthermore, in case of excessive adenoid hyperthophy, the tongue was found to be downward and forward away from the soft palate [101].

These findings agreed with the study of Taylor because the range of the mean value of the control group was 9.75 - 11.59 years. It was attributed to inactive growth of soft tissue of the oropharynx.

There was a statistically significant difference ($P<0.05$) in

- Vertical airway length (VAL) in orthognathic females and males, grew by an insignificant increase in the retrognathic patients of both genders.

King [55] studied longitudinal growth over the period from three months to sixteen years of age and found that the increase in length of the pharynx was continuous with a slight prepubertal spurt in females and a slight postpubertal spurt in males.

These findings agreed with a study of King, because there were increases of VAL in all groups, although it is not significant in retrognathic female and male groups. This work suggests that the orthognathic group has normal growth while the retrognathic group could not reach to normal level of growth because of the retrusion of the mandible or/and maxilla in both females and males. The inference follows that the orthognathic groups have more normal growth than does the retrognathic group.

However, insignificant reduction of the retropalatal airway space (U-MPW), middle airway space (MAS), and / or hypopharyngeal space (Eb-LPW) are in agreement with the result of a study of sleep disordered breathing (SDB) [103] which found that the narrowing of the airway space in the oropharynx area seemed to be the main problem of OSA patients. Another consistent finding was that the hyoid bone was displaced inferiorly and anteriorly in individuals with SDB [109].

Although, there was no statistically significant difference in each control group, it may be presumed that the control group has a tendency towards sleep disordered breathing.

5.2.3 Soft palate

No statistically significant difference was found in the soft palate measurements for each group, although there was reduction of soft palate thickness (SPT) in retrognathic males. (Table 5 – 8)

Taylor [105] found that the soft palate increased 1 mm in length and 0.5 mm in thickness every 3 years after age of 9.

Comparison of this study with Taylor's, infers that in the time duration of the present experiment, the soft palate should be 0.50 mm longer and 0.25 mm thicker than at the first observation. However, these values may be clinically and statistically insignificant. It may be presumed that growth of soft palate over this duration was not statistically significantly different.

5.3 Comparison of pre- and post-treatment result of RME

There were changes in the values of measurements made in the nasopharyngeal and oropharyngeal areas in comparison with the pre- and post-treatment within subgroups, orthognathic and retrognathic, in female and male groups. There was no statistically significant difference in soft palate data in any group except the orthognathic males.

5.3.1 Nasopharyngeal measurements

There are changes overall in the nasopharynx data resulting from the treatment given during the period of the clinical treatment. There were increases in statistically significant differences ($P < 0.05$) in all variables except for the thickness of the soft tissue on the superior nasopharynx (ad2-So) in retrognathic females. In the male group reduced thickness of the soft tissue on the superior nasopharynx (ad2-So) was noted, as was an increase in thickness of the soft tissue on the posterior nasopharyngeal wall (ad1-Ba) in retrognathic groups, while increased values for every variable were noted for the orthognatic data. (Tables 9 - 12)

The results of discriminating analysis showed that RME modifications are involved in overall treatment effects of rapid maxillary expander therapy. In particular, statistically significant increases were shown for:

- Superior (Pm-ad2) and inferior (Pm-ad1) nasopharyngeal depth, and sagittal depth of the bony nasopharynx (Pm-Ba) in orthognathic females,
- Superior nasopharyngeal depth (Pm-ad2) and sagittal depth of the bony nasopharynx (Pm-Ba) in retrognathic females,
- Inferior nasopharyngeal depth (Pm-ad1) and sagittal depth of the bony nasopharynx (Pm-Ba) in orthognathic males,
- Superior (Pm-ad2) and inferior (Pm-ad1) nasopharyngeal depth in retrognathic males.

The increase size of the sagittal depth of bony nasopharynx (Pm-Ba) may result from movement of the maxilla after RME treatment. This corroborates many articles found that reported the maxilla were displaced anteriorly and inferiorly[20,25,39-41,120]. Displacement of the maxilla, dental extrusion, lateral rotation of the maxillary segments, and cuspal interferences had also been ascribed to open the bite.

