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Grado en Odontología

PALATAL EXPANSION IN ADULT PATIENTS

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Abstract

Introduction: Palatal expansion remains one of the most important therapies in orthodontics. Being an established standard treatment method for enlarging the upper jaw, it is a successful form of therapy for crossbite and transverse micrognathia in growing patients. However, in skeletally mature patients, the possibility of successful orthodontic maxillary expansion decreases as sutures close and resistance to mechanical forces increases.

Objectives: Four treatment techniques, including Rapid Palatal Expansion (RPE), Surgically Assisted Rapid Maxillary Expansion (SARPE), Le Fort 1 Osteotomy, and Micro-implant Assisted Rapid Palatal Expansion (MARPE) were evaluated and compared with each other.

Methods: Literature was elected through electronic databases Medline and PubMed. Full text articles were included after screening titles and abstracts according to inclusion criteria.

Results and discussion: A significant increase in maxillary width was observed in all expansion groups. The choice of treatment method depends on the age, type and degree of malocclusion and the individual characteristics of the patient.

Conclusion: There is still no agreement on specific indicators and benchmarks relating surgical and non-surgical approach in adult patients. More research with equal measurement parameter will be necessary to have more representing results.

Resumen

Introducción: La expansión palatina sigue siendo una de las terapias más importantes en ortodoncia. Al ser un método de tratamiento estándar establecido para agrandar la mandíbula superior, es una forma exitosa de terapia para la mordida cruzada y la micrognatia transversal en pacientes en crecimiento. Sin embargo, en pacientes esqueléticamente maduros, la posibilidad de una expansión ortodóncica maxilar exitosa disminuye a medida que las suturas se cierran y aumenta la resistencia a las fuerzas mecánicas.

Objetivos: Se evaluaron y compararon entre sí cuatro técnicas de tratamiento, incluida la expansion rápida palatina (ERP), la expansión rápida del maxilar quirúrgicamente asistida (SARPE), la osteotomía Le Fort 1 y la expansión palatina rápida asistida por microtornillos (MARPE).

Métodos: La literatura se eligió a través de las bases de datos electrónicas Medline y PubMed. Los artículos de texto completo se incluyeron después de la selección de títulos y resúmenes según los criterios de inclusion.

Resultados y discusion: Se observó un aumento significativo en el ancho del maxilar en todos los grupos de expansión. La elección del método de tratamiento depende de la edad, el tipo y el grado de maloclusión y las características individuales del paciente.

Conclusion: Todavía no hay acuerdo sobre indicadores y puntos de referencia específicos en cuanto al abordaje quirúrgico y no quirúrgico en pacientes adultos. Será necesaria más investigación con los mismos parámetros de medición para tener más resultados representativos.

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1. Introduction

The palatal expansion is still one of the most important and longstanding therapies in orthodontics. Being considered as an established standard orthodontic treatment method for enlarging the upper jaw it is progressively used to correct maxillary transverse deficiencies. These can appear both solitary and in connection with other changes in the facial skull such as sagittal or vertical defects. (1) Beyond that, they may be responsible for unilateral or bilateral posterior cross-bite as well as anterior teeth crowding. (2)

Defects of the transverse width of the maxilla are not only related to a narrow skeletal base and a reduced dentoalveolar bone supply but they also have a negative impact on the aesthetics of the midface. Furthermore, as they lead to a less stable occlusion, the chewing ability is compromised. Even though, in some instances, jaw repositioning can lead to the correction of maxillary transverse defects, in the rest of the cases a transverse augmentation is indispensable to attain a tolerable occlusion. (1)

There is agreement in the literature that palatal expansion is a successful form of therapy, which can be used without problems in growing patients. The subject of many studies in recent years, however, was the question of whether non-surgical RPE may be applied in skeletally mature patients and when a surgical approach is rather considered.

1.1. History of Palatal Expansion

Already in ancient times, narrow jaws were considered as a skeletal problem. Around 400 BC, Hippocrates presented in his encyclopedic work *"Corpus Hippocraticum"* some manifestations due to transverse maxillary tightness and long, narrow skulls. Without giving therapeutic recommendations, he identified the correlation between strongly arched palates with misaligned, missing or crowded teeth and general symptoms such as headache, mouth breathing as well as ear discharge. (3,4)

25 BC – 50 AD, Celsus recommended in his work „*De medicina*" that persistent deciduous teeth should be removed after the permanent teeth had erupted and suggested to move misaligned permanent teeth into the correct position using the bare fingers. (4, 5)

The First Orthodontic Appliance

In the beginning, the treatment of narrow jaws was purely symptomatic by means of moving, extractions or grinding of teeth. Later on, in 1728, slow expansion of the dental arch was initially reported in the first complete scientific description of dentistry, "*Le Chirurgien Dentiste"* (*"The Surgeon Dentist"*) by Pierre Fauchard, credited as being the "father of modern dentistry". (6) His first orthodontic appliances named "*Bandalette*" consisted of a horseshoe shaped strip of precious metal to which the teeth were ligated. (4, 5)

Modern Orthodontic Appliances

In 1860, a fixed device for rapid expansion of the palatal suture was introduced for the first time in the frequent cited work of Emerson C. Angell from San Francisco, USA, ("father of rapid palatal expansion") published in the "*Dental Cosmos*". As an opponent of extraction therapy, he used an appliance to gain space in the upper jaw that consisted of an expansion screw which was attached between four maxillary teeth and had to be maintained by the patient in constant lateral tension using a small wrench [Figure 1 and 2]. After two weeks, the result of the treatment was an expansion of approximately 6.35 mm and a medial diastema, which Angell explained as the result of the “rupture of the median palatine suture”. Since he could not prove his theory radiologically, he received a skeptical response from his colleagues. (4, 5)

Figure 1 Illustration of first device for palatal expansion by Angell (7)

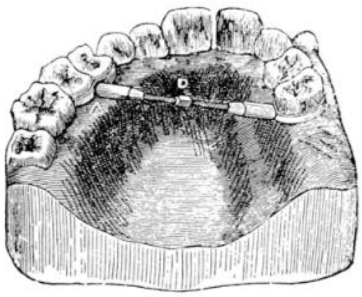

Figure 2 Illustration of first described device by Angell in the upper arch (7)

In 1893, when C.L. Goddard gave lectures on the "separation of the superior maxilla at the symphysis" and spoke about an orthodontic device that consisted of ligaments as well as double screws, the palatal expansion received greater recognition. (8)

Palatal Expansion in the 20th Century

Later on, in 1909, Landsberger was the first confirming the opening of the median palatine suture by means of a X-ray. (5) Since then, various constructions of devices have been described and maxillary expansion has been developed and improved, becoming a relatively simple and routinely applied technique in orthodontics. (9)

Schroeder-Benseler published the first comprehensive work on the palatal expansion in 1913, presenting an appliance in which the screwing force was transferred merely from the teeth to the jawbone.

Many years later, in 1956, Derichsweiler described a device in which the walls of the palate were included for support and force transmission, with the aim to prevent the tilting of the anchor teeth. While first there have been described mainly fixed devices to ensure adequate fixation, later in 1958 Öhler and Schönherr recommended removable appliances with the same objective.

Overall, there has been introduced a large variety of orthodontic devices, among these one manufactured by Haas in 1961. His appliance consisted of an acrylic base attached to the palate which disposed of a median screw as well as metal bands that grasp the teeth physically [see Figure 3]. (10)

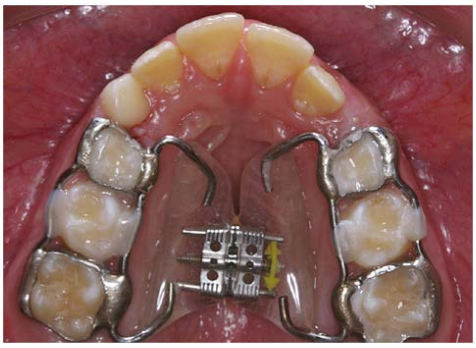

Figure 3 Haas appliance (11)

Due to the large surface area on the palate, the force was able to act on the covered bone areas in addition to the teeth. Indeed, this extensive palate coverage was a functional advantage, but it resulted in a drawback regarding hygienic ability. (3) The "acrylic cap splint expander" was a modification of this construction. Here, the teeth are physically held in acrylic which is kept 1 mm short of the gingival margin allowing maintenance of good oral hygiene. (5)

A new era in the manufacture of the palatal expansion opens up when Biederman introduced the "Hyrax" (Hygienic Rapid Expander) in 1968. This screw with retention arms is firmly welded or soldered to tapes, allows simple laboratory work and better oral hygiene conditions in the patient [see Figure 4]. (12) On that basis, many modifications of the device design were made, all of which remained anchored in the dental field.

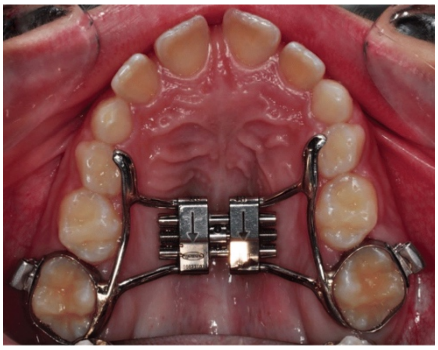

Figure 4 Hyrax Expander (13)

Latest Goals of Palatal Expansion

During the past decades, palatal expansion developed in a different way, trying to reduce undesired side effects of the purely dental anchoring (e.g., dental tilting of the anchor teeth), or even to eliminate them. This was pursued by means of skeletal anchorage using implants. One of these implant-borne Hyrax screw constructions was the "Dresden Distractor" by Harzer et al [see Figure 5]. It is placed in the course of general anesthesia and used to surgically weaken the ossified midpalatine suture (MPS) at an advanced age.

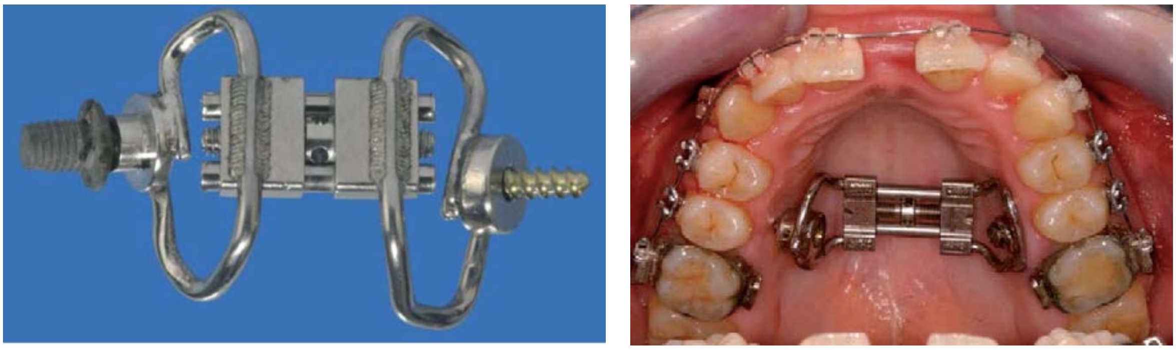

Figure 5 Bone-borne Dresden Distractor, fixed with an implant and osteosynthesis-screw **(left)**; Dresden Distractor in situ; appearance of a central diastema. **(right)** (14)

A less invasive method is the insertion of the Transpalatal Distractor (TPD), described by Mommaerts in 1999. (5, 10) It consists of telescopic cylinders, so-called distracters, that are supported on two bony attachments on the palate in regions 14 and 24 [see Figure 6]. A daily activation by 0.33 mm leads to a separation of the MPS, reaching a maximum expansion of up to 12 mm. As there is a direct transmission of forces to the bone, there is neither tooth tilting nor changes to the palatal mucosa. (8)

Figure 6 38-year-old male patient: initial situation **(left)**; intraoperative situation during activation of TPD after modified osteotomies for unilateral palatal expansion **(middle)**; situation after termination of distraction. **(right)** (15)

In 2008, Ludwig and Wilmes introduced the Hybrid-Hyrax expander (HHE) as an additional innovation of palatal expansion. This construction combines the dental and skeletal support by strapping the first molars and the minimally invasive insertion of orthodontic mini-implants (OMI) in the anterior part of the palate [see Figure 7]. (5)

Figure 7 Hybrid Hyrax expander adapted to two OMI (16)

1.2. Transversal Underdevelopment of the Maxilla

There are several clinical signs of maxillary hypoplasia, including a V-shaped, narrow upper arch, a high, pointed palate with a narrowed apical base of the upper jaw as well as pronounced buccal corridors when smiling. Other features, reported by Beds et al., are a nasal base narrowing and a deep nasolabial fold. (3)

Transverse underdevelopment of the maxilla can occur either in isolation, or in association with a vertical excess growth of the maxilla, with class II or class III toothing. Also, nasal breathing and the resulting mouth breathing is a common concomitant and causes a number of clinical problems, such as xerostomia, increased caries activity and recurrent upper respiratory infections. (9)

Importance of the Tongue

The tongue has a fundamental function regarding a correct formation of the maxilla. Its growth stimulation role is getting eliminated when mouth breathing occurs as the resting position of the tongue and the mandible resting position shifts caudally, leading to a high, narrow palate. (17) Commonly, there is an increase in perioral and buccal muscle activity to achieve lip closure, as well as a protrusion of the fronts due to an often-arising incompetent lip seal. (3)

Posterior Crossbite

A clinically conspicuous feature of a narrow upper arch is the posterior crossbite, noticeable by a positional deviation of the posterior teeth in occlusion. In such case, the buccal cusps of the maxillary teeth contact with the central fissure of the mandibular teeth. (3) It can be distinguished between unilateral or bilateral crossbite when the patient bites into maximum intercuspidation. (4, 12)

In the literature, various etiological factors such as heredity, restricted nasal breathing, crowding, disturbances during tooth change and oral digit habits are discussed. Even though, cross bites occur more frequently in primary dentition, which suggests that there is a possibility of spontaneous correction, it often persists in permanent teeth. (3)

The cause of a cross bite is almost always skeletal, implying a discrepancy in the transverse dimension of the maxilla and mandible. As a compensation, an aberrant relationship between both dental arches occurs, showing buccally tilted upper and lingually tilted lower teeth. In rarer cases, the crossbite is purely dentoalveolar origin, caused by a pronounced palatal inclination of the maxillary teeth as well as a buccal inclination of the mandibular teeth. A combination of skeletal and dentoalveolar causes is likewise possible. (3, 9)

It is desirable to apply therapeutic measures for maxillary constriction already in the deciduous dentition and in the early mixed dentition to allow a neutral toothing of the posterior teeth of the permanent dentition to be set as well as prevent a forced bite. Treatment options are the grinding of primary teeth or a transversal redevelopment of the maxillary dental arch by means of orthodontic plate devices, Quad helix or RPE. Thus, palatal expansion and its possible complications can be avoided in adulthood.

A posterior cross bite in adult patients is often associated with a shortened dental arch length resulting due to a nesting position of the front teeth. A method to enlarge the dental arch is the enlargement of the maxilla in the transverse plane creating thereby the necessary space for the front teeth in the front. In some cases, in this way, extractions can be avoided. (3)

1.3. Treatment Methods for Palatal Expansion

The aim of the treatment is to restore physiological function and aesthetics. Ideally, it should lead to sufficient dimensions of the alveolar bone to enable an eugnathic occlusion, providing an adequate mastication as well as a proper deglutition. Other important therapeutic goals are a correct relation between both jaws, preservation of function of the mucosa and a proper lip seal.

Selection Criteria

Today, a correction of upper jaw width is usually carried out combining orthopedic and orthodontic treatment. Therapy methods are selected depending on the patient´s age and acceptability, present malocclusion as well as the practitioner´s personal experience. (12)

As presented above in a summarized form, there is a great variety of conservative treatment methods that lead to an enlargement of the alveolar bone in growing patients and show relatively stable results. However, in mature patients there is an increased risk of complications such as root resorption or undesirable movements of anchor teeth. As gained space is obtained mainly by tooth movements, there is also a higher risk of recurrence.

Nowadays, the following expansion treatment modalities are used: Rapid Maxillary Expansion (RME or also called Rapid Palatal Expansion, RPE), Slow Maxillary Expansion (SME) and Surgically Assisted Rapid Maxillary Expansion (SARME or also called Surgically Assisted Rapid Palatal Expansion, SARPE). (12) Furthermore, the Le Fort I Osteotomy is a possibility of treating a bimaxillary transverse deficit purely by oral surgery. (18)

Age Factor

As in growing RPE can be performed conservatively, it is advocated as the selected treatment for maxillary transverse skeletal deficiency in children and adolescents. While here good results can be achieved, it is challenging in adults due to the difficulty of separation of the ossified MPS. However, the higher resistance is also attributed to other bony structures adjacent to the maxilla, including the midface pillars, the temporozygomatic sutures, zygomaticofrontal sutures and zygomaticomaxillar sutures, as well as the zygomaticoalveolaris crist. According to Jafari and Shetty the greatest resistance is in the area between the roots of the two central incisors. (19) Baumrind and Korn found that the palatal suture closes in women between the ages of 14 and 15 and in men between 15 and 16 years. (12, 19) Hence, after puberty it becomes increasingly complicated to separate the two interdigitated maxillary halves without fracturing.

(20) Therefore, in mature patients, often surgical support by means of SARME or Le Fort 1 osteotomy is advocated. (5)

Figure 8 Interdigitation of the median palatine suture in the various stages of age: early childhood **(left)**; puberty **(middle)**; adulthood. **(right)** (3)

Patients Acceptability

As surgical treatment methods are being often refused by patients, there is an alternative treatment for non-growing patients using a bone-borne expander. This so-called Micro-implant assisted rapid palatal expansion (MARPE) reduces harmful dental effects and consequently preserves the periodontal health to a greater extent. (12, 21, 22)

Hereafter, the above-mentioned treatment methods are depicted in detail.

1.3.1 Rapid Palatal Expansion

The RPE method is premised on the division of the MPS and the following maxillary transverse expansion according to the principle of distraction osteogenesis. (12, 22, 23)

Sequencing of RPE

In general, when implementing RPE, the use of an orthodontic appliance leads to an interwoven sequence: compression of the periodontal ligament, bending of the alveolar process, tipping movement of the anchor teeth and furthermore, a progressively opening of the maxillary sutures, among them the MPS.

In the case of tooth-supported appliances, the transverse expansion screw built into the appliance exerts pressure on the anchor teeth through activation, which is repeated one to six times a day, and this pressure is transferred to the maxilla. In order to achieve not only an orthodontic widening of the dental arch, that is purely of the teeth, but the desired orthopedic, i.e., skeletal effect, the pressure and the speed of activation must exceed a certain level. (5) Forces, which exceed the required limit for orthodontic tooth movement to the posterior teeth, are transferred to the MPS. These amount as much as 2-5 kg per quarter-turn with accumulated loads of more than 9 kg. (24)

The repeated activation prevents the start of bone remodeling processes in the alveolus and transverse forces continue to act directly on the suture leading to its expansion. The opening takes place through the large forces of 15 to 100 N accumulating on the anchor teeth and the palatal parts of the maxilla.

In addition to the MPS, also deeper cranial structures are changed by the force exerted on the expansion screw. (5, 26) The mucous membrane and the periosteum are retained in their continuity. (24)

Figure 9 Expansion screw **(left)**; Key used for activation of appliance **(right)** (25)

According to Wertz RPE leads to a wedge-shaped division of the two halves of the upper jaw in sagittal and vertical directions [see Figure 10]. This also results in the arch widening of 2:1 measured by Krebs. The typical medial diastema arises due to the increased anterior expansion. (12) It can be observed a maximum division at the anterior incisor region which is progressively reducing until it finally closes at the posterior part of the palate. (2, 27) After the activation period of usually 2 to 3 weeks, a retention period of three months is recommended to ensure the ossification of the generated opening of the MPS. (2)

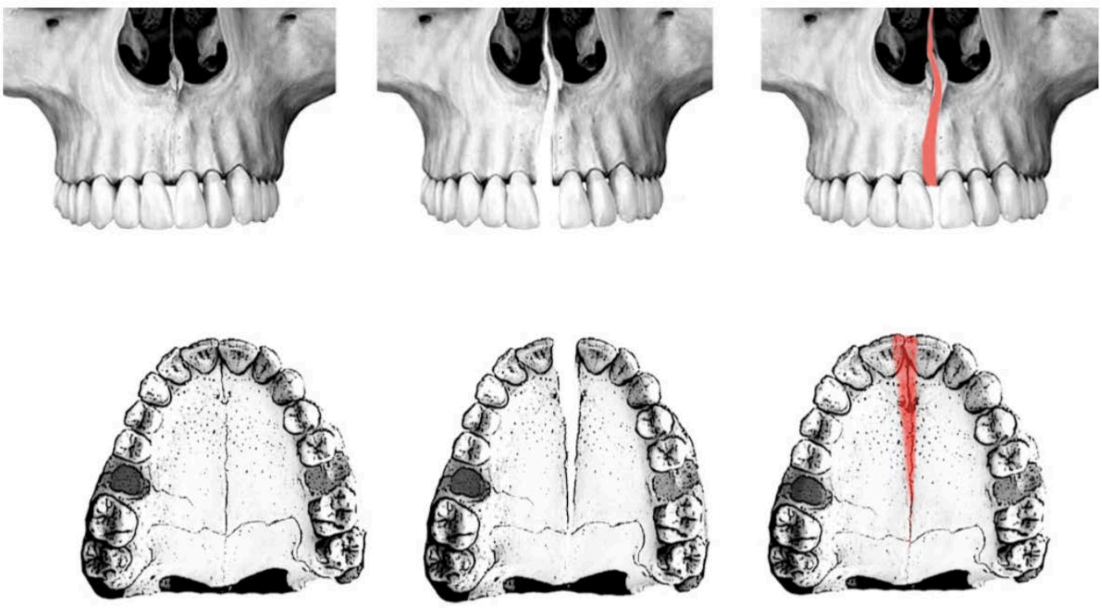

Figure 10 Anterior view of RPE **(top)**; Occlusal view of RPE, wedge-shaped division of the palate **(bottom)** (7)

Indication for RPE

In orthodontics, RPE is indicated in unilateral or bilateral cross bite and in cases of forced lateral bites with maxillary transversal discrepancy of minimum 4 mm. It can be also used in case of buccal inclination of the upper molars or in moderate maxillary crowding**.** (2, 28, 29) Furthermore, it is commonly applied in patients with a class III to facilitate the protraction of the upper arch by disrupting the complex of the maxillary sutures, and thereby their connection to the cranial base. (2) RPE is also implemented as an alternative to extraction therapy in patients with Angle Class II and a large transversal deficit of the maxilla or a narrow apical base and the associated dental crowding. (30, 31) Today, RPE is used particularly successfully in patients with micrognathia in combination with a Delaire mask as well as in patients with cleft lip and palate with a collapsed maxilla. (32-35)

Contraindications for RPD

Generally, RPE is contraindicated in skeletal maturity, skeletal asymmetry of the maxilla or mandible, in severe anteroposterior and vertical skeletal defects, as well as in those patients who present poor compliance. (36) It is also unsuitable in patients with convex profile, anterior open bite or steep mandibular plane. Besides, it is not recommended in cases of molars which present recessions on the buccal aspect. (12)

However, various information about the age limit for successful RPE can be found in the literature. The results of further studies also give concrete indications that RPE can be performed successfully in some adult patients. According to Capelozza et al., Northway and Meade, as well as Handelman et al., minor transverse deficits, mainly of a dental origin, can be corrected even in adulthood without surgical support. Before or during pubertal growth, RPE is indicated and easily implemented. However, many clinicians report difficulties when performing this after pubertal growth. (3)

Disadvantages of RPE

As the maxilla is affiliated with various bones of the face and head, RPE does not only increase the width of the upper arch but its impact goes much further. Two relevant side effects are dental tipping due to minimal tooth movement and skeletal movement. (12, 22, 23) Clear disadvantages are also the traumatic separation of the MPS, microtrauma of the temporomandibular joint, pain as well as discomfort due to the applied heavy forces by the expander. Other drawbacks are relapse, bite opening, root resorption and tissue impingement. Furthermore, RPE is not appropriate to correct rotated molars. Also, a successful outcome is always based on the patient's cooperation by means of the steady daily activation. RPE implies also time-consuming preparation of the respective expander in the laboratory. (12)

Fastening of the Rapid Palatal Expander

RPE can be executed by different kinds of appliances, all of which have an expansion screw to connect the right and left half of the device and to activate the construction.

Fastening can be achieved on the one hand by gluing the teeth with acrylic coatings ("bonded"), on the other hand by banding the teeth ("banded"). (5)

Banded Expanders

Banded expanders are usually fixed to the first molars and, when indicated, also to the first premolars by the use of orthodontic bands.

Two types of banded expanders can be distinguished: tooth borne, and tooth and tissue borne. Tooth borne RPE include the Hyrax and the Issacson expander.

Tooth Borne Rapid Palatal Expander

Hyrax

The Hyrax expander implies a non-spring-loaded palatal jackscrew, the Hyrax-screw, with a rigid wire framework that follows the palatal contours and is soldered to the bands [see Figure 11]. The activation of the screw from front to back leads to a separation of the MPS of 11 mm within a short amount of time. Generally, each turn equals approximately 0.2 mm of lateral expansion, whereby a maximal expansion of 13 mm can be reached. (37)

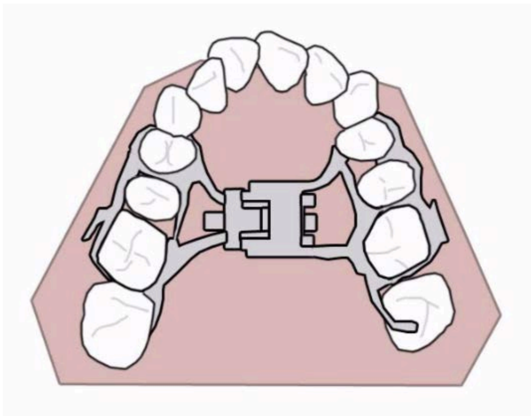

Figure 11 Hyrax type of expansion appliance (38)

Isaacson

The Issacson expander consists of the spring-loaded screw “Minne” expander (developed by the dental school of the university of Minnesota) which is soldered directly to the bands of the abutment teeth. It consists of a nut that, when being turned, compresses the coil, extends between two palatal metal flanges which are perpendicular to the coil, and expands the heavily calibrated coil spring [see Figure 12]. (37, 38) The screw is activated by closing the nut and thereby compressing the spring. Whenever it is activated, it is able to exert expansion forces even after the expansion phase is completed. (12, 39)

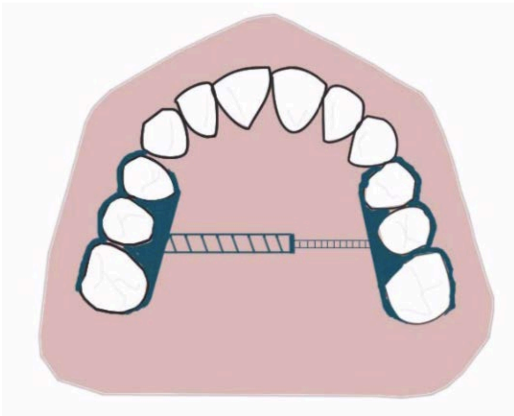

Figure 12 Isaacson type of expansion appliance (38)

Advantages of tooth borne rapid palatal expanders are the minimal interference with speech and good possibility of cleaning. Also, the palatal mucosa is not getting irritated as it is not covered by the device. (40)

Tooth Borne and Tissue Borne Rapid Palatal Expander

Despite of the hygienic skeletonized appliances there still exist other devices that cover the palate. These tooth and tissue borne rapid palatal expander are attached to the left and right first premolars and first molars by means of bands and contain a jack screw which is incorporated in acrylic pad that closely contact the palatal mucosa. (38, 39)

According to Haas, the use of these appliances yields to numerous benefits. One of them is increased bodily movement and diminished tipping when a palatal coverage is provided. Thus, the acrylic closely contacts the palatal mucosa and forces are generated not only against the teeth but also against soft and hard palatal tissues. Other clear advantages include better parallelism of the expansion, a higher treatment stability and an increased mobility of the upper jaw instead of teeth. Furthermore, a more beneficial relation regarding the transversal and sagittal plane of the denture bases, and also a higher gain regarding the apical base and the nasal cavity is achieved. (39)

A clear disadvantage of these tooth and tissue borne expanders is the higher tendency to irritate the soft tissue, especially the palatal mucosa. (40)

A distinction can be made between two types: Haas and Derichsweiler.

Haas

The Haas appliance consists of two rigid acrylic plates, which incorporates a jack screw in their midline, and adapts closely to the palatal vault [see Figure 3 and 13]. Besides, it implies lingual arms that are fixed to the molar and premolar bands which in turn are integrated into the acrylic. (38) Forces produced by this device have been reported in the range of 1,3 to 4,5 kg and make an immediate separation of the MPS and, thereby, an expansion within 10 to 14 days possible. (39)

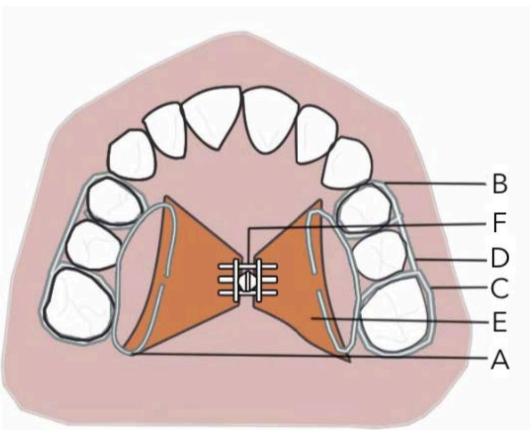

Figure 13 Haas type of expansion appliance: **A** Lingual support wire **B** Premolar bands **C** Molar bands **D** Buccal support wire **E** Acrylic plate **F** Expansion screw (38)

Derichsweiler

The Derichsweiler expansion device implies also wire tags, which on one side are soldered to the palatal surfaces of the molar and premolar bands, and on the other side are inserted into the acrylic plate which covers the palate and contains a central jack screw [see Figure 14]. (12, 38)

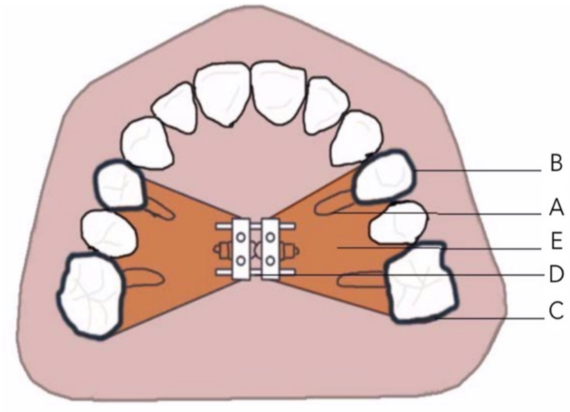

Figure 14 Derichsweiler type of expansion appliance: **A** Wire tags **B** Premolar bands **C** Molar bands **D** Expansion screw **E** Acrylic plate (38)

Bonded Expander

Bonded expanders imply Cast cap splints or Acrylic splints, that cover a variable number of posterior maxillary teeth on both sides, and to which a jack screw is fixed [see Figure 15]. (41)

Advantages include good retention, in comparation to other devices, due to easy management of cementing during mixed dentition. Moreover, tipping and extrusion of posterior teeth is reduced due to the buccal capping, improving vertical control. (41) Due to the block effect, anterior crossbite can be corrected and in total, less appointments are needed. (42)

To limit the extent of the midline diastema that comes along with the RPE treatment, another device has been designed. This so-called "Inman Palatal Component" E-Arch/Arnold Expander, in short, IPC Expander, can be implied when in addition to orthopedic expansion also labial alignment of the anterior teeth is searched [see Figure 15]. It provides to control forces applied by means of an NiTi open coil spring, to the lingual surface of the incisors and minimizes the diastema by means of wire at the distal surface of the lateral incisors. (12, 40)

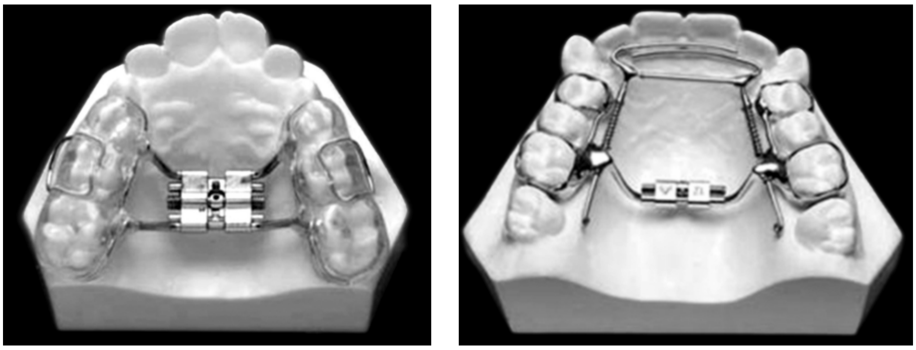

Figure 15 Bonded palatal expander **(left)**; IPC expander **(right)** (12)

1.3.2. Slow Palatal Expansion

An alternative procedure to correct a narrow maxilla in adults is SPE.
There are a number of arguments which indicate the use of this treatment method, including the favorable bone formation in the MPS due to reduced resistance of the structures surrounding the maxilla as well less chance of relapse, whenever an appropriate retention period is provided. (12) The applied devices assure adequate retention of the expansion since they present a high wearing comfort which is due to their extremely low weight and convenient use. Moreover,

additional appointments for impression-taking as well as expenditure of time and extense in the laboratory can be avoided due to the prefabrication of the devices.

By delivering a constant physiological force, with slow expansion the palate can be separated approximately 1 mm per week by applying 450-900 gm of force. A total expansion of 3.8 to 8.7 mm can be reached. SPE uses weaker forces (10-20 N) than RPE to separate the maxillary sutures. Hence, it might not be high enough for a palatal expansion in mature adults. (12)

There exists a variety of devices to perform SPE, including the Coffin appliance, Quadhelix, W-Arch, as well as Spring Jet, Nickel Titanium Expanders ("NiTi Expander") and Magnets [see Figure 16]. (12)

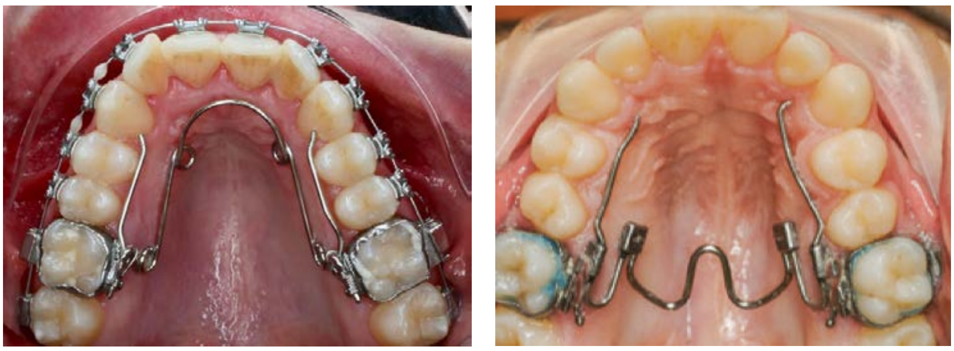

Figure 16 Quadhelix **(left)** (43); NiTi Expander **(right)** (44)

1.3.3. Surgically Assisted Rapid Maxillary Expansion

As already mentioned, when reaching adolescence, the MPS is getting progressively interlocked, and its opening becomes difficult by conservative means with advancing age. (19,

45) Therefore, after the maxillary ossification is completed, a narrow jaw is rather expanded with surgical support (19). Otherwise, since the expander is fixed to the teeth, the force is transmitted directly to the teeth and the alveolar bone. (46 – 48) Consequently, the expansion does not take place by separating the MPS but by expanding the alveolar processes. Activation of the expansion screw can then lead to numerous side-effects as pain, pressure, buccal tilting or extrusion of the posterior teeth as well as gingival recession, devitalization, root resorption, bone fenestration, and even fractures of the alveolar process. (46)

Sequencing of SARME

Division of the Palatal Plate

SARME is conducted under general anesthesia with naso-endotracheal intubation.

The surgical division of the palatal plate is performed by means of a chisel or a fine saw, starting with a vertically guided buccal incision in the area of the upper central incisors, and proceeding towards the incisive foramen until reaching an interradicular cut. Then, a palatal incision of the gingival margin in the area of 14 to 24 is made. Afterwards, the palatal plate behind the incisive foramen is chiseled through para-septally on both sides, keeping a distance of 2 – 3mm to the center. The anterior and the posterior cut is merged behind the incisive foramen with a cross connection. (3, 19) When the surgical part is fulfilled, the expansion device is cemented in and the screw is turned immediately until a strong resistance impedes a further rotation.

