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A Palatal Expansion: A Literature Review

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Abstract:
Transverse deficiency is most common skeletal change on maxilla which may lead to serious health issues. This article aims to overview the palatal expansion modifications and describes the efforts to encourage the growth of the maxilla in transversal direction with different methods. Discussed are factors to be considered prior to expansion, as well as effects on maxillary complex, maxillary teeth, palatal vaults, nasal volume, pharyngeal airways and extraoral features. SARPE and MARPE as treatment modalities are well established, promoted important occlusal benefits, showed good success rate and has been considered as an alternative for adult patients.

Key Words: *crossbite, rapid palatal expansion, SARPE, MARPE*

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I. Introduction

The craniofacial complex shows continuous and dynamic changes during the growth, from birth to the age of 20 years. The face grows mostly in the sagittal, less in the vertical and least in the transversal direction. Posterior crossbite is orthodontic irregularity in the transverse direction, with occlusal disorder in the bucooral direction and the mandibular lateral teeth overlap the maxillary from the vestibular and can be unilateral, bilateral, single-tooth or entire segment crossbite. The etiological factors that contribute to underdeveloped maxilla may be inheritance, obstructive sleep apnea, cleft lip and palate, inadequate dental arch length, early loss of primary teeth, impaired orofacial habits like thumb sucking or some exogenous factors[1]. If a high and narrow palate forms during the period of primary dentition, and is not corrected in a timely and appropriate manner, the incorrect palate configuration remains permanent, which further generates insufficient space for proper placement of all maxillary teeth, arch asymmetry and cross-bite formation in the lateral region[2]. Maxillary atresia can result in occlusal, speeching, swallowing, periodontal and gingival problems, as well as TMJ and muscle function disorders, with functional deviation of the mandible that can progress to asymmetric mandibular growth[3].

Prevalence varies significantly between ethnic groups. In the world population, an incidence of 7-23% has been reported more common in Caucasians, compared to other races. Latest study have shown that the prevalence of crossbite ranges up to 38.4%[4]. In terms of gender distribution, there are no significant differences.

II. Orthopedic maxillary expansion

Since malocclusion does not show spontaneous correction, palatal expansion therapy is intended for the expansion of the maxilla and correction of the discrepancy between the maxillary and mandibular apical bases. The devices are designed to transmit biomechanical transversal forces with activation. The size of the applied force depends on the design of the appliance used for palatal expansion[5].

Orthopedic maxillary expansion was first described in a case report by Angell, over 160 years ago in “Dental Cosmos”, and accompanying comment for expansion possibility was “exceedingly doubtful”. Procedure was reintroduced in the middle of XX century by Haas. In past few decades, it has become a routine procedure in treating maxillary transverse deficiency[6].

Types of expansion are: slow palatal expansion (SPE) with Coffin apparatus, magnets, W-arc, NiTi expander, Quad helix, asymmetric maxillary expander (AMEX) which produce a one-third skeletal changes and two-thirds dental changes and are more effective compared to removable orthodontic devices as well as more comfortable; rapid palatal expansion (RPE) with Hyrax expander, Isaacson expander, Haas device, Derischweiler device, bonded expander; surgically assisted rapid palatal expansion (SARPE) and assisted with implants (MARPE).

When choosing the expansion method, the age of the patient, skeletal and muscular form, degree of maxillary constriction, periodontal type and parafunctions should be taken into account. Skeletal expansion is most easily performed when the palatal suture is not fused or present only minimal initial bridging.

The biological response of the midpalatal suture, skeletal and dental tissues to maxillary expansion has traditionally been reported to correlate with chronological age of the patient. As a result, the age of the patient is usually accepted as a decisive factor in the planning of maxillary expansion. With advancing age, the palatal suture becomes more firmly interdigital merged. During the early permanent dentition, sutural expansion often requires placement of a device that produces relatively strong forces along the suture, which microfractured the interdigital bony spicules so the halves of the maxilla can be separated. To achieve this, it is necessary to install a fixed device with a Hyrax screw[7].

Regarding the timing of closure of the circummaxillary suture, there are many dilemmas but one it is clear that growth stops earliest in the transversal dimension and according to some authors approximatelly 2 years before full growth is complete. According to Melsen[8] the transversal growth of the palatal suture continues until the age of 16 in females, 18 in males. Björk[9] observed that sutural growth stops at the age of 17 years, average 2 years before the cessation of condylar growth and growth in height. Perssoni and Thilander[10] suggest that the palatal suture shows signs of closure in the juvenile period, but to a limited degree they found a still unclosed suture