The maxillary halves split along the median palatine suture, creating a triangular radiolucent area with its base toward the anterior region in which the resistance of the facial structures was weaker [119-120]. This behavior of the maxilla was easily determined by examination of an occlusal radiograph, (Figure 35-37). In the frontal plane, the separation of the two maxillary halves also followed a triangular pattern[39-40,120] with its base downward and the center of rotation located near the frontonasal suture [120].

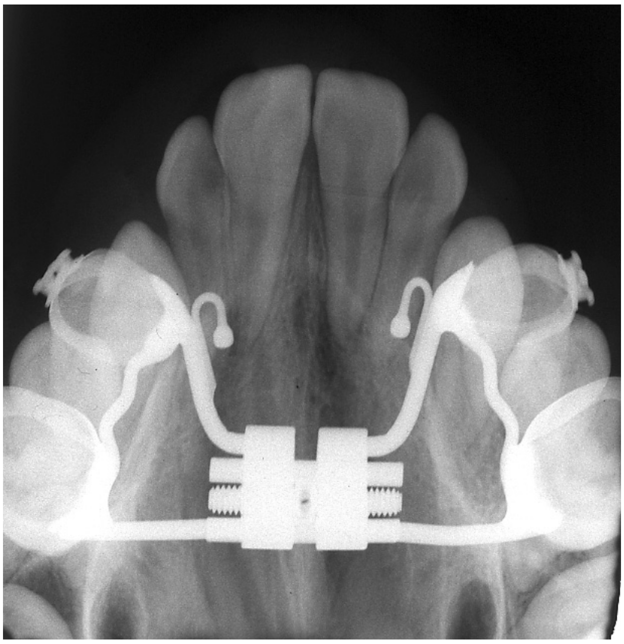


Fig.35. Maxillary occlusal radiograph before active RME showing normal midpalatal

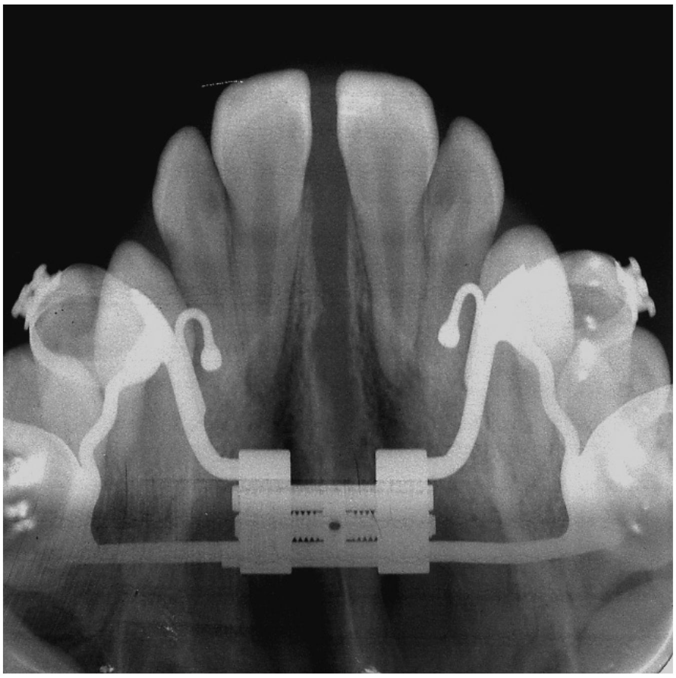


Fig.36. Maxillary occlusal radiograph of patient after active RME showing separation of midpalatal suture

Fig.37. Maxillary occlusal radiograph after retention period showing restoration of ossification at midpalatal area

That mean pterygomaxillary (Pm) moving forward and downward plays a major role in total changes induced by RME treatment by increasing the distance from Pm to bony pharynx (Ba) or Pm to nasopharyngeal soft tissue (ad1 and ad2). Furthermore, the result of the RME treatment ran concurrently with the normal phenomenon of growth in the nasopharyngeal area. The nasopharyngeal airway is frequently limited during the early school years, due to hyperthrophy of adenoid tissue. The nasopharyngeal airway tends to increase in size during early adolescence due to a concurrent increase in nasopharyngeal area and decrease in adenoid size.