Division of the Zygomatico-Maxillary Crest and the Pterygopalatine Process

The surgical division of the zygomatico-maxillary crista and the pterygopalatine process can be excuted in two ways, either by performing a bilateral mucosal incision from the canine to the first molar high in the vestibule or a continuous incision from premolars to premolars [see

Figure 17]. Hereby, the facial maxillary sinus wall can be exposed from the piriform aperture to the zygomatico-maxillary crest. (3, 19)

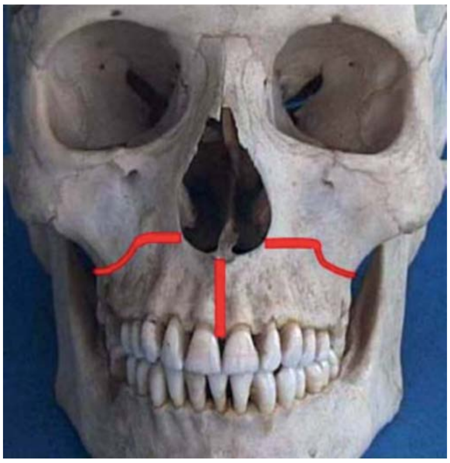

Figure 17 Human skull: red lines show the surgical division of the zygomatico-maxillary crest and the pterygopalatine process (19)

The incision is made with a bone saw posterior to the zygomatico-maxillary process up to the piriform aperture. By using a curved chisel and while protecting the soft tissue, the pterygopalatine process is severed. As there is practically no view when the maxilla is separated from the base of the skull, this is a crucial point of the procedure and requires a careful identification of the anatomical structures. In addition, the intermaxillary suture must also be severed with this method. (3, 19)

Indication for SARME

There is no unanimous opinion between orthodontists and surgeons regarding the indication for SARME. However, some consistent indications can be found in the literature, which all apply to adult patients with an upper narrow jaw. (3, 49) These include cross bites, if no further surgical positional changes are planned or the requirement for a preparatory measure, if further surgical interventions to change the position of the jaws are planned. The latter aims to avoid the risks, inaccuracies, and instability associated with segmented maxillary osteotomy. Moreover, its used to create space in case of crowding of maxillary teeth when extraction therapy is not indicated. Other indications are hypoplasia of the maxilla, which is associated with a cleft lip and palate, large buccal corridors when smiling and weaknesses in the bony resistance in a failed RPE. (3, 19)

Most authors see the age of the patient as the strongest indication for SARME. The skeletal age should therefore be given special consideration when selecting a patient, as it may differ from the chronological age. (3)

When establishing the indication, a distinction must be made between skeletal and/or dental causes, considering also the presence and extent of skeletal discrepancy. According to Jacobs et al. a crossbite situation on more than 2 teeth indicates skeletal involvement. (48)

As a result, a distinction is made between "relative transverse discrepancy" and "absolute transverse discrepancy". In the first situation, there is a horizontal mismatch, which is corrected by setting the study models in a Class I toothing [see Figure 17]. In the case of an absolute transversal discrepancy, the cross bite does not disappear or becomes only visible when in Class I [see Figure 18]. (48)

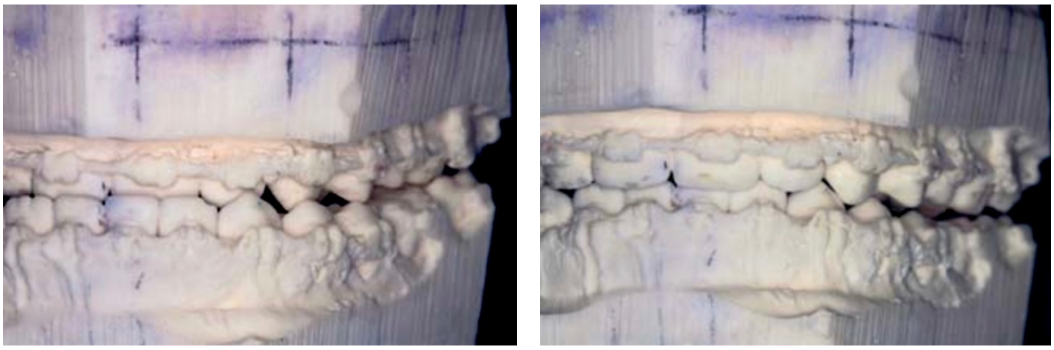

Figure 17 Patient with skeletal Class III, post-crossbite (**left**); Absolute micro-maxillary view, frontal view; crossbite disappears after setting in Class-I toothing **(right)** (19)

Figure 18 Absolute micro-maxilla, lateral view of dental/skeletal class II **(left)**;
after setting in Class I teeth: post. crossbite **(right)** (19)

Contraindication for SARME

There is no absolute contraindication described in the literature. However, a side effect of the SARME can be a slight bite opening due to the tilting. Therefore, a strongly pronounced vertical growth pattern can be named as a relative contraindication. (3)

Advantages of SARME

In total, SARME is a recognized as an effective, stable and easy-to-use method. According to Byloff and Mossaz, the SARME ensures the transfer of the cross bite in the posterior region. This leads to aesthetically pleasing results in the anterior region and a secure support in the posterior region, which can prevent abrasion and periodontal damage. (3) In comparison to a separation of the palate, an important advantage of the method is the already firmly cemented expansion device. The maximum possible expansion of the maxilla occurs immediately, and incompletely severed bone areas are directly visible if the stretching is not symmetrical. (3)

Disadvantages of SARME

Although severe complications are rare, some of them may lead to further consequences as intraoperatively bleeding when severing the pterygopalatine (50) and unilateral blindness due to an Orbital compartment syndrome (OCS), triggered by a retrobulbar hematoma. (3, 19, 50) Postoperatively, if the sutures have been severed insufficiently, pain occurs when the screw is turned. Furthermore, bone areas that remain fused, lead to the tilting of the teeth, hence, the sought movement of the maxilla stays away. This may result in gingival recessions and an asymmetrical enlargement. In rare situations it may even lead to the fracture of the expansion plates. (3, 19)

Appliances for SARME

Removable appliances are not recommended for performing the SARME, as adequate anchoring and stability cannot be achieved intraoperatively or postoperatively (49). Hence, fixed devices, which provide a much better attachment to the anchor teeth or in the palate are the means of choice. Here, a distinction can be made between dental and skeletal anchored appliances.

Dental Anchored Appliances

When using dental anchored devices, the expansion force is generated by an expansion screw and transferred to the bone via the posterior teeth. The Hyrax appliance, which was described previously, is used most frequently. (3, 51)

There is a risk that unwanted movements of the anchor teeth such as extrusion or tilting take place during the expansion and retention phases. A subsequent relapse must be then counteracted with overcorrection. Moreover, it can also damage the gingiva and the periodontium of the anchor teeth. In addition, oral hygiene can be difficult or restricted, which can lead to gingivitis and tooth decay.

In syndrome patients with an extremely narrow palate, the available space is often so limited that a dentally anchored appliance cannot be used. (3) In patients with symptoms of craniomandibular dysfunction or in patients with periodontally impaired teeth, it is possible to connect a splint to the appliance that completely covers the occlusal plane. Hereby, more anchor teeth are included for the transmission of force to the bone. (3)

Skeletal Anchored Appliances

In order to reduce the problems caused by dental anchored devices, various skeletal anchored devices have been developed. These are fixed in the palate and transfer the force of the expansion screw directly to the palatal bone. (3)

Mommaerts states that skeletal anchored devices have the advantage over dental anchored devices as they provide better anchorage which consequently results in a better control of the bony movement. Hence, a lower tendency to relapse during and after expansion can be observed. There is also the possibility of attaching the device in cases with a reduced number of teeth. Another advantage is that postoperative orthodontic treatment can be started earlier. (46) Many of the bone-supported appliances can also be used in patients with a very narrow palate, as they are slender and available in different sizes.

There are a number of differently designed skeletal anchored appliances that are attached to the palatal bone using mandrels, mini screws or implants. These include, among others, the Rapid Palatal Expander, the Trans Palatal Distractor [see Figure 6], the Dresden Distractor [see Figure 5], and the Rotterdam Palatal Distractor [see Figure 19 and 20]. (3, 50)

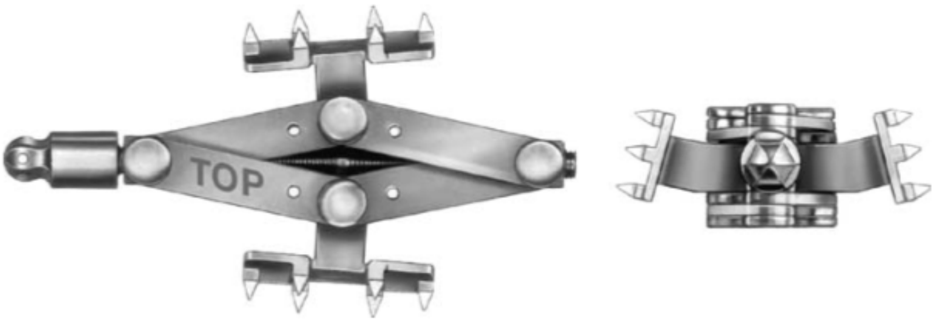

Figure 19 Design of the Rotterdam Palatal Distractor, made of titanium grade II. The basic part has holes to secure the device with stainless steel wires around the premolars. The two abutment plates (5 mm × 12 mm) contain six nails each 2 mm long. The plates are angled-attached (65°) to the part with a joint providing rotation. The activation part exists of a small hexagonal activation rod that is positioned directly behind the maxillary central incisors with a little hole at the tip of the activation part for blocking the device. (52)

Figure 20 Rotterdam Distractor in place **(left)**; Clinical situation after the distraction **(right)** (52)

Activation of the Appliance during SARME

There exist various activation protocols that have been used in studies on SARME.

In order to check that an adequate osteotomy has taken place in the crucial areas and that the maxilla halves can be separated without resistance, most authors recommend intraoperative activation of the appliance until a diastema can be seen between the upper central incisors. An activation of 0.75 mm to 3 mm is recommended. (3, 53, 54)

Those authors who recommend intraoperative activation of over 2.0 mm reduce this by 1.0 to 2.0 mm during the operation in order to reduce the stress on the palatal mucosa.

According to some authors, this initial activation is followed by a resting phase of five to seven days. In other studies, a resting phase is not mentioned. (54)

The subsequent activation of the expander is indicated at a rate of 0.25 mm to 1 mm per day. This is done once or twice a day by the patient himself, depending on the equipment used, in steps of 0.25 mm to 0.33 mm. (3)

Cureton and Cuenin recommend adapting the activation rate to the condition of the gingival attachment and whether a symmetrical fracture of the alveolar bone between the upper central incisors has been achieved. This ensures a healthy interdental papilla and intact surrounding soft tissue. (3, 55)

Too rapid expansion can lead to the separated maxilla halves not connecting or only insufficiently connecting to one another. On the other hand, a distraction that is performed too slowly leads to premature consolidation before the desired amount of expansion has been achieved. (3, 50)

Figure 21 Upper jaw before enlargement with SARME, transversal narrowing in the upper jaw **(left)**; Upper jaw after enlargement with SARME; medial diastema **(right)** (19)

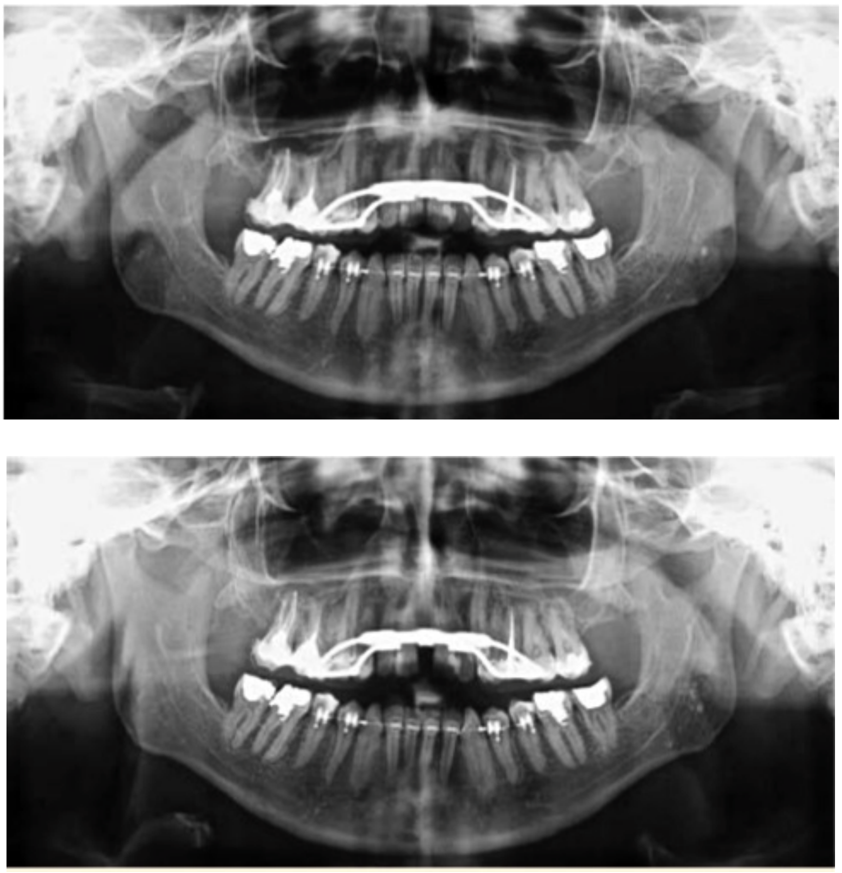

Figure 22 Panoramic X-Ray before SARPE **(top)** and after SARPE **(bottom)** (19)

1.3.4. Le Fort I Osteotomy

Another surgical method used to treat the underdevelopment of the maxilla is the Le Fort I osteotomy, described by the French physician Rene Le Fort in 1901 and the most commonly used for defining midface fractures. (18) Here, the alveolar process of the maxilla above the apices of the maxillary teeth is completely separated and also divided.

In the two-part osteotomy a sagittal separation is made along the mid-palatal suture.

With the three-part osteotomy, the former premaxilla is also separated dorsal to the incisive foramen. This method is preferred when, in addition to the transverse expansion of the maxilla, a vertical or sagittal repositioning of the maxilla and mandible is planned in one operation. (50)

As an alternative to the one-step correction in the presence of maxillo-mandibular discrepancies, treatment can be carried out in two interventions. The underdevelopment of the maxilla is first treated with SARME before the repositioning of the maxilla and mandible takes place in a second operation. (3, 18)

Sequencing of Le Fort I Osteotomy

Surgical technique

After performing a stab incision, a pin is inserted into the bone in order to establish external landmarks at the nasofrontal area. Thereby, the vertical measurements from the pin to the incisal edge of the maxillary incisors are recorded for proper vertical positioning of the maxilla after the osteotomy. Some authors find external reference more reliable than reference mark on the maxilla. However, multiple control references are indispensable since a correct maxillary repositioning is fundamental to achieve a postoperative final symmetry of the face. Therefore, a crucial factor for a satisfactory outcome is a direct control of the bipupillary line and occlusal planes symmetry as well as the midline alignment of the frontonasal (Nasion), interincisal and Pogonion points before final fixation of the maxilla.

Moreover, the use of an intermediate maxillary splint for maxilla repositioning is not fully reliable due to the risk of displacement of the mandibular condyles from the glenoid fossae during repositioning and fixation procedures. (18)

Soft tissue incision

First, in order to reduce bleeding and increase anesthesia during surgical procedure, a solution of local anesthetic with epinephrine (2% lidocaine with 1:100000 epinephrine) is infiltrated into the buccal mucosa along the entire surface of the maxilla. The palate is not anesthetized, since its soft tissue constitutes a significant vascular pedicle for the maxilla after surgery is completed. According to Shepher, blood loss during surgery is also reduced by elevating of 15 degrees patient's head and by systolic blood pressure control (about 90 mmHg) with hypotensive anesthesia. (18)

A bilaterally incision of the soft tissues, including mucosa, muscle and periosteum, is performed from the midline of the fornix above the central incisors to first molar region [see Figure 23]. Blood supply of the maxilla is ensured by a wide pedicle of buccal tissue over the teeth. After, the lateral wall of the maxilla is exposed from the pterygomaxillary junction to the anterior nasal spine by means of a subperiosteal dissection made with a periosteal elevator. Here, it is fundamental to identify and protect the infraorbital neurovascular bundle. Hence, in order to maintain the best possible perfusion of the maxilla, dissection should not be extended to tissues set behind the incision. (18)

Figure 23 Buccal mucosa incision starts from the zygomatic buttress 5 mm over the dental root apices and proceeds across the median region up to the opposite site, from 1.6 to 2.6. (18)

Further on, the dissection is performed toward the maxillary tuberosity and pterygoid plate. After the exposure of the piriform aperture, the mucoperiosteum is elevated and reflected to expose the anterior floor of the nose. To completely uncover the anterior nasal spine, the septopremaxillary ligament and the transverse nasalis muscle are transected. (18)

Osteotomy

The osteotomy begins placing a bur or a surgical saw posteriorly at the zygomatic buttress, about 35 mm above the occlusal pane, and continues through the lateral maxillary wall to the piriform rim. A flexible retractor must be placed under the periosteum at the junction of the maxillary tuberosity with the pterygoid plates, to avoid the risk of damaging the maxillary artery or one of its branches.

The osteotomy line should always run at least 5 mm above the second molar roots to reduce the risk of devitalizing teeth. The same procedure is repeated on the opposite side and wet gauzes are introduced in the posterior aspect of the wound to minimize blood loss. At this point osteotomy of the septum and the lateral nasal wall are performed by separating the cartilaginous and bony septum from the septal crest of the maxilla [see Figure 24, left]. (18)

In order to avoid a higher fracturing line than the nasal floor plane, a partial section of the perpendicular plate of the palatine bone must be carried out. The same procedure is performed on the opposite lateral nasal wall to execute the osteotomy of the nasal septum. Sometimes, the maxilla remains attached to its bony base after section is completed. In such cases, osteotomy of the pterygomaxillary junction is performed.

After removing all gauze sponges previously placed, a retractor is inserted subperiosteally in order to place an osteotome at the junction of the maxilla and pterygoid plate. In order to feel the tip of the osteotome when malleting, the index finger is placed on the palate at the Hamular notch region [see Figure 24, middle]. (18)

After down-fracture, the mobilized maxilla can be freely moved in all of the three planes. Then, an occlusal wafer splint is inserted and maxillomandibular fixation is performed by using a 25-Gauge. Finally, the maxillomandibular complex is placed up to the proper position. Here, it is important to detect bone premature contacts and to avoid dislocation of condyles from glenoid fossae as well as to identify septum deviation with possible nasal airflow obstruction. [see Figure 24, right]. (18) In order to make sure that correct maxilla repositioning has been achieved, the distance between intraoral and extraoral reference points is measured.

Figure 24 Nasal septum disarticulation from anterior nasal spine and septal crest of the maxilla. **(left)**; Section of the pterygo-maxillary junction by curved chisel under finger control on the palatal side. **(middle)**; Maxillary fixation after maxillo-mandibular block checking centric condylar position in the glenoid fossae. **(right)** (18)

Disadvantages of Le Fort I Osteotomy

Possible drawbacks are insufficient adaptation of the mucous membrane due to the abrupt change in position of the bone fragments and consequently recurrences as well as functional and aesthetic problems. In treatments of large maxillary transverse of more than eight millimeters a pronounced relapse is very common. (3) Furthermore, the palatal mucosa and its vascular system are affected by the abrupt expansion. (50)

Avascular necrosis related to lack in blood supply is one of the main problems after Le Fort I osteotomy. According to Lanigan et al., possible complications related to vascular compromise after maxillary mobilization are rupture of the descending palatal artery, thrombosis post-operatively, perforation of the palatal mucosa and partial stripping or excessive tension of the palatal fibro mucosa in maxillary expansion. Kramer et al. state there is an increased risk of vascular complications when anatomic irregularities are present, including craniofacial dysplasias, orofacial clefts, or vascular anomalies. (18) Especially in the segmented Le Fort I, it is important to preserve the palatal fibro mucosa in order to avoid partial necrosis and malunion of the maxillary bone fragments. This is particularly essential in patients with orthodontic appliances or palatal splint causing pressure on the palatal mucosa. (47)

1.3.5. Micro-Implant Assisted Rapid Palatal Expansion

A possibility to expand the maxilla in skeletally mature patients with no need of osteotomy, is using micro-implants anchorage. These mini-implant-assisted rapid palatal expansion appliances have been designed with the purpose to augment the orthopedic outcome effected by RPE. According to Nienkemper et al., a hybrid hyrax appliance that is attached to two in the anterior palate fixed orthodontic micro-implants and is also anchored to the first upper molars can reduce the side effects of RPE devices. (56, 57, 59)

By the incorporation of micro-implants into the palatal jackscrew expansion of the underlying basal bone is ensured. Hence, it allows a simultaneous maxillary expansion and retention via bony anchoring points and leads at the same time, according to Tausche et al., to a reduction of dentoalveolar tipping and expansion of the posterior maxillary segment by 10° as well as to protection of teeth. In general, forces are applied to the micro-implants, instead of teeth, which is why there are less adverse dental effects and consequently harm for the periodontium. (57, 57) This mini anchor screw-carried expander has also proven itself to be successful in combination with SARPE or simply an alternative to it, as orthognathic surgery is often refused by patients. (56) In addition, MARPE seems to have a considerable influence regarding the reduction of upper airway resistance. Its stability also allows innovative orthodontic options to treat different types of malocclusions. (58)

Disadvantages of MARPE

Disadvantages of MARPE include invasiveness of the orthodontic micro-implants, the increased risk of infection and the difficulty in keeping the respective palatal area clean. (56) (59) Although, MARPE is used frequently in practical or educational settings, there is a lack of studies regarding this treatment method, hence literature is limited. Even though several case presentations have been published, there is no scientific data regarding the impact of MARPE on cranial bone and the circummaxillary sutures. (56, 58, 59)

MICRO 4/6

A great variety of purely miniscrew-supported expanders (MICRO 4/6), i.e., bone- borne expander without anchorage on the molars, have been used since 2010 [see Figure 25]. With the aid of this relatively new devices, it has been succeeded to treat palatal width defects in teenagers and adults with only skeletal anchored expanders. Also, teeth can be shaped using a fixed treatment technique at once. (56, 59)

Figure 25 15-year-old patient: Despite a primarily broad upper arch, there is a bilateral head bite **(top);** After 25 days (with 2 x 0.17 mm/day); total expansion: 9 mm. Due to the large diastema composite was placed on 11 and 21 (mesially) **(middle)**; After 8 months of MICRO-Expander retention and simultaneous multi-brackets **(bottom)**; Total treatment time: 21 months. (59)

2. Objectives

Main Objective

- To analyze and compare non-surgical and surgical palatal expansion in skeletally mature patients.

Secondary Objectives

- To evaluate the surgical methods SARME and Segmental Le Fort I-Osteotomy.
- To investigate the reliability of non-surgical micro implant assisted rapid palatal expansion.

3. Methodology

In this bibliographic research data collection was carried out between November 2020 and December 2020 by means of electronic online platform search (PubMed, Medline) taking into account suitable publications available here up to December 2020.

First, the databases were searched for the terms “palatal expansion” and “maxillary expansion”. In each approximately 3500 articles from the years 1952 to 2020 were identified. Since the aim of the analysis was the palatal expansion in adult patients only, the search was further restricted by about a quarter of data to about 930 in PubMed and 700 in Medline study descriptions by adding the term “adult” – i.e., “palatal expansion in adults” or “maxillary expansion in adults”.

Overall, the following keywords have been used: Maxillary expansion in adults, Palatal expansion in adults, Rapid palatal expansion/RPE, Surgical assisted rapid palatal expansion/SARPE, Surgical assisted rapid maxillary expansion/SARME, Surgical segmental palatal expansion, Le Fort I-Osteotomy, Mini-implant assisted rapid palatal expansion/MARPE, Mini-screw-assisted rapid palatal expansion, Maxillary transverse discrepancy.

Only full text articles published between 1952-2020 were included for the introduction.

For the evaluation of each objective articles published between 2000-2020 were considered.

Whether or not articles could be included in the study was determined by reading the abstracts of the articles and checking them against the previously defined inclusion and exclusion criteria listed below. This reduced the number of publications eligible for the work to 82. After analyzing the remaining articles in the full version, 6 fulfilled the criteria according to which the criteria the literature review should be carried out.

Inclusion Criteria

- The article had to be found in PubMed or Medline
- The language of the chosen publications was set to be English
- It had to be a study on the subject of "maxillary expansion in adult patients" or a study including the above-named keywords
- The examinations took place on humans and/or study models, cephalometric and/or CBCT measurements

Exclusion Criteria

Studies were not taken into account in their designs

- Worked on prepared human skull
- Worked with immature patients being not suitable for the aim of this work, but can still be found under the above-mentioned terms in "PubMed" and Medline

Studies that falsified the treatment effect of the expansion device by carrying out further treatments with the help of orthodontic measures such as brackets and arches during the active expansion phase were also not considered in the selection of the items.

Selected items

All of the remaining 6 articles fulfilled the above criteria and should now be merged into a literature review. A table was created, in which the studies were listed from most to least recent, and the parameters of the individual studies could be entered and compared.

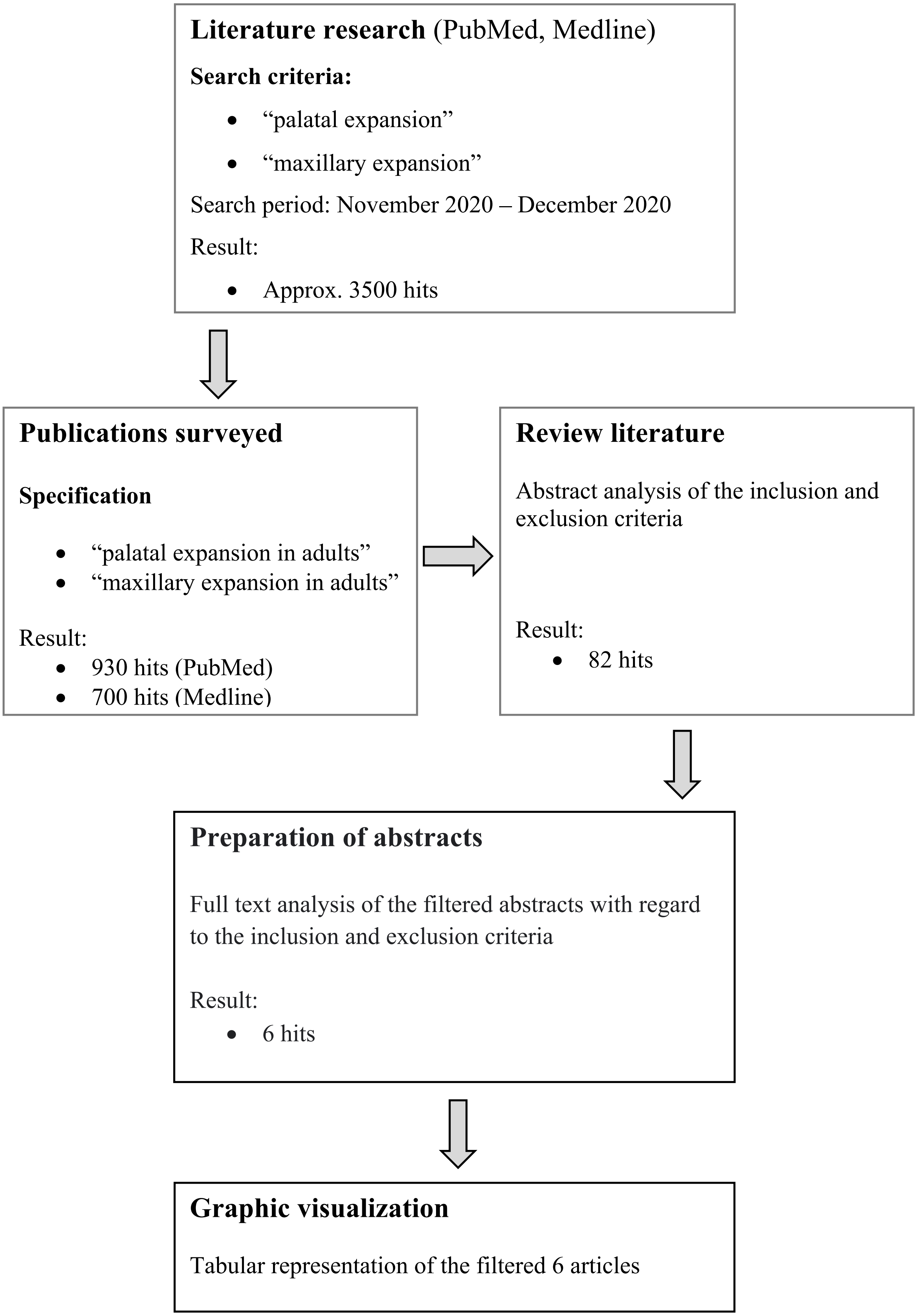

Figure 26 Search strategy and workflow

4. Results and Discussion

In the following, the individual results of the selected studies on palatal expansion in adult patients are described in more detail and compared with each other.

Since, in total, 4 treatment techniques including Non-surgical Palatal Expansion, SARME, Le Fort 1 Osteotomy and MARPE are assessed it is problematic to perform a direct comparison the way it was originally intended. This is partly due to the fact that no defined common measurement parameters could be found [Annexe 1].

Instead, examined study groups vary in applied devices and fastening variations, screws and rotation interval as well as the active expansion period, retention time, imaging and anatomical measurements.

Furthermore, a wide variety of maxillary transverse deficiencies could be observed in the study participants, which makes a straightforward confrontation unfeasible.

Therefore, on the one hand, evaluations are made concerning the study procedure, implying the initial general state of the patients examined, including and excluding criteria, as well as conducted treatment procedure. On the other hand, treatment outcomes including dental and skeletal changes, efficacy of expansion and clinical implications are assessed.

The aim of this work is to investigate the palatal expansion in mature patients only, hence, the results of growing patients described in the study by Kurt et al. and Handelman et al. are not assessed in detail.

Due to the fact that no defined criterions could be determined, it is indispensable to describe the individual articles briefly in the following section.

4.1. Comparison between Non-Surgical RPE and SARME in Adults

Author	**Patients (n)**	**Sex and Age**	**Material and methods**			**Significant findings**
			Objective	Material	Measurement time	
Kurt et al. 2016 (60)	54	SARME: Male: 2 Female: 16 ∅ 19.9 years RPE: Male: 1 Female: 17 ∅ 16.41 years	Short-term changes after surgical and non-surgical RPE	Study models	3 months	SARME: expansion by rotation of the maxillary halves RPE: lateral displacement of dentoalveolar structures
Handel-man et al. 2000 (61)	47	Male: NR Female: NR ∅ 29.9 ± 8.0 years	Effective-ness of non-surgical RPE in skeletally mature subjects and the frequency of possible side effects	Study models Cepha-lometry	5 years	RPE: clinically successful and safe method for correcting transverse maxillary arch deficiency

Table 1 Comparison between the study by Kurt et al. and Handelman et al.

Study description

First, non-surgical and surgical palatal expansion in adult patients is evaluated at large. Handelman et al. investigate in 2000 the effectiveness of non-surgical RPE in skeletally mature subjects and the frequency of possible side effects. (61) In the study by Kurt et al. from 2016, short-term changes after surgical and non-surgical RPE are described. (60)

While exclusion criteria as cleft lip or palate, and inclusion criteria as appropriate records for pre-expansion and post-expansion evaluation, as well as no previous orthodontic treatment or expansion coincide in both studies (60, 61), there can still be observed some variations. Apart from mandatory conditions as good oral hygiene, healthy periodontal tissues and the absence of indication for a future orthognathic surgical treatment, Kurt et al. included only subjects presenting maxillary constriction with bilateral posterior skeletal crossbite. (60)

Handelman et al. did not constrain their study to only one type of malocclusion, but instead patients examined had some form of absolute or relative maxillary width defect, manifested as unilateral or bilateral crossbite as well as maxillary or bimaxillary constriction, for which palatal expansion was indicated. However, a crucial including criterion was a deficiency by 6 mm in the maxillary trans 6-6 width compared to the control group. (61)

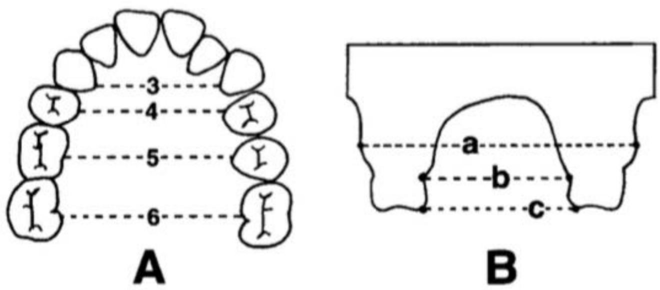

Figure 27 Study by Handelman et al: **A** Maxillary transarch widths, occlusal view. **B** Maxillary first molar widths: **(a)** alveolar 6–6; **(b)** trans 6–6; **(c)** cusp 6–6. (61)

Hence, discrepancies are not only found in examined parameter as range of variation of selected anatomical measuring points, measuring planes and measuring methods, but in addition, also the initial occlusal state of the participants differed before the start of treatment. This is another important subsidiary reason why a direct comparison is not possible.

	Adult-RME	Adult-Control
Number	47	52
Male	19	21
Female	28	31
Age start of treatment, y		
Mean ± SD	29.9 ± 8.0	32.7± 7.4
Range	18.8 – 49.3	20.9 – 46.3
	2.0 ± 0.6	2.1 ± 0.7
Treatment time, y	2.0 ± 0.6	2.1 ± 0.7
Posterior occlusion		
Unilateral crossbite	21	0
Bilateral crossbite	18	0
Constriction, no crossbite	7	0
No constriction or crossbite	1	52
Anterior Crossbite		
Yes	13	4
No	34	48

Table 2 Distribution of Sex, Age, Treatment Time, and Crossbite for the Study Groups by Handelman et al. (61)

Another condition for participation in the study on non-surgical RPE by Handelman et al. was a minimum age of 18 years, including also patients in their fifth decade of life, resulting in an average age of 29.9 years. (61)

Kurt et al. defined skeletal maturity by means of hand-wrist films according to Helm et al. Consequently, the mean age of participants pertaining to the Non-Growing group was 16.41 years presenting a range of 15.41 – 17.6 years, whereas the SARME-Group was composed of patients with a mean age of 19.9 years with a range from 17.5 – 26.3 years. Moreover, only subjects presenting a transversal skeletal crossbite > 5mm were included in Study Group to perform SARME. (60).

The Growing group composed of subjects in growing age is not being considered further.

Generally, age has been used as an elementary criterion to decide which treatment method is indicated and to predict long-term outcomes respectively. Especially in the field of RPE and SARME, the intention of a scientific work determined the choice of the age group of the examined patients. (60) Based on the fact that until a few years ago the general scientific opinion was that palatal expansion could not be performed without prior surgical intervention in skeletally mature patients, the largest proportion of studies was conducted with patients before or during the pubertal growth peak. Nonetheless, other authors, Kurt et al., Handelman et al. included, proved a successful outcome of RPE in skeletally mature patients. (60,61)

Treatment procedure

Observation period

The authors carried out effect measurements on the equipment they used at different times. Generally, a baseline before the start of treatment at measurement time is always recorded. This starting point is named T0 by Kurt et al T1 by Handelman et al. While in the study of Kurt et al. T1 was defined as the moment when measurements were taken 3 months after the retention period, Handelman et al. defined this moment as T2 without giving specific information about the time interval. (60,61) Additionally, a third measurement T3 was carried out by Handelman et al., limited to those participants who had interrupted maxillary retainers for a minimum of 1 year. Recordings show the measurements taken five years after the start of treatment or 10 years after the T2 records. (61)

Imaging

Pre- and post-study models were used in both studies (60,61), whereby Handelman et al. used cephalograms as an additional imaging measure. (61)

Appliance and Activation Interval

Overall, the course of study and treatment varied with regard to the appliance and fastening variations used, the rotation interval of the activatable screws, as well as the opening, active expansion and retention time.

In the study by Kurt et al., the SARME group was treated with a tooth-borne, fixed palatal expander with hyrax screw, which was cemented 1 or 2 days before the surgical intervention, where an activation with a total widening of 1.5 mm was performed. After 5 days, the appliance was activated by means of 2 turns per day until enough expansion was achieved.

The retention period in which the device stayed affix was 4 months.

In the Non-Growing Group, initially, 20 patients were indicated to undergo non-surgical RPE. Due to pain and discomfort during the treatment procedure, 2 subjects were finally treated with SARME. For the non-surgical RPE a full-coverage bonded expander with hyrax screw was applied and activated 2 times per day and 1 turn per day after the separation of the mid-palatal suture until enough expansion was achieved. The retention time was at least 3 months, bonded in the first 4 weeks and removable in the last period. (60)

Handelman et al. performed non-surgical RPE using fixed tooth and tissue borne Haas expanders. No further information with regard to the type of screw is provided. (61)

Regarding the time interval between the individual activation phases by the patient or his supervisor, specified by the practitioner, some difference to the study by Kurt et al. can be observed. While on the first day, the screw was turned twice, on the following days it was activated once by the patients. Check-ups were performed every 2 weeks. In case of pain or tissue swelling, it was recommended to turn the expander back a few turns and taking a rest for one week. After, expansion was continued by activating the screw every second day.

When either of the palatal cusps of the maxillary molars were close to provoke a buccal crossbite, the expansion was stopped, and the screw was blocked out with some acrylic.