5.3.2 Oropharyngeal measurements

There were increases in all measured values of the variables in the oropharynx due to treatment during the clinical period except for the retropalatal airway space (U-MPW) and middle airway space (MAS) data in orthognathic females, whereas reduction in the retropalatal airway space (U-UPW) in retrognathic females was recorded. (Table 9 - 12)

There were statistically significant different increases in:

- Hypopharyngeal space (Eb-LPW) in orthognathic females,
- Vertical airway length (VAL) in retrognathic females and orthognathic males,
- Nasopharyngeal space (Pm-UPW) and vertical airway length (VAL) in retrognathic males.

The result showed that the vertical airway length (VAL) increased after treatment except in orthognathic females. The results for this group, as a consequence of the joint effect of treatment and growth agreed with the study of King [55], whereas the VAL variable in the control group increased the statistically significant difference ($P<0.05$) only in orthognathic males and females. It may well be that RME helped the subject to increase VAL by spontaneous movement of the mandible. However, Pae *et al*. [90] stated that VAL might not best represent pharyngeal length.

5.3.3 Soft palate

There were increases in the soft palate length (SPL) and thickness (SPT) ($P< 0.05$) only in orthognathic males. (Table 9 – 12)

This investigation found that only orthognathic males had a soft palate longer than 0.59 mm and thicker than 0.83 mm somewhat larger than the findings of Taylor[105]. This suggests that RME may have an effect on the soft palate.

5.4 Comparison to the difference change due to growth in each group

Handelman and Osborne [43] studied the growth of the nasopharynx and adenoid development from age one to 18 years and found that the growth patterns of the nasopharynx from nine months to 18 years were different between girls and boys. Whereas Jeans and coworker [52] found that the area of the nasopharyngeal soft tissues in boys increased from the age of 3 to 5 years, then, with minor fluctuations, it remained the same until age 19 years while in girls there is a steady increase from age 3 to age 6, followed by a gradual fall in size from age 11 to age 19. The difference in area between the sexes was significant only at age 5 years. There was a significant difference in nasopharyngeal area between males and female at the age of 13 onwards due to the prepubertal spurt in growth rate of the nasopharynx, which starts at 9 in girls and 10 in boys. In addition, Enlow [31] concluded that on the average girls reach the pubertal growth spurt 2 years earlier than boys.

Malhotra *et al.* [78] found a difference between the sexes with the male increasing pharyngeal length, size of soft palate, and airway volume when compared with the female. They suggested that these differences were sex-specific and not a function of body size.

Mergen and Jacobs [85] found that the midsagittal nasopharyngeal area and the nasopharyngeal depth in subjects with normal occlusion were significantly larger than in subjects with Class II malocclusion. The convexity of the soft tissue on posterior nasopharyngeal wall was more frequent in Class II malocclusion subjects (95%) than in normal occlusion subjects (35%).

This current study disagrees with the previous studies because the present set of experiments found that there was no statistically significant difference in each group. The present data shows that the growth and development of pharynx and soft palate in each area during the course of 1.62 years had no statistically significant difference ($P < 0.05$) with gender and facial type (Table 13 – 16). This may infer that there are some characteristics that show no difference between gender and facial type for these subjects who have been used for the control groups. In addition, the time duration may not have been enough to detect any significantly different effect of the growth.

5.5 Comparison to the difference for changes of treatment in each group

5.5.1 Comparison to subgroup of females and males

In a comparison of female groups, there is no difference apparent between the female groups, while there was difference between orthognathic and retrognathic male groups in the thickness of soft tissue on the superior nasopharynx (ad2-So) and the thickness of soft tissue on the posterior nasopharyngeal wall (ad1-Ba), by means of a decrease after RME treatment in the retrognathic group and an increase in the orthognathic group. (Table 17 – 18)

5.5.2 Comparison to the sex groups

Comparison of the different sex groups found that there was a difference between orthognathic females and males in soft palate thickness (SPT), caused by a decrease after treatment in females and an increase after treatment in males. This investigation found there is no difference in retrognathic patients according to sex grouping. (Table 19 – 20)

In the study of effects of RME, there were differences between the sexes which may prove to be important, as it is known that the facial skeletal structure significantly increases its resistance to expansion with increasing age and maturity[123]. As girls complete puberty earlier than boys this may affect resistance to the forces of expansion. However, Hartgerink *et al.* [44] found no significant difference in a comparison of the boys and girls in their nasal resistance values, in the expansion and control groups.

5.6 Comparison of each subgroup of RME with each subgroup of the control groups

The measurement of the pharyngeal area was made for the control group and for the patient group treated with RME. There was a statistically significant difference in each group ($P < 0.05$) of RME and the control group for certain variables. (Tables 21-24)

A comparison of the control group with the treatment group after expansion demonstrated that following treatment no significant differences in sagittal measurements of nasopharynx remained between these groups.

This could be interpreted as evidence that the RME had normalized the treatment group, or it could suggest that severe maxillary skeletal narrowness was required to present a significant affect. However, there remained differences between these groups as indicated by the data given in tables 21-24.

5.7 Summary of the discussion

5.7.1 Cephalometric radiographs

The nasopharynx consists of group of muscular organs. The size and shape of nasopharynx depend on the surrounding bony structures, of which the base of the cranium bones is the most significant part. Cephalometric radiographic measurement is a possible technique to evaluate their structure and anatomy in the sagittal plane [94].

Cephalometric radiographs have been used for many years to evaluate facial growth and development [100], to examine dentofacial structures, nasal airways, and related areas [74]; it enables analysis of dental and skeletal anomalies as well as soft tissue structures and form.

Many authors [37,65,118] had quantified specific airway parameters, although the obvious limitations of two-dimensional images were recognized, to study anatomic regions, which consist of complex three-dimensional structures. Many observations were also made by other authors [35,89,93], who found that lateral skull radiographs provide a good image to record the size of the nasopharyngeal airway in children of all ages.

Linder-Aronson [65] found a high correlation between the results of posterior rhinoscopy and cephalometric radiography in the assessment of adenoid size. However, Lowe [72] coated the tongue with a mixture of barium sulfate and carboxymethylcallulose in order to enhance the x-ray opacity in his obstructive sleep apnea study.

This study, which used cephalometric radiographs to assess the bony and soft tissue landmark, found that sometimes it was not clear in some regions.

However, orthodontic consultants do not advise the use of three-dimensional computerized tomography because the patient is exposed to high doses of radiation and it can be an expensive waste of money and time. A cephalometric study is usually recommended in any patient with craniofacial syndrome or facial dysmorphism.

5.7.2 Methodology

The optimum control group should be a match for race, sex, and age with each subject. In this study, the control group as chosen was selected from patients waiting for proper treatment; so that there were insufficient numbers to match with the subject.

This study was focused on the facial type of subject, orthognathic and retrognathic in order to compare the difference in the effect of RME on each facial type, based on the facial characteristics associated with craniofacial morphology and mode of breathing. Mouth breathers have been stated to include a retrognathic mandible, proclined maxillary incisors, high V-shaped palatal vault, constricted maxillary arch, flaccid and short upper lip, and flaccid perioral musculature.

The children with upper airway obstruction exhibit a high frequency of posterior crossbite in primary and permanent dentition, particularly in those with enlarged lymphoid tissue [89]. Linder-Aronson [65] established the relationship between the presence of adenoid tissue and the following features: retrognathic of the maxilla and mandible relative to the cranial base, narrow dental arches, crossbite, retroclination of the maxillary and mandibular incisors, retrognathic mandibular arches, increased facial height, and a low tongue position.