After a stabilization period of 3 months (range 2 to 6 months), the expander was withdrawn, and a removable acrylic palatal retainer was placed directly whose acrylic plate has been relieved in order to achieve a palatal adjustment of the overexpansion. By means of a fixed lingual expansion arch or a removable Schwartz-type expansion device with occlusal coverage as recommended by Hamula, a simultaneous mandibular expansion was conducted in 5 patients. (61)

In the study by Kurt et al. the device was activated until the required expansion was achieved, (60) whereas Handelman et al. terminated the expansion when a crossbite on one of the maxillary molars was observed. (61)

Retention time

The retention time indicates how long the orthodontic appliance stayed in the mouth without actively expanding it in order to stabilize the result achieved. The frequency distribution in the studies examined ranged from 2 to 6 months. (60, 61)

Anatomical measurements

As mentioned before, there was no conformity regarding the anatomical measurements performed in both studies. Both times, evaluation was executed on study models. (60, 61)

While in the study by Kurt et al. it was implemented by 1 investigator in form of 13 linear and 2 angular measurements recorded to the nearest 0.1 mm by means of a vernier caliper, (60) Handelman et al. used an electronic caliper (Mitutoyo number 573, Tokyo, Japan) for the linear measurements to the nearest 0.1 mm and a protractor for the angular measurements to the nearest 0.5°. (61)

Evaluation was done by 1 investigator in form of linear and 2 angular measurements by

Kurt et al. measured the distance between the left and right vestibular and palatal cusp tips of maxillary canine, first and second premolar, as well as the first molar. [Figure 28 A]. The palatal contours were traced as described in the table below. [Table 3]

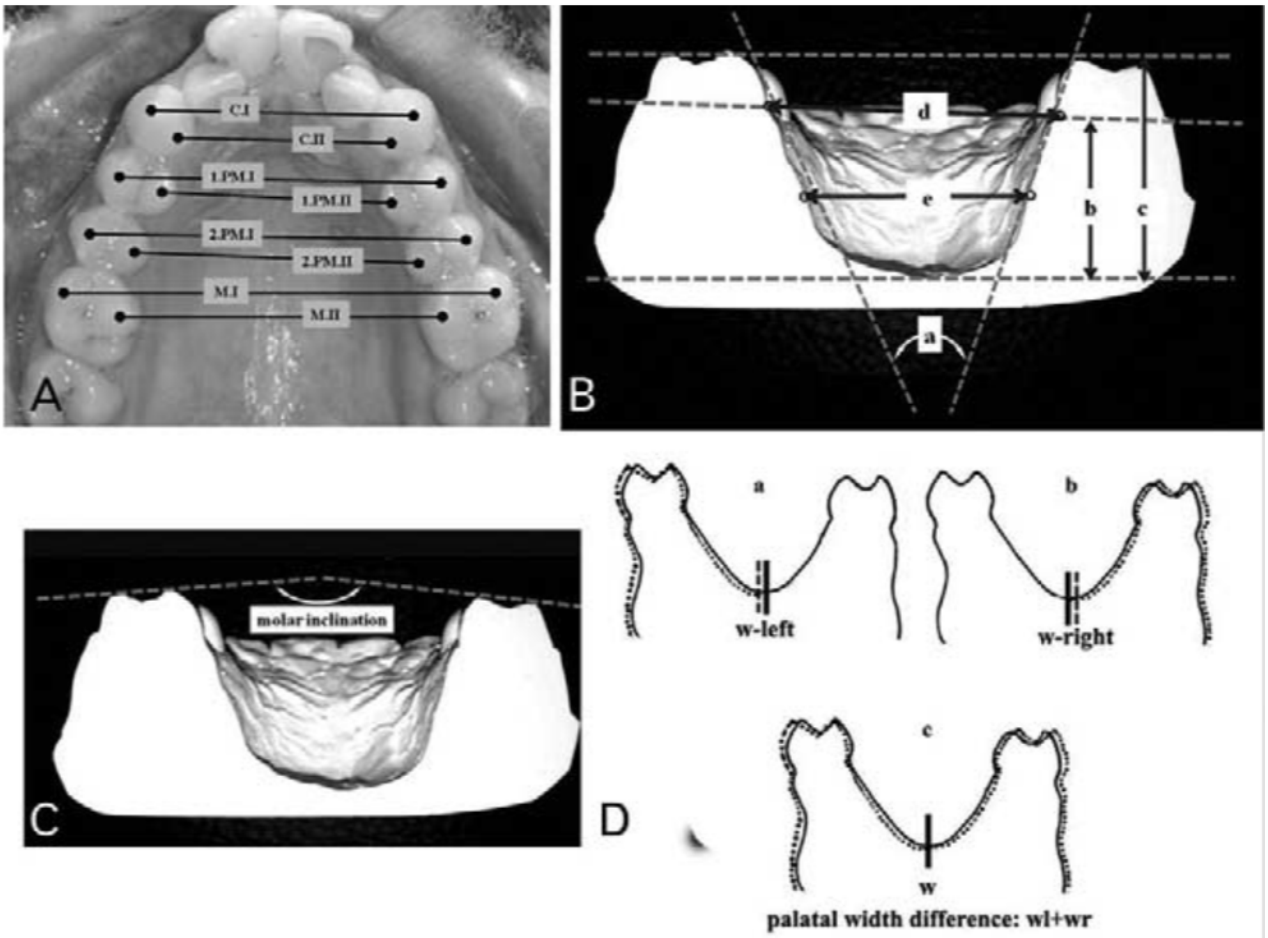

Figure 28 A B C D: Measurements on study models by Kurt et al. (60)

Measurements	Description
a) Palatal vault angle (**Fig. 29 B**)	The intersecting lines tangent to the middle two thirds of the right and left palatal surfaces
b) Palatal depth from the gingival height (**Fig. 29 B**)	The shortest distance between the midpalatal raphe and the line connecting the points on the gingival crest of the first molars
c) Palatal depth from the molar cusp (**Fig. 29 B**)	The shortest distance from the midpalatal raphe to a line connecting the occlusal surfaces of the first molars
d) Palatal width at the gingival height (**Fig. 29 B**)	The distance between the first molars at the level of the palatal gingiva
e) Palatal width at midpalate (**Fig. 29 B**)	The distance between the halfway points of the gingival height line and the deepest point of the palatal vault
Maxillary first molar axial angulation (**Fig. 29 C**)	The angle formed between the intersecting lines of the mesial buccal and mesial lingual cusp tips of both the right and left first molars
Palatal width difference (**Fig. 29 D)**	The palatal contour tracings of T0 and T1 initially were superimposed on the left palatal outline and then on the right palatal outline while remaining parallel to the occlusal plane. The displacements of the midpalatal raphe for right and left sides were summed and the total amount of palatal width difference was measured

Table 3 Description of the measurements and contour tracings used for the study by Kurt et al. (60)

To perform the statistical analysis, the arithmetic mean and standard deviation were determined for each variable. A high data reliability could be guaranteed since measurements were undertaken twice by the same examiner and only minimal insignificant method errors were observed. (60)

Treatment Outcomes

Dental and Skeletal Measurements

In the study conducted by Kurt et al., the Non-growing RPE group showed the most significant palatal width changes at gingival height (6.85 ± 3.25 mm) and at midpalatal level (5.84 ± 3.11 mm), whereas the SARME Group presented the highest increase in the palatal vault angle (9.77

± 5.95°). (60) The vertical displacement of the molars was irrelevant in all groups. Growing patients showed more parallel displacement of maxillary halves compared with other groups. At the level of the palatal vault an expansion of 3.17 ± 1.35 mm in the Non-growing RPE Group and 4.42 ± 1.23 mm in the SARME Group was reported. (60) Both studies reported nonsignificant changes in palatal depth in all of the treatments. (60, 61)

Molar and Palatal Angle

The molar angle in patients treated with RPE in the study by Handelman et al. decreased by 6.2 ± 11.5°, showing increased inclined molars buccally. The palatal angle increased by 7.9 ± 7.8°. (61)

Kurt et al. report most significant molar tipping in the Non-growing RME Group (15 ± 11.25°), followed by SARME patients (11.28 ± 8.35°). The least molar inclination was observed in growing patients (9.95 ± 4.85°). (60)

Palatal Width at Gingival Height, at Midpalate and Palatal Width Difference

Handelman et al. refer width change by 5.1 ± 2.9 mm at the gingival crest and by 3.0 ± 2.0 mm at the level of the midpalate. The expansion of the apex of the palate was minimal (0.9 ± 1.3mm). (61)

Kurt et al. report a change in palatal width at gingival height by 6.85 ± 3.20 mm and 5.84 ± 3.11 mm at the midpalate level in the non-growing RPE Group. The SARME Group presented a lower expansion by 5.77 ± 2.31 at the gingival crest and by 4.03 ± 1.82 at the midpalate level.

The palatal width increased by 3.17 ± 1.35 mm in the RPE Group and by 4.42 ± 1.23 in the SARME Group. (60)

In general, all transversal width changes of the study by Kurt et al. were higher than those of Handelman et al. This is due to the fact that Kurt et al. overexpanded the maxillary posterior, whereas Handelman et al. performed their records after a normal occlusion by means of lingual adjustment of the posterior teeth were completed. Also, SARME patients, who had the narrowest arch before expansion, showed greater transversal changes at the molar and premolar level in comparison to patients undergoing RPE. (61) This can be reduced to the higher expansion need in this group.

Mandibular Plane and Lower Anterior Face Height

There were nor alterations in SN-MP, hence no changes in the mandibular divergence, neither alterations in the ANS-Me observed by Handelman et al. (61)

Kurt et al. did not provide any information about these parameters.

Clinical Crown Height

While Kurt et al. did not report any records regarding the clinical crown height neither, (60) Handelman et al. reveal an inhomogenous response to RPE when comparing female and male participants with members of the same gender of the control group. Generally, female patients presented a higher buccal attachment loss by 0.6 mm for the maxillary first molars and first premolars, albeit this minimal recession was neither noticed by the patients nor it posed a risk for the dental health. (61)

However, the measurement of the clinical crown height, being an indirect determination of the buccal attachment loss, is not completely reliable since it depends on various factors as gingival hyperplasia, attrition and furthermore, it does not consider pocket depth or bone dehiscence.

Efficacy of Expansion

In both studies, a sufficient expansion could be achieved to correct the respective malocclusion. The extent of the jaw expansion was determined individually depending on the severity of the initial misalignment. Although no precise guideline values are given, according to Handelman et al. upper limits do exist to the correct execution of the RPE. (61)

Kurt et al. state that indications for SARME are skeletally mature subjects presenting significant maxillary width defects, augmented vertical dimensions and presence of buccal inclination in upper molars. (60)

However, comparing RPE in adults with RPE in children, where around 56% of the expansion was probably skeletal by means of separation of left and right maxillae and additionally due to dental-alveolar changes, some differences could be found according to Handelman et al. (61) Although the palate width changed by 0.9 mm and 5.1 mm at the level of the palatal gingiva, a diastema between the central incisors was rarely observed, which is why a distraction between both maxillary halves is less probable. (61) Since similarities at the mid-palatal level in adults and children were found by Handelman et al., based on 4.1 mm in the expansion, or 80% of the total trans arch expansion, control measurements were also performed on the maxillary buccal surface. Results showed an expansion of 96%, or more specifically a width change by 5.5 out of 5.7 mm at the alveolar level of the first molars in children, and 72% or rather 3.3. out of 4.6

mm in adults, accordingly. These observations suggests that in children expansion is leaded back to skeletally and dentoalveolar changes equally and the percentage of alveolar expansion increases with age. (61)

Trans Arch Width, Maxilla

Handelman et al. refer an increase of the maxillary trans arch widths by 4.6 ± 2.8 mm at the level of the first molars and 5.5. ± 2.4 mm at the level of the second premolars, resulting in relevant expansion changes at T2. In the first molars, the greatest expansion resulted between the cusps (5.7 mm), followed by the transversal width (4.6 mm) and the alveolar width (3.3 mm). (61)

In the study by Kurt et al., patients that underwent SARME presented significantly lower dental and skeletal transversal dimensions than those undergoing RPE before expansion. A relevant augmentation at all transversal and angular measurements could be observed, whereby patients treated with SARME presented the highest dental transversal increases. Overall, differences between groups were statistically significant, except those between the left and right palatal cusps tips of canine and molar teeth. (60)

Trans Arch Width, Mandibula

The 5 patients in the study by Handelman et al., who underwent an active mandibular expansion simultaneously to RPE showed noticeable transversal changes. An increase of 0.9 to 1.2 mm was observed. Due to the small sample size data of these patients were not included. However, study results show that mandibular devices bring benefits to maxillary expansion, providing more space for the correction of crowding. (61)

Kurt et al. did not report any treatment in the lower arch. (60)

Stability of Trans Arch Expansion

The stability of the treatment was measured by Handelman et al. after a mean time of 5.9 ± 3.9 years, but at least one year after discontinuity of retention. By comparing the T2 and T3 transarch measures, only a minimal, but statistically significant, decrease of 0.5 - 0.6 mm was observed. While the transversal width of the maxillary first molars did not show any changes, the respective transversal width between the cusp as well as the alveolar width decreased by 0.6 mm. Relapses into cross-bite were not reported. (61)

Kurt et al. do not report about any relapses that have occurred. (60)

Maxillary Expansion at Different Stages of Growth

The findings regarding a positive outcome of non-surgical RPE in young adult patients of the studies examined coincides with results of other studies performed by Altug-Atac et al. and Baydas. (60) All investigators agree in respect to the positive effect on palatal expansion in mature patients by means of RPE, achieving a successful outcome attributed to important dental and skeletal changes. The latter resulted most significant in the midpalatal suture, where the metabolic activity augmentation was the highest. The coincidence of the results let Kurt et al. conclude that a successful RPE can be achieved using an acrylic expansion device which covers the palate. (60)

Clinical Implications

In the study by Kurt et al. two patients of the RPE Group reported pain and discomfort, which is why they were indicated for surgical expansion. Apart from this, none of the patients experienced excessive pain, paresthesia nor healing complications of the maxillary sinus. There were neither cases of root resorption or loss of tooth vitality.

The only secondary effect that all participants had in common was slight discomfort post-operatively. One patient of the SARME Group with pterygomaxillary disjunction presented nosebleed. (60)

Handelman et al. report 9 cases of palatal swelling and pain which corresponds to approximately 19.15 % of the 47 participants treated with RPE. Only one patient referred headache. Expansion could be still completed by reducing the activation interval as mentioned above. However, Handelman et al. perceive a fewer morbidity in RPE compared to that of SARME which is 100% including edema, pain and a long recovery period, which implies incapacity to work.

Since none of the complications found in literature related with RPE in adults as edema, gingival recessions or ulceration were observed, Handelman et al. state to evaluate always the possibility of a non-surgical expansion. (61)

Kurt et al. also recognize RPE as an effective treatment method in young adults but consider SARME the only option for patients presenting severe maxillary width defects, advanced gingival recessions or periodontal bone loss. (60)

4.2. Surgical Techniques for Palatal Expansion in Adults

Author	Patients (n)	Sex and Age	Material and methods			Significant findings
			Objective	Material	Measure-ment time	
Rachmiel et al. 202 (62)	32	Le Fort I: Male: 17 Female: 15 Range: 19-54 years	Demonstration of stable results using a L-shaped osteotomy	Study models Panoramic XR Cephalo-grams	12 months	SARME: effective and stable method in adults Le Fort I: enables to maintain the correct position of premaxilla and maxillary midline and allows division of newly created bone bilaterally leading to more stable results
Marchetti et al. 2009 (63)	20	SARME: Male: 4 Female: 6 ∅ 23.5 years Le Fort I: Male: 3 Female:7 ∅ 27.75 years	Comparison of the long-term stability of SARME and segmental Le Fort I osteotomy.	Study models	2 years	High relapse rate in the mean intercanine and intermolar distances SARME: relapse rate was more remarkable Le Fort I: more stable, especially in terms of the intermolar distance

Table 4 Overview of studies examined for comparison of surgical techniques for palatal expansion in adults

Study Description

Rachmiel et al. and Marchetti et al. carried out a study investigating surgical methods for palatal expansion in adult patients. While Rachmiel et al. aimed at demonstrating stable results using a L-shaped osteotomy, Marchetti et al. compared the long-term stability of SARME and segmental Le Fort I osteotomy. (62, 63)

In the study conducted by Rachmiel et al. SARME was performed in thirty-two patients aged between 19 and 54 years by means of a bilateral transverse L-shaped Osteotomy followed by a tooth-borne Hyrax appliance. Skeletally maturity, maxillary hypoplasia with or without another disgnathia as open bite or retruded maxilla were the inclusion criteria. Patients with cleft palate or syndromes have been excluded.

At the end, all included subjects presented bilateral transverse posterior crossbite, dental crowding and a narrow palatal vault.

Marchetti, instead, analyzed plaster models of 20 patients, half of which have been treated with SARME and half with a Le Fort 1 bipartition. Inclusion criteria were apart from skeletally maturity and contracted palate with malocclusion, also intermolar transverse deficiency of > 6 mm for the SARME Group and < 6 mm for the Le Fort 1 Group, respectively. The latter presented additionally deficits related with other maxillary anomalies as sagittal or vertical deficiencies, for which both maxillary and mandibular osteotomy was indicated. A mean age of 23.5 years in the SARME Group and 27.75 years in the Le Fort 1 Group was reported. (63)

Treatment Procedure

Observation Period

Both times, the first record was carried out prior to treatment start (T1), the second one after palatal expansion (T2) and the last measurement was done after the desired expansion was achieved (T3). The last record was taken by Marchetti et al. 2 years following the end of expansion, whereas Rachmiel et al. recorded it 1 year after. (62,63)

Imaging

In total, three records were taken by means of plaster models in both studies. (62,63) Additionally, Rachmiel et al. performed panoramic radiographs as well as lateral and posteroanterior cephalograms prior to the treatment. (62)

Appliance and Activation

An orthodontic leveling was undertaken prior to SARME. Patient with dysgnathia were treated with a further bimaxillary orthognatic surgery such as Le Fort I maxillary osteotomy and bilateral sagittal split mandibular osteotomy.

Prior to surgery, a Hyrax appliance has been attached. While in six patients general anesthesia with nasotracheal intubation was performed, in twenty-six patients deep sedation in combination with administration of local anesthesia was undertaken. One day after surgery, the expansion was started by activating the Hyrax appliance by 0.5 mm twice daily. (62)

The clinical protocol for SARME was equal in each patient in the study by Marchetti et al., applying a palatal expander 7 days before the first procedure. Afterwards, skeletal resistance was diminished surgically performing a lateral maxillary osteotomy starting from the anterior nasal aperture and proceeding to the maxillary zygomatic region and separating the pterygo-maxillary suture as well as the midpalatal suture.

A “Spider” device was used to achieve disjunction [see Figure 29]. This expander consists of metal parts fixed to all maxillary teeth from the canine to the second molar providing stability, rigidity as well as a removable screw-type unit body to allow intra-operative surgical intervention and to facilitate the oral hygiene measures. After Surgery, activation of the expansion device by 2 mm was performed.

A one-week latency period was performed, followed by an activation by 0.25 mm twice daily resulting in a total expansion rate of 0.5 mm until the desired intermolar width was achieved. The orthodontic treatment was initiated after a consolidation period of 3 months and after the removal of the palatal appliance.

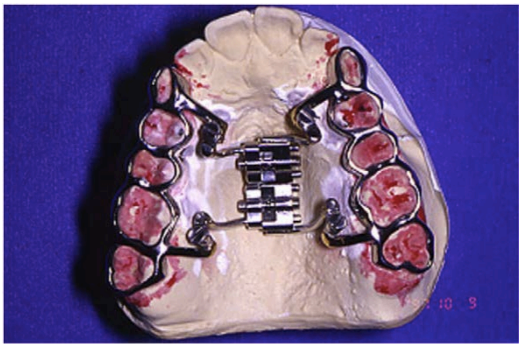

Figure 29 “Spider” device for SARME used in the study by Marchietti et al.

Also, the treatment protocol for the Le Fort 1 Osteotomy was equal in every patient. It consisted of a pre-orthodontic treatment following a bi-segmental Le Fort 1 osteotomy, conducted by means of an intermediate acrylic intra-surgical splint which was used for stabilization post-surgically for 6 weeks, except during mealtimes. The distracted maxilla was stabilized by two titanium plated bilaterally.

While in the study by Marchetti et al. none of the treatments require tooth extractions, Rachmiel et al. removed impacted or ectopic third molars before surgery. (62, 63)

Retention Time

In the study by Marchetti et al, the patients of both groups were instructed to use a Hawley-type retainer during night for 1 year. (63)
Rachmiel et al. do not provide any information about the retention time.

Anatomical Measurements

Measurements were carried out by using different points of reference.
In the study by Rachmiel et al. the following measuring points were analyzed: Canine incisal (Ci), canine gingival (Cg), molar occlusal (Mo) and molar gingival (Mg). (62)

Marchetti et al. measured the maxillary intercanine distances from cusp to cusp as well as the intermolar width between both mesio-palatine cusps of the left and right first upper molar. (63)

Treatment Outcomes

As seen in Table 5, Rachmiel et al. observed a mean expansion of 6.2 mm and 6.4 at the Ci and Mo as well as stable results after one year in all patients with 0.4 mm and 0.2 mm in Ci and Mo, respectively, compared to the initial measurements. (62)

On account of the bilateral osteotomies on the side of the upper second incisors the length of the distraction could be divided resulting in two distraction sites and a reduced charge to the maxillary buttresses. According to the authors, hereby, it is important to not injure the infraorbital nerve or the dental roots and apices. Furthermore, an adequate healing is essential, hence, it is indispensable that the mucosa and periomucosa cover the osteotomy. A rupture of this muco-periostal-flap may lead to unsatisfactory esthetic appearance and complications in healing processes that may result in bony distraction and following difficulties in the tooth alignment. Overall, in the study by Rachmiel et al. no change in the position of the maxillary midline nor of the premaxilla was observed. (62)

mm ± SD (range)		
	Mean expansion	**Mean expansion after 1 year**
Ci	6.2 ± 0.2 (5.8 – 6.6)	5.8 ± 0.2 (5.5 – 6.1)
Cg	5.9 ± 0.2 (5.4 – 6.4)	5.8 ± 0.2 (5.3 – 6.1)
Mo	6.4 ± 0.3 (5.9 – 6.9)	6.2 ± 0.2 (5.8 – 6.5)
Mg	6.1 ± 0.2 (5,8 – 6.4)	6.0 ± 0.2 (5.8 – 6.3)
SD: Standard deviation, Ci: Canine incisal, Cg: Canine gingival Mo: Molar occlusal, Mg: Molar gingival		

Table 5 Study by Rachmiel et al.: Maxillary palatal expansion measured on dental models at the end of expansion and orthodontic alignment and 1 year later at canine incisal, canine gingival, molar occlusal, and molar gingival regions. (62)

In patients presenting two occlusion planes prior to treatment start, a higher post-operative stability was also achieved thanks to maxillary width enlargement and dental alignment.

A normognathic occlusion, and stable dental and skeletal results were also observed in initially dysgnathic patients. These have been first treated by means of dental leveling and stabilization of occlusion following bimaxillary surgery after 1 year.
Neither tooth loss nor root damage was observed. However, two patients presented gingival recessions in the canines and one subject showed exposure of the alveolar bone that required treatment by means of debridement as well as mucosal graft. (62)

In the study by Marchetti et al. the SARME Group showed a width enlargement between 4.5 to 10.5 mm, showing a mean increase of 29% (8.5mm) in the intercanine distance and between 5 to 9.5 mm or rather 18% (7mm) in the intermolar distance. The relapse at the level of the canines and molars was +1 to -6 mm and +3 to -3.5 mm, resulting in a mean reduction of 28% (2.5 mm) and 36% (3 mm) respectively, compared to the initially recorded values.
In comparison, the intercanine distance of the Le Fort 1 Group was smaller ranging from 0.5 to 4.5 mm or rather 8% (2.75 mm), whereby the intermolar width augmented by 2.5 to 7.5 mm or rather 9% (3.75 mm), respectively. The relapse was between + 3.5 to – 2.5 mm or rather 25% (0.25 mm) and between 0 and -5 mm or rather 20% (0.75 mm) at the level of the canines and molars, respectively. This demonstrates a higher relapse in the subjects treated with SARME.

These values can be attributed to the investigator´s experience and to the great range resulted by using two techniques. Although, Marchetti et al. experience the Le Fort 1 osteotomy less practical due to the complexity in expanding the palatal mucosal and periosteal layer, this method shows more stable long-term results. Unless the stabilization period it not extended, an overexpansion of 25 – 30% or rather 20 – 25% in SARME and Le Fort I, respectively, is recommended by the authors. (63)

Efficacy of Expansion

Rachmiel et al. opine that, rather than undertaking directly a Le Fort I Osteotomy, in adult patients with maxillary width deficiencies, it is easier, safer and more predictable to begin with SARME, following dental alignment and ultimately performing a Le Fort1 Osteotomy.

The authors established some advantages regarding the bilateral transverse L-shaped maxillary osteotomy method for SARME. First, a better stability is achieved due to two sites of expansion in combination with bone generation between the lateral incisor and canine. Also, results show a more symmetric expansion and simultaneously esthetic repercussions as upper diastema can be avoided. Furthermore, there is no risk of damage to premaxillary area including nerves and blood supply, as it remains unaffected. (57)

4.3. MARPE in Adults

Author	Patients (n)	Sex and Age	Material and methods			Significant findings
			Objective	Material	Measurement time	
Elkenawy et al. 2020 (64)	31	Male: 17 Female: 15 ∅ 20.4 ± 3.2 y	To quantify the magnitude, parallelism, and asymmetry of MARPE in adults	CBCT	6 months	MARPE leads to distinctly parallel expansion in the sagittal plane but may exhibit asymmetrical expansion in the transverse plane
Park et al. 2016 (65)	14	Male: 9 Female: 5 ∅ 20.1 y	Evaluation of skeletal and dentoalveolar changes after MARPE in young adults by CBCT	CBCT	1-5 weeks	MARPE is an effective method for the correction of maxillary transverse deficiency without surgery in young adults.

Table 6 Overview of studies examined for comparison of SARME in adults

Study description

MARPE was investigated in the studies conducted by Park et al. and Elkenawy et al.

While Park et al. looked into the skeletal and dentoalveolar changes after MARPE in young adults, Elkenawy et al. assessed the magnitude, parallelism, and asymmetry of MARPE in non-growing patients. Overall, skeletally mature patients presenting maxillary transverse deficiency were studied. In general, both groups of researchers used similar treatment procedures, including cone-beam computed tomography images taken before and after expansion. (64, 65)

Fourteen subjects with mean age of 20.1 ± 2.4 years (range 16 – 26 years) were included in the study by Park et al. in regard to the previously established exclusion criteria such as former orthodontic treatment, craniofacial syndromes, systemic diseases and unsuccessful distraction of the midpalatal suture. (65)

Eklenawy et al. also excluded subjects with systemic diseases and those craniofacial anomalies that might affect the treatment outcome as well as patients with history of orthodontic treatment, yielding to a total number of 31 study participants with a similar mean age of 20.4 ± 3.2 years (range 17 – 27 years). (64)

Treatment Procedure

Imaging

CBCT images were taken by different devices.

Elkenawy et al. used a NewTom 5G scanner and images were captured for 18 seconds. (64)

In the study by Park et al. a Alphart VEGA scanner and a scan time of 17 s was used. (55)

Voxel sizes were 0.3 mm both times. (64, 65)

Appliance and Activation

Park et al. used a modified hyrax-type expander cemented to the upper first premolars and molars and implying 4 micro-implants, of which two anterior helical hooks were positioned in the rugae area and two posterior hooks were located in the para-midsagittal area. The day after the appliance was attached, the expansion was started at a rate of one activation of 0.2 mm daily until achieving the desired distraction. (65)

Elkenawy et al. also chose a device with a central jackscrew unit, which was also attached by bands to the maxillary premolars and molars and positioned with 4 micro-implants at the posterior palate. The expander was activated by turning the screw by 0.4 mm twice daily until a diastema was observed. Afterwards, the activation protocol changed to one turn per day.
To achieve proper bone formation, the expander stayed in situ for 6 months, once sufficient expansion was reached. (64)

While in the study by Park et al. the average duration of expansion was 38 days (range 24 – 66 days), in the study conducted by Elkenawy et al. the completion of expansion was achieved in 35 ± 10 days. (64, 65)

Anatomical Measurements

Overall, different measuring points have been used.
Elkenawy et al. chose the mid-sagittal plane (MSP), a plane that passes through the nasion (N), anterior nasal spine (ANS), and posterior nasal spine (PNS), as reference for all measurements. By superimposing pre- and post-expansion CBCT images, changes in relation to the MSP were detected. Lateral measurements were conducted by creating axial sections at the level of the axial palatal plane (APP), a perpendicular plane to the MSP which passes though the ANS and PNS. To know the quantity of distraction at the level of the midpalatal suture, the MSP was examined. Expansion was measured by assessing the distance from the landmarks on the left or right side to the MSP. The anterior nasal spine (ANS), posterior nasal spine (PNS), and zygoaticomaxillary point (ZMA) were included.

In the CBCT done prior to expansion, linear measurements were done from the MSP to ANS and PNS, whereas in the post-expansion CBCT axial cuts at the level of the APP were used to assess the distances from ANS and PNS on both sides to the MSP.
The lateral expansion was defined as the Rt and Lt distances of each landmark after expansion. When seen in the coronal zygomatic section, the most medial aspect of the zygomaticomaxillary suture was represented by the zygomaticomaxillary point (ZMA).

In the CBCT scans taken prior to treatment and after expansion, also the distances from the zygomaticomaxillary suture were measured from the left and right side to the mid-sagittal plane at the level of the coronal plane. The total amount of expansion was assessed by summing up the entire quantity of displacements on both sides. (64)

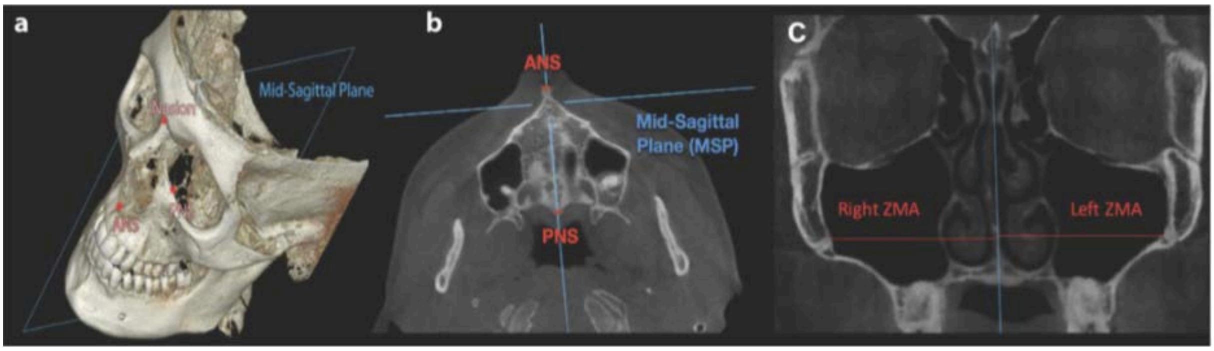

Figure 30 Study by Elkenawy: **a** CBCT image showing mid-sagittal plane (MSP) on subject's initial CBCT using OnDemand (Cybermed, Korea). ANS, PNS, and nasion can be viewed as separate skeletal landmarks on the MSP. **b** Axial slice at pre-expansion with vertical line passing through ANS and PNS. **c** Coronal view of pre-expansion CBCT displaying measurements from the MSP to both the right and left ZMA. Right and left ZMA landmarks indicated in red at the most medial-superior location of the zygomatic-maxillary suture

In the study by Park et al., first, measurements of interpremolar width (IPMW) and intermolar width (IMW) were done on 3D tooth scans. IPMW and IMW are the distances between the left and right buccal cusp tips of the first upper maxillary premolars and the mesio-buccal cusp tips of the first upper molars, respectively.

Also, two-dimensional posteroanterior cephalograms were reconstructed perpendicular to the midsagittal plane to measure transverse widths between the following bilateral landmarks: Z, N, J, MA, C6 and Ag [Figure 31]. Moreover, three-dimensional images of the skull taken pre-expansion and post-expansion were superimposed [Figure 33]. (65)

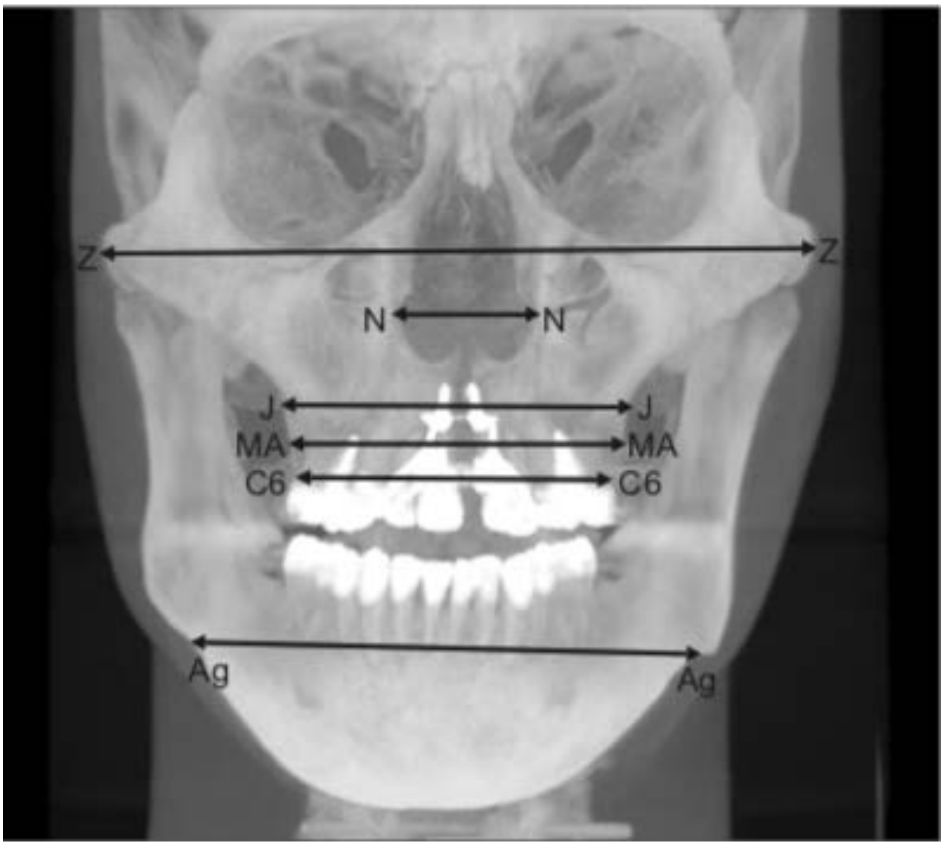

Figure 31 Study by Park et al: Two-dimensional posteroanterior cephalogram reconstructed from a three-dimensional skull model. Refer to Table 7 for the definitions of abbreviations. (65)

Landmark	Description
Z	The most lateral point of the zygomatic arch
N	The most lateral wall of the nasal cavity
J	The junction between the maxillary tuberosity outline and the zygomatic process
MA	Midpoint of the J and C6 points on the lateral contour of the maxillary alveolus
C6	The most lateral point of cemento-enamel junction of the maxillary first molar
Ag	Antegonial notch
Alare	The most infero-lateral point of the nasal aperture in a transverse plane
Ectocanine	The most infero-lateral point on the alveolar ridge opposite the center of the maxillary canine
A-point*	The most posterior and deepest point on the anterior contour of the maxillary alveolar process in the mid-sagittal plane
Prosthion*	The most antero-inferior point on the maxillary alveolar margin in the mid-sagittal plane
Ectomolare	The most infero-lateral point on the alveolar ridge opposite the center of the maxillary first molar
Processus zygomaticus	The most infero-lateral point of the processus zygomaticus

Z, N, J, MA, C6, and Ag were identified on the reconstructed two-dimensional posteroanterior cephalogram of a three- dimensional skull model.
Alare, ectocanine, A-point, prosthion, ectomolare, and processus zygomaticus were defined according to the study by Magnusson et al.

*Although A-point and prosthion were one-point landmarks before expansion, they were separated into right and left landmarks after expansion.

Table 7 Study by Park et al.: Definition of landmarks used in this study (65)

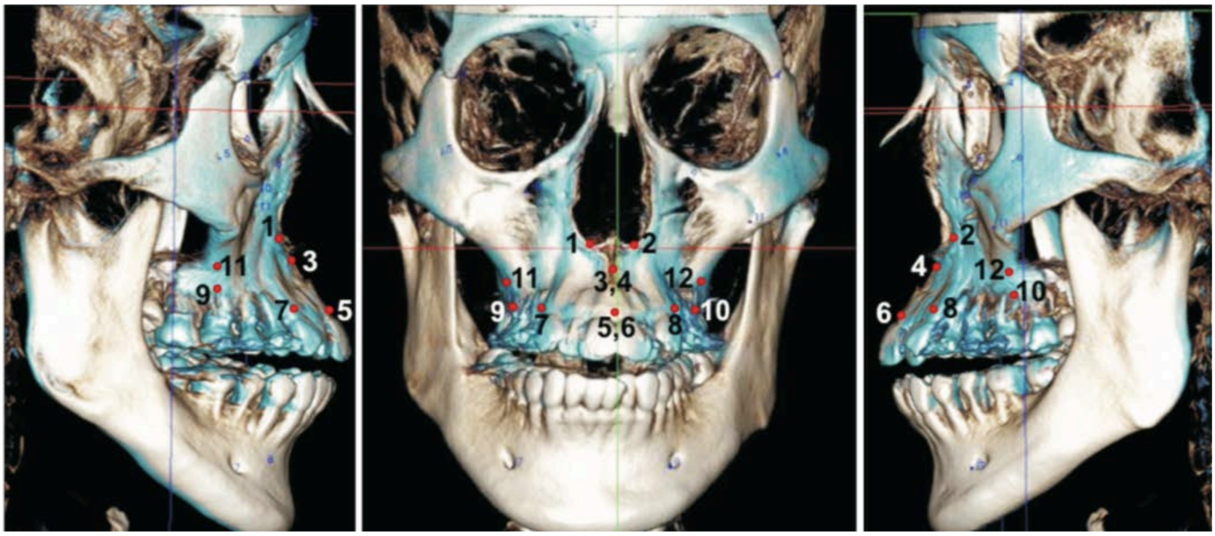

Figure 32 Study by Park et al.: Superimposition of three-dimensional cone-beam computed tomography images acquired before (white) and after (blue) miniscrew-assisted rapid palatal expansion; **1 and 2**, alare, right and left; **3 and 4**, A-point, right and left; **5 and 6**, prosthion, right and left; **7 and 8**, ectocanine, right and left; **9 and 10**, ectomolare, right and left; **11 and 12**, processus zygomaticus, right and left. (65)

Furthermore, two coronal images were acquired perpendicular to the midsagittal plane, going through both the buccal and mesio-buccal cusp tips as well as furcations of the premolars and molars, respectively. In the single-rooted maxillary first premolars coronal scans were done perpendicular to the midsagittal plane going through the buccal and palatal cusp tips [Figure 33]. (65)

Ultimately, the nasal cavity and the width of the basal bone were measured by means of an anterior-most slice that shows the entire root of the right first upper premolars and molars. Measurements on each scan were done considering various parameters. One of them, was the nasal cavity width, which is the transverse distance between the lateral-most points of each nasal cavity.