In 1960, Korkhaus [59] found that many patients could achieve nasal respiration and move the mandible into the correct occlusion by a widening of the maxilla and the palate.

In 1993, McNamara [81] also stated the same, by widening the maxilla; this often relocates the mandible to a forward position during the period of retention. The spontaneous Class II condition may correct itself during the first 6 to 12 months of the post-RME period in the mild and moderate Class II patients.

5.7.3 Results

Many of the researchers into craniofacial growth have realized that the control mechanisms of the growth processes in the face are very complex, interrelated, and interdependent. There are numerous theories concerning facial growth, ranging from intrinsic genetic factors controlling the mechanisms of growth to functional or environmental determinants. The effect of adenotonsillar hypertrophy on facial growth and development remain controversial.

This study found the changes after treatment with RME and growth in the nasopharyngeal area, but there is no statistical significance when comparison is made between each. It may be assumed that RME activated or preceded normal growth of the subjects, after obstruction due to environmental or any other factors, to the proper position.

Previous workers had suggested that most of the resistance to RME was due to circummaxillary structures [50,120], and it was reasonable to assume that resistance would increase as these structures grew and matured. It may be reasonable to assume that the increased maturation of facial structures and sutures in the elder patients helped resist the forces of expansion and possibly result in more bone bending. Some of this resistance may be due in part to the partial ossification of the median palatine suture beginning at its posterior aspect, and there were large variations among individuals with the beginning of closure and ongoing growth with age [92]. No feature could be identified that would help predict those subjects most likely to respond to RME either skeletally or intra-nasally. It is likely that patients respond to RME on a highly individual basis.

Hartgerink and coworker [44] found that there was a significant decrease in nasal resistance after RME treatment and this steadied up to 1 year. There was a high individual response variability of subjects; consequently, RME was not a predictable means of reduction of nasal resistance.

Many studies stated that RME assisted upper airway obstruction in the nasopharyngeal area while the problem of SOA was found mainly at the oropharngeal area. On the other hand, Johnston and Richardson [54] found that pharynx changed throughout adult life by a variable tendency to become a narrower oropharynx, and a longer and thicker soft palate formed during adulthood.

In the oropharyngeal airway, this study found an insignificant reduction in the U-MPW, MAS, and / or Eb-LPW, only in RME female subjects whereas it was found in every control group. This may assume that the RME subjects and the control group harmonized characteristics by a tendency to sleep disordered breathing (SDB). The effect of RME assistance in the male group has less resistance to RME than in a female sample**,** because the females grew to the pubertal growth spurt 2 years earlier than male [31]. This earlier growth made the nasomaxillary complex of female more mature and all sutures were more fused. Comparing females and males at the same age, the nasomaxillary complex of the females would be strong enough to offer more resistance to the force from RME than would be equivalent male patients. It coincided with Korkhaus [59] and McNamara and co-worker [81] by the forward movement of the mandible after RME treatment, enlarging the oropharyngeal airway, while the mandibular advancement is the basic function of sleep apnea appliance. This finding may state that RME not only improves nasopharyngeal airways, but is also beneficial to the oropharyngeal area.

McNamara [82] confirmed that widening the maxilla often leads to a spontaneous forward positioning of the mandible during the retention period in cases of Class II malocclusion in mixed dentition associated with maxillary constriction. Haas [41] noted that virtually all Class II, division 2 and most Class II, division 1 patients present mandibular functional retrusion. In the Class II, division 2 group, the retrusion was due to lingual inclination of the upper central incisors. In the Class II, division 1 group, the retrusion was due to constriction of the maxillary dental arch, especially between the canines. Haas emphasized that in such cases, it was important to expand the maxillary arch to obtain a permanent orthopedic effect on the maxilla by releasing the mandible to allow forward movement. Lima Filho [64] confirmed this by presenting a long-term follow-up of a Class II, division malocclusion with maxillary constriction case report. RME was the only treatment provided for this patient. After expansion, the mandible seemed to be carried forward to its normal position, resulting in a spontaneous correction of the Class II malocclusion.

The current study leaves a few unanswered questions. However, whereas the preceding explanations for treatment response may not be enough to explain the entire range of individual variations, it provides useful explanations to key changes that occur due to treatment.

6. CONCLUSIONS

From the results of this study, it can be concluded that RME is effective in patients with maxillary transversal deficiency and nasal respiration problems. However, while planning the treatment, the localization of etiologic factors should be taken into account. The classically described skeletal changes resulting from RME, such as maxilla displacement; anterior open bite, and downward and backward rotation of the mandible, seem to be compensated for, or corrected in the course of the orthodontic treatment procedure. However, this compensation does not seem to be a major result or effect of the treatment itself, but of function, which permits normal growth progress, without extensive variations. The continued changes would likely be a consequence of normal growth or the orthodontic treatment assisting nature in the normal process of growth.

The treatment options for a patient with a malocclusion associated with nasal obstruction, enlarged adenoids, and allergies require a team approach for appropriate care. Optimally, the respiratory mode should be assessed early and treated for any problems detected in order to undertake proper preventive management. The pediatrician is usually the first health professional to consult children at this early age. Nevertheless, the orthodontist educated and empowered to oversee facial growth should routinely assess the breathing patterns of this group of patients in order to detect any potential problem that may lead to an altered form of facial growth or malocclusion.

7. SUMMARY

The purpose of this study was:

1. (1) to assess the cephalometric variables of the nasopharynx, oropharynx and laryngopharynx including soft palate among male and female subjects with different anteroposterior jaw relationships, orthognathic and retrognathic, treated with a rapid maxillary expander, a Hyrax-Type expansion appliance, in two dimensions;
2. (2) to assess the cephalometric variables of the pharyngeal area in the control group;
3. (3) to compare the variables of both groups in order to investigate the pharyngeal area.

Seventy-one maxillary constriction subjects, 39 females and 32 males, were selected from the records section of the Department of Orthodontics of the Ludwig Maximilian University, Munich, on the basis of the following criteria:

- (1) patient with skeletal maxillary constriction;
- (2) no observable craniofacial abnormalities;
- (3) no previous orthodontic treatment;
- (4) first permanent molars, primary molars or premolars were in occlusion; and
- (5) each lateral cephalometric radiograph was taken with teeth in centric occlusion.

The RME group was compared with a control group comprising 47 samples with normal transversal maxilla. The average age of the control group at the first observation was 9.94 ± 2.11 years and RME group before treatment was 10.15 ± 2.22 years.

In 71 patients, orthodontic treatment was started with RME, followed by conventional orthodontic treatment, not combined with any other form of orthodontic device. Twelve linear measurements, including pharyngeal airway and soft palate dimensions were determined. The lateral cephalometric radiographs were taken at the first examination for pretreatment and annual follow up for post-treatment was undertaken.

All cephalometric radiographs were hand-traced by one investigator using 0.35 mm lead 2H pencil on 0.003 mm matte acetate tracing paper in a darkened room with extraneous light from the viewing box. All tracings were measured with a digital caliper.

The differences between the RME and the control group were compared. The pharyngeal area and soft palate changed following RME treatment in the RME group and with growth in the control group. In the RME treatment group, there were statistically significant differences between the facial type of males and sex-related differences in orthognathic patients. No statistically significant differences were found between subgroups of the control patients and between the RME and control groups with the Mann Whitney *U*-test ($P < 0.05$).

The results suggest that airway dimension and soft palate underwent noticeable changes after treatment with RME whereas the control group changed after growth factor event and changing environment. These changes are usually produced and may be compensated in time by natural growth. Thus RME has been shown to be capable of assisting nature in the natural process of growth.

Finally, all patients considered for RME should be examined for nasal obstruction and if obstruction is found, prior to commencing orthodontic treatment, they should be referred to an otolaryngologist for examination and treatment of the problem.