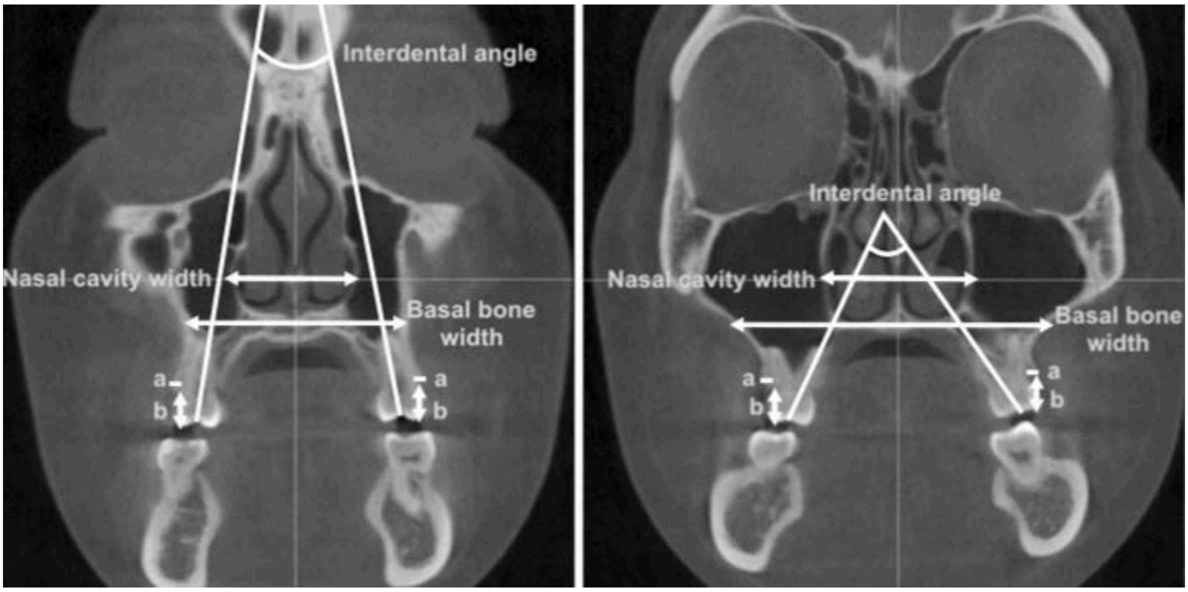

Figure 33 Study by Park et al.: Coronal cone-beam computed tomography images acquired before expansion at furcations of the first premolar **(left)** and first molar **(right)**. (65)

a buccal bone thickness; **b** buccal alveolar height. Buccal bone thickness and alveolar height were measured on the right and left sides, and the mean value of the two measurements was calculated.

Another parameter was the basal bone width, defined by the left and right intersection points of the maxillary outer border and a line passing through the nasal floor. Also, the angle between the left and right tooth axes was established by joining the central fossa and the apex of the palatal root, resulting in the interdental angle. Furthermore, the buccal bone thickness was assessed by measuring the width between the buccal root surface and the lateral border of the alveolar bone, along a horizontal level going through the furcation. The buccal alveolar height was another parameter, determined as the distance from the buccal and mesio-buccal cusp tip to the buccal alveolar crest. For statistical analysis, the alveolar height and the buccal bone thickness were measured bilaterally, and mean values were used. (65)

Efficacy of Expansion

After MARPE, a distraction of the mid-palatal suture and consequently an expansion of the maxilla was observed in both present studies. However, different parameters have been used to assess the treatment outcome.

Park et al. refer changes at the level of IPMW and IMW by 5.5. and 5.4 mm, respectively. The widening of the zygomatic arch was 0.8 mm, and the increase of the nasal cavity was 1.4 mm. Also, the outer border of the maxillary alveolus expanded by 2.0 - 3.2 mm.

All landmarks evaluated presented important lateral expansion. While the position of the alare and ectocanine had moved forward, the prosthion and ectomolare had changed towards upward. Coronal scans of the first premolars and molars showed an augmentation of the nasal cavity width as well as nasal bone width on the one hand, and a reduction in the buccal bone thickness and alveolar bone height on the other. Furthermore, buccal tipping of the maxillary first molars was reported. When comparing the basal bone width with the nasal cavity, the latter showed a lower increase presenting a pyramidal pattern of maxillary expansion. As a whole, a general pyramidal pattern, i.e., a decrease in the amount of maxillary expansion was detected with the superior positioning of the anatomical structures. (65)

Elkenawy et al. report considerable changes at the level of ANS, PNS, and ZMA in transverse dimension comparing pre- and post-expansion values. In regard to the extent of expansion, PNS and ZMA showed a lower shifting by 4.77 mm and 3.99 mm, respectively, compared to ANS which changed by 4.98 mm. However, PNS showed the greatest range of expansion (0 – 13.3 mm), including two participants without any expansion at PNS. This may be either simply due to unsuccessful separation or for improper visualization of the expansion due to thresholds of the bone density. (64)

With respect to the parallelism in the sagittal dimension, Elkenawy et al. report a 95.7% parallel expansion in anterior posterior dimension, by evaluating the above-mentioned values of ANS and PNS. (64)

Furthermore, Elkenawy et al., examined the deviation after MARPE, reporting a standard deviation (SD) of ANS of 1.1 mm. 15 subjects presenting a lower SD, formed the symmetric group, while 16 participants with a higher deviation were assigned to the asymmetric group.

The comparison of the lower and higher values of each patient demonstrates statistically significant differences regarding ANS, PNS and ZMA. The landmark ANS presents the greatest deviation with a mean of 2.22 mm, followed by PNS showing an expansion by 1.77 mm, whereas ZMA underwent the least changes in the amount of 1.3 mm.

Overall, in the asymmetric group, a tendency of expansion to the left side was observed. While 10 of 16 participants demonstrated an expansion to the left side by – 2.21 mm, the rest of the patients presented changes of 2.21 mm to the opposite direction. (64)

5. Conclusion

- Significant increase of the maxillary width was observed in all expansion groups. It is evident that in adult patients the orthopedic expansion of the upper arch consists of both separation of the maxillary halves and a lateral displacement of the alveolar structures. Therefore, increased vertical dimensions or molar tipping constitute a general contraindication for RPE. Although, some studies report that non-surgical treatment in adults of advanced age is predictable and stable, it is still not a commonly used method and rather performed in young skeletally mature patients.

  SARME, instead, is often the treatment of choice in severe skeletal cases, even though it also includes side effects such as slight molar tipping and lateral rotation of the maxillary halves. Since it is a cost-intensive treatment modality and associated with a higher risk and morbidity, each case should be evaluated individually.
- When performing Le Fort I osteotomy mid-palatal osteotomy is avoided. Due to bilateral distraction and bone generation higher stability can be achieved.

  SARPE presents higher relapse regarding the intercanine and intermolar distances in comparison to Le Fort I bipartition.

  As a result, despite a smaller expansion, Le Fort I bipartition shows more stable long-term outcomes, especially at the level of the molars.
- MARPE is an advisable treatment option for young adults. However, asymmetric results in the transverse dimension were found in more than 50% of the patients. Furthermore, there is a clearly visible pyramidal pattern of expansion at dental, skeletal and alveolar level. Again, here, clinicians must be aware of possible side effects such as buccal tipping of the upper teeth, the associated reduced alveolar bone thickness on the buccal side and decreased crest height.

6. Limitations

During the literature research on the present work, it quickly became apparent that a meta-analysis as a serious and meaningful study on the subject of palatal expansion in adult patients is difficult to achieve since there are many individual studies with different examination criteria and effects. For meaningful results it is essential to investigate compatible effects. Hence, more research with equal measurement parameter will be necessary to have more representing results.

8. Responsibility

This work includes aspects of economic and environmental sustainability. By choosing the proper treatment method for palatal expansion in adult patients, accelerated healing, better regeneration and thus, improvement in human health will be observed. Aesthetics, function and thereby quality of life can be improved. Patients´ and clinicians' expectations can be met. Also, further complications, expenditure of time and additional financial expenses can be avoided.

8. List of Abbreviations

- RPE: Rapid Palatal Expansion
- SARME: Surgically-assisted Maxillary Expansion
- SARPE: Surgically-assisted Palatal Expansion
- MARPE: Micro-implant Assisted Rapid Palatal Expansion/ Micro-screw Assisted Rapid Palatal Expansion
- Hyrax: Hygienic Rapid Expander
- HHE: Hybrid-Hyrax expander
- MPS: Midpalatine Suture
- TPD: Transpalatal Distractor
- OMI: Orthodontic Mini-implants
- IPC Expander: Inman Palatal Component E-Arch/Arnold Expander
- OCS: Orbital compartment syndrome
- N: Nasion
- ANS: Anterior Nasal Spine
- PNS: Posterior Nasal Spine
- APP: Axial Palatal Plane
- ZMA: Zygomaticomaxillary Point
- IPMW: Interpremolar Width
- IMW: Intermolar Width

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10. Annexes

Author	Patients (n)	Study type	Material and methods			Outcome measures			
			Method	Material	Measurement time	Skeletal expansion (mm)*	Dental expansion (mm)	Skeletal relapse (mm)	Dental relapse (mm)
Rachmiel et al. 2020	32	Retrospective study	LF 1	Study models OPG Cephalograms	12 months	Ci: 5.8 Cg: 5.8 Mo: 6.2 Mg: 6.0	NR	Ci: 0.4 Cg: NR Mo: 0.2 Mg: NR	NR
Elkenawy et al. 2020	31	Retrospective study	MARPE	CBCT	6 months	ANS: 4.98 PNS: 4.77 ZMA: 3.99	NR	NR	NR
Kurt et al. 2016	54	Clinical study	SARME	Study models	3 months	a: 9.77 ° b: 0.39 c: - 0.58 d: 5.77 e: 4.03 Molar inclination: -11.28 ° Palatal width: 4.42	C I: 4.43 C II: 4.58 1. PM I: 7.55 1. PM II: 8.06 2. PM I: 7.65 2. PM II: 7.98 M. I: 7.55 M. II: 7.44	NR	NR
			NS- RME			a: 6.71 ° b: 0.72 c: - 0.87 d: 3.20 e: 3.11 Molar inclination: -11.25 ° Palatal width: 1.35	C I: 4.52 C II: 4.80 1. PM I: 6.40 1. PM II: 6.13 2. PM I: 6.75 2. PM II: 6.79 M. I: 6.34 M. II: 7.09	NR	NR
Park et al. 2016	14	Retrospective study	MARPE	CBCT	1-5 weeks	IPMW: 44.7 IMW: 55.7 Z-Z: 125.7 N-N: 25.2 J-J: 67.0 MA-MA: 64.7 C6-C6: 62.9 Ag-Ag: 89.0	Interdental angle: PM I: 2.7 °	NR	NR
Marchetti et al. 2009	20	Retrospective study	SARME	Study models	2 years		Intercanine distance: 4.5-10.0 Intermolar distance: 5 - 9.5		Intercanine distance: +1 - -6 Intermolar distance: +3 - 3.5
			LF 1				Intercanine distance: 0- 4.55 Intermolar distance: 2.5 – 7.5		Intercanine distance: 3.5 - -2.5 Intermolar distance: 0 – 5
Handel-man et al. 2000	47	Retrospective study (Case-Control)	NS-RME	Study models Cephalograms	5 years		C: 24.7 PM I: 27.9 PM II: 23.8. M I: 36.0		0.5 - -0.6

Annexe 1 Overview of the high variety of the parameters in the studies examined

Stability of the Transverse Dimension of the Maxilla After Surgically Assisted Rapid Expansion

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The aim of this study was to evaluate the behavior of the transverse dimension of the maxilla after surgically assisted rapid expansion with and without using a transpalatal arch fixed retention. Sixty cast models of the maxilla and 60 posteroanterior radiographs from 30 adult subjects, 16 male subjects and 14 female subjects, were evaluated. The subjects were 18.1 to 53.2 years old (mean age, 27.3 years), had been submitted to surgically assisted rapid maxillary expansion, and were using the expansion appliance for four months. The subjects were randomly assigned into two groups of 15 subjects. One group, called the group with retention, received a transpalatal arch fixed retention and another group, which received no retention, was called the group without retention. The assessments were performed at two time points: at the removal of the expansion appliance (T1) and 6 months after the removal of the expansion appliance (T2). In the cast models, interpremolar distances (A–A1) and intermolar distances (B–B1) were measured and in the posteroanterior radiographs, maxillomandibular discrepancy was used. A reduction in the distances A–A1 (−0.76 mm) and B–B1 (−1.54 mm) was observed among the time points studied in the group without retention and this difference was statistically significant. In the group with retention, the difference between the time points T1 and T2 was not statistically significant. The assessment of the maxillomandibular difference showed an increase between the time points T1 and T2 in the group with retention (1.54 mm) and the group without retention (0.84 mm), which means a reduction in the maxillary width in the posteroanterior radiograph. In the comparison between the groups, the assessment of the cast models and the assessment of the posteroanterior radiograph showed no statistically significant difference in any of the variables studied.

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Key Words: Maxilla, maxillary expansion, cross bite, orthognathic surgery

Skeletal changes involving the maxilla may be classified as horizontal, vertical, and transverse. Transverse alterations are noteworthy, because they are more prevalent[1] and appear both as a lonely entity and related to other alterations. The most common maxillary transverse alteration is the reduction in the transverse distance, or transverse deficiency of the maxilla as it is commonly called.[2] Maxillary transverse deficiency is one of the concerns of the health professionals who work with the stomatognathic system, and the procedures and the consequences of its correction are discussed in the literature.[1,3,4] The correction of the transverse deficiency of the maxilla was initially demonstrated in 1860,[5] being known as rapid expansion of the maxilla. The transverse correction was initially reported as a low predictable procedure and with only temporary results.[6] The process of rapid expansion of the maxilla is based on the separation of the median palatine suture by the expansion appliance, and evidence indicates that this separation is compromised by increasing age.[7] In consequence, adult individuals might be submitted to surgery, which allow the separation of the palatine suture without causing inclination of the teeth involved in the process of expansion; this process was named surgically assisted rapid maxillary expansion (SARME).[6,8] The assessments of the results after SARME are based in two distinct periods: the first period encompasses the time range between the end of activation of the maxillary expansion screw

Annexe 2

CT SCANNING – TECHNIQUES AND APPLICATIONS

Edited by **K. Subburaj**

INTECHWEB.ORG

Annexe 3

Aus der Klinik und Poliklinik für Kieferorthopädie
der Universität Würzburg
Direktorin: Professor Dr. med. dent. Angelika Stellzig-Eisenhauer

Dentale Auswirkungen bei der chirurgisch unterstützten Gaumennahterweiterung durch skelettal verankerte Apparaturen im Vergleich zur Anwendung dental verankerter Apparaturen

Inaugural-Dissertation
zur Erlangung der Doktorwürde der
Medizinischen Fakultät
der
Julius-Maximilians-Universität Würzburg

vorgelegt von
Gregor Ludwig Viktor Baunach
aus Würzburg

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Annexe 4

SPECIAL ARTICLE

A Brief History of Orthodontics

Milton B. Asbell, DDS, MSc, MA
Cherry Hill, N.J.

Man's ancestry may be traced back for more than one hundred millenia. One of the earliest known types of man is Neanderthal Man. The name is derived from a valley in western Germany where the skeletal remains were found in 1856. He was distinguished by a stocky, heavily muscled build, proportionately short forearm and lower leg, and an extremely dolichocephalic skull with projecting occiput, heavy supraorbital tori, receding forehead, and underdeveloped chin.

Another type of man in the early Pleistocene period was Heidelberg Man. His skeletal remains—the famous Heidelberg jaw—consisted of a massive fossilized chinless jaw with distinctly human dentition. The specimen was discovered in 1907 near the town of the same name.

Next in the ancestral line of man is pithecanthropus, a primitive man that is known from a skull and other bone fragments found near the village of Trinil, Java, in 1890. The profile is similar to that of the ape, with a very low forehead and an undeveloped chin. The teeth are characteristically like those of human beings.

Another link is the sinjanthropus, whose skeletal remains were discovered near Peking, China, in 1929, and is also known as Peking Man. Skulls, many teeth, and other skeletal parts reveal a close anatomic relationship to pithecanthropus. It is considered "close to the main line of descent to modern man."

It was not until the postglacial period, which extended back 30,000 to 40,000 years, that modern man, *homo sapiens*, appeared. The Cro-Magnon Man is an outstanding representative of the first "true man." Many of his skeletal remains have been found in various parts of Europe. The name is derived from a cave near Les Eyzies, France. The shape of the skull, face, and brain are characteristic of the modern Caucasian man, except for the difference in size.

During the years from prehistoric time, man has undergone certain evolutionary changes. These changes include the development of an increased cranial capacity; the change in the skull conformation; a heightening of the forehead and a receding of the brow ridges; the reduction of the dental and jaw arches that gave form and prominence to the chin; the progressively human-like appearance of the teeth; and the increase in stature, with the body becoming more erect.

Contrary to popular belief, early man also suffered from dental and oral diseases. This was probably because of the type of food he ate and altered occlusion due to excessive wear, causing edge-to-edge or a minimal overbite pattern.[1,2]

ANCIENT CIVILIZATIONS

The history of orthodontics has been intimately interwoven with the history of dentistry for more than 2000 years. Dentistry, in turn, had its origins as a part of medicine.

To properly study our orthodontic origins, we must return to the Greek civilization of the preChristian era. The Greek physician Hippocrates (460 to 377 BC) is revered as a pioneer in medical science, chiefly because of his medical authorship. He was the first to separate medicine from fancy or religion, and with his reports of critical observation and experience, he established a medical tradition based on facts. This collected information was gathered into a text known as the *Corpus Hippocraticum*, the medical testament of the pre-Christian era.

This treatise does not discuss the dental art independently but contains many references to the teeth and the tissues of the jaws as part of the medical text. An example:

> . . . the first teeth are formed by the nourishment of the fetus in the womb . . . the shedding of the first teeth generally takes place about seven years of age. Children who cut their teeth in winter time get over the teeth period best. Among those individuals whose heads are long-shaped, some have thick necks, strong members and bones; others have strongly arched palates; thus teeth are disposed to irregularity, crowding one on the other and they are molested by headaches and otorrhea. (*Epidemics*, chapter: de camibus.)[3]

Aristotle (384 to 322 BC), the Greek philosopher, had equal stature in the fields of statesmanship, art, and biology. His interest in biology gave to medical science the first system of comparative anatomy and the studies of zoology and physiology. He was the first writer who studied the teeth in a broad manner, having examined them in relation to the dentitions of various types of

Annexe 5

Aus der Klinik für Kieferorthopädie

Universitätsklinikum des Saarlandes, Homburg/Saar

Direktor: Univ.-Prof. Dr. Jörg Lisson

Systematisches Review zur forcierten Gaumennahterweiterung

Dissertation zur Erlangung des Grades eines Doktors der Zahnheilkunde

der Medizinischen Fakultät

der Universität des Saarlandes

2013

vorgelegt von Sandra Spliethoff

geboren am 08.11.1969 in Rheinhausen, jetzt Duisburg

Annexe 6

DISCOVERY!
Martin Taubman, Editor

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J Dent Res 86(10):922-926, 2007

The Birth of the Most Important 18th Century Dental Text: Pierre Fauchard's *Le Chirurgien Dentist*

ABSTRACT

Pierre Fauchard (1678-1761) is considered the father of modern dentistry. His seminal book, *Le Chirurgien Dentiste, ou Traité des Dents* (1728), is the discipline's first complete work. During the five years preceding its publication (1723-1728), Pierre Fauchard sought the opinions, contributions, and "*approbation*" (approval) of 19 of his colleagues: six physicians, 12 surgeons, and one dentist. The first and most important contributor to the manuscript was Jean Devaux, surgeon and mentor to Fauchard. The next six reviewers were illustrious physicians and scientists of the time: Philippe Hecquet, Jean-Claude Adrien Helvetius, Jean Baptiste Silva, Antoine DeJussieu, Raymond Jacob Finot, and Antoine Benignus Winslow. The subsequent 12 reviewers were all sworn-surgeons (certified by St. Côme), including a lone dentist, Laudumiey, surgeon-dentist to His Majesty, Philip V, King of Spain. Fauchard knew that for dentistry to be regarded as a learned profession, and perhaps for Fauchard to be recognized as its leader, he needed the support and approval of the establishment before publishing his book. This is an account of how he attained this endorsement.

KEY WORDS: Fauchard, history of dentistry, chirurgien dentist, surgeon dentist.

Received April 3, 2007; Last revision May 24, 2007; Accepted May 30, 2007

What was it like to write a textbook early in the 18th century in a new field like dentistry? How did the original manuscript get put together? How did Fauchard go about running his ideas past other professionals? Who, exactly, were the people Fauchard consulted between 1723 and 1728, and why? These are some of the questions I asked in looking at *Le Chirurgien Dentiste, ou Traité des Dents* (1728) (Fig. 1), the first complete work in dentistry, and the textbook that made Pierre Fauchard (1678-1761) the "Father and Founder of Dental Surgery" (Viau, 1923a). This paper is not an account of Fauchard's life or his seminal contributions to the field. Several excellent reviews, including some recent ones, have done that (Viau 1923a,b; Weinberger, 1941; Hoffmann-Axthelm, 1981; Angot, 1983; Lynch *et al.*, 2006). This is an account of the peer review process that his manuscript went through during a five-year period between 1723 and 1728.

Pierre Fauchard worked on his famous manuscript on and off while practicing as a certified "mâitre" (master) chirurgien-dentist. His manuscript was over 600 written pages in 1723, when he first registered it. However, it took him five more years to bring it to its final form of 783 pages, after making corrections in response to feedback from 19 of his peers, highly prominent members of society and the medical profession, pre-eminent scholars in the fields of science and healing. Many of them referred patients to Fauchard; some were his patients. Fauchard sought and obtained their endorsements for his book.

Pierre Fauchard was hailed by his contemporaries as a pioneer and became a pre-eminent "Chirurgien-Dentiste", the term he coined and used for himself. This new term was meant to create a 'pecking order', to distinguish those with surgical training from those untrained. Dentistry was practiced by a variety of individuals, some formally trained, some not at all. The hierarchy that started with physicians and surgeons was thus extended to trained surgeon dentists and to untrained dentists, some less reputable than others (barbers, blacksmiths, itinerant handymen, or even charlatans).

Fauchard's education began at age 15, in 1693, while serving as a young naval surgeon apprentice to Alexandre Poteleret, surgeon-in-chief to His Majesty's ships. As Fauchard witnessed the ravaging effect of scurvy on the dentition of sailors, he became interested in dentistry. Fauchard never completed his training as a surgeon, due to lack of funds. Dentistry, in contrast, did not require a costly apprenticeship. His experience with Poteleret was more than many practicing dentists had at the time. He became a dental surgeon, initially in Angers, Tours, Rennes, and finally, starting in 1718, in Paris (Hoffmann-Axthelm, 1981).

His book is a compilation of the knowledge of dentistry at the turn of the 18th century. No doubt many of his observations were from first-hand experience. His manuscript has many original elements, such as the description of tooth dysplasia (dentinogenesis imperfecta), and descriptions of cysts, which Fauchard linked to caries lesions. However, its most important attribute was its systematic, scientific, and comprehensive character—its amazing thoroughness—a first for dentistry. Through the book, Fauchard established a new profession that, until that time, was practiced by an assortment of other professionals. Attempts to publish on aspects of dentistry

Annexe 7

Aus dem Zentrum der Zahn-, Mund- und Kieferheilkunde
der J.W. Goethe-Universität, Frankfurt am Main
Poliklinik für Kieferorthopädie

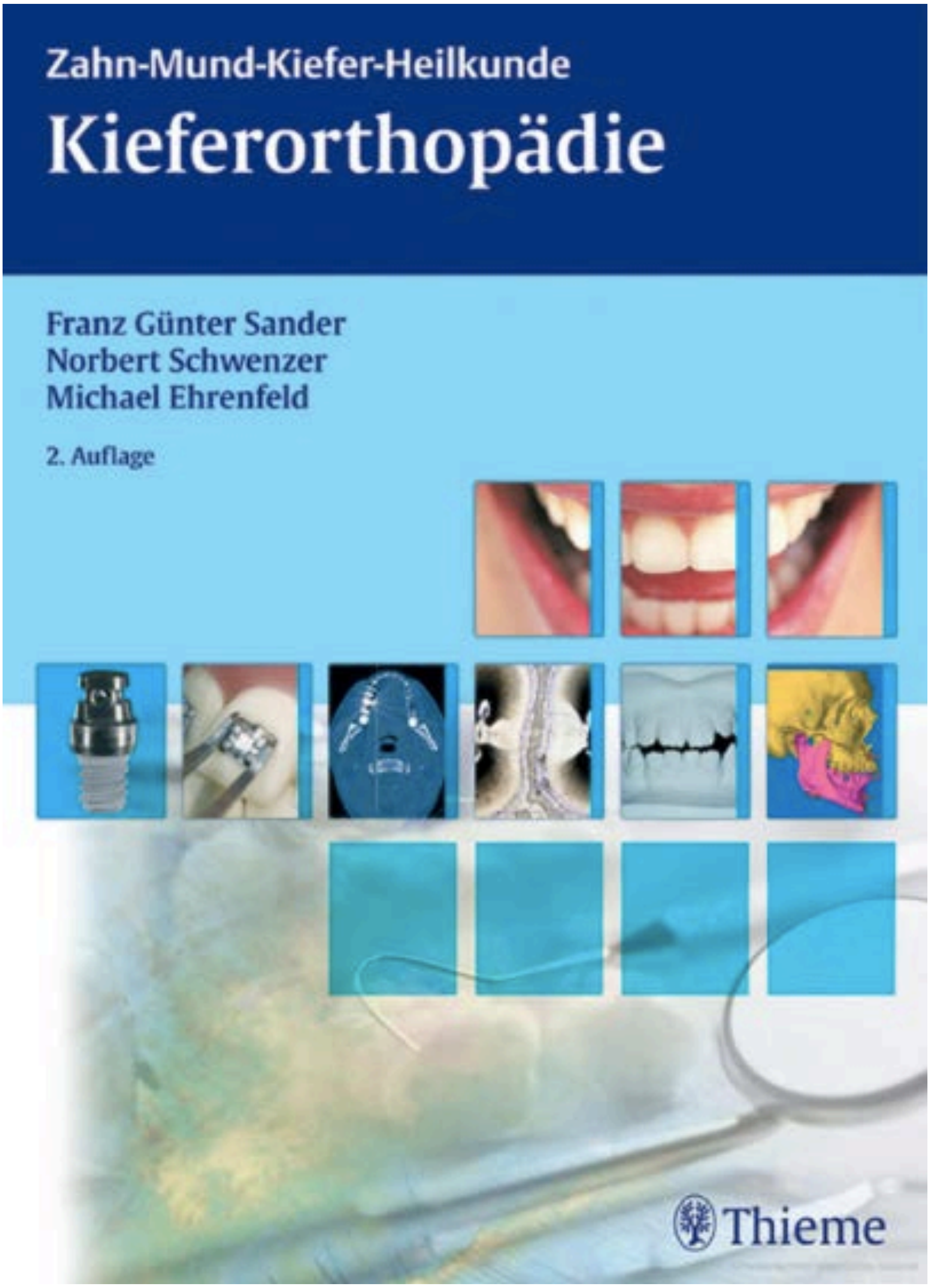
**NEBENWIRKUNGEN DER
FORCIERTEN GAUMENNAHTERWEITERUNG**

Dissertation
zur Erlangung des Doktorgrades der Zahnmedizin
des Fachbereichs Medizin der
Johann Wolfgang Goethe-Universität
Frankfurt am Main

vorgelegt von
Iris Borel-Scherf
aus Frankfurt am Main

Frankfurt am Main, 2007

Annexe 8


Zahn-Mund-Kiefer-Heilkunde
Kieferorthopädie
Franz Günter Sander
Norbert Schwenzer
Michael Ehrenfeld
2. Auflage
Thieme

Annexe 9

Mandibular dentoalveolar reactions to rapid palatal expansion

Meienhofer, Martin Andreas

Annexe 10

Aus der Poliklinik für Kieferorthopädie der
Ludwig-Maximilians-Universität
München

Direktorin: Prof. Dr. Ingrid Rudzki-Janson

Die Wirkung der Gaumennahterweiterung auf die Nasenatmung im Verlauf der aktiven Dehnung bei Patienten mit transversaler Enge im Oberkiefer
Eine rhinomanometrisch - röntgenologische Studie

Dissertation

Zum Erwerb des Doktorgrades der Zahnheilkunde
an der Medizinischen Fakultät der
Ludwig-Maximilians-Universität zu München

vorgelegt von
Steffi Bössner

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Annexe 11

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original article

Transverse effects on the nasomaxillary complex one year after rapid maxillary expansion as the only intervention: A controlled study

Carolina da Luz Baratieri[1], Maheus Alves Jr[2], Claudia Trindade Mattos[3], Geórgia Wain Thi Lau[2], Lincoln Issamu Nojima[3], Margareth Maria Gomes de Souza[3]

The aim of this study was to assess by means of cone-beam computed tomography (CBCT) scans the transverse effects on the nasomaxillary complex in patients submitted to rapid maxillary expansion (RME) using Haas expander in comparison to untreated individuals. This prospective controlled clinical study assessed 30 subjects (18 boys and 12 girls) with mixed dentition and during pubertal growth. The treated group was submitted to RME with Haas expander, retention for six months and a six-month follow-up after removal. The control group matched the treated group in terms of age and sex distribution. CBCT scans were taken at treatment onset and one year after the expander was activated. Maxillary first molars (U6) width, right and left U6 angulation, maxillary alveolar width, maxillary basal width, palatal alveolar width, palatal base width, right and left alveolar angulation, palatal area, nasal base width, nasal cavity width and inferior nasal cavity area on the posterior, middle and anterior coronal slices were measured with Dolphin Imaging Software® 11.5, except for the first two variables which were performed only on the posterior slice. All transverse dimensions increased significantly ($P < 0.05$) in the treated group in comparison to the control, except for alveolar angulation and inferior nasal cavity area ($P > 0.05$). Results suggest that increase of molar, maxillary, palatal and nasal transverse dimensions was stable in comparison to the control group one year after treatment with RME.

Keywords: Palatal expansion technique. Longitudinal studies. Orthodontics. Cone-beam Computed Tomography.

Objetivo: avaliar, por meio de tomografias computadorizada de feixe cônico (TCFC), as dimensões transversais do complexo nasomaxilar de pacientes submetidos à expansão rápida da maxila (ERM) e sem intervenção. **Métodos:** este estudo clínico prospectivo e controlado avaliou 30 indivíduos (18 meninos e 12 meninas) durante o período de crescimento puberal e dentição mista. O grupo tratado foi submetido à ERM com expansor de Haas, permanecendo 6 meses em contenção e sendo acompanhados por mais 6 meses após a remoção. O grupo controle foi acompanhado durante o mesmo tempo. Foram realizadas TCFC ao início e um ano após a fase ativa. Com o programa Dolphin Imaging 11.5, a largura entre os primeiros molares superiores (U6), angulação dos U6 direito e esquerdo, largura maxilar alveolar, largura maxilar basal, largura alveolar do palato, largura basal do palato, angulação alveolar direita e esquerda, área palatina, largura da base nasal, largura da cavidade nasal e área da cavidade nasal inferior foram obtidas em cortes coronais posterior, médio e anterior, com exceção das duas primeiras medidas, que foram obtidas apenas no corte coronal posterior. **Resultados:** todas as medidas foram significativamente ($p < 0,05$) maiores no grupo da ERM, com exceção da angulação alveolar e da área da cavidade nasal, as quais não foram significativas ($p > 0,05$) entre os grupos. Os resultados sugerem que, um ano após a ERM, a dimensão transversal na cavidade nasal, maxila, palato e região dos molares são maiores do que em indivíduos não tratados. O protocolo de ERM utilizado foi eficaz na manutenção da dimensão transversal durante período de acompanhamento.

Palavras-chave: Técnica de expansão palatina. Estudos longitudinais. Ortodontia. Tomografia computadorizada de feixe cônico.

» The authors report no commercial, proprietary or financial interest in the products or companies described in this article.

» Patients displayed in this article previously approved the use of their facial and intraoral photographs.

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Annexe 12

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REVIEW ARTICLE

Maxillary Expansion

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Abstract

Maxillary transverse discrepancy usually requires expansion of the palate by a combination of orthopedic and orthodontic tooth movements. Three expansion treatment modalities are used today: rapid maxillary expansion, slow maxillary expansion and surgically assisted maxillary expansion. This article aims to review the maxillary expansion by all the three modalities and a brief on commonly used appliances.

Keywords : Maxillary expansion, Rapid maxillary expansion, Slow maxillary expansion, Surgically assisted maxillary expansion.

INTRODUCTION

Maxillary expansion treatments have been used for more than a century to correct maxillary transverse deficiency. The earliest common cited report is that of E.C. Angell published in *Dental Cosmos* in 1860.[1] The work was discredited at the time, but the technique is now generally accepted as a relatively simple and predictable orthodontic therapy. Correction of the transverse discrepancy usually requires expansion of the palate by a combination of orthopedic and orthodontic tooth movements. Three expansion treatment modalities are used today: rapid maxillary expansion (RME), slow maxillary expansion (SME) and surgically assisted maxillary expansion. Since each treatment modality has advantages and disadvantages, controversy regarding the use of each exists. Practitioners select treatment appliances based on their personal experiences and on the patient's age and malocclusion.[2,3] Normal palatal growth is nearly complete by age 6,[9] and increasing interdigitation of the suture makes separation difficult to achieve after puberty.[10-15] During treatment, transverse forces tip the buccal segments laterally[4] and with proper appliance design, 3rd-order moments will induce bodily translation.[5-8] If the force is strong enough, separation occurs at the maxillary suture. The clinical conditions indicating maxillary expansion include crossbites, distal molar movement, functional appliance treatment, surgical cases for instance arch coordination or bone grafts, to aid maxillary protraction and mild crowding. This article aims to review the maxillary expansion and commonly used appliances.

RAPID MAXILLARY EXPANSION (RME)

Rapid maxillary expansion was first described by Emerson Angell in 1860[1] and later repopularized by Haas. The main object of RME is to correct maxillary arch narrowness but its effects are not limited to the maxilla as it is associated with 10 bones in the face and head.[16] Advocates of rapid maxillary expansion believe that it results in minimum dental movement (tipping) and maximum skeletal movement.[3] When heavy and rapid forces are applied to the posterior teeth, there is not enough time for tooth movement to occur and the forces are transferred to the sutures. When the force delivered by the appliance exceeds the limit needed for orthodontic tooth movement and sutural resistance, the sutures open up while the teeth move only minimally relative to their supporting bone. The appliance compresses the periodontal ligament, bends the alveolar process, tips the anchor teeth, and gradually opens the midpalatal suture and all the other maxillary sutures.

Effect of RME on Maxillary and Mandibular Complex

Maxillary skeletal effect: When viewed occlusally, Inoue found that the opening of the midpalatine suture was nonparallel and triangular with maximum opening at incisor

Annexe 13

Original Article

Pain and discomfort during the first week of rapid maxillary expansion (RME) using two different RME appliances: *A randomized controlled trial*

Ingalill Feldmann[a]; Farhan Bazargani[b]

ABSTRACT

Objectives: To evaluate and compare perceived pain intensity, discomfort, and jaw function impairment during the first week with tooth-borne or tooth-bone–borne rapid maxillary expansion (RME) appliances.

Materials and Methods: Fifty-four patients (28 girls and 26 boys) with a mean age of 9.8 years (SD 1.28 years) were randomized into two groups. Group A received a conventional hyrax appliance and group B a hybrid hyrax appliance anchored on mini-implants in the anterior palate. Questionnaires were used to assess pain intensity, discomfort, analgesic consumption, and jaw function impairment on the first and fourth days after RME appliance insertion.

Results: Fifty patients answered both questionnaires. Overall median pain on the first day in treatment was 13.0 (range 0–82) and 3.5 (0–78) for groups A and B, respectively, with no significant differences in pain, discomfort, analgesic consumption, or functional jaw impairment between groups. Overall median pain on the fourth day was 9.0 (0–90) and 2.0 (0–71) for groups A and B, respectively, with no significant differences between groups. There were also no significant differences in pain levels within group A, while group B scored significantly lower concerning pain from molars and incisors and tensions from the jaw on day 4 than on the first day in treatment. There was a significant positive correlation between age and pain and discomfort on the fourth day in treatment. No correlations were found between sex and pain and discomfort, analgesic consumption, and jaw function impairment.

Conclusions: Both tooth-borne and tooth-bone–borne RME were generally well tolerated by the patients during the first week of treatment. (*Angle Orthod.* 0000;00:000–000.)

KEY WORDS: Rapid maxillary expansion; Pain and discomfort; Mini-implants; Questionnaire

INTRODUCTION

Rapid maxillary expansion (RME) is a common procedure in young children with a constricted maxilla and transverse discrepancies between the maxilla and the mandible.[1,2] The primary goal of RME is to maximize dentofacial orthopedics and minimize orthodontic movement, but a recently published systematic review[3] indicates that the skeletal effects (ie, the opening of the midpalatal suture) account for only approximately 20%–50% of the total screw expansion, meaning that the dentoalveolar effects in terms of molar tipping and alveolar bending account for over 50% of the total effect. To minimize these dental side effects, which likely increase the risk of relapse, skeletally anchored RME appliances have been introduced.[4–6]

Pain and discomfort are well-known side effects of orthodontic treatment with fixed appliances,[7–9] but few studies[10–12] have explored pain and discomfort during RME treatment. These few studies have concluded that most children undergoing RME report pain, which generally occurs during the initial phase and diminishes thereafter. The highest pain levels were reported during the first 10 activations and peaked on days 3 and 4. Activation protocols with two turns/d result in

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Annexe 14

Skeletally-anchored Rapid Maxillary Expansion using the Dresden Distractor

Skelettal verankerte Gaumennahterweiterung mit dem Dresden Distraktor

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Abstract

Introduction: It was the aim of this study to carry out a 3-D analysis of the teeth, alveolar and skeletal structures during bone-borne, surgically-assisted rapid maxillary expansion (RME) with the Dresden Distractor (DD). We aimed to determine whether a translatory and skeletal movement of the segments would be possible while reducing the dento-alveolar side effects associated with tooth-borne RME.

Materials and Methods: Standardized axial computed tomography (CT) was performed on twelve patients averaging 25.3 years of age prior to and after RME with the DD. Reference planes and the triple-0-ELSA were defined bilaterally referring to the following anatomic points: the foramina spinosa, external auditory meati and the anterior margin of the foramen magnum. We measured the amount of movement that occurred before and after RME with the DD against ELSA.

Results: A screw activation of 6.0 mm led to a transverse expansion of 5.55 mm in the alveolar process in the premolar region, and of 4.87 mm in the molar region, with 8° to 9.8° of buccal tipping and an increase in width of 6.07 mm and 5.71 mm, respectively, occurred in conjunction with only slight buccal tipping of the premolars (3.1°–4.6°) and molars (1.1°–2.6°). These data signify, beyond the considerable skeletal efficacy, an uprighting of the teeth due to the multibracket appliance's torque effect, and a direct transfer of the expansion forces onto the bone. Autorotation of the mandible in forward and upward directions was possible due to the considerably less dental tipping resulting from RME with the DD in comparison to tooth-borne RME. This fact demonstrated that the DD is also well-suited for patients with vertical growth pattern.

Conclusion: The bone-borne DD is an effective therapeutic method that spares the patient the negative side effects associated with tooth-borne RME such as root resorption, bone dehis-

Zusammenfassung

Ziel: Ziel der Studie war die 3-D-Analyse von Zähnen, alveolären und skelettalen Strukturen bei der knochenverankerten, chirurgisch unterstützten Gaumennahterweiterung (GNE) mit dem Dresden Distraktor (DD). Es sollte überprüft werden, ob eine körperliche und skelettale Bewegung der Segmente mit einer Reduktion der bei der zahngetragenen Gaumennahterweiterung auftretenden dentoalveolären Nebenwirkungen erreicht werden kann.

Material und Methodik: Bei zwölf Patienten, Durchschnittsalter 25,3 Jahre, wurden vor und 6,8 Monate nach der GNE mit dem DD standardisierte axiale Computertomogramme (CTs) erstellt. Mittels der anatomischen Referenzpunkte Foramina spinosa und Pori acustici externi beidseits sowie dem Vorderrand des Foramen magnum wurden Referenzebenen und der Tripel-Nullpunkt ELSA definiert. Bewegungen der Messpunkte vor und nach GNE wurden gegen ELSA vermessen.

Ergebnisse: Die Schraubenerweiterung von 6,00 mm führte am Alveolarfortsatz in der Prämolarenregion zu 5,55 mm und in der Molarenregion zu 4,87 mm transversaler Erweiterung mit 8°–9,8° Bukkalkippung. Die geringere Bukkalkippung der Prämolaren von 3,1°–4,6° und der Molaren von 1,1°–2,6° bei einer Breitenzunahme von 6,07 mm bzw. 5,71 mm verdeutlichte neben der großen skelettalen Effektivität eine Aufrichtung der Zähne durch den Torqueeffekt der Multibracketapparatur und die direkte Einleitung der Expansionskräfte auf den Knochen. Die im Gegensatz zur zahngetragenen GNE geringe Zahnkippung der GNE mit dem DD erlaubte eine Autorotation der Mandibula nach ventral und kranial, so dass der DD auch bei vertikalem Wachstum gut geeignet war.

Schlussfolgerung: Der knochenverankerte DD ist eine effektive Therapiemethode, welche vor unerwünschten Nebenwirkungen zahngetragener GNE wie Wurzelresorptionen, Knochendehiszenzen, Bissöffnung und exzessiver Bukkalkippung

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Annexe 15

Journal of Cranio-Maxillo-Facial Surgery xxx (2014) 1–6

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Journal of Cranio-Maxillo-Facial Surgery

journal homepage: www.jcmfs.com

Transpalatal distraction – State of the art for the individual management of transverse maxillary deficiency – A review of 50 consecutive cases

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Keywords:
Transpalatal distraction
Transversal maxillary deficiency
Maxillary expansion

ABSTRACT

Transpalatal distraction has been established as a technique for surgical assisted rapid palatal/maxillary expansion (SARPE/SARME) in order to correct transverse maxillary deficiency.

From 2007 until 2013 bone borne transpalatal distraction devices have been inserted in 50 patients affected by transverse maxillary deficiency and transpalatal distraction has been performed by the same surgical team. Patient records were retrospectively evaluated after ending of the active distraction phase with respect to indication, achieved expansion, additional procedures and side effects.

In all cases the existing transverse maxillary deficiency was corrected by means of transpalatal distraction according to the individual needs. No complications were observed that interfered with that therapeutic aim. Evaluation of the records showed a wide variance of parameters which impedes evidence based statements.

According to that series transpalatal distraction is a safe, powerful and reliable procedure and can be recommended as a state of the art procedure for the individually adapted correction of transverse maxillary deficiency if well known parameters of distraction are respected.

1. Introduction

Since it's introduction by Mommaerts and co-workers in 1999 (Mommaerts, 1999) transpalatal distraction (TPD/TPDO) has been established as a bone borne variant for surgically assisted rapid maxillary or palatal expansion (SARPE/SARME). It is indicated in cases of transverse maxillary deficiency that cannot be corrected by orthodontic means alone.

Basically SARPE can be performed either by individually designed tooth borne expansion devices (Hyrax/Haas screws) where expansion forces are indirectly transmitted to the palatal bone or by commercially available bone borne distraction devices which are directly acting on the palatal bone. Both methods are known to provide reliable results (Koudstaal et al., 2009; Verstraaten et al., 2010; Nada et al., 2012). Main advantage of bone borne devices is a more skeletal expansion without dentoalveolar movement which cannot be excluded when tooth borne devices are applied (Landes et al., 2009; Zemann et al., 2009).

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Another advantage of bone borne devices is the fact that orthodontic treatment and closure of the interincisival diastema can basically be started at an earlier stage when compared with tooth borne devices as dental movements are not impaired by bone borne distraction devices. This can help to reduce overall treatment time and acceptance especially in adult patients (Mommaerts, 1999; Pinto et al., 2001).

An individually adapted correction of the present transverse maxillary deficiency can be performed by selection of an appropriate device, the intraoperative positioning of the device and modification of the osteotomies which are required for surgically assisted maxillary expansion. The options for the individual management of transverse maxillary deficiency by transpalatal distraction should be demonstrated according to the clinical experiences after a series of 50 patients that have been treated from 2007 to 2013.

2. Materials and methods

Since 2007 50 patients affected by transverse maxillary deficiency have been treated by transpalatal distraction (TPD) with or without subsequent combined orthognathic treatment.

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Annexe 16

Stability of the anterior arm of three different Hyrax hybrid expanders: an *in vitro* study

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Introduction: The force applied to the teeth by fixed orthopaedic expanders has previously been studied, but not the force applied to the orthodontic mini-implant (OMI) used to expand the maxilla with Hyrax hybrid expanders (HHE). **Objective:** The aim of this article was to evaluate the clinical safety of the components (OMI, abutment and double wire arms) of three different force-transmitting systems (FTS) for conducting orthopaedic maxillary expansion: Jeil Medical & Tiger Dental™, Microdent™ and Ortholox™. **Methods:** For the realization of this *in vitro* study of the resistance to mechanical load, three different abutment types (bonded, screwed on, and coupling) and three different OMIs' diameters (Jeil™ 2.5mm, Microdent™ 1.6mm and Ortholox™ 2.2mm) were used. Ten tests for each of these three FTS were carried out in a static lateral load in artificial bone blocks (Sawbones™) by a Galdabini universal testing machine, then comparing its performance. Comparisons of loads, deformations and fractures were carried out by means of radiographs of FTS components in each case. **Results:** At 1-mm load and within the elastic deformation, FTS values ranged from 67±13N to 183±48N. Under great deformations, Jeil & Tiger™ was the one who withstood the greatest loads, with an average 378±22N; followed by Microdent™, with 201±18N, and Ortholox™, with 103±10N. At 3mm load, the OMIs shaft bends and deforms when the diameter is smaller than 2.5mm. The abutment fixation is crucial to transmit forces and moments. **Conclusions:** The present study shows the importance of a rigid design of the different components of HHEs, and also that HHEs would be suitable for maxillary expansion in adolescents and young adults, since its mean expansion forces exceed 120N. Furthermore, early abutment detachment or smaller mini-implants diameter would only be appropriate for children.

Keywords: Microscrew. Mini-implant. Hybrid hyrax expander. Rapid maxillary expansion. Abutment stability.

Introdução: a força aplicada sobre os dentes por expansores ortopédicos fixos já foi estudada antes, mas não a força aplicada sobre os mini-implantes ortodônticos (MIOs) usados para expandir a maxila com expansores do tipo Hyrax híbrido (EHH). **Objetivo:** o objetivo desse artigo foi avaliar a segurança clínica dos componentes (MIO, *abutment* de fixação, e braços de fio duplo) de três sistemas de transmissão de força (STF) usados para expansão ortopédica da maxila: Jeil Medical & Tiger Dental™, Microdent™ e Ortholox™. **Métodos:** para realizar esse estudo *in vitro* sobre a resistência à carga mecânica, foram usadas três tipos de sistema de fixação (colado, aparafusado e *coupling*) e MIOs de três diâmetros diferentes (Jeil™ 2,5mm; Microdent™ 1,6mm e Ortholox™ 2,2mm), com suas respectivas mecânicas de STF. Foram realizados 10 testes para cada STF, usando uma carga lateral estática em blocos de osso artificial (Sawbones™), com uma máquina universal de testes e, depois, comparou-se, por meio de radiografias, os desempenhos, levando-se em consideração as cargas, deformações e fraturas dos componentes de cada STF. **Resultados:** com a carga a 1mm e sem exceder o limite de deformação elástica, os valores dos STFs variaram de 67±13N a 183±48N. Sob deformações maiores, o sistema Jeil & Tiger™ foi o que apresentou maior resistência às cargas elevadas, com valor de 378±22N; seguido pelo Microdent™, com 201±18N, e Ortholox™, com 103±10N. Com a carga a 3mm, o eixo do MIO se dobrou e deformou quando seu diâmetro era menor que 2,5mm. O *abutment* de fixação é crucial para a transmissão das forças e momentos. **Conclusões:** o presente estudo evidenciou a importância da rigidez no *design* dos diferentes componentes dos STFs dos EHH. Também revelou que eles são adequados para a expansão da maxila em adolescentes e adultos jovens, pois as forças de expansão, em média, excederam os 120N. Além disso, a desconexão precoce do *abutment* ou o uso de mini-implantes de menor diâmetro no *design* do STF seriam apropriados apenas em crianças.

Palavras-chave: Microparafusos. Mini-implantes. Expansor Hyrax híbrido. Expansão rápida da maxila. Estabilidade do *abutment*.

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» Patients displayed in this article previously approved the use of their facial and intraoral photographs.

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Annexe 17

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Die Bedeutung der Zunge für die Nasen- und Mundatmung

Von Prof. Dr. Adolf Eckert-Möbius, Halle

Mit 17 Abbildungen

Das Thema meines heutigen Vortrages müßte eigentlich vollständiger lauten: „Die Bedeutung der Mundweichteile für die Nasen- und Mundatmung". Wenn ich als pars toto bewußt die Zunge in den Vordergrund meiner Betrachtungen stelle, so deshalb, weil diese für das Zustandekommen der Mund- oder Nasenatmung die wesentliche Rolle spielt und sich am ehesten als formender Faktor bei der normalen und pathologischen Entwicklung der Kiefer und des Gaumens auswirken kann.

Sie alle wissen, daß der Mensch mit normalen Nasen-, Mund- und Rachenverhältnissen gewöhnlich durch die Nase atmet und bei stärkerer Atmungsbeanspruchung automatisch den Mund für die Atmung zu Hilfe nimmt. Sie wissen ferner, daß wir auch bei geöffnetem Munde willkürlich durch die Nase oder durch den Mund atmen können.

Und schließlich ist Ihnen bekannt, daß es zwei verschiedene Formen unwillkürlicher pathologischer Mundatmung gibt:

1. die nasal bedingte infolge erschwerter oder behinderter Nasenatmung, z. B. durch Stockschnupfen oder Rachenmandelhyperplasie;
2. die oral bedingte infolge unzureichenden Lippen- und Kieferschlusses verschiedenster Ursache.

Wie verhalten sich in allen diesen Fällen die Mundweichteile, insbesondere die Zunge und welche Auswirkungen auf die Formgestaltung der Kiefer und des Gaumens können von ihr unter normalen und pathologischen Atmungsverhältnissen ausgehen?

Die im Schrifttum darüber vertretenen Auffassungen sind keineswegs einheitlich, zum Teil sogar voller Widersprüche, auf die ich aus Zeitgründen im einzelnen nicht näher eingehen kann. Ich will mich darauf beschränken, Ihnen meine eigenen Untersuchungsergebnisse darzustellen und die biologischen Schlußfolgerungen, die sich daraus ergeben.

Annexe 18

Le Fort I Osteotomy for Maxillary Repositioning and Distraction Techniques

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1. Introduction

Despite the widespread acceptance of various classifications for midface fractures, the most commonly used for describing these fractures remains the classical one described by the French physician Rene Le Fort in 1901 (Le Fort, 1900, 1901).

The technique for maxillary osteotomy type Le Fort I was performed for the first time by Cheever in 1864 for rinofaringeal tumor resection (Halvorson & Mulliken, 2008).

In 1921 Herman Wassmund performed a Le Fort I osteotomy for dentofacial deformity correction without intraoperative mobilization, which was achieved by orthopedic traction in the post operative time (Wassmund, 1927, 1935).

In 1934 Auxhausen performed a Le Fort I osteotomy mobilization for open bite correction (Axhausen, 1934), but only in 1952, in the USA, Converse described his cases operated by maxillary osteotomy and large vestibular and palatal elevation for Le Fort I osteotomy combined with midpalatal osteotomy (Converse, 1952).

After this report some other surgeons performed maxillary osteotomies for open bite correction, but results were not stable (Steinhausen, 1996). Only in 1974 Stoker and in 1975 Epker, reported encouraging results in dentofacial deformity correction using down fracture technique for complete maxillary mobilization by Le Fort I osteotomy (Stoker, 1974; Epker, 1975).

After encouraging reports by some American surgeons (Converse, 1969) who published several methods for correction of jaw deformities and stressed the importance of close collaboration between surgeon and orthodontist, other surgeons (Obwegeser, Wilmar, Bell) started to widely adopt maxillary osteotomies for dentofacial deformity correction (Obwegeser, 1969; Bell, 1975, Hogeman & Wilmar, 1967).

An important contribution to orthognatic surgery came from Obwegeser's unit in Zurich (Switzerland) and from many excellent textbooks on orthognatic surgery published in the 80s by different American surgeons (Bell, 1980; Bell, 1985, Epker and Fish, 1986; Profitt and White, 1991).

Before 1965 this kind of deformities were commonly treated only by mandibular osteotomies even if skeletal problems were present in maxillary bones, but final results were not aesthetically satisfactory. An important progress in orthognatic surgery was the 'two-

Annexe 19

Kieferorthopädische Gaumennahterweiterung (RPE) versus chirurgisch unterstützte Gaumennahterweiterung (SARPE) – eine Gegenüberstellung

Orthognathic Maxillary Expansion (OME) Versus Surgical Assisted Rapid Palatal Expansion (SARPE): A Comparison

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Schlüsselwörter
- Gaumennahterweiterung
- Expansion
- transversale Diskrepanz
- SARPE

Key words
- rapid maxillary expansion
- expansion
- transverse discrepancy
- SARPE

Zusammenfassung

Der Schmalkiefer, auch Mikromaxillie, kann als Teil eines Fehlbisses unterschiedlich korrigiert werden. Die Erweiterung erfolgt je nach Alter der Patienten mit verschiedenen Methoden. Während bei Kindern und Jugendlichen die Verbreiterung konservativ mit Dehnplatten erfolgen kann (rapid palatal expansion = RPE) ist dies bei Erwachsenen mit abgeschlossener Verknöcherung nicht mehr möglich, sondern muss chirurgisch unterstützt erfolgen. In beiden Fällen wird die Expansion mit Dehnplatten durchgeführt. Die ersten Dehnplatten wurden bereits im 18. Jahrhundert entwickelt. Die chirurgisch unterstützte Erweiterung (Surgically assisted rapid palatal expansion = SARPE) ist seit der ersten Hälfte des 20. Jahrhunderts möglich. Die angewandte Methode wird durch die Verknöcherung der Sutura palatina bestimmt, wobei diese früher als Hauptwiderstand galt. Die heutigen Erkenntnisse haben gezeigt, dass die Resistenz im Bereich der Crista zygomatico-maxillaris und des Processus pterygoideus mit zunehmendem Alter den Hauptwiderstand bilden. Diesem Umstand Rechnung tragend, hat sich die Methode der chirurgischen Erweiterung gewandelt.

Abstract

Many possible treatment modalities exist for correction of maxillary transverse width discrepancies. Opening of the midpalatal suture with expansion appliances was used in children and young adults to widen a deficient maxilla in the nineteenth century. This marks the beginning of rapid palatal expansion (RPE). Surgically assisted rapid palatal expansion (SARPE) was introduced in the first half of the last century as conservative treatment of maxillary deficiency in adults was not successful. Historically the midpalatal suture was thought to be the area of resistance to expansion. However, studies have shown that the facial skeleton increases its resistance to expansion as it ages and that the major site of resistance are zygomatic-maxillary buttress and pterygopalatinal process. Therefore SARPE is a useful technique for maxillary deficiency in adults.

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Einleitung

Beißen die bukkalen Höcker der Unterkieferseitenzähne seitlich an den bukkalen Höckern der Oberkieferseitenzähne vorbei, liegt ein Kreuzbiss vor. Dieses Missverhältnis der Transversalen von Oberkiefer zu Unterkiefer kann relativ oder absolut sein (siehe unter Methode, SARPE). Als Bestandteil eines Fehlbisses oder isoliert in Form einer Mikromaxillie tritt dies bei 8–14% jener Patienten auf, die sich einer kieferorthopädischen Behandlung unterziehen. Die Korrektur einer Mikromaxillie kann je nach Alter und Schwere unterschiedlich durchgeführt werden. Aus kieferorthopädischer Sicht kann bei Kindern, Jugendlichen und jungen Erwachsenen die Dehnung konservativ mit Platten erfolgen (OME), während bei Erwachsenen dies nur mit chirurgischer Unterstützung möglich ist (SARPE).

Kennzeichnende Symptome für eine Mikromaxillie sind transversale Enge, schmale Zahnbögen im Oberkiefer, frontaler Engstand und ein hoher Gaumen. Meist sind diese Patienten Mundatmer. Negative Folgen einer transversalen Enge können sich in Form eines lateralen Kreuzbisses oder distalen Zwangsbisses äußern. Die Therapie ist eine transversale Erweiterung des Gaumens, um eine Verbreiterung der Zahnbögen zu erreichen [1].

Annexe 20

Palatal growth studied on human autopsy material

A histologic microradiographic study

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The most important information on the vertical growth of the hard palate has been obtained in longitudinal roentgen-cephalometric studies by Björk[3, 5, 7] by means of the implant method. These studies have shown that lowering of the maxillary area of the hard palate is due to bone resorption on the nasal side of the hard palate and to apposition on the oral side. It was further shown by Björk and Skieller[8] that remodeling of the nasal side of the hard palate is differentiated, as the resorption is usually greater on the anterior part of the nasal surface. The information obtained in these studies applies only to the growth of the maxillary part of the hard palate, as the implants were always placed in the maxilla. The vertical growth pattern of the horizontal plate of the palatine bone has not previously been studied.

The growth in length of the hard palate has been described by, among others, Koski,[15] Bambha,[1] Taylor,[31] Björk,[4] Melsen,[18] and Fishman,[14] and in all of these studies the growth was found to continue until adulthood. However, there has not been any investigation of the extent to which the increase in palatal length is due to growth in the transverse palatal suture and the extent to which it is due to apposition on the posterior margin.

Regarding the growth activity of the midpalatal suture, various opinions have been expressed. Scott[26] considered that growth in the suture ceased at the age of 1 year. On the other hand, Latham and Burston[16] and Latham,[17] who studied the suture histologically, observed growth at the age of 3 years, and Persson[23] observed signs of growth in the suture at the age of 13. Björk[5] had previously pointed out that growth activity in the midpalatal suture continues for a considerably longer period than formerly believed. This has recently been confirmed in implant studies reported by Björk and Skieller.[9]

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Annexe 21

Original Article

Assessment of respiratory muscle strength and airflow before and after microimplant-assisted rapid palatal expansion

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ABSTRACT

Objectives: To assess alterations in respiratory muscle strength and inspiratory and expiratory peak flow, as well as skeletal and dental changes in patients diagnosed with transverse maxillary deficiency before and after microimplant-assisted rapid maxillary expansion (MARPE).

Materials and Methods: Twenty patients (13 female and 7 male) were assessed by respiratory tests in three different periods: T0 initial, T1 immediately after expansion, and T2 after 5 months. Tests included: maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP), oral expiratory peak flow, and inspiratory nasal flow. Cone-beam computed tomography measurements were performed in the maxillary arch, nasal cavity, and airway before and immediately after expansion.

Results: There was a significant increase in MIP between T0 and T2 and MEP between T0 and T1 ($P<.05$). Oral and nasal peak flow increased immediately after and 5 months later, especially in patients with initial signs of airway obstruction ($P<.05$). In addition, after expansion there was a significant enlargement of the nasal cavity, alveolar bone, and interdental widths at the premolar and molar region. Molars tipped buccally ($P<.05$) but no difference was found in premolar inclination. MARPE increased airway volume significantly.

Conclusions: Skeletal changes promoted by MARPE directly affected airway volume, resulting in a significant improvement in muscle strength and nasal and oral peak flow. (*Angle Orthod.* 0000;00:000–000.)

KEY WORDS: Nasal cavity; Nasal obstruction; MARPE; Airway volume

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INTRODUCTION

Transverse maxillary deficiency is characterized by lateral growth failure resulting in a narrow maxilla, narrow palatal vault and, often, posterior crossbite.[1] Patients with maxillary constriction tend to have airway problems. Mouth breathing can also cause muscle imbalance, postural axis alteration, disorganization of muscle groups, inhibition of nasal afferent nerves, decreased pulmonary compliance, and restricted chest expansion as well as alveolar ventilation.[2]

Once the nasal airway is obstructed, reducing airflow, the patient starts breathing through the mouth, causing air to arrive faster to the lungs. With less effort to breathe, the entire ventilatory mechanism is compromised, with reduced diaphragm action and less strength of the respiratory muscles.[3,4]

The most common methods used for nasal flow studies are rhinomanometry, acoustic rhinomanometry, and nasal inspiratory peak flow (NIPF). All of them offer accurate results to measure airflow throughout the nasal cavity. The NIPF is used to detect clinical changes caused by respiratory problems. It is a low-

Annexe 22

The effect of rapid maxillary expansion on conductive hearing loss

İsmail Ceylan, DDS, PhD; Hüsamettin Oktay, DDS, PhD; Münir Demirci, MD

Auditory disorders are broadly classified as conductive (external and middle ear) and sensorineural (referring to lesions in the cochlea or involving the eighth nerve). The major dysfunction observed in conductive disorders is a loss in hearing sensitivity reflected by elevated air-conduction thresholds. The loss varies greatly depending on the severity and type of physical change imposed on the mechanical system of the outer or middle ear. Because the cochlea and eighth nerve are often unimpaired in individuals with only a conductive lesion, bone-conduction thresholds are found at normal or near-normal levels.[1]

The primary audiologic tests to distinguish a conductive hearing loss from a sensorineural one are the comparative measurements of air- and bone-conduction thresholds and acoustic immittance as measured at the plane of the tympanic membrane. The magnitude of the hearing loss is usually measured at selected octave frequencies within the major useful range of human hearing (0.25 to 8.0 kHz).[1] Hearing abilities vary, and threshold values within 20 dB of 0 are considered normal hearing, according to the American National Standards Institute.[2]

In normal hearing, air- and bone-conduction thresholds interweave. The difference between these two thresholds—called the air-bone gap—provides an estimate of the magnitude of the conductive component and has considerable clinical usefulness. An air-bone gap of 20 to 30 dB indicates a mild or very early conductive loss; 30 to 45 dB a moderate conductive loss; and 45 to 60 dB a maximum conductive loss.[1,3]

Maxillary arch contraction or maxillary width

Abstract

The effects of rapid maxillary expansion (RME) on conductive hearing loss were investigated in 14 subjects (11 females and 3 males). The subjects ranged in age from 10 years 4 months to 16 years 9 months (mean age 12 years 11 months ± 1 year 9 months) and had narrow maxillary arches and conductive hearing loss. Hearing levels were determined by means of pure-tone audiometric records. Three records were taken for each subject. The first was taken before RME, the second after sufficient midpalatal suture opening was achieved (mean=15 days), and the third after the retention period (mean=4.5 months). All the audiometric records were assessed by an otolaryngologist. Changes in both hearing level and air-bone gap were investigated by means of analysis of variance. It has been determined that hearing improved at a statistically significant level ($P<0.05$) after the active treatment period, but that the improvement reversed at the end of the retention period. Five patients experienced significant and stable hearing improvement over the duration of this study.

Key Words

Rapid maxillary expansion • Conductive hearing loss

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Annexe 23

A review of maxillary expansion in relation to rate of expansion and patient's age

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Treatment variables such as patient age, rate of expansion, magnitude of applied transverse force, appliance design, and retention protocol produce an array of interactions which affect orthopedic and orthodontic movements during maxillary expansion procedures. The purpose of this article is to review the quantitative and qualitative changes of sutural, skeletal, and dental tissues demonstrated in human and animal studies of maxillary expansion procedures. The association of the reported tissue responses with the treatment variables of patient age and rate of expansion serve as the focus of discussion. While the accumulated evidence appears to support a treatment rationale of early correction using a slow expansion procedure, individual variables must be considered in determining an expansion protocol that will optimally affect the quantity and quality of the expansion changes.

Key words: Review, maxillary, expansion, rate, age

The early correction of posterior cross-bites requiring maxillary expansion has been advocated to redirect the developing teeth into more normal positions,[1-3] eliminate untoward temporomandibular joint positions and mandibular closure patterns,[2, 5, 7] and make beneficial dentoskeletal changes during growth periods involving a reduced treatment complexity and time.[8-10] The purpose of this article is to review the literature concerning the quantitative and qualitative effects of maxillary expansion on connective, skeletal, and dental tissues. The role that patient age and rate of expansion may play as treatment variables in maxillary expansion procedures will serve as a focus for review and discussion.

REVIEW OF LITERATURE

Increased maxillary arch width has been related to orthodontic movements, orthopedic movements, or a combination of these movements during expansion procedures.[8, 11, 12] While the relative degree and nature of these movements is affected by various factors, the general pattern of maxillary expansion may be described. Upon the application of transverse biomechanical forces, initial changes involve the lateral tipping of the posterior maxillary teeth as the periodontal and palatal soft tissues are compressed and stretched.[13-19] This stage of orthodontic response appears to be essentially complete within a week.[14, 15, 17, 19] Subsequent orthodontic movements will occur through bodily translation as the compressed buccal alveolar plate resorbs at the root-periodontal interface from continued force application.[19-23] If the applied transverse forces are of sufficient magnitude to overcome the bioelastic strength of sutural elements, orthopedic separation of the maxillary segments can occur.[13-19, 21, 22, 24, 25] The separation and repositioning of the palatal segments will continue until the force distribution is reduced below the tensile strength of the sutural elements.[19, 21, 22, 24, 25] Reorganization and remodeling of the sutural connective and skeletal tissues may then proceed in the stabilization of the expanded maxillary arch.[13, 19, 21, 22, 26, 27] When orthopedic separation of the maxillary segments occurs, asymmetric linear and angular responses have generally been observed.[13-19, 21, 22, 24, 25, 28-35] The asymmetric expansion has been attributed to variations in the rigidity of the different maxillary articulations.[24, 35] A frontal view of orthopedic sutural separation shows a lateral rotation or tipping of the palatal halves.[19, 21, 22, 24, 25, 33, 36] The palatal movement is greater at the alveolar crest and less at the palatal vault, presenting a triangular expansion pattern with the base near the incisors and the apex toward the nasal area[14, 15, 19, 21, 22, 24, 26, 29, 30, 34-47] (Fig. 1, *A*). From an occusal view, the greatest opening of the midpalatal suture has been found anteriorly, with progressively less separation toward the posterior[26, 33, 38, 40-42, 48]

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0002-9416/82/010032+06$00.60/0

Annexe 24

Forces Produced By Rapid Maxillary Expansion

III. Forces Present During Retention

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Introduction

Rapid mechanical maxillary expansion procedures as presently employed utilize large loads designed to produce a maximal skeletal repositioning with a minimum of individual tooth movement. A fundamental similarity exists, however, between these procedures and the more conventional orthodontic procedures designed to produce maximum tooth movement. In both instances the displacement of a skeletal part (individual tooth or maxillary half) produces a cellular response at an articulation (periodontal ligament or maxillary suture). The magnitude of the load is important only insofar as greater loads are required to overcome skeletal resistance in the displacement of the maxillary halves than in the displacement of individual teeth. It should not be construed, however, that the one treatment may be substituted for the other as each has its specific indications.

The dentition erupts into an environment completely dominated by a muscular system which dictates individual tooth position. In patients demonstrating severe maxillary constriction, the conventional slow expansion procedures only encourage relapse by tipping the teeth beyond the boundaries dictated by the surrounding musculature. As the rationale governing rapid maxillary expansion is orthopedic rather than orthodontic in nature, the teeth themselves are displaced only slightly in their alveoli while the maxillary bones with the attached musculature are separated. Thus, the teeth occupy the same positions over basal bone and will be subject to relatively the same musculature influences.

Heretofore, appliance activation has been determined on a highly empirical basis and only recently has a quantitative appraisal of some of the forces produced during rapid maxillary expansion been presented.[10] At present there is no information available concerning the duration of these forces and their fate during the retention phase of treatment.

During the evolvement of rapid expansion techniques over the past century, a conflicting array of information has been directed at insuring against the relapse of the involved skeletal and dental structures. The fact that the void created by the opening of the midpalatal suture is subsequently filled with new bone has been suggested as the primary indication of when permanency of the treatment is assured.[1,2,6,13] Suggestions as to the length of time fixed retention should be maintained include: "until the bicuspids erupt into occlusion",[16] "until the teeth are in their upright positions with their buccal cusps

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Annexe 25

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Inhalt:

Annexe 26

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Hyalinization during orthodontic tooth movement: a systematic review on tissue reactions

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SUMMARY The purpose of this study was to perform a meta-analysis on the literature concerning hyalinization in relation to experimental tooth movement in animals and humans. A structured search of electronic databases as well as hand searching retrieved 70 publications concerning the subject. After application of inclusion and exclusion criteria, 39 studies remained, of which three were in humans. Articles on animal experiments were in the majority with most studies performed in rats. Among other data force magnitude, type of tooth movement, duration of the experimental period, and moment of first and last appearance of hyalinization were extracted from the included studies. The heterogeneity of the published studies and the limited data on appearance of hyalinization made it impossible to perform a meta-analysis. Therefore, the literature was systematically reviewed.

It appears that there are no major differences in tissue reaction between species during experimental tooth movement. Although hyalinization is considered to be an undesirable side-effect of orthodontic tooth movement, little attention has been paid to the phenomenon itself and its possible relationship with stress/strain levels in the periodontal ligament (PDL) and alveolar bone or the rate after the initial phase of tooth movement. There is a need for well-designed experimental studies to elucidate the role of hyalinization in orthodontic tooth movement.

Introduction

The purpose of orthodontic treatment is to move teeth as efficiently as possible with minimal adverse effects for the teeth and supporting tissue. Over the past 100 years, many studies on cellular, molecular, and tissue level reactions related to orthodontic tooth movement have been published, which were recently summarized in four reviews (Krishnan and Davidovitch, 2006; Masella and Meister, 2006; Meikle, 2006; Wise and King, 2008). It is assumed that an optimal force system is important for an adequate biological response in the periodontal ligament (PDL; Burstone, 1984). Factors such as the type and magnitude of force (Storey and Smith, 1952; Reitan, 1985; Maltha *et al.*, 2004) or treatment duration (Pilon *et al.*, 1996) are found to be coherent with undesirable tissue reactions such as sterile necrosis or root resorption. The appearance of necrotic tissue (also called hyalinization) is an important component in the process of tooth movement.

Mainly based on histological research, a pressure and a tension side are distinguished during orthodontic tooth movement. Although more recent research has shown that the pressure/tension side theory is not that straightforward as was previously assumed (Melsen, 2001), this terminology is still used for descriptive purposes. On the pressure side, the biological events are as follows: disturbance of blood flow in the compressed PDL, cell death in the compressed area of the PDL (hyalinization), resorption of the hyalinized tissue by macrophages, and undermining bone resorption by osteoclasts beside the hyalinized tissue, which ultimately results in tooth movement. On the tension side, blood flow is activated where the PDL is stretched, which promotes osteoblastic activity and osteoid deposition, which later mineralizes. Studies over the past 100 years have reported that hyalinization appears in local pressure zones of the PDL during 'the initial phase' of orthodontic tooth movement. Experimental studies have demonstrated advanced vascular and cellular changes in the PDL after only a few hours of force application. Recently, von Böhl *et al.* (2004b) showed that not only in the initial phase of orthodontic tooth movement could hyalinization be observed but also in the later stages small hyalinized patches were found. These findings confirmed the outcome of a study on changes of the PDL during experimental tooth movement with a similar experimental set-up by Kohno *et al.* (2002). However, these findings are contrary to the commonly accepted theory of the relationship between tooth displacement and hyalinization. Hyalinization during the later stages of tooth movement could, partly, explain the differences observed clinically in the rate of tooth movement between different patients.

Therefore, the aim of the present study was to perform a systematic review of the literature on hyalinization in relation to experimental tooth movement in animals and humans.

Material and methods

Search strategy for identification of studies and data selection

Medline, PubMed, and Embase were searched until 16 May 2008 using the following search strategy:

Furthermore, an Entrez cross-database search was performed using the same search strategy. The Cochrane

Annexe 27

Skeletal and dental changes accompanying rapid midpalatal suture opening

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Although the concept of widening the maxillary dental arch by means of opening the midpalatal suture dates back to 1860, only in recent years has orthodontic research pointed its resources at uncovering the total effects of such a procedure. Studies have been reported concerning the histologic response of the sutures, change in nasal permeability, and general skeletal and dental reaction following the application of heavy forces in such a manner as to open the midpalatal suture and thereby widen the maxillary dental arch. However, documentation of the effects of rapid maxillary expansion in routine clinical practice remains limited.

The purpose of the investigation reported here was to study the skeletal alterations brought about by midpalatal suture opening during routine orthodontic treatment in my private practice. Of special concern is the magnitude and direction of displacement of the maxillary halves, the effect of disruption of the occlusion upon mandibular position, and the change in selected tooth relations.

Review of the literature

To many in the fields of orthodontics and rhinology, the early 1900's are known as the "maxillary expansion years." At this stage in orthodontic history numerous articles pointing to the interrelations of certain orthodontic and rhinologic treatment problems appeared in the literature. These led readers to believe that orthodontic procedures had influences far beyond the teeth and alveolar process. Such thoughts regarding skeletal change of the maxillofacial

This thesis, which was given as a partial fulfillment of the requirements for certification by the American Board of Orthodontics, is being published with the consent and the recommendation of the Board, but it should be understood that it does not necessarily represent or express the opinion of the Board.

Annexe 28

Rapid maxillary expansion in the primary and mixed dentitions: A cephalometric evaluation

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The present study evaluated the skeletal alterations induced by rapid maxillary expansion procedures in 30 patients in the primary and mixed dentitions. The results were obtained with the use of lateral cephalometrics before and immediately after the active phase of expansion. The time span between these two cephalometric films ranged from 14 to 21 days; therefore the "growth factor" was not considered. Based on the differences in the cephalometric measurements studied on the first and second tracings, it seems that anterior displacement of the maxilla with significant changes in the SNA angle should not be expected, although point B was repositioned more posteriorly (SNB) because of the mandibular downward and backward rotation, with subsequent increase of the inclination of the mandibular plane. The alterations in the A-P position of the mandible was reflected in the increase of ANB and NAP angles. The maxilla always dislocates downward, displaying a downward and backward rotation in the palatine plane, significantly altering the following measurements: N-ANS, PNS-PNS', A-A', SN.PP. The anchoring molars also follow the downward maxillary displacement (M-M') and, as a direct consequence of the vertical displacement of the maxilla and upper molars (N-ANS, A-A', ANS-Me, N-Me, PNS-PNS'), the facial heights increase.
(AM J ORTHOD DENTOFAC ORTHOP 1991;100:171-81.)

The present concepts concerning posterior crossbites are well defined in the literature and widely accepted by orthodontists. Among mixed dentition children displaying malocclusions in the region of Bauru (São Paulo, Brazil), we found an 18.2% incidence of posterior crossbites.[1] This entity may occur in the primary dentition and manifest itself as a constriction in the lateral dimensions of the upper arch and, as a rule, will not self-correct. On the basis of these concepts, it is necessary to correct this form of malocclusion as early as possible, preferably in the primary dentition stage.

Modern orthodontics has a wide variety of mechanical appliances that will release forces to laterally expand upper constricted arches.[2] The jackscrew has been applied in removable[3,4] or fixed appliances[2,5-9] as a source to generate forces against the palatine surfaces of the upper teeth. When the jackscrew is used in removable appliances, it produces only slow expansion, which is indicated for dentoalveolar constrictions. In our clinical practice, we do not use the jackscrew for the particular purpose aforementioned. For slow expansions we use mainly the quad-helix appliance.[10] In rapid maxillary expansion procedures (RME) indicated for the correction of skeletal constrictions, even in early occlusal developmental stages, we use the jackscrew in fixed appliances, following the basic standards proposed by Haas[7] with a few modifications (Fig. 1).

Rapid maxillary expansion procedures are indicated in the primary and mixed dentitions every time the crossbite is associated with a skeletal constriction, which might be clinically identified as:

1. Unilateral or bilateral posterior crossbite with normal inclination of the dentoalveolar processes
2. Unilateral or bilateral posterior crossbite with retrusion of the middle third of the face (Class III tendency)
3. Total crossbite

REVIEW OF THE LITERATURE

Rapid maxillary expansion procedures have been proposed since the past century by Angell[11] and consolidated clinically by Haas.[6-8] This procedure leads to an increase in the upper arch transverse dimensions by mainly skeletal alterations associated with dental alterations, which may manifest themselves distinctly, de-

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Annexe 29

Original Article

Rapid Maxillary Expansion. Is it Better in the Mixed or in the Permanent Dentition?