ZUSAMMENFASSUNG

Ziel dieser Studie war es:

1. die kephalometrischen Variablen des Nasopharynx, Oropharynx, und weichen Gaumens unter männlichen und weiblichen Patienten mit unterschiedlichen skelettalen Konfigurationen (orthognath und retrognath) zu beurteilen, die behandelt wurden mit der forcierten Gaumennahterweiterung oder dem Hyrax-Typ Gerät;
2. die kephalometrischen Variablen des Pharynxbereichs in der Kontrollgruppe zu beurteilen;
3. die Variablen von beiden Gruppen zu vergleichen und deren Pharynxbereichwerte zu evaluieren.

Einundsiebzig Patienten mit maxillärem Engstand, 39 Mädchen und 32 Jungen, wurden aus der Poliklinik für Kieferorthopädie der Ludwig-Maximilian-Universität München aufgrund der folgenden Kriterien ausgewählt:

1. Patient mit maxillärem Engstand;
2. keine kraniofazialen Abnormitäten;
3. keine vorhergehende kieferorthopädische Behandlung;
4. erste Molaren, Milchzahnmolaren oder Prämolaren waren in Okklusion; und
5. jedes kephalometrische Röntgenbild wurde in zentrischer Okklusion aufgenommen.

Diese Patientengruppen wurden verglichen mit einer Kontrollgruppe bestehend aus 47 Individuen, die die gleichen Kriterien erfüllten, jedoch eine transversal regelrechte Maxilla aufwiesen.

Der Altersdurchschnitt zum ersten Zeitpunkt (T1) waren bei der Kontrollgruppe 9,94 ± 2,11 Jahre, und bei der GNE Gruppe 10,15 ± 2,22 Jahre war.

Bei 71 Patienten wurde die kieferorthopädische Behandlung mit einer GNE-Apparatur durchgeführt und die Behandlung bis zum Termin T2 nicht mit anderen kieferorthopädischen Geräten kombiniert. Eine Weichteilanalyse, die zwölf lineare Messungen umfasst, wurde durchgeführt, um den Pharynxbereich und den weichen Gaumen zu vermessen. Als Basis dafür dienten zwei Fernröntgenseitenbilder, aufgenommen jeweils vor der GNE-Behandlung sowie ein Jahr nach der Behandlung.

Alle Fernröntgenseitenaufnahmen wurden von einer Untersucherin durchgezeichnet; dabei wurde ein 2 H Bleistift (0,35 mm) verwendet. Alle Durchzeichnungen wurden mit einer digitalen Schieblehre vermessen.

Die Unterschiede zwischen GNE- und Kontrollgruppe wurden verglichen. Pharynxbereich und weicher Gaumen änderten sich durch die GNE Behandlung und das Wachstum in allen Gruppen. Bezüglich der GNE Behandlungsgruppe gab es statistisch signifikante Unterschiede zwischen dem Gesichtstyp (orthognath und retrognath) der Männer sowie im Vergleich männlich/weiblich der orthognathischen Patienten zum Zeitpunkt T1 und T2. Keine signifikanten Unterschiede wurden zwischen den Kontrollgruppen mit dem Mann Whitney *U* – Test gefunden ($P < 0{,}05$). Es gab keine signifikanten Unterschied zwischen den GNE- und den Kontrollgruppen.

Die Ergebnisse zeigen, dass die Dimensionen des Pharynx und des weichen Gaumens zusätzlich durch die GNE-Behandlung geändert wurden, während sich die Kontrollgruppe schon durch das normale Wachstum änderte. Diese durch die GNE-Behandlung hervorgerufenen Veränderungen können in der Zeit durch Wachstum ausgeglichen werden. Mit der Therapie der forcierten Gaumennahterweiterung, wird das Wachstum des Pharynxbereiches zeitlich offenbar vorgezogen.

Alle Patienten, die für eine GNE-Behandlung in Betracht gezogen werden, sollten auf ein nasales Hindernis überprüft werden und bei entsprechender Problematik einem HNO-Arzt vorgestellt werden.

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