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Abstract: The aim of this study was to compare the dentoskeletal effects of a modified acrylic-bonded rapid maxillary expansion (RME) device when it is used in the mixed and permanent dentitions. The study group consisted of 51 patients in the mixed and permanent dentition (26 girls and 25 boys) who underwent RME treatment. Group 1 was composed of 34 subjects in the mixed dentition (19 girls and 15 boys; mean age, 9.2 ± 1.3 years). Group 2 consisted of 17 subjects in the permanent dentition (seven girls and 10 boys; mean age 12.7 ± 1.2 years). Lateral and frontal cephalograms and upper dental casts were collected before treatment (T1), after treatment (T2), and after retention (T3). Intragroup and intergroup changes were evaluated by paired *t*-test and Student's *t*-test, respectively. In both groups after RME, the maxilla moved forward; mandible rotated posteriorly; facial height increased; nasal, maxillary, and maxillary intercanine and first molar widths increased; and the upper molars tipped buccally. Almost all these significant changes were stable at follow-up (T3). When overall (T1 − T3) differences were considered, upper molars tipped more, and the ANB angle increased less in the mixed dentition group compared with the permanent dentition group ($P < .01$). Within the limits of this study, the results suggest that the orthopedic effects of RME are not as great as expected at early ages, and it might be a better alternative to delay RME to early permanent dentition. (*Angle Orthod* 2003;73:654–661.)

Key Words: Rapid maxillary expansion; Mixed dentition; Early treatment

INTRODUCTION

The present concepts concerning posterior crossbites are well defined in the literature and are widely accepted by orthodontists.[1] Posterior crossbite is one of the most frequently observed malocclusions of the different dentition periods.[2] This entity may occur in the primary or mixed dentition and manifest itself as a constriction in the lateral dimensions of the upper arch. Among 965 Turkish children, in the region of Konya, Turkey, a 9.5% incidence of posterior crossbite was found.[3] The prevalence of this malocclusion in the deciduous dentition was reported to be 8% by Kutin and Hawes[4] and in the mixed dentition, 12% by Hanson et al[5] and 2.7% by Sandıkçıoğlu and Hazar.[6] Various investigators claim that this abnormality is not self-correcting, and they recommend treatment at an early period.[4,7–10] On the basis of these concepts, it is necessary to correct this form of malocclusion as early as possible.

Many different methods have been used to expand the constricted maxillary arches. When evaluated on the basis of the frequency of the activations, magnitude of the applied force, duration of the treatment, and the patient's age, different mechanics produce rapid, semirapid, and slow expansions.[8] In rapid maxillary expansion (RME) procedures, indicated for the correction of skeletal constriction, even in early occlusal development stages, many orthodontists use the jackscrew in banded or bonded appliances, following the basic standards proposed by Haas[11] with a few modifications.

Slow expansion appliances do promote a slight opening in the median palatine suture in the primary and mixed dentition stages.[12–14] However, cephalometrically and clinically, the results cannot be compared with the orthopedic effects of the Haas-type of appliance.[15] RME increases the upper arch transverse dimensions mainly by separation of the two maxillary halves (orthopedic effect), followed by buccal movement of the posterior teeth and alveolar processes (orthodontic effect).[1]

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Annexe 30

A study of basal movement with rapid maxillary expansion

Dr. Timms

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This investigation was undertaken to examine the effect of rapid maxillary expansion horizontally and posterior to the dental arch, there being some doubt that the expansion would be carried in this dimension and whether dilation of the non-tooth-bearing bones (palatines and sphenoidal pterygoid processes) was possible. The increases in the intermolar arch widths and the interpterygoid hamular widths were recorded in a group of thirty-two orthodontic patients, (twelve male and twenty female, aged 8 to 24 years), before and after rapid maxillary expansion. The mean percentage increase in interhamular widths to intermolar widths was 58 percent (range, 35 percent to 89 percent). The correlation between the relative increases was weak ($r = +0.55$). A slight reduction in the percentage increases in interhamular widths to intermolar widths as age advanced suggested an age factor, but the correlation was very weak ($r = -0.33$). From this evidence, it would seem that rapid maxillary expansion will separate the palatine bones and splay outward the pterygoid processes of the sphenoid bone.

Key words: Interhamular width, rapid maxillary expansion

If a lateral force with reciprocal action is applied across the maxillary arch, not only will the arch be widened, but the maxillary bones will be reshaped. The extent of this transformation will depend upon a number of factors, one of which is the rate of expansion. When the rate is increased, less time is allowed for physiologic movement based on osteoblastic and osteoclastic activity and the maxillary bones move apart by disarticulating along their common midpalatal suture.

The extradental expansion or basal movement has, in the past, been investigated almost exclusively by the analysis of teleradiographic frontal head films. From the literature, the works of Krebs[1, 2] and Hershey and associates[3] are noteworthy for their precision and analytical content. However, this procedure shows only basal movement in the vertical plane, that is above the application of force, and yet the effect of rapid maxillary expansion (R.M.E.) is carried not only upward but backward.

To date there is very little information on the movements of the bones posterior to the applied force, and what can be found is largely speculative. Wertz,[4] after scrutinizing occlusal radiograms which showed the typical triangular opening of the midpalatal suture with R.M.E., came to the conclusion that the suture did not open throughout its entire length and that it was doubtful whether the palatine bones separated. Later he revised his theory and considered that the suture did open completely.[5]

Lines[6] stated that the effects of R.M.E. were carried only as far back as the

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Annexe 31

SPECIAL ARTICLE

Rapid palatal expansion in the absence of crossbites: Added value?

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As noted in a recent article,[1] interest in rapid palatal expansion (RPE), which has traditionally been used to resolve crossbites, has increased markedly in the past 2 decades. Orthodontists using this procedure might be seeking to gain arch perimeter to avoid extractions. This treatment, which is most often started in the mixed dentition, raises some interesting questions. One question is this: In the absence of a crossbite, is RPE necessary to gain arch width to avoid extraction treatment? If so, then is the maxillary arch perimeter the determinant in the extraction-nonextraction decision?

These questions are fundamental, because using the maxillary arch to decide whether to extract challenges the concept of mandibular arch-based diagnosis and treatment planning. For this reason, it might be useful to evaluate the rationale for RPE treatment in the correction of crowding. RPE increases the perimeter of the maxillary arch and can provide space to correct moderate (3-4 mm) amounts of crowding.[2] Because no treatment occurs in the mandibular arch, a logical question is this: How is space to be gained to resolve crowding in the mandibular arch? One view is that expansion of the maxillary arch is accompanied by spontaneous transverse expansion of the mandibular arch, with the implication that space would be available to resolve any lower arch-tooth size discrepancy.[3] This supposition is easy to assess because there are adequate data; the conclusion is that any spontaneous expansion provides almost no space to resolve crowding. Brust and McNamara,[2] in a 2-phase treatment protocol, evaluated both mandibular intercanine and intermolar expansion and noted that, immediately after RPE, both dimensions increased approximately 1 mm. However, the intercanine distance decreased before phase 2 treatment, and the net intercanine gain was only 0.3 mm. The 1-mm intermolar increase remained stable. These results are similar to those noted by others who recorded spontaneous mandibular arch change incident to RPE treatment.[4-8] The increase in intercanine width in these studies was less than 1 mm. As an example, the increase observed by Grayson[5] was only 0.22 mm and led the author to conclude that "the use of rapid palatal expansion as a method of increasing lower arch length cannot be justified." Interestingly, Brust and McNamara[2] observed that the mandibular arch perimeter decreased 1.3 mm from phase 1 to the beginning of phase 2 treatment.

In an investigation of 17 subjects whose comprehensive treatment included RPE, the intercanine dimension increased 2.2 mm during treatment and relapsed 50% postretention, to yield a net long-term gain of only 1.1 mm.[9] In this study, there were no recordings of the intercanine width immediately after RPE to indicate the amount of spontaneous expansion that occurred. Also, variation in response was remarkable, ranging from −0.3 to +3.8 mm. (This large variation is a reason that anecdotal information can be misleading—if one cites only the extreme positive response.)

One motive for focusing on the mandibular intercanine dimension in the preceding descriptions is that, in the transverse plane of space, an increase in this area provides the most space to resolve mandibular incisor crowding. Specifically, Germane et al[10] determined that a 1-mm increase in intercanine dimension provides 0.73 mm of space to correct incisor position. In contrast, 1 mm of molar expansion provides only 0.27 mm of space. (Subsequent increases in width provide slightly more space per millimeter. For instance, expansion of 2 mm yields 0.27 mm for the first millimeter and 0.31 mm for the second millimeter, for a total of 0.58 mm.)

Clearly, the available data indicate that spontaneous expansion of the mandibular arch usually does not supply adequate space to align crowded incisors.

Because spontaneous expansion of the mandibular arch is extremely limited, appliances, such as the Schwartz appliance, have been placed to expand it

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Annexe 32

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Thin-plate spline analysis of treatment effects of rapid maxillary expansion and face mask therapy in early Class III malocclusions

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SUMMARY An effective morphometric method (thin-plate spline analysis) was applied to evaluate shape changes in the craniofacial configuration of a sample of 23 children with Class III malocclusions in the early mixed dentition treated with rapid maxillary expansion and face mask therapy, and compared with a sample of 17 children with untreated Class III malocclusions. Significant treatment-induced changes involved both the maxilla and the mandible. Major deformations consisted of forward displacement of the maxillary complex from the pterygoid region and of anterior morphogenetic rotation of the mandible, due to a significant upward and forward direction of growth of the mandibular condyle. Significant differences in size changes due to reduced increments in mandibular dimensions were associated with significant shape changes in the treated group.

Introduction

One of the most compelling tasks of dentofacial orthopaedics is the achievement and diffusion of adequate morphometric tools in cephalometric diagnosis and in the appraisal of treatment results. Conventional cephalometrics, based on linear and angular measurements, has shown an increasing number of limitations along with the proposal and implementation of new biometric analyses of landmark data (e.g. elliptic Fourier analysis, finite element analysis, tensor and shape co-ordinate analysis; Blum, 1973; Bookstein, 1982; Lestrel, 1982; Cheverud *et al*., 1983; Lavelle, 1985; Moss *et al*., 1985; Lestrel and Roche, 1986). The major advantages of these still evolving methods include separate evaluation of shape (or of shape change) and size, no need for reference structures or lines, and visualization of morphological changes.

A recent morphometric approach to the comparison of configurations of landmarks in two or more specimens is known as 'Thin-Plate Spline analysis', developed by Bookstein (1989). Thin-Plate Spline (TPS) transformation produces a rigorous quantitative analysis of the spatial organization of shape change that can be decomposed into a series of components ranging in scale from features that span the entire form ('principal warps') to those that are highly localized ('partial warps'; Swiderski, 1993). In TPS analysis, the differences in two configurations of landmarks are expressed as a continuous deformation using regression functions in which homologous points are matched between forms to minimize the bending energy (Richtsmeier *et al*., 1992). 'Bending energy' can be defined as the energy that would be required to bend an infinitely-thin metal plate over one set of landmarks, so that the height over each landmark is equal to the co-ordinates of the homologous point in the other form (Bookstein, 1989). TPS analysis facilitates the construction and display of transformation grids that capture the shape change between forms as an evolution of the

Annexe 33

The Grummons Face Mask as an Early Treatment Modality within a Class III Therapy Concept*

Die Frühbehandlung mit der Fazialmaske nach Grummons als Teil eines Klasse-III-Behandlungskonzeptes*

Michael Hegmann, Anne-Kathrin Rüther[1]

Abstract

Background and Aim: An underdeveloped maxillary complex is a major cause of the problems underlying skeletal Class III cases. The efficiency of early orthodontic therapy is shown with reference to a treatment method acting primarily on the maxillary complex.

Patients and Method: The collective comprised 21 patients whose orthodontic therapy at the age of 5 to 9 years was invariably started with a palatal expander. This was followed by further development of the nasomaxillary complex, using a Grummons face mask for a period ranging from 3 to 15 months. With reference to findings from plaster casts and lateral cephalograms, the efficiency of early treatment as an important part of the overall therapy concept was evaluated.

Results: The mean improvement in anterior overbite was 3.4 mm. The lateral cephalograms revealed a marked improvement in the distance between the upper first molars and the pterygoid vertical (+ 4.1 mm), in the convexity of A (+ 2.2 mm), and in the SNA angle (+ 2.3°).

Conclusion: Early treatment combining rapid maxillary expansion and Grummons face mask resulted in a decisive improvement in the sagittal-basal relations.

Key Words: Class III early treatment · Face mask · Rapid maxillary expansion · Maxilla

Zusammenfassung

Hintergrund und Ziel: Die Unterentwicklung des maxillären Komplexes stellt eine Hauptursache der Problematik der skelettalen Klasse III dar. Anhand einer Behandlungsmethode, die überwiegend auf den maxillären Komplex wirkt, soll die Effizienz einer kieferorthopädischen Frühbehandlung dargestellt werden.

Patienten und Methode: Das Patientengut bestand aus 21 Patienten, deren Behandlung im Alter von 5 bis 9 Jahren stets mit einer Gaumennahterweiterungsapparatur (GNE) begonnen wurde. Im Anschluss erfolgte eine Nachentwicklung des nasomaxillären Komplexes mittels einer Fazialmaske nach Grummons über einen Zeitraum von 3 bis 15 Monaten. Anhand von Modell- und FRS-Befunden soll die Effizienz der Frühbehandlung als wichtiger Bestandteil des Gesamtbehandlungskonzeptes evaluiert werden.

Ergebnisse: Der frontale Überbiss konnte im Mittel um 3,4 mm verbessert werden. Im FRS zeigte sich eine deutliche Verbesserung des oberen 6-Jahr-Molaren zur Pterygoidvertikalen (+ 4,1 mm) sowie der Konvexität von A (+ 2,2 mm) und des SNA-Winkels (+ 2,3°).

Schlussfolgerung: Durch die Kombination von GNE und Fazialmaske nach Grummons konnten im Rahmen der Frühbehandlung die sagittal-basalen Relationen entscheidend verbessert werden.

Schlüsselwörter: Klasse-III-Frühbehandlung · Fazialmaske · Gaumennahterweiterung · Maxilla

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Annexe 34

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Surgically Assisted Rapid Maxillary Expansion by Opening the Midpalatal Suture

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The results of surgically assisted rapid maxillary expansion by opening of the midpalatal suture in 25 patients are reported. Osteotomy of the lateral wall of the maxilla combined with pterygomaxillary dysjunction and midpalatal suture separation allowed for successful rapid maxillary expansion in 23 patients. The two patients who did not respond to treatment were found to have unusually thick midpalatal sutures, which were successfully expanded after the midpalatal sutures were osteotomized.

Maxillary expansion is needed to correct real and relative maxillary horizontal deficiency, maxillary collapse, nasal stenosis, and Class III malocclusions, as well as selected arch length problems.[1,2] Nonsurgical rapid maxillary expansion (RME) was used as early as 1860 by Angell[3] and continues to be used by orthodontists with a high rate of success for growing children.[1,2,4–6] Although in growing children RME results in opening of the midpalatal suture, the problem of stability is exceedingly complex following use of this procedure for these patients.[4] The expansion due to alveolar bending, periodontal membrane compression, lateral tooth displacement, and tooth extrusion is most assuredly lost.[1,4,6] Haas[1] states that for orthodontists the treatment error potential in performing RME is not carrying the expansion far enough; he considers 10 mm to be minimal expansion and 12 mm average, recommending that the mandibular arch be completely contained by the maxillary arch at the conclusion of expansion. Timms[4] corroborates Haas's opinion, stating that between one-third and one-half of the expansion is lost before stability is achieved. He documents the inescapability of relapse, stating that of nearly 1000 patients treated by RME, only two showed no relapse.[4]

In 1975, Lines[2] reported three cases of RME in non-growing patients following corticotomy. A year later, Bell and Epker[6] reported 15 cases of surgical-orthodontic expansion of the maxilla in which selected maxillary osteotomies were used to facilitate RME to correct five unilateral and 10 bilateral crossbites. Both Lines[2] and Bell[6] stated the reason for failure of nonsurgically assisted RME in adults is the increased rigidity of the facial skeleton; they cited fusion of various combinations of frontomaxillary, zygomaticotemporal, zygomaticofrontal, and zygomaticomaxillary sutures as being the primary anatomic sites of resistance to RME in adults. Messer et al.[7] were more definitive and stated, "the midpalatine suture is not the main deterrent to palatal separation." They directed surgery toward the zygomaticomaxillary complex, reporting relative ease in RME once the "lateral deterrent is removed."[7] Corroboration of this clinical observation can be found in an animal study of RME in adult Rhesus monkeys, which concluded that the major resistance to RME is the zygomaticomaxillary buttress area.[8] Persson and Thilander[9] studied palatal suture closure in 24 humans aged 15–35 years and concluded that great variations exist with regard to age of closure. They agreed with previous authors that with RME most of the resistance to separation is due to circummaxillary sutures and went on to state that, "if a 5% closure is set as a limit for split-

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The opinions or assertions contained herein are the private views of the author and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense.

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Annexe 35

ORIGINAL ARTICLE

Long-term effects of Class III treatment with rapid maxillary expansion and facemask therapy followed by fixed appliances

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Ann Arbor, Mich, San Diego, Calif, Florence, Italy, and Vestavia Hills, Ala

In this cephalometric investigation, we compared the long-term effects of an initial phase of rapid maxillary expansion and facemask (RME/FM) therapy followed by comprehensive edgewise therapy with the effects of growth in untreated, matched controls. The treated sample consisted of 34 patients who underwent RME/FM treatment before the pubertal growth spurt (average age, 8 years 3 months at the beginning of treatment). At the final observation period (average age, 14 years 10 months), all patients were in decelerative growth phases as determined by the cervical vertebral maturation (CVM) method. After the first 10 months of active treatment, significant favorable changes in both the maxillary and the mandibular skeletal components were noted. The forward movement of the maxilla was 1.8 mm greater than in the controls, mandibular projection was reduced by almost 3 mm, and the relative sagittal intermaxillary discrepancy improved by 4.3 mm, as measured by the Wits appraisal. During the posttreatment period, the treated and untreated Class III subjects generally grew similarly, although the skeletal relationship of the maxilla to the mandible remained unchanged in the RME/FM group, whereas the controls had an increased skeletal discrepancy of 3.0 mm. Over the long term, there was a slightly greater increase in midfacial length (1.6 mm) in the treatment group than in the controls. Similarly, the distance from Point A to nasion perpendicular decreased by 1.2 mm in the treated group. The overall increase in mandibular length was 2.4 mm less in the RME/FM group than in the controls, and mandibular projection relative to nasion perpendicular was 3.0 mm less in the treated group. The change in the Wits appraisal was substantial between groups (6.1 mm), with an improvement in the intermaxillary relationship in the treated group (3.4 mm); the Wits appraisal worsened (−2.7 mm) in the untreated controls. No clinically significant differences were observed between the groups in the vertical dimension. Overjet increased significantly in the treated group relative to the controls (4.4 mm), whereas the molar relationship decreased significantly (−3.9 mm). It appears that the favorable skeletal change observed over the long term is due almost entirely to the orthopedic correction achieved during the RME/FM protocol. During the posttreatment period that includes the pubertal growth spurt, craniofacial growth in RME/FM patients is similar to that of untreated Class III controls. Aggressive over-correction of the Class III skeletal malocclusion, even toward a Class II occlusal relationship, appears to be advisable, with the establishment of positive overbite and overjet relationships essential to the long-term stability of the treatment outcome. (Am J Orthod Dentofacial Orthop 2003;123:306-20)

Treating a Class III malocclusion in a young patient is one of the most challenging and perplexing orthodontic endeavors, mainly because of the uncertainty of a stable outcome after the active growth period. The clinical success of early Class III treatment in most patients through growth modification, however, has resulted in the development of several strategies to treat Class III disharmony, including the chincup,[1-3] the function regulator of Fränkel,[4,5] and the orthopedic facemask.[6,7]

During the past decade, a number of studies[8-13] have described the general treatment effects of rapid

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Annexe 36

Review Article

Rapid Maxillary Expansion: A Unique Treatment Modality in Dentistry

Dentistry Section

S. ARVIND KUMAR, DEEPA GURUNATHAN, MURUGANANDHAM, SHIVANGI SHARMA

ABSTRACT

Rapid Maxillary expansion or palatal expansion as it is sometimes called, occupies unique niche in dentofacial therapy. Rapid Maxillary expansion is a skeletal type of expansion thatinvolves the separation of the mid-palatal suture and movement of the maxillary shelves away from each other. An objective approach to the design of a suitable appliance should be made by preparing a list of criteria based on the biomechanical requirements of RME.RME effects the maxillary complex, palatal vaults, maxillary anterior and posterior teeth, adjacent periodontal structures tobring about an expansion in the maxillary arch.The majority of dental transverse measurements changed significantly as a result of RME.

Key Words: Rapid maxillary expansion, Nasal obstruction, Maxillofacial complex

INTRODUCTION

Rapid maxillary expansion (RME) is a dramatic procedure with a long history. Rapid Maxillary expansion or palatal expansion as it is sometimes called, occupies unique niche in dentofacial therapy. Rapid Maxillary expansion or Split palate is a skeletal type of expansion that involves the separation of the mid-palatal suture and movement of the maxillary shelves away from each other.

ANATOMY

The tenacity of circummaxillary attachments due to buttressing is strong postero-supero-medially and postero supero laterally. A palatine bone forms an intimate relationship with maxilla to form complete hard palate (or) floor of nose and greater part of lateral wall of nasal cavity.

It articulates anteriorly with maxilla through transverse palatal sutures and posteriorly through pterygoid process of the sphenoid bone. The interpalatine suture joins the two palatine bones at their horizontal plates and continous as inter maxillary sutures. These sutures forms the junction of three opposing pairs of bones: the premaxillae, maxilla, and the palatine. The entire forms mid-palatal suture [Table/Fig 1], [Table/Fig 2].

SUTURES

Mid Palatine Suture plays a key role in R.M.E [1].

- i. Infancy - Y-shape [Table\Fig 3]
- ii. Juvenile - T-shape
- iii. Adolescence - Jigsaw puzzle [Table\Fig 4]

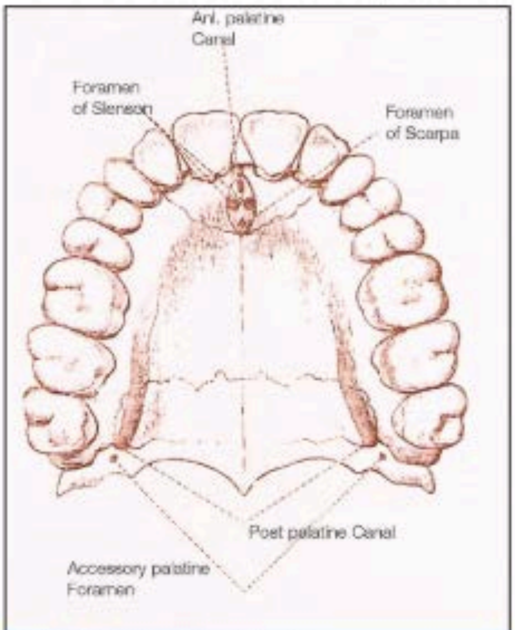
As sutural patency is vital to R.M.E, it is important to know when does the suture closes by synostosis [2] and on an average 5% of suture in closed by age 25 yrs.Earliest closure occurs in girls aged 15 yrs. Greater degree of obliteration occurs posteriorly than anteriorly.

Ossification comes very late anterior to incisive foramen – this is important when planning surgical freeing in late instances of RME [3].

FACTORS TO BE CONSIDERED PRIOR TO EXPANSION

Important factors to be considered in Rapid Maxillary Expansion:

1. **Rate of Expansion:** By expanding at the rates of 0.3-0.5mm per day, active expansion is completed in 2-4 weeks, leaving little time for the cellular response of osteoclasts and osteoblasts seen in slow expansion.
2. **Form of Appliance:** As the thrust is delivered to the teeth at the inferior free borders of the maxilla, expansion must



[Table/Fig-1]: Anatomy of maxilla (adopted)

Annexe 37

Maxillary expansion: Clinical implications

Samir E. Bishara, D.D.S., D. Ortho., M.S.,* and Robert N. Staley, D.D.S., M.A., M.S.*
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Clinicians frequently expand the maxilla to correct certain malocclusions. The effects of expansion on facial structures, dentition, and periodontium are reviewed. The implications of these findings for the treatment of patients who need maxillary expansion are discussed. (AM J ORTHOD DENTOFAC ORTHOP 1987;91:3-14.)

Key words: Maxillary expansion, review, treatment

Rapid maxillary expansion (RME) is a dramatic procedure with a long history. E. H. Angell[1] reported on the procedure in 1860, and since then it has gone through periods of popularity and decline. In the late 1940s, Graber[2] advocated RME for the treatment of cleft lip and palate patients. Since then clinicians have increasingly included RME in the treatment of their patients.

Although clinicians agree about many of the indications for and outcomes of RME, a review of the literature[1-65] indicates that numerous disagreements persist about the procedure. Haas,[22] Isaacson and Murphy,[32] and Wertz[64] advocated splitting of the midpalatal suture to widen narrow maxillary arches. On the other hand, Graber[2] believed that the technique was originally dropped because of development of open bites, relapse, and the fact that improvement of nasal breathing was only temporary. Furthermore, orthodontic appliances routinely achieve the needed maxillary intercanine and intermolar expansions. Graber asks, "What are the criteria for lateral apical base deficiency?"

Indications for RME. Patients who have lateral discrepancies that result in either unilateral or bilateral posterior crossbites involving several teeth are candidates for RME.[23,24,64] The constriction may be skeletal (narrow maxillary base or wide mandible), dental, or a combination of both skeletal and dental constriction.

Anteroposterior discrepancies are cited as reasons to consider RME.[2,23-25,64] For example, patients with skeletal Class II, Division 1 malocclusions with or without a posterior crossbite, patients with Class III malocclusions, and patients with borderline skeletal and pseudo Class III problems are candidates if they have maxillary constriction or posterior crossbite.

Cleft lip and palate patients with collapsed maxillae are also RME candidates. Finally, some clinicians use the procedure to gain arch length in patients who have moderate maxillary crowding.

According to Bell,[3] the enhanced skeletal response that accompanies RME redirects the developing posterior teeth into normal occlusion and corrects asymmetries of condylar position. This should allow more vertical closure of the mandible, and eliminates both functional shifts and possible temporomandibular joint dysfunction.

Contraindications for RME.[3,64] Patients who cannot cooperate with the clinician are not candidates for RME. Patients who have a single tooth in crossbite probably do not need RME. Patients who have anterior open bites, steep mandibular planes, and covex profiles are generally not well suited to RME. Patients who have skeletal asymmetry of the maxilla or mandible, and adults with severe anteroposterior and vertical skeletal discrepancies are not good candidates for RME. Reservations about the patients who have marked skeletal problems are qualified if orthognathic surgery is planned.

The following factors need to be considered during treatment planning to determine whether to expand the dental arches conventionally or with RME: (1) the magnitude of the discrepancy between the maxillary and mandibular first molar and premolar widths; if the discrepancy is 4 mm or more, one should consider RME, (2) the severity of the crossbite, that is, the number of teeth involved, and (3) the initial angulation of the molars and premolars—when the maxillary molars are buccally inclined, conventional expansion will tip them further into the buccal musculature; and if the mandibular molars are lingually inclined, the buccal movement to upright them will increase the need to widen the upper arch.

ETIOLOGY

The causes of buccolingual discrepancies could be either genetic or environmental. According to Graber,[2] and Harvold, Cheirici and Vargervik,[26] many con-

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Annexe 38

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Rapid Maxillary Expansion and Appliance

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Abstract

The purpose of this article is to know more about the rapid maxillary expander. It produces significant changes in the maxillary arch. RME has fundamental effect on the dentofacial structures which results in major change occurring in the basal structures of the maxilla. The concept of maxillary expansion has also been extended to the nasal cavity. Early orthodontic treatment with RME is able to reduce the symptoms of obstructive sleep apnea syndrome. This technique is more suited for younger patients and faster duration of action.

Keywords: Obstructive Sleep Apnea Syndrome, Rapid Maxillary Expander

1. Introduction

RME is otherwise known as Rapid palatal expander or split palate. RME produce skeletal type of expansion. It consists of enlargement of dental arch and widening of the palate. This concept was widely supported by ENT surgeons. RME is more useful in mixed dentition. It places an important role in the orthopaedic therapy. Orthopaedic expansion is the procedure by applying a lateral force against the posterior maxillary dentition producing a separation of midpalatal suture and produces increase in the transverse width of maxillary basal bone[1,2].

2. Effect of the Rapid Maxillary Expansion

2.1 Effect on Maxillary Teeth

In anterior teeth, RME opens the midpalatal suture which creates midline spacing between two maxillary central teeth, Bodily displacement of tooth along its long occlusal direction of molars in the posterior teeth[3,4].

2.2 Effect on Mandible

Decreases the overbite and increases the facial height of the mandible because of the extrusion and buccal tipping of the maxillary molars[4].

2.3 Effect of RME in Nasal Cavity

Increase the intranasal space due to separation of the outer walls during activation of RME. Patients with narrow maxillary arch along with malocclusion can lead the OSAS. So RME is more affective in patient with OSAS[2,4].

2.4 Effect on Alveolar Bone

During activation of RME because of compression of periodontal ligament the alveolar bones bends buccally[5].

3. Indication

- Unilateral/bilateral cross bite of the molars.
- Patient with class II and class III malocclusion.
- RME is useful for cleft lip and cleft palate patient.
- Severe construction of the maxillary arch.
- Poor nasal airway and allergic rhinitis[4,6].

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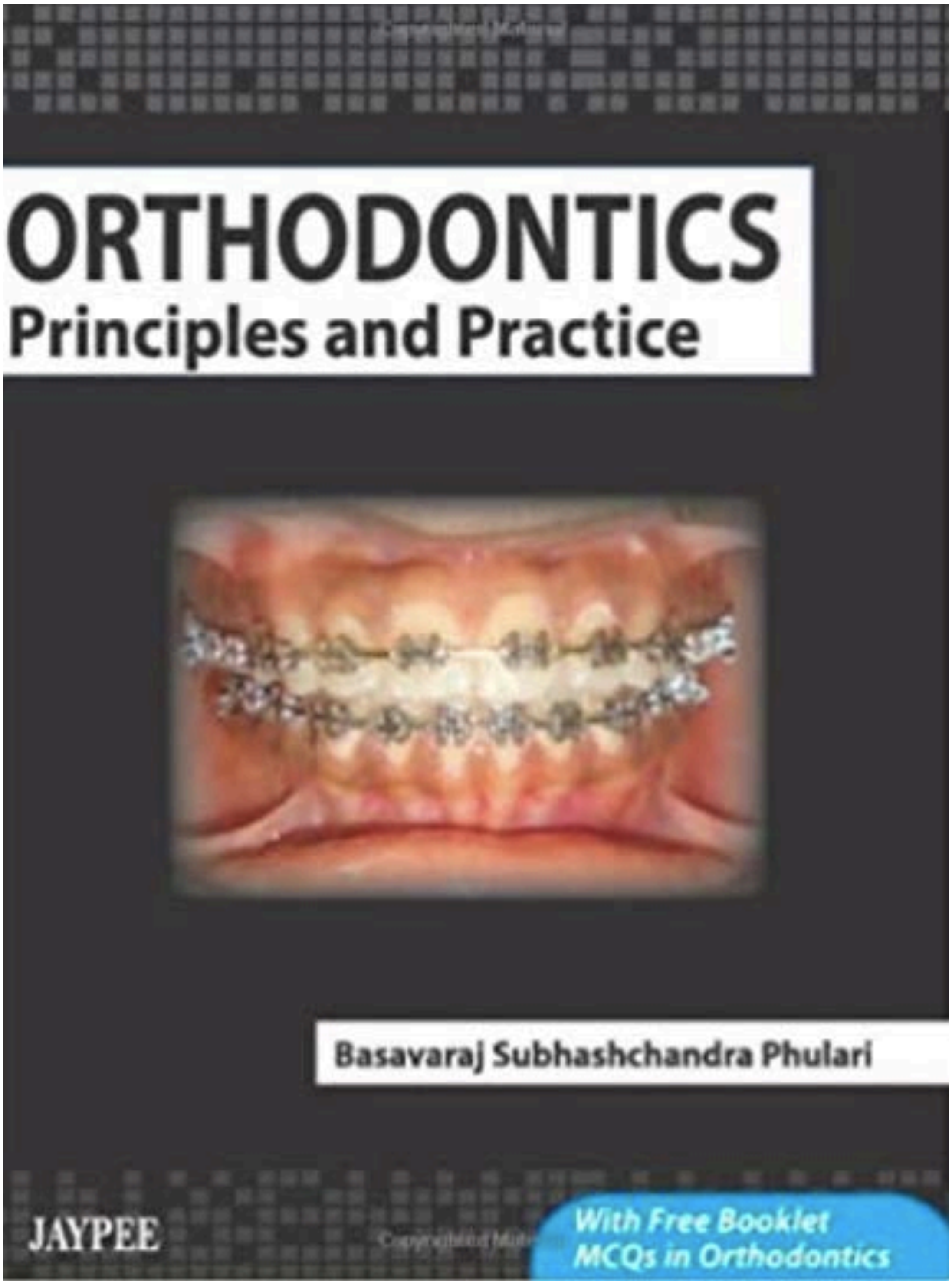
ORTHODONTICS
Principles and Practice
Basavaraj Subhashchandra Phulari
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With Free Booklet
MCQs in Orthodontics

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International Journal of Dental Research, 5 (x) (2017) 103-107

International Journal of Dental Research

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Review Paper

Expand the constricted-review article

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Abstract

A combination of orthopaedic and orthodontic tooth movements are required for expansion of palate to correct maxillary transverse discrepancy. Expansion of the palate can be achieved by three different treatment methods mainly Rapid maxillary expansion, slow maxillary expansion and surgically assisted maxillary expansion. Among the different methods rapid maxillary expansion brings about significant changes in the dental transverse measurements (Agarwal A, Mathur R International journal of clinical pediatric dentistry 2010). This article aims to review the various appliances used for maxillary expansion.

***Keywords**: Maxillary Expansion; Types of Maxillary Expansion; Appliances Used for Maxillary Expansion*

1. Introduction

Palatine bone forms intimate articulation with maxilla to form hard palate and greater part of lateral wall of nasal cavity. Palatine bone articulates with maxilla anteriorly through transverse palatal sutures and posteriorly through pterygoid process of sphenoid bone, the interpalatine suture joins the two palatine bones at their horizontal plates and continues as intermaxillary sutures(Kumar SA, Gurunathan D et al, Journal of clinical and diagnostic research 2011).Normal palatal growth is nearly complete by age 6(Moyers RE, Van der Linden et al craniofacial growth series,1976).Maxillary transverse deficiencies can be corrected by expansion of palate, which requires a combination of orthopaedic and orthodontic tooth movements. Treatment modalities currently used for correction of maxillary transverse deficiencies are rapid maxillary expansion, slow maxillary expansion and surgically assisted maxillary expansion. Appliances for expansion are selected based on the experience of the practitioner, patient's age and malocclusion(Ficarelli JP, J Pedod 1978 and Bell RA, Am J Orthod 1928).The clinical/major indications for maxillary expansion are correction of transverse discrepancies such as crossbite, cases requiring distal molar movement, to aid maxillary protraction, cases requiring correction of mild crowding(Agarwal A, Mathur R International journal of clinical pediatric dentistry 2010).This article aims to review the various appliance used for maxillary expansion.

2. Appliances used for rapid maxllary expansion (RME)

Appliances used for RME can be either banded appliance or bonded appliances.

➢ Banded RME-TYPES:
1) Tooth and tissue born RME
- HAAS
- DERICHSWEILER

2) Tooth borne RME:
- HYRAX expander
- Issacson expander

➢ Bonded Rapid palatal expander
➢ IPC Rapid palatal expander

3. Appliances for slow maxillary expansion (SME)

1) Coffin appliance
2) W-arch
3) Quad Helix
4) Spring jet
5) NiTi Expander

4. Tooth borne RME appliances

1) HYRAX Expander:

Hyrax-Hygienic Rapid Expander. HYRAX is a tooth borne appliance introduced by William Biedermann in 1968.The HYRAX expander is essentially a non-spring loaded jackscrew with an all wire frame (Bishara SE Stanley RN,Am J Orthod Dentofacial Orthop 1987).Heavy gauge wire extensions are soldered to bands on premolars and molar and are adapted to follow the palatal contours.The screw is activated from front to back and produces 0.2 mm of lateral expansion.11-13 mm of sutural separation can be achieved with the help of HYRAX expander.

Annexe 41

Skeletal changes in vertical and anterior displacement of the maxilla with bonded rapid palatal expansion appliances

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The purpose of this study was to determine whether anterior and inferior displacement of the maxilla seen with rapid palatal expansion when done with a banded rapid palatal expansion appliance is significantly different from an occlusally bonded rapid palatal expansion appliance. It was hypothesized that the bonded appliance would limit unwanted displacement of the maxilla by producing vertical forces on both arches in a manner similar to a functional appliance. The study was conducted using the bonded appliance on 20 adolescents and comparing the results with those of a banded appliance population—namely, 60 cases from Wertz's study.[1] Lateral cephalometric radiographs were taken before treatment and again after the expansion appliances were removed. The results of this study suggest that the downward and anterior displacement of the maxilla often associated with the banded rapid palatal expansion appliance may be negated or minimized with the more versatile bonded appliance. (AM J ORTHOD DENTOFAC ORTHOP 1989;95:462-6.)

Rapid palatal expansion has long been a commonly used means of correcting maxillary transverse deficiency. Although many articles have been published concerning structural and histologic changes of sutures, alterations in maxillary airway resistance, and general skeletal and dental changes, few articles have specifically addressed the basic problem of anterior and inferior displacement of the maxilla caused by skeletal changes.[2-4] This movement is an obviously undesirable characteristic for many dental and skeletal types of patients. For example, the patient with a Class II dentition, long face, and open bite pattern could ill afford the extrusive characteristics of rapid palatal expansion.

Rapid palatal expansion is performed in two phases. The first phase is an active expansion of the maxilla by sutural expansion; the second phase of retention allows for reorganization and calcification of the midpalatal suture. Haas[4] described the sequence of events that occurs during rapid palatal expansion with a bonded appliance:

- A parallel opening of the midpalatal suture in an anterior-posterior direction and a triangular opening inferior-superiorly with the apex in the nasal cavity.
- Separation of the central incisors (coincidental as the suture separates) with convergence of the clinical crowns and divergence of the roots due to transseptal fibers
- A downward and lateral movement of the maxilla with coincidental inferior movement of the palatal processes
- A downward and backward movement of the mandible resulting in an increased vertical dimension

Wertz not only recorded data from his clinical study but used dried skulls to supplement his work concerning skeletal changes.[1] The skulls showed changes to the maxillonasal, maxillofrontal, and maxilloethmoidal sutures but little or no changes to the pterygopalatine and maxillopalatine junctions.[1] In the clinical part of his study, the lateral cephalograms showed that the maxilla consistently moved inferiorly but rarely moved anteriorly to a significant degree. Other authors had similar findings for vertical movement, but also state that their studies showed various degrees of anterior movement of the maxilla.[3-5] The inferior movement of the maxilla accounted for the consequential opening of the mandibular angle while also promoting an anterior open bite.[6,7] Although for some patients it is beneficial to have an increase in vertical dimension, often it is an unwanted characteristic.

Other adverse features commonly seen with banded rapid palatal expansion appliances are lack of rigidity and tooth extrusion.[2] Proper rigidity of the appliance is necessary to prevent unwanted tipping of the dentition. Several authors point out that increasing the rigidity of an appliance decreases the rotational component of force along the long axis of the tooth.[2,8] Extrusion of abutment teeth should be limited to prevent further vertical opening.

Bonded rapid palatal expansion appliances were designed to cover the maxillary posterior occlusal-buccal segments so that the appliance not only serves as an expansion device but intrudes on the freeway space through its vertical thickness. It acts as a functional

Annexe 42

An Orthopedic Approach to the Treatment of Class III Malocclusion in Young Patients

VOLUME 21 : NUMBER 09 : PAGES (598-608) 1987
JAMES A. MCNAMARA, JR., DDS, PHD

Most orthodontists are familiar with the difficulties associated with the treatment of Class III malocclusion, particularly when this condition is identified in patients in the late deciduous or early mixed dentition period. Such patients frequently present with maxillary skeletal retrusion, mandibular skeletal protrusion, or some combination of the two conditions. These patients also often exhibit maxillary constriction that is manifested as an anterior and/or posterior crossbite. Petit describes such patients as having a "prognathic syndrome" in which the underlying skeletal elements may be out of balance in all three planes of space.[1]

The treatment of this malocclusion raises the clinical dilemma: Is it better to intervene at an early age or to wait for craniofacial growth to be fully expressed?

Many clinicians have chosen to intervene early, using such appliances as the chin cup, reverse extraoral traction, or the function regulator (FR-3) of Frankel. Most cases of minimal to moderate severity are managed satisfactorily with these approaches, particularly if underlying etiological problems have been resolved. However, other cases, while improved, must be characterized as at best a compromised result at the end of the growth period. In these cases, the attainment of a Class I occlusion--if achieved at all--occurs very slowly, and the underlying skeletal discrepancy remains unresolved.

Because of a lack of success in certain early treatment cases, some clinicians have not initiated treatment until growth has been fully expressed. This approach almost always involves a combination of orthognathic surgery and orthodontic treatment. Although such an approach is generally effective in resolving the underlying skeletal and dental malrelationships and may be the treatment of choice in severe cases, the patient still faces the psychosocial problems during childhood that have been shown to be associated with this type of malocclusion.[2]

The purpose of this article is to describe a treatment approach that permits a rapid resolution of certain Class III malocclusions in young patients. The components of this treatment--a bonded rapid palatal expander and an orthopedic facial mask--are not new, but when they are used in combination they produce a more rapid treatment response than when either is used alone.

Components

Facial Mask

The facial mask was first described more than 100 years ago,[3] with other descriptions appearing early in this century.[4,5] Perhaps the individual most responsible for reviving interest in this technique is Delaire.[6-8] More recently, Petit[1] has modified the basic concepts of Delaire by increasing the amount of force generated by the appliance, thus decreasing the overall treatment time.

The Petit facial mask was originally constructed on a patient-by-patient basis, using .25" round lengths of stainless steel, to which pads for the forehead and chin were attached (Fig. 1). Later, several versions of the Petit facial mask became available commercially, reducing the amount of chair time needed to deliver the appliance.

The current version of the Petit facial mask (Fig. 2) is made of two pads that contact the soft tissue in the forehead and chin regions. The pads are made from acrylic and are lined with a soft closed-cell foam that is nonabsorbent, easily cleanable, and replaceable. The pads are connected by a midline framework made from a round, contoured length of .15" stainless steel with acorn nuts on each end.

In the center of the midline framework is a crossbar, made from .075" stainless steel, which is secured to the main framework by a set screw, thus allowing the position of the crossbar to be adjusted vertically. The crossbar ends are contoured for patient safety (Fig. 2).

Maxillary Splint

The second component of this orthopedic treatment is the maxillary splint (Fig. 3), an acrylic and wire maxillary expansion appliance that is bonded to the posterior dentition. The splint is similar in design to the maxillary portion of the acrylic splint Herbst appliance.[9,10] In mixed dentition cases, the splint usually covers the first and second deciduous molars. The upper canines may also be included in patients who present with complete deciduous dentitions.

The maxillary splint is made of a framework of .045" round stainless steel wire, to which an expansion screw is attached. If second molars are present, an occlusal rest is extended to the second molars to prevent overeruption of these teeth during treatment (Fig. 4). Two hooks, to which elastics are attached, are soldered to the wire framework. These hooks usually lie adjacent to the canines or first deciduous molars. A sheet of 3mm-thick splint Biocryl is heated and adapted to the framework and associated teeth using a

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Annexe 44

J Oral Maxillofac Surg
55:725-727, 1997

Surgically-Assisted Rapid Palatal Expansion for Management of Transverse Maxillary Deficiency

KEITH SILVERSTEIN, DMD, MD,* AND PETER D. QUINN, DMD, MD†

An adequate transverse maxillary dimension is a critical component of a stable and functional occlusion.[1] Orthopedic rapid palatal expansion in skeletally immature patients is the procedure of choice to correct this condition in that age group. However, as skeletal maturity approaches, bony interdigitation increases as the sutures fuse.[2,3] This leads to difficulty separating the maxillas with orthopedic forces alone and bending of the alveolus, dental tipping and minimal maxillary expansion. The result is relapse despite overcorrection, periodontal defects, and malocclusion.[4]

A variety of surgical procedures including surgically-assisted rapid palatal expansion (SARPE) and segmental LeFort I osteotomies have been advocated in the treatment of transverse maxillary deficiency in skeletally mature patients. The decision to choose one surgical procedure over another has led to some controversy in the literature. The reasoning behind advocating SARPE will be discussed in this article.

The isolated transverse maxillary deficiency can be treated either orthodontically or surgically with rapid palatal expansion. However, the long-term stability of the expansion is directly related to the skeletal maturity of the suture lines.[5] Krebs[6] showed that as sutures mature the majority of orthopedic rapid palatal expansion occurs by dental tipping and alveolar bone bending rather than by skeletal movement. Relapse, with an open bite deformity, may result when fixation is removed. Activation of an appliance against mature sutures can lead to the sensation of pressure, pain, and necrosis under the appliance. These forces can also result in periodontal defects as the teeth are pushed through the buccal cortical plate and lead to bony defects and gingival recession. These complications can be avoided by surgically releasing the osseous structures that resist the expansile forces.[7,8] Advantages of the SARPE include improved periodontal health; improved nasal air flow; elimination of the negative space, which results in less visible tooth and gum structure showing during smiling; and a cosmetic improvement of the buccal hollowing secondary to post-expansion prominence at the site of the lateral wall osteotomy.[9] Also, tooth extraction for alignment of the arches is often unnecessary.

Early use of SARPE was based on the hypothesis that the palatal suture was the main resistance to expansion and a midpalatal osteotomy was suggested. Many authors have since studied the resistance of maxillary expansion in the adult population.[5,10-16] All of the maxillary articulations and suture lines have been found to contribute in different degrees to the resistance to maxillary expansion. This has led to multiple osteotomy and corticotomy designs for separation of the hemi-maxillas in skeletally mature individuals. Results differ based on the placement of the corticotomies and the timing and placement of the orthodontic devices, but all surgical procedures are more stable than orthodontic expansion alone. Kennedy et al[14] found that the lateral maxillary wall corticotomy combined with a midpalatal osteotomy was the most effective method in their study on Rhesus monkeys. Other authors[11-13,15,17] have recommended sectioning of nearly all of the maxillary bony articulations (zygomaticomaxillary buttresses and midpalatal and ptergomaxillary junctions).

The indications for SARPE include any case where orthodontic expansion has failed and resistance of the sutures must be overcome. Transverse maxillary deficiencies of more than 5 mm in a skeletally mature patient are also a consideration. The figure 5 mm is chosen because the orthodontist can camouflage discrepancies less than this size with orthopedic forces alone. If a discrepancy of more than 7 mm exists,

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Annexe 45

TECHNICAL NOTES

J Oral Maxillofac Surg
63:711-713, 2005

Surgically Assisted Rapid Palatal Expansion Using a New Distraction Device: Report of a Case With an Epimucosal Fixation

Klaus Louis Gerlach, MD, DMD, and Christian Zahl, MD, DMD†*

Surgically assisted rapid palatal expansion (SARPE) is an efficient method for the treatment of transverse maxillary deficiencies in skeletal mature patients. Although this technique has a low morbidity using the traditional orthodontic appliances like Hyrax-screws, this may be accompanied by undesired effects such as buccal tooth tipping or extrusion, gingiva recessions, root resorption, or bone fenestration. Because the appliances are fixed to the teeth, therefore transmitting forces directly on the teeth and supporting bone. These problems will not occur if a bone supported palatal distractor is used.[1,2] The aim of the article is to present a new developed palatal distractor for SARPE with an epimucosal fixation.

Material and Methods

APPLIANCE DESIGN

The functional component of the newly developed distractor consists of a cylindrical body (24 mm) with 2 longitudinal slides. The cylinder incorporates an angular drive with a central spindle featuring 2 counteracting threads (a right-handed one and a left-handed one). At the beginning of each thread, an offset bar with an internal thread is located. Each of these bars connects to a 4-hole miniplate located at a right angle to the cylinder body. The height of the angle bar (5 mm) allows easy adaptation of the plates to the shape of the palatal surface (Fig 1). The distractor is activated transorally at its frontal part using a special screwdriver. One full turn is equivalent to a distraction length of 0.2 mm.

SURGICAL PROCEDURE

Under general anesthesia, via naso-endotracheal intubation, a bilateral vestibular mucosa incision from the canine tooth to the 6-year molar, plus a vertical midline incision are made. Following exposure of the maxillary sinus walls, an osteotomy is performed from the piriform aperture to the maxillary tuberosity, using the oscillating saw; additionally a maxillary-pterygoid disjunction is recommended. If there is ossification of the central palatal suture, often seen in patients over 25 years of age, the anterior nasal spine and piriform rim are identified, the nasal mucosa is then dissected with a periosteal elevator, bilaterally from the medial nasal wall and floor. A small osteotome is then placed beyond the incisive foramen and tapped to the posterior margin of the palatine bone bilaterally to the nasal septum and vomer. Mobilization of the maxilla halves is conducted with an osteotome applied between the roots of the central incisors below the nasal spine.

After verifying sufficient mobility and diastema formation, the distractor is adapted to the shape of the palate, via bending of the miniplates. On each side, the cylindrical body of the distractor is located between the second premolar and the first molar. Fixation is performed epimucosally with 7 mm long miniscrews after predrilling through the holes of the plates and the palatal mucosa. For this purpose, the use of an angled screwdriver is recommended. Following fixation, the distractor is activated (2 mm) to check proper functioning and is then reset to the starting position.

Distraction is started after a latency period of 6 days. Every morning and evening the screwdriver is applied and rotated in a marked direction by 1 full turn each time (which amounts to a distraction length

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Annexe 46

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Surgically Assisted Rapid Palatal Expansion:
An Outpatient Technique With Long-Term Stability

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This study presents the results of surgically assisted rapid palatal expansion done on an outpatient basis in 19 patients with a mean age of 30 years. Post-surgical and postorthodontic evaluation (mean, 2.4 years) showed a mean relapse rate of 8.8% in the canine region, 1% in the premolar region, and 7.7% in the molar region. These results show that the surgical procedure is feasible on an outpatient basis and the technique, as outlined, yields a stable long-term result.

In 1860, E. H. Angel[1] reported correction of maxillary transverse width discrepancies by opening the midpalatal suture. In 1961, Haas[2] reintroduced rapid palatal expansion (RPE, or rapid maxillary expansion, RME) appliances to correct real and relative maxillary transverse deficiencies, maxillary collapse, maxillary retrusion, and skeletal class II division 1 malocclusions.[3-5] In growing children, RPE appliances opened the midpalatal suture, but the long-term stability remained a problem.[6] Although RPE has been relatively successful in children and adolescents, it has been fraught with failure in adults.[2,6,8-10] In adults, orthodontic RPE may result in alveolar bending, periodontal membrane compression, lateral tooth displacement, and tooth extrusion.[5-8] Haas[5] believed that the most common error was underexpansion, so 50% overexpansion was advocated. Even with overexpansion, the very factors that allowed the expansion are the same factors associated with relapse and subsequent failure of the procedure.

Historically, the midpalatal suture was thought to be the area of resistance to expansion, but Isaacson et al[11,12] have shown that the facial skeleton increases its resistance to expansion as it ages and matures, and that the major site of resistance is not the midpalatal suture but the remaining maxillary articulations. Haas[13] believes the maxillae separate from each other in a tipping fashion due to the strength of the zygomatic buttresses. Lines[2] and Bell[14] demonstrated that the area of increased facial skeletal resistance to expansion was not the midpalatal suture, but the zygomaticotemporal, zygomaticofrontal, and zygomaticomaxillary sutures. Wertz[10] theorized that resistance was caused by the zygomatic arches.

Identification of these areas of resistance in the craniofacial skeleton stimulated the development of various maxillary osteotomies to expand the maxilla laterally in conjunction with orthodontic RPE appliances.[14-19] The osteotomy techniques vary, as does the time of placement of an active orthopedic expansion device, but anecdotally all reports note that the surgical expansion is more stable than orthodontic RPE alone.[7,9,14-22]

Indications

The role of surgery with RPE is to first release the areas of resistance in the maxillae.[8] According to Moss,[8] whether RPE is done alone or in conjunction with surgery will depend on the patient's age and the condition of the midpalatal suture, and not on the maxillomandibular relationship. Lines[2] states that orthodontic RPE is extremely valuable in young patients (growing children) exhibiting maxillary collapse, maxillary retrusion, and/or pseudo class III malocclusions. Haas[5] recognizes six indications for nonsurgical RPE: 1) real and relative maxillary deficiency, 2) nasal stenosis, 3) all type class III cases, 4) the mature cleft palate patient, 5) anteroposterior maxillary deficiency, and 6) selected arch length problems.

Determination of the necessity for surgery in a maxillary transverse deficiency patient requires differentiation between skeletal and dental problems, and an initial determination of the existence and extent of the discrepancy. Jacobs et al[20] state that only in rare instances are crossbites (either buccal or palatal) involving more than one or two teeth not skeletal. They divide

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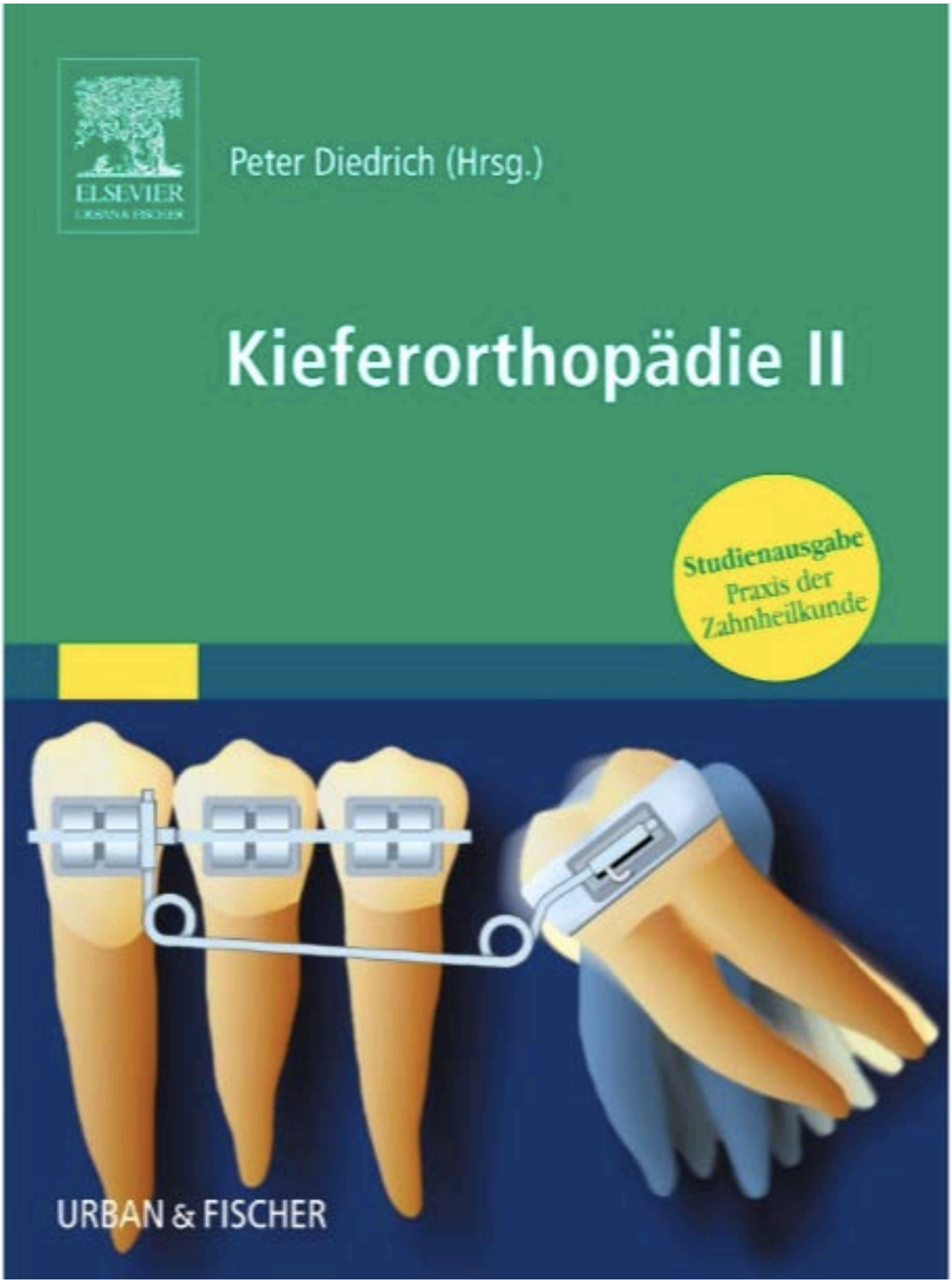
Annexe 47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Annexe 48

Surgically assisted rapid palatal expansion: A literature review

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Transverse maxillomandibular discrepancies are a major component of several malocclusions. Orthopedic and orthodontic forces are used routinely to correct a maxillary transverse deficiency (MTD) in a young patient. Correction of MTD in a skeletally mature patient is more challenging because of changes in the osseous articulations of the maxilla with the adjoining bones. Surgically assisted rapid palatal expansion (SARPE) has gradually gained popularity as a treatment option to correct MTD. It allows clinicians to achieve effective maxillary expansion in a skeletally mature patient. The use of SARPE to treat MTD decreases unwanted effects of orthopedic or orthodontic expansion. Our aim in this article is to present a comprehensive review of the literature, including indications, diagnosis, guidelines for case selection, a brief overview of the surgical techniques, orthodontic considerations, complications, risks, and limitations of SARPE to better aid the clinician in the management of MTD in skeletally mature patients. (Am J Orthod Dentofacial Orthop 2008;133:290-302)

Orthopedic maxillary expansion (OME) was first described over 145 years ago by Angell in a case report.[1,2] An accompanying commentary on the article suggested that the possibility of achieving OME was "exceedingly doubtful." After initially falling to disrepute, it was reintroduced in the middle of the last century by Andrew Haas.[3] Presently, OME has become a routine procedure in treating maxillary transverse deficiency (MTD) in a variety of malocclusions in young orthodontic patients. There is, however, a lack of definitive guidelines that would enable the orthodontist to select an age-appropriate procedure for treating MTD. OME can produce unwanted effects when used in a skeletally mature patient, including lateral tipping of posterior teeth,[4,5] extrusion,[6-8] periodontal membrane compression, buccal root resorption,[9-11] alveolar bone bending,[5] fenestration of the buccal cortex,[11-14] palatal tissue necrosis,[15] inability to open the midpalatal suture, pain, and instability of the expansion.[5,8,16-18] Several reasons have been speculated regarding factors that limit orthopedically induced maxillary expansion in skeletally mature patients. These are all related to changes with increasing age in the osseous articulations of the maxilla with the adjoining bones. However, a few reports in the literature contradict these findings and state that nonsurgical maxillary expansion is as successful in adults as it is in children.[19,20]

The incidence of MTD in the deciduous and mixed dentitions is estimated at 8% to 18% of patients having orthodontic consultations.[21] The incidence of MTD in the adult population or in skeletally mature people could not be elucidated from the literature.

Because of more complications after attempts to orthopedically alter the transverse dimension of the maxilla with advancing age, surgical procedures have been recommended to facilitate correction of transverse discrepancies. These procedures have conventionally been grouped into 2 categories: segmenting the maxilla during a LeFort osteotomy to reposition the individual segments in a widened transverse dimension, and surgically assisted rapid palatal expansion (SARPE).

The criteria for selection of either of these to correct the MTD have not been clearly defined. The preference of the surgeon often determines the choice of the procedure.

Our aim in this article is to present a comprehensive review of the literature, including indications, diagnosis, guidelines for case selection, a brief overview of the surgical techniques, orthodontic considerations, complications, risks, and limitations of SARPE to better aid the clinician in the management of MTD in skeletally mature patients.

Current standards for reviews require performing a

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Annexe 49

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Orbital Compartment Syndrome Following Orthognathic Surgery

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AND PETER A.D. RUBIN, MD†

Vision can be threatened by acute retrobulbar hemorrhage following maxillofacial trauma,[1,2] trauma surgery,[3,4] blepharoplasty,[5,6] and orthognathic surgery.[7] Although blindness is a disastrous complication under any circumstance, its occurrence following blepharoplasty or orthognathic surgery is even more devastating because these procedures are considered elective. Fortunately, visual loss associated with orthognathic surgery is rare. Lanigan et al[7] reported eight cases of ophthalmic complications associated with orthognathic surgery. In one case in which retrobulbar hemorrhage occurred following Le Fort I osteotomy, the patient had no long-term visual problem due to prompt intervention by the oral and maxillofacial surgeon and the ophthalmologist. In the same article, Lanigan also noted that the etiology of orbital injury might have resulted from "forces transmitted during the pterygomaxillary dysjunction using an osteotome or from fractures extending to the base of the skull or orbit associated with the pterygomaxilary dysjunction or the maxillary down fracture." Hueston[8] suggested that during retrobulbar hemorrhage, the retina or optic nerve can only tolerate ischemia for 60 to 90 minutes. If there is no immediate intervention, permanent visual sequelae may occur. Experimental studies also show that the retina only tolerates temporary ischemia up to 100 minutes before potential for visual recovery is lost.[9,10] This report describes an unusual case of blindness resulting from orbital compartment syndrome caused by retrobulbar hemorrhage following bilateral posterior maxillary segmental osteotomy.[11] It also outlines a treatment plan for orbital compartment syndrome.

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Report of a Case

A 34-year-old woman with transverse maxillary deficiency underwent bilateral posterior maxillary segmental osteotomies and placement of an expansion appliance. The operation started at 8 AM and ended approximately 2 hours later without incident. When the drapes were being removed from the patient on completion of the case, the left eyelid was noted to be edematous and the eye proptotic. An urgent ophthalmology consult was requested, and immediate evaluation by the ophthalmologist revealed a very tense left orbit with a minimally reactive 5-mm pupil. Acute retrobulbar bleed was diagnosed and supported by a concurring otolaryngology evaluation. An incision into the lateral orbit from a point lateral to the lateral commissure was performed in attempt to drain any blood collection. A left nasoantral window was also made to allow egress of possible blood collection in the antrum. Decadron 20 mg (dexamethasone; Merck, West Point, PA) was given to decrease swelling, and mannitol was infused to reduce intraocular pressure. A postoperative axial computed tomographic (CT) scan showed a left retrobulbar hemorrhage. At 12:45 PM examination by the ophthalmologist revealed a fixed, nonreactive 7-mm pupil with no light perception. The disc was noted to be "pale, with vessels looking okay." A decision was made to transfer the patient to Massachusetts Eye and Ear Infirmary for possible orbital decompression and further management.

On arrival at the Eye and Ear Infirmary at 4:52 PM examination of the patient revealed visual acuity 20/30 by near card in the right eye and no light perception in the left eye to the most intense light source. Pupillary examination of the right eye revealed a briskly reactive pupil. The left pupil was 8-mm, nonreactive, with an afferent pupillary defect. Full extraocular movement was present in the right eye, but the left eye was limited in all fields of gaze (Fig 1). The left eye was 10-mm proptotic with 360° chemosis. The left orbit was very tense, with an estimated pressure of 45 mm Hg. A small superficial skin incision in the area of the lateral canthus was present; however, the lateral commissure, lateral canthal tendon and the inferior crus were intact. Funduscopic examination with an indirect ophthalmoscope revealed arterial pulsations, retinal edema, and venous congestion.

Because of the apparent persistence of an orbital compartment syndrome, a formal lateral canthotomy, including inferior and superior cantholysis, was performed and this resulted in rapid softening of the orbit. Immediately following the procedure, fundus examination revealed resolution of the arterial pulsations. The globe appeared to soften to gentle

Annexe 50

Sagittal and Vertical Maxillary Effects After Surgically Assisted Rapid Maxillary Expansion (SARME) Using Haas and Hyrax Expanders

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São Paulo, Brazil

The purpose of this study was to evaluate the effect of surgically assisted rapid maxillary expansion on the sagittal and vertical maxillary planes. Thirty-three adult patients aged between 18 and 40 years who required surgically assisted rapid maxillary expansion were included in this study. They were divided into two groups: the Haas type expander (16) and the Hyrax type expander (17). All patients were subjected to subtotal LeFort I osteotomy with pterygomaxillary disjunction. Lateral cephalometric radiographs were taken during the preoperative assessment (T1), soon after completion of the expansion (T2), and 4 months after the end of the expansion (T3). The following cephalometric measures were obtained in each of the three radiographs for all the patients: SNA, SN palatal plane, Frankfurt horizontal plane. NA, CF-A, CF-NA, Nperp-A, CF-A, Frankfurt horizontal plane–ANS, and Frankfurt horizontal plane–PNS. Statistically significant changes were observed in the cephalometric measures: SNA, Frankfurt horizontal plane, NA, Nperp-A in the patients in the Haas group, and CF-A in the patients in the Hyrax group, demonstrating anterior displacement of the maxilla. The cephalometric measures SN.palatal plane, CF-A, CF-NA, Frankfurt horizontal plane-ANS, and Frankfurt–PNS plane that evaluated vertical displacement did not show changes in either group. The surgically assisted rapid maxillary expansion caused anterior displacement of the maxilla in both groups, but only the Haas group had statistical significance. Neither the Haas group nor the Hyrax group showed vertical displacement of the maxilla. When Hyrax and Haas groups were compared, there were no statistically significant differences for sagittal and vertical changes.

Key Words: Surgically assisted rapid maxillary expansion, rapid palatal expansion, Haas appliance, Hyrax appliance

The transverse maxillary deficiency is a dentofacial deformity characterized clinically by the presence of posterior crossbite (unilateral or bilateral), high arch palate, crowding and flaring of anterior teeth, and difficulty in nasal breathing. It can be an isolated trait or associated with vertical maxillary excess with class II or class III malocclusion.[1] It may also be associated with a narrow nasal base, deep nasolabial fold, and zygomatic hypoplasia.[2]

In adult patients, in whom the midpalatal suture has become completely consolidated, the treatment with surgically assisted rapid maxillary expansion (SARME) allows the separation of the maxilla with an orthodontic appliance made and adjusted for that purpose. This procedure requires collaboration between an orthodontist and a surgeon,[3] and the surgical part consists of removing bony resistance to the expansion forces.[4]

Several authors such as Haas,[5] Wertz,[6] Davis and Kronman,[7] and Silva Filho et al[8] have published studies about sagittal changes after rapid maxillary expansion. The sagittal and vertical changes after SARME have been evaluated only by a few authors. Their samples consist of a small number of patients and include both adults and growing subjects.[9,10] The ideal sample for this type of study should include only adult patients, considering that the occurrence of structural alterations resulting from craniofacial

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Annexe 51

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International Journal of Oral & Maxillofacial Surgery

Clinical Paper
Distraction Osteogenesis

The Rotterdam Palatal Distractor: introduction of the new bone-borne device and report of the pilot study

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M. J. Koudstaal, K. G. H. van der Wal, E. B. Wolvius, A. J. M. Schulten: The Rotterdam Palatal Distractor: introduction of the new bone-borne device and report of the pilot study. Int. J. Oral Maxillofac. Surg. 2006; 35: 31–35.

Abstract. Transverse maxillary hypoplasia, in adolescents and adults, is frequently seen as an acquired deformity and in congenital deformities patients and can be corrected by means of surgically assisted rapid maxillary expansion. Traditionally, the distractors for expansion are tooth-borne devices, i.e. hyrax appliances, which may have some serious disadvantages such as tooth tipping, cortical fenestration, skeletal relapse and loss of anchorage. In contrast, with bone-borne distractors most of the maxillary expansion is orthopedic and at a more mechanically desired level with less dental side effects. A new bone-borne palatal distractor has been developed. By activation the nails of the abutments plates automatically stabilizes the device and no screw fixation is necessary anymore. This new distractor is presented and the data of five acquired deformity and eight congenital deformity patients that were treated with this distractor are reported.

Key words: Rotterdam, palatal, distractor, transverse, maxillary, expansion.

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Transverse maxillary hypoplasia, in adolescents and adults, is frequently seen as an acquired deformity and in congenital deformities patients including cleft patients[7]. In skeletally mature patients the uni- or bilateral transverse hypoplasia can be corrected by means of a surgically assisted rapid maxillary expansion[2–4]. Traditionally, the distractors for expansion are tooth-borne devices, i.e. hyrax appliances, which have some serious disadvantages: periodontal problems, like buccal root resorption and cortical fenestration, segmental tipping and anchorage-tooth tipping, loss of anchorage, dental caries in congenital patients with mental retardation and poor oral hygiene[2,4].

In contrast, with bone-borne distractors applied at a higher level in the palatal vault, most of the maxillary expansion is orthopedic and at a more mechanically desired level[4–6]. In addition the forces are directly on the bone and no tooth tipping and other unwelcome side effects are to be expected. The now commercially available bone-borne distractors like the Transpalatal Distractor (TPD™) and the Magdenburg palatal distractor[9] have to be fixed with screws on the palatal bone and have proven to be useful in acquired deformation patients. The MDO-R device (Orthognathics Ltd.) has no screw fixation, however it has a minimal width of 1.5 cm. In congenital patients with extreme narrow maxillas these devices seem to be impractible due to difficulties

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Annexe 52

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BRITISH JOURNAL OF ORAL & MAXILLOFACIAL SURGERY

Surgical and orthodontic rapid palatal expansion in adults using Glassman's technique: retrospective study

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SUMMARY. **In 1984, Glassman *et al.* described a conservative surgical method of separation of the midpalatal suture in which an osteotomy is done only at the lateral and anterior wall of the maxilla. Between 1991 and 1997, we have operated on 21 patients with maxillary transverse discrepancies using the method that they described. This gave good results in 20 patients. The other, who was operated on at the age of 38 years, developed a fracture of the alveolar process of the maxilla on one side because of ossification of the midpalatal suture. The surgically assisted rapid palatal expansion described by Glassman *et al.* is suitable for patients up to the age of 30. Older patients require additional surgical separation of the midpalatal suture.**

INTRODUCTION

A permanent increase in maxillary transverse width is attained routinely in children and adolescents using orthodontic expansion appliances and retention,[1,2] and this treatment does not normally cause any problem. However, in skeletally mature adults, attempts at orthopaedic rapid maxillary expansion often cause appreciable problems. Inability to activate the appliance and expand the maxilla is common. The treatment can also result in buccal tipping of the teeth,[3,4] and bone dehiscences and gingival recession have been described.[5] Overcorrection to compensate for these undesirable changes is often frustrated by unpredictable and uncontrolled relapse after the palatal expansion appliance has been removed.[6]

Investigations on cadaver skulls by Persson and Thilander showed that the ossification of the midpalatal suture has wide individual variations in different age groups and is unpredictable under the age of 30.[7]

Initially, the midpalatal suture was identified as an area of bony resistance to palatal expansion in patients after their late teens.[7,8–11] Later studies indicated that the construction of the zygomaticomaxillary buttress is the critical area of resistance to palatal expansion.[9,12,13]

The procedure for rapid palatal expansion is still controversial and many different methods have been described[6,9,14–18] since the time of Angell,[19] when he presented the first case of correction of maxillary transverse discrepancy in 1860.

We present 21 cases treated by rapid palatal expansion without midpalatal or pterygomaxillary surgery. The technique was first described by Glassman *et al.* in 1984.[20]

PATIENTS AND METHOD

Twenty-one patients with discrepancies in the width of the maxillary arch were treated from 1991 to 1997 by rapid palatal expansion as described by Glassman *et al.*[20] The age of the patients ranged from 14 to 38 years (mean 21) (Table 1). All patients were seen by an interdisciplinary team of orthodontists and oral surgeons and the operations were done by two surgeons.

The preparation for the technique by Glassman is to cement an orthodontic Derichsweiler appliance to the first premolar and the first molar preoperatively. The appliance is activated by a centrally placed Hyrax screw (Fig. 1). One screw turn is equivalent to 0.25 mm. If simultaneous first premolar extraction is needed, the Derichsweiler appliance may be cemented to the second premolar and second molar without compromising treatment.

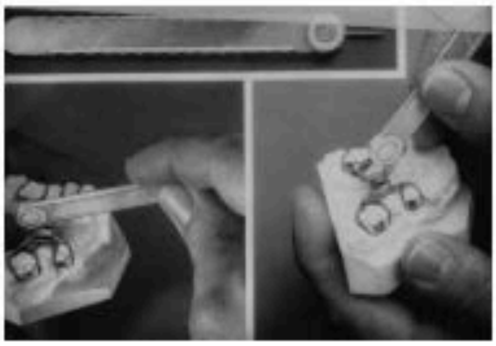

Fig. 1 – Model of orthodontic Derichsweiler appliance with central Hyrax screw.

Annexe 53

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Feasibility and long-term stability of surgically assisted rapid maxillary expansion with lateral osteotomy

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SUMMARY Surgically assisted rapid maxillary expansion (SARME) has become a widely used and acceptable means to expand the maxilla in adolescents and adult patients. The method takes advantage of bone formation at the maxillary edges of the midline, while they are separated by an external force. The purpose of the present retrospective investigation was to evaluate the feasibility and long-term stability of maxillary expansion in patients in whom lateral pre-expansion osteotomy had been performed. The subjects were 20 patients (14 females, six males, mean age 30.6 years, range 16.2–44.2 years) whose malocclusions were treated solely or partly with SARME during 1988–1996. Two orthodontists carried out the post-orthodontic expansion treatment. The surgical technique followed a minimally invasive osteotomy on the lateral maxillary walls. Study models were obtained before surgery (T1), once expansion and the following orthodontic treatment were completed, before possible second-stage osteotomy (T2), and at long-term follow-up (T3). Using the study models, the width of the dental arch was measured with a digital sliding calliper. In addition, transverse occlusal relationships were examined at each time point.

The results indicated that (1) SARME is possible when the minimally invasive operation technique is used, (2) long-term stability of maxillary expansion following the present technique compares favourably with the widening and stability achieved with other, more invasive, osteotomies. With age, several possible uncertainties are introduced to affect the course of SARME adversely. Therefore, more extensive osteotomies can be recommended in older patients.

Introduction

Surgically assisted rapid maxillary expansion (SARME) has become a widely used and acceptable means to expand the maxilla in adolescents and adult patients. The method takes advantage of bone formation at the maxillary edges of the midline, while they are separated by an external force. However, some controversies still exist concerning the indications, osteotomy technique, particularly in terms of the age of the patient, and long-term stability.

Primarily, SARME is indicated when the patient has isolated, considerable (more than 5 mm) transverse maxillary deficiency and is older than 15 years of age, and, therefore, not a good candidate for ordinary rapid maxillary expansion (Betts *et al.*, 1995; Bailey *et al.*, 1997; Silverstein and Quinn, 1997).

Several modifications to the surgical approach have been recommended and used. The rationale for choosing a particular osteotomy technique is based on the assumption of what structure(s) offers the most resistance to maxillary expansion. Those who consider the intermaxillary suture to be the essential resisting structure recommend first performing an osteotomy in the palate (MacIntosh, 1974; Timms and Vero, 1981). Others regard the pterygomaxillary buttress, with its strong cortical bone, to be more important in preventing adequate expansion of the maxilla (Glassman *et al.*, 1984; Lehman *et al.*, 1984) and consequently perform an osteotomy only in the lateral areas. Many clinicians favour using combined osteotomies in the palate, anterior and lateral maxilla, and particularly at the pterygomaxillary buttress (Lines, 1975; Bell and Epker, 1976; Bays and Greco, 1992; Pogrel *et al.*, 1992; Betts *et al.*, 1995; Northway and Meade, 1997). It is evident that no consensus has been reached about the minimum osteotomy required to facilitate maxillary expansion, and that the question posed by Pogrel *et al.* (1992): 'What is the minimal procedure required to produce consistent and stable maxillary expansion in adults?' has not yet been answered.

Although the amount of maxillary expansion and its stability following SARME have been the topics of many investigations, the many different treatment regimes and follow-up periods make interpretation of the findings difficult. In general, it can be stated that expansion is greater in the anterior than in the posterior area, and relapse is 9–30 per cent in the canine area and 8–23 per cent in the molar area (Bays and Greco, 1992;

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CASE REPORT

Surgically assisted rapid palatal expansion: Orthodontic preparation for clinical success

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Close root proximity between the maxillary central incisors presents a problem in the surgical management of a maxillary palatal expansion. During the surgical fracture of this interdental area, the possibility exists for a separation to occur between the root surface and the bone. If this does occur, it is paramount that the gingival attachment remain intact. Asymmetric separation places more stress on the mesial gingival attachment because of the anatomy of the gingival fiber apparatus. Gingival detachment results in epithelial downgrowth in an apical direction, which in turn prevents bone apposition in a coronal direction. The resulting osseous defect is difficult to treat with an osseous graft procedure, as there are few if any intrabony walls. Treatment planning should include analysis of a recent periapical radiograph of the incisor roots to determine the need for orthodontic root separation before surgery. A postsurgical periapical radiograph should be taken to determine where the interdental separation has occurred. The expansion schedule should be adjusted depending on the symmetry of the separation and the health of the gingival attachment. (Am J Orthod Dentofacial Orthop 1999;116:46-59)

Nonsurgical rapid palatal expansion (RPE) was used by Angle[1] as early as 1860 and continues to be used by orthodontists with a high rate of success for growing children. Although RPE has been relatively successful in children and adolescents, it has been fraught with failures in adults.[2-5] In adults, orthodontic RPE may result in alveolar bending, periodontal membrane compression, lateral tooth displacement, tooth extrusion, and transverse relapse, which can subsequently lead to failure of the procedure.[6,7] Historically, the midpalatal suture was thought to be the area of resistance to expansion, but Lines[5] and Bell and Jacobs[8] demonstrated that the area of increased facial skeletal resistance to expansion was not the midpalatal suture, but the zygomaticotemperal, zygomaticofrontal, and zygomaticomaxillary sutures. This stimulated the development of various maxillary osteotomies to expand the maxilla laterally in conjunction with orthodontic RPE appliances.[9-14]

INDICATIONS

Treatment in adults with dentofacial deformities is frequently complicated by the existence of discrepancies in the transverse dimension. Control of these transverse discrepancies in the correction of dentofacial deformities is extremely important for the ultimate satisfactory achievement of a stable and functional occlusion. Jacobs et al[15] divide maxillary transverse width discrepancies into two categories: real and relative. Relative implies that a horizontal discrepancy apparently exists clinically, but the study models examined in a class I canine relationship show that the apparent deficiency is in reality the result of a discrepancy of the maxilla or both jaws in the sagittal dimension. Absolute implies a true horizontal width insufficiency. Once the diagnosis of absolute maxillary deficiency has been made and it is ascertained that the need for expansion of the maxillary arch does exist, several factors must be considered to determine whether such expansion should be achieved through lateral maxillary osteotomies and rapid maxillary expansion[8,9,16,17] as an integral part of the presurgical orthodontic therapy or by segmentalizing the maxilla at the time of surgery to achieve transverse correction concomitantly with vertical and/or sagittal treatment objectives.[18-28]

In cases of minimal to moderate arch length deficiencies, rapid palatal expansion can increase arch circumference sufficiently to permit alignment of the crowded anterior teeth thus avoiding the necessity of extraction of premolars or excessive forward tipping of incisors. It may obviate the need for a second maxillary surgical procedure.

Most cases in which a transverse deficiency exists will characteristically exhibit a narrow tapering arch form. The discrepancy will, therefore, be pronounced in the canine region. In order to achieve a functional

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Progress in Orthodontics
a SpringerOpen Journal

RESEARCH **Open Access**

The effects of micro-implant assisted rapid palatal expansion (MARPE) on the nasomaxillary complex—a finite element method (FEM) analysis

Matt MacGinnis[1], Howard Chu[1], George Youssef[2], Kimberley W Wu[1], Andre Wilson Machado[3] and Won Moon[1*]

Abstract

Background: Orthodontic palatal expansion appliances have been widely used with satisfactory and, most often, predictable clinical results. Recently, clinicians have successfully utilized micro-implants with palatal expander designs to work as anchors to the palate to achieve more efficient skeletal expansion and to decrease undesired dental effects. The purpose of the study was to use finite element method (FEM) to determine the stress distribution and displacement within the craniofacial complex when simulated conventional and micro-implant-assisted rapid palatal expansion (MARPE) expansion forces are applied to the maxilla. The simulated stress distribution produced within the palate and maxillary buttresses in addition to the displacement and rotation of the maxilla could then be analyzed to determine if micro-implants aid in skeletal expansion.

Methods: A three-dimensional (3D) mesh model of the cranium with associated maxillary sutures was developed using computed tomography (CT) images and Mimics modeling software. To compare transverse expansion stresses in rapid palatal expansion (RPE) and MARPE, expansion forces were distributed to differing points on the maxilla and evaluated with ANSYS simulation software.

Results: The stresses distributed from forces applied to the maxillary teeth are distributed mainly along the trajectories of the three maxillary buttresses. In comparison, the MARPE showed tension and compression directed to the palate, while showing less rotation, and tipping of the maxillary complex. In addition, the conventional hyrax displayed a rotation of the maxilla around the teeth as opposed to the midpalatal suture of the MARPE. This data suggests that the MARPE causes the maxilla to bend laterally, while preventing unwanted rotation of the complex.

Conclusions: In conclusion, the MARPE may be beneficial for hyperdivergent patients, or those that have already experienced closure of the midpalatal suture, who require palatal expansion and would worsen from buccal tipping of the teeth or maxillary complex.

Keywords: Finite element method (FEM); Rapid palatal expansion (RPE); Micro-implant assisted rapid palatal expansion (MARPE); Nasomaxillary sutures

Background

Rapid palatal expansion

The prevalence of maxillary transverse deficiency is 8% to 23% in the deciduous and mixed dentitions and less than 10% in adult orthodontic patients [1-5]. While the cause of maxillary constriction is multifactorial [6], one way to alleviate this skeletal deficiency is through rapid palatal expansion (RPE).

RPE separates the two maxillary bones at the midpalatine suture [7,8]. During expansion, the force of the appliance counteracts the existing anatomical resistance from the dentoalveolus, midpalatal suture, zygomaxillary buttress, and circummaxillary sutures [9-15]. Chaconas and Caputo concluded that the major resistance to expansion forces was not the midpalatal suture but other articulations in the maxilla, such as the zygomatic and sphenoidal sutures [16]. Other RPE studies have proposed

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Research Article

Dental and Skeletal Changes after Transpalatal Distraction

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Maxillary constriction is a common skeletal craniofacial abnormality, and transverse maxillary deficiency affects 30% of patients receiving orthodontic and surgical treatment. The aim of the study was to analyse craniofacial skeletal changes in adults with maxillary constriction after transpalatal distraction. The study group consisted of 36 patients (16 women) aged 17 to 42 years ($M = 27.1$; $SD = 7.8$) with a known complete skeletal crossbite and who underwent transpalatal distraction procedure. The measurements were obtained on diagnostic models, and cephalometric PA radiograms were obtained at time points, i.e., before treatment (T1) and after the completion of active distraction (T2). The analysis of diagnostic models involving the arch width measurement at different levels demonstrated a significant increase in L1, L2, L3, L4, L5, and L6 dimensions after transpalatal distraction. The largest width increase (9.5 mm) was observed for the L3 dimension (the intercanine distance). The analysis of frontal cephalograms displayed a significant increase in W1, W2, and W3 dimensions after transpalatal distraction. The largest width increase (4.9 mm) was observed for the W1 dimension at the level of the alveolar process of the maxilla. Transpalatal distraction is an effective treatment for transverse maxillary deficiency after the end of bone growth. The expansion observed on diagnostic models is close to a parallel segment shift mechanism, with a mild tendency towards a larger opening anteriorly. The maxillary segment rotation pattern analysed based on the frontal cephalograms is close to a hand fan unfolding with the rotation point at the frontonasal suture.

1. Introduction

Maxillary constriction is a common skeletal craniofacial abnormality. 30% of patients receiving any complex orthodontic and surgical treatment suffer from transverse maxillary deficiency [1]. The appropriate transverse dimension of the upper arch ensures stable occlusion and significantly affects facial proportions and aesthetics [2, 3]. Clinically, transverse maxillary deficiency manifests as a complete crossbite (unilateral or bilateral), high-vaulted, V-shaped palate, with anterior tooth crowding and visible buccal corridors when smiling [4–7]. Laptook identified core clinical features of "skeletal malocclusion syndrome" if a complete crossbite is present, which include increased nasal breathing difficulty, reduced nasal cavity volume, mouth breathing, crossbite with a high-vaulted hard palate, and turbinate hypertrophy. Presence of at least two of the aforementioned clinical features indicates skeletal malocclusion and necessitates treatment aimed at increasing the transverse maxillary dimension and its skeletal expansion [8].

Using orthodontic expanders for the treatment of maxillary deficiency in adults leads to a number of dental and periodontic complications [7, 9–13]. By acting indirectly on the midpalatal suture, the tooth-borne appliances adversely affect lateral teeth, causing buccal inclination and extrusion, alveolar bone fenestration along its buccal aspect, dental root resorption, and gingival recession in the proximity of the teeth on which the appliance is borne [9]. The adverse effects of such appliances on periodontium worsen with the patient's skeletal maturity [14].

Due to the limitations of dental anchorage in the rapid maxillary expansion (RPE) in adult patients, the skeletal anchorage was introduced in the method of microimplant-assisted rapid palatal expansion (MARPE), as an alternative to surgically assisted jaw expansion modalities. MARPE involves the use of a hybrid device: bone anchored with 2 mini-implants on each side of the midpalatal suture and tooth-borne on the first upper molars [15].

Midface anatomy and architecture are key aspects of maxillary expansion [16–18]. The flexibility of the bone skeleton decreases with age, which limits the possibility of

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special **article**

Non-surgical treatment of transverse deficiency in adults using Microimplant-assisted Rapid Palatal Expansion (MARPE)

Daniel Paludo Brunetto[1], Eduardo Franzzotti Sant'Anna[2], Andre Wilson Machado[3], Won Moon[4]

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Introduction: Maxillary transverse deficiency is a highly prevalent malocclusion present in all age groups, from primary to permanent dentition. If not treated on time, it can aggravate and evolve to a more complex malocclusion, hindering facial growth and development. Aside from the occlusal consequences, the deficiency can bring about serious respiratory problems as well, due to the consequent nasal constriction usually associated. In growing patients, this condition can be easily handled with a conventional rapid palatal expansion. However, mature patients are frequently subjected to a more invasive procedure, the surgically-assisted rapid palatal expansion (SARPE). More recently, researches have demonstrated that it is possible to expand the maxilla in grown patients without performing osteotomies, but using microimplants anchorage instead. This novel technique is called microimplant-assisted rapid palatal expansion (MARPE). **Objective:** The aim of the present article was to demonstrate and discuss a MARPE technique developed by Dr. Won Moon and colleagues at University of California – Los Angeles (UCLA). **Methods:** All laboratory and clinical steps needed for its correct execution are thoroughly described. For better comprehension, a mature patient case is reported, detailing all the treatment progress and results obtained. **Conclusion:** It was concluded that the demonstrated technique could be an interesting alternative to SARPE in the majority of non-growing patients with maxillary transverse deficiency. The present patient showed important occlusal and respiratory benefits following the procedure, without requiring any surgical intervention.

Keywords: Microimplant-assisted Rapid Palatal Expansion. Palatal expansion technique. Polysomnography. Obstructive Sleep Apnea Syndrome. Adult patients. Maxillary transverse deficiency. Posterior crossbite.

Introdução: a deficiência transversa da maxila é uma má oclusão com alta prevalência em todas as faixas etárias, da dentição decídua à permanente. Se não for corrigida, pode agravar-se com o passar do tempo, prejudicando o crescimento e desenvolvimento facial. Além dos prejuízos oclusais, essa deficiência pode trazer problemas respiratórios também severos, devido à consequente constrição da cavidade nasal. Em pacientes em crescimento, a sua resolução é relativamente simples, por meio da expansão rápida convencional da maxila. Porém, os pacientes já maduros geralmente são encaminhados para um procedimento mais invasivo, a expansão rápida de maxila assistida cirurgicamente (SARPE). Mais recentemente, pesquisadores têm demonstrado que é possível executar a expansão palatal esquelética em pacientes adultos sem auxílio de osteotomias, mas sim com auxílio de mini-implantes. Essa técnica é denominada *Microimplant-Assisted Rapid Palatal Expansion*, ou MARPE. **Objetivo:** o objetivo do presente artigo é demonstrar e discutir uma das técnicas disponíveis de MARPE, desenvolvida por Won Moon e colaboradores, na *University of California, Los Angeles* (UCLA). **Métodos:** a técnica encontra-se detalhadamente descrita, com as etapas laboratoriais e clínicas que devem ser seguidas para sua correta execução. Para descrevê-la, é apresentado o caso clínico de uma paciente adulta, detalhando toda a sequência do tratamento e os resultados obtidos. **Conclusão:** a técnica apresentada pode ser uma alternativa não invasiva à SARPE na resolução da deficiência transversa de maxila, podendo ser empregada na maioria dos pacientes com crescimento facial finalizado. A paciente apresentada demonstrou benefícios significativos nos aspectos oclusal e respiratório, sem a necessidade de intervenção cirúrgica.

Palavras-chave: Expansão rápida da maxila assistida por mini-implantes. Técnica de expansão palatina. Polissonografia. Síndrome da apneia obstrutiva do sono. Pacientes adultos. Deficiência transversa de maxila. Mordida cruzada posterior.

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» The authors report no commercial, proprietary or financial interest in the products or companies described in this article.

» Patients displayed in this article previously approved the use of their facial and intraoral photographs.

Annexe 58

Miniankerschrauben getragene Gaumennahterweiterung

Der MICRO-4 oder MICRO-6 Expander

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Einleitung

Seit der Einführung der nicht-chirurgischen Gaumennahterweiterung (GNE) im Jahr 1860 ist diese Form der Behandlung eine der wichtigsten im kieferorthopädischen Alltag. Die dabei auftretende Belastung der Zähne führte immer wieder zu unerwünschten Nebenwirkungen wie Wurzelresorptionen, Bissöffnung oder dentalen Verankerungsverlusten. Nach der Einführung des Orthoimplantats (Straumann Orthosystem) gelang es, Expander teilweise skelettal abgestützt im Gaumen zu verankern. Zusätzlich war zur Erweiterung des Oberkiefers eine chirurgischer Unterstützung (SARPE) erforderlich (Harzer et al 2004, Hansen et al 2007, Harzer et al 2010). Eine dental und skelettal abgestützte Apparatur (Hybrid-Hyrax) wurde erstmals von Wilmes et al. 2010 vorgestellt. Die Expanderschraube war dabei an 2 paramedian im vorderen Gaumen inserierten Miniankerschrauben (MAS) befestigt. Gleichzeitig wurden die hinteren Arme der Expanderschraube an Molarenbändern fixiert. Basierend auf einer zusammenführenden Studie zur Knochenhöhe und Knochendichte im vorderen Gaumen (Winsauer 2012) setzte die Winsauer-Gruppe 2010 erstmals 4 bis 6 Miniankerschrauben paramedian im anterioren Gaumen. Dabei wurde der Expander über ein Klebehülsensystem mit den beiden Miniankerschrauben im anterioren Gaumenn verbunden.
Seit 2010 wurden aber auch zahlreiche, rein Miniankerschrauben-getragene Expander (MICRO 4/6), also ohne Mitverankerung an den Molaren, eingesetzt. Dies bewies die Praktikabilität dieses Verankerungssystems. Dadurch war es möglich, Dysgnathiebehandlungen neben skelettal und dental verankerten Expandern (HYBRID-HYRAX) für Kinder auch mit rein skelettal verankerten Expandern (MICRO-4/6) für Teenager und Erwachsene durchzuführen. Während der Oberkiefer über knöcherne Verankerungspunkte expandiert und retiniert wurde, konnten zur selben Zeit sämtliche Zähne des oberen Zahnbogens mittels festsitzender Behandlungstechnik ausgeformt werden. Auch in Kombination mit kieferchirurgischer Schwächung des Oberkiefers (SARPE) hat sich dieser Miniankerschrauben getragene Expander ausgezeichnet bewährt.

Material und Methode

4 – 6 Dual Top Jet Miniankerschrauben (Durchmesser 2,0 – 2,5 mm, Länge 12 – 16 mm, Tiger Dental, Bregenz, Österreich oder Promedia, Siegen, Deutschland) werden dabei beinahe vertikal (äußerer Winkel ca. 5° – 10°) in den anterioren Gaumen paramedian platziert. (Bild 1 – 2)

Bild 1: 4 bis 6 überwiegend vertikal paltzierte Miniankerschrauben.

Bild 2: Zur Modellherstellung werden Transferkappen auf die MAS-Köpfe gesteckt. Alginatabdruck ausreichend.

Hilfreich hierzu ist das sogenannte „Fußabdruckschema" zum Auffinden idealer Knochenverhältnisse (Bild 3).

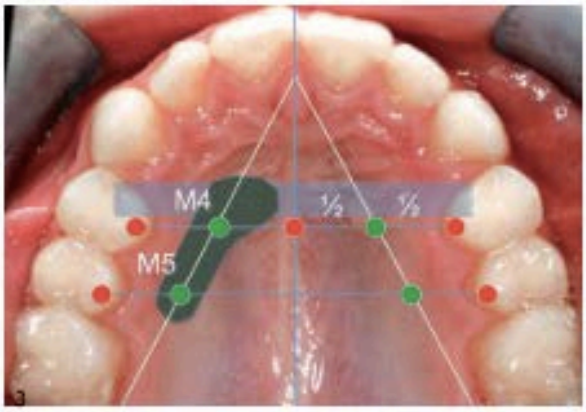

Bild 3 : „Footprint Schema": Ideale Region zur vertikalen Platzierung von 2 bis 3 Miniankerschrauben pro Seite.

Anschließend werden die Schraubenköpfe mit lichthärtendem Harz (Triad® Gel, Dentsply) gegen einander fixiert. Bei Jugendlichen ist eine Sofortbelastung möglich. Für die Herstellung von Arbeitsmodellen werden Transferkappen über die Schraubenköpfe gesteckt, der Abdruck kann mit normalem Alginat durchgeführt werden. Mittels Laboranalogen wird dann ein Gipsmodell erstellt. Darauf werden 4 – 6 Klebehülsen (Tiger Dental, Bregenz, Österreich) gesteckt und mit den Armen der Expanderschraube verschweißt. Als derzeit kleinste Expanderschraube wird häufig die sogenannte Superscrew® Schraube verwendet.

Bild 4 – 6: (4) Nach dem Abdruck werden Laboranaloge in die Transferkappen zurückgesteckt. So ist die Insertionsrichtung der MAS gut zu erkennen. (5) Präzises Arbeitsmodell zur Gerätefertigung. (6) MICRO-6-Expander eingesetzt, jedoch noch nicht geklebt.

Micro-4/6 Expander

Der Name **M**ICRO-Expander leitet sich ab von „**M**ini-**I**mplant-**C**ollar-**R**etained **O**rthodontic **E**xpander" (= Miniankerschrauben getragener mit Klebehülsen befestigter orthodontischer Expander). Die Zahl beschreibt die Anzahl der zur Verankerung verwendeten Miniankerschrauben. Bei Einsatz des MICRO4/6-Expanders wird der Oberkiefer ausschließlich über knöcherne Verankerungspunkte expandiert und retiniert. Gleichzeitig und unabhängig können sämtliche Zähne des oberen Zahnbogens mittels festsitzender Behandlungstechnik ausgeformt werden. Auch in Kombina-

Annexe 59

Effects of Surgical and Nonsurgical Rapid Maxillary Expansion on Palatal Structures

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Aim: The aim of the present study was to compare the effects of surgical and nonsurgical rapid maxillary expansion (RME) in skeletally mature patients.

Materials and methods: Surgically assisted rapid maxillary expansion (SARME) was used in 18 patients (2 males, 16 females) with a mean age of 19.90 years. Two nonsurgical RME groups were constructed to compare the expansion changes of SARME. Eighteen patients in maximum pubertal peak (12 males, 6 females) with a mean age of 13.04 years comprised the growing RME group, while the nongrowing RME (NG-RME) group consisted of 18 skeletally mature patients (1 male, 17 females) with a mean age of 16.41 years. Thirteen linear and 2 angular measurements were made on the study models taken before expansion (T0) and after 3 months of retention period (T1). Intragroup differences were evaluated with paired *t* test and the intergroup differences were analyzed with 1-way analysis of variance.

Results: All groups showed significant transversal skeletal and dental expansion. The palatal width changes at gingival and midpalate levels were the highest in the NG-RME group (6.85 and 5.84 mm, respectively). The most molar tipping was in the NG-RME group (15.00°) and the palatal vault angle showed the most increase in the SARME group (9.77°). The greatest expansion at the base of palatal vault was in the SARME group (4.42 mm).

Conclusions: The pattern of expansion was rotation of the maxillary halves for SARME and lateral displacement of the dentoalveolar structures for NG-RME. Patients with severe skeletal discrepancy or increased age are good candidates for SARME.

Key Words: Palatal structures, rapid maxillary expansion, surgically assisted rapid maxillary expansion

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Rapid maxillary expansion (RME) is widely used to correct transverse maxillary skeletal or dental deficiency, nasal airway resistance, and skeletal Class II and III patients and to gain arch length in moderate crowding instances.[1–3] Although RME is routinely used during the growth period, the nonsurgical expansion in adult or mature adolescent patients is still questionable in the literature.[4] The studies that evaluated the effects of RME in skeletally mature patients showed more dental and less skeletal response to palatal expansion, so these studies suggested the use of surgery when skeletal expansion of the maxilla is needed.[4–6]

Bishara and Staley stated that the optimal age for expansion is before 13 to 15 years.[5] Melsen histologically showed that after the ages of 15 in girls and 17 in boys, the transverse growth of the midpalatal suture ends and the separation of the maxilla is impossible without fracturing the interdigitated 2 maxillary halves.[6] On the other hand, Malkoç et al[7] evaluated the long-term stability of semi-RME in 14 patients with a mean age of 20.09 ± 2.36 years and found stable dental and skeletal transversal measurements after 5 years of follow-up period. Handelman et al[8] showed successful nonsurgical expansion with the Haas expander in an adult sample with a mean age of 30 years and reported long-term stability of the expansion after 5.9 years of follow-up.

Undesirable side effects or results have been reported after use of RME in skeletally mature patients such as buccal tipping of posterior teeth, extrusion, periodontal tissue recession, fenestration of buccal cortex, necrosis of palatal tissue, failure in opening of midpalatal suture, pain, and relapse of expansion.[9] Surgically assisted rapid maxillary expansion (SARME) has been suggested to achieve successful transverse maxillary expansion without such complications.[7] Patients with skeletal asymmetries or patients having minimum 5 mm of transverse alveolar discrepancy are considered as good candidates for SARME.[10]

Few reports exist in the literature about the effects of nonsurgical RME in adult or skeletally mature patients.[4,7,8,11–15] Generally, transversal skeletal and dental changes are assessed with posteroanterior films and dental models in RME studies. However, these studies are limited to evaluate the changes in the palatal vault area. Contour tracings of study models can show both the level of the expansion at the palatal region and the nature of maxillary expansion.[8,13] To our knowledge, no study has compared the effects of SARME on the palatal area with conventional RME using contour tracings until the time of this writing. Therefore, the aim of our study was to evaluate the effects of SARME on palatal area, and to compare these effects with growing RME (G-RME) and nongrowing RME (NG-RME) patients.

MATERIALS AND METHODS

The patients indicated for maxillary expansion were included in this study.

Patient selection criteria were as follows:

1. Bilateral posterior skeletal crossbite
2. The absence of cleft lip and palate or other craniofacial anomalies

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Original Article

Nonsurgical Rapid Maxillary Expansion in Adults: Report on 47 Cases Using the Haas Expander

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Abstract: Rapid maxillary expansion (RME) in the adult is thought to be an unreliable procedure with several adverse side effects and, consequently, surgically assisted RME is considered the preferred procedure. The purpose of this paper is to study the efficacy of nonsurgical RME, and to determine the incidence of complications such as relapse of the expansion, pain and tissue swelling, tipping of the molars, opening rotation of the mandible and gingival recession. Rapid maxillary expansion using a Haas expander was examined in 47 adults and 47 children. A control group of 52 adult orthodontic patients who did not require RME was also studied. Students' *t*-test, and the analysis of variance followed by the Scheffé test were used to determine if there were significant differences among time periods and among the 3 study groups. The mean transarch width increase was similar in adults and children who had RME; 4.6 ± 2.8 compared to 5.7 ± 2.4 mm for the molars and 5.5 ± 2.4 compared to 5.7 ± 2.5 mm for the second premolars. In the adults, transarch expansion and the correction of the posterior crossbites were stable following discontinuance of retainers (mean 5.9 years). If the expander was properly fabricated, and turned no more than once a day, the procedure was well-tolerated. Rapid maxillary expansion in adults flared the molars buccally only 3° per side. The mandibular plane and lower facial height were unchanged. The adults achieved 18% of their transmolar expansion at the height of the palate and the remainder with buccal displacement of the alveolus. The children achieved 56% of their expansion by an increase at the height of the palate with the remainder due to displacement of the alveolus. There was some buccal attachment loss (0.6 ± 0.5 mm) seen in the female subjects associated with RME, but the extent was clinically acceptable. This resulted in significantly longer clinical crowns, but rarely caused exposure of buccal root cementum. Complications were infrequently observed or of minimal consequence. The results indicate that nonsurgical RME in adults is a clinically successful and safe method for correcting transverse maxillary arch deficiency. (*Angle Orthod* 2000;70:129–144.)

Key Words: Maxillary expansion; Surgically assisted maxillary expansion; Haas expander; Posterior crossbite; Transverse dimension; Adult treatment; Mandibular rotation; Gingival recession

INTRODUCTION

Transverse malocclusions due to maxillary width deficiency have been uniquely responsive to rapid correction in children and adolescents since Haas[1–3] popularized the fixed palatal expander in the 1960s. In contrast, the use of expanders to widen the maxillary arch in mature patients is often reported as not feasible in standard texts and review papers.[4–7]

This pessimistic view of rapid maxillary expansion (RME) in adults is based in part on anatomic studies of the maturing face which show the midpalatal suture and adjacent articulations to be more rigid and beginning to fuse by the late teens.[8–11] In order to overcome the fusion and resistance of the adult sutures to expansion, surgically assisted rapid maxillary expansion (SA-RME) has been advocated. Surgery ranging from a subtotal Le Fort I[12,13] to more limited lateral and midline maxillary osteotomies,[14–19] combined with fixed palatal expanders, has been successful in allowing the midpalatal suture to separate and the maxilla to be widened.

Surgery, however, is costly and requires either outpatient surgery or hospitalization with attendant morbidity and time loss from work. Patients and their orthodontists may feel that the malocclusion is not sufficiently disfiguring or functionally compromising to justify the risks and costs of

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Annexe 61

Original Article - Retrospective Study

Surgically Assisted Rapid Palatal Expansion to Correct Maxillary Transverse Deficiency

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Abstract

Background: Transverse maxillomandibular discrepancies are widespread. Treatment is comprised of orthodontic expansion in patients younger than 15 years or by surgically assisted rapid palatal expansion (SARPE) in skeletally mature patients where the possibility of successful orthodontic maxillary expansion decreases as sutures close and resistance to mechanical forces increases. Aim: To present our experience of treating transverse maxillary deficiency using a unique L-shaped osteotomy and to demonstrate stable results. **Patients and Methods:** 32 patients aged between 19 and 54 years exhibiting transverse maxillary deficiency. L-shaped osteotomy was performed laterally from the pterygoid plate posteriorly to above the roots of the second incisive anteriorly continuing with a vertical osteotomy between the lateral incisive and canine teeth toward the horizontal osteotomy. In 18 patients with dysgnathia, bimaxillary surgery was performed one year following the SARPE procedure. **Results:** Mean transverse maxillary expansion of 6.2mm at the canine incisal and 6.4mm at the first molar occlusal regions were obtained. One year postoperatively results were relatively stable, 5.8mm and 6.2mm respectively. The SARPE procedure resulted in overcoming the maxillary buttress resistance, expansion of the anterior dental arch and bilateral distraction creating bone on both sides of the premaxilla contributing to better alignment of the anterior teeth and superior stability. **Conclusions:** We conclude that SARPE is an effective and stable method for addressing severe maxillary transverse discrepancy in adults while the unique osteotomy performed allowed for maintaining proper position of the premaxilla and maxillary midline and allowing for division of the newly created bone bilaterally thus resulting in a more stable outcome.

Keywords: Maxillary distraction osteogenesis, maxillary transverse deficiency, surgically assisted rapid palatal expansion

Introduction

Maxillary deficiency and accompanying crossbite is a common malocclusion encountered clinically with a prevalence of 4%–23%.[1] Maxillary transverse deficiency (MTD) can be treated either orthodontically using rapid maxillary expansion (RME) or surgically using surgically assisted rapid palatal expansion (SARPE). In children and adolescents, conventional orthodontic RME has been successful when used prior to sutural closure.[2-6] In skeletally mature patients, the possibility of successful maxillary expansion decreases as sutures close and resistance to mechanical forces increases.[2,4,6] SARPE is an effective method of addressing the severe maxillary transverse discrepancy in patients over the age of 15 years. In young adults and adults in their 20s and 30s, palatal expansion may result in the tipping of the molars with little expansion of the maxillary arch. It has also been suggested that the intermaxillary suture anterior to the incisive canal never ossifies until very late in life, resulting in some relapse.[7-9] A number of modifications for the traditional SARPE surgical technique have been described. The traditional method describes a midpalatal osteotomy between the two central incisors, followed by maxillary expansion using a tooth- or bone-borne device.[5]

Various combinations of maxillary, pterygopalatine lateral nasal, septal, and palatine osteotomies have been used based

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Surgically assisted rapid palatal expansion *vs.* segmental Le Fort I osteotomy: Transverse stability over a 2-year period

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SUMMARY. Introduction: **We compared the long-term stability of surgically assisted rapid palatal expansion (SARPE) and segmental Le Fort I osteotomy (bipartition) for expanding the maxillae in adult patients.** Methods: **The upper jaw plaster models of 10 patients who underwent transverse expansion of the maxillae using the SARPE technique and 10 patients who underwent Le Fort I bipartition were examined. For each patient, the intercanine and intermolar distances before expansion (T1), after expansion (T2), and 2 years after expansion (T3) were measured. Consequently, we could evaluate the degree of expansion (between T1 and T2) and the relapse distance after 2 years (between T2 and T3). The palatal stability (*i.e.*, extent of relapse) was used to assess the outcomes in both methods.** Results: **In the SARPE group, the average increase in the intercanine and intermolar distance was +8.5 and +7 mm, respectively. In the Le Fort I bipartition group, the average respective increase was +2.75 and +3.75 mm. Two years after expansion, in the SARPE group, the intercanine distance decreased by 2.5 mm or 28% of the overall expansion, and the intermolar distance decreased by 3.0 mm or 36% of the overall expansion. In the Le Fort I bipartition group, the intercanine distance decreased by 0.25 mm or 25% of the overall expansion, and the intermolar distance decreased by 0.75 mm or 20% of the overall expansion.** Conclusions: **In the patients that we assessed, there was a high relapse rate in the mean intercanine and intermolar distances 2 years following the expansion. The overall relapse rate was more pronounced in the SARPE patients, whereas the Le Fort I bipartition technique was more stable, especially in terms of the intermolar distance. © 2008 European Association for Cranio-Maxillofacial Surgery**

Keywords: **orthognathic surgery, maxillary expansion, surgically assisted rapid palatal expansion, segmental Le Fort I osteotomy**

INTRODUCTION

Surgically assisted rapid palatal expansion (SARPE) and segmental Le Fort I osteotomy (bipartition) are both commonly used to increase the transverse diameter of the maxilla in adult patients with skeletal deficits. Normally, the SARPE technique is used in cases with a severe deficit or when the transverse defect of the maxillary bone is an isolated skeletal anomaly. Conversely, the Le Fort I bipartition technique is recommended for more modest defects (up to 6–7 mm) or when the transverse deficit is one of a number of maxillary skeletal deficits, including sagittal and vertical defects that would require surgical attention anyway.

Two interesting points emerge from the literature. First, the long-term stability of both techniques varies, and the relapse rate varies by author. Second, few studies have compared the two techniques directly in terms of their long-term stability. *Bailey* et al. (1980) reported data on the long-term stability of each technique described separately in the literature. Many studies discuss the stability of the outcome of the SARPE technique, whereas fewer studies discuss the same issue for Le Fort I bipartition. For the SARPE technique, *Byloff* and *Mossaz* (2004) reported relapse rates of 20% (1.05 mm) intercanine distance and 33% (2.9 mm) intermolar distance. *Anttila* et al. (2004) reported relapse rates of 10% (0.4 mm) intercanine distance and 18% (1.3 mm) intermolar distance. *Schimming* et al. (2000) reported no relapse rate (0%), whereas *Berger* et al. (1998) reported relapse rates of 23% (1.12 mm) intercanine distance and 17% (1.01 mm) intermolar distance. *Northway* and *John* (1997) reported relapse rates of 4% (0.2 mm) intercanine distance and 3% (0.2 mm) intermolar distance. *Stromberg* and *Holm* (1995) also documented a 4% (0.2 mm) intercanine relapse rate, whereas the intermolar relapse rate was 14% (1.2 mm). *Sesenna* and *Raffaini* (1993) documented relapse rates of 15% (0.9 mm) intercanine and 7% (0.5 mm) intermolar. *Bays* and *Greco* (1997) described relapse rates of 8% (0.39 mm) intercanine and 7% (0.45 mm) intermolar, and *Pogrel* et al. (1992) reported a relapse rate of 12% (0.9 mm) intermolar.

For segmental Le Fort I osteotomy, *Proffit* et al. (1996) reported 5% (0.1 mm) intercanine distance and 50% (2 mm) intermolar distance relapse rates. *Clivio* et al. (1996) also described a 50% intermolar relapse rate. *Phillips* et al. (1992) reported 8% (0.1 mm) intercanine and 48% (2.6 mm) intermolar relapse rates.

In the light of these reported data, we thought that it would be informative to compare directly the long-term

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Progress in Orthodontics

RESEARCH **Open Access**

An assessment of the magnitude, parallelism, and asymmetry of micro-implant-assisted rapid maxillary expansion in non-growing patients

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Abstract

Background and objectives: Micro-implant-assisted expanders have shown significant effects on the mid-face, including a degree of asymmetry. The aim of this study is to quantify the magnitude, parallelism, and asymmetry of this type of expansion in non-growing patients.

Methods: A retrospective study on a sample of 31 non-growing patients with an average age of 20.4 years old, with cone beam computed tomography images taken before and right after expansion using maxillary skeletal expander (MSE) were assessed for skeletal expansion at three landmarks bilaterally.

Results: Average magnitude of total expansion was 4.98 mm at the anterior nasal spine (ANS) and 4.77 mm at the posterior nasal spine (PNS) which showed statistical significance using a paired *t* test with $p < 0.01$. Average expansion at the PNS was 95% of that at the ANS. The sample was divided into symmetric ($n = 15$) and asymmetric ($n = 16$) based on the difference in expansion at the ANS, with 16 out of 31 patients exhibiting statistically significant asymmetry.

Conclusions: MSE achieves distinctly parallel expansion in the sagittal plane but can exhibit asymmetrical expansion in the transverse plane.

Highlights

- MSE-type expander can expand non-growing patients with an average of 5 mm at ANS
- Mean expansion at PNS was 4.7 mm, giving 96% parallelism in the sagittal direction
- 50% of the sample size exhibited asymmetric expansion in the transverse plane
- Within the asymmetric samples, the split was on average 2.22 mm more on one side
- Possible correlation between the direction of asymmetry and unilateral crossbites

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Introduction

Transverse maxillary deficiency (TMD) is a common malocclusion that is diagnosed when the maxilla is narrow in relation to the mandible [1]. Patients with TMD often present with unilateral or bilateral posterior crossbite, anterior crowding, and large buccal corridors upon smiling [2]. Adequate transverse maxillary dimension is essential for stable, well-balanced, and proper functional occlusion. Traditionally, rapid palatal expander (RPE) is often considered the appliance of choice to treat patients diagnosed with TMD to increase transverse maxillary dimension. It is usually performed in childhood or adolescence before the midpalatal suture has matured [3, 4]. With age, the

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Original Article

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Skeletal and dentoalveolar changes after miniscrew-assisted rapid palatal expansion in young adults: A cone-beam computed tomography study

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Objective: The aim of this study was to evaluate the skeletal and dentoalveolar changes after miniscrew-assisted rapid palatal expansion (MARPE) in young adults by cone-beam computed tomography (CBCT). **Methods:** This retrospective study included 14 patients (mean age, 20.1 years; range, 16–26 years) with maxillary transverse deficiency treated with MARPE. Skeletal and dentoalveolar changes were evaluated using CBCT images acquired before and after expansion. Statistical analyses were performed using paired t-test or Wilcoxon signed-rank test according to normality of the data. **Results:** The midpalatal suture was separated, and the maxilla exhibited statistically significant lateral movement ($p < 0.05$) after MARPE. Some of the landmarks had shifted forwards or upwards by a clinically irrelevant distance of less than 1 mm. The amount of expansion decreased in the superior direction, with values of 5.5, 3.2, 2.0, and 0.8 mm at the crown, cementoenamel junction, maxillary basal bone, and zygomatic arch levels, respectively ($p < 0.05$). The buccal bone thickness and height of the alveolar crest had decreased by 0.6–1.1 mm and 1.7–2.2 mm, respectively, with the premolars and molars exhibiting buccal tipping of 1.1°–2.9°. **Conclusions:** Our results indicate that MARPE is an effective method for the correction of maxillary transverse deficiency without surgery in young adults.
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Key words: Cone-beam computed tomography, Miniscrew-assisted rapid palatal expansion, Adults, Expansion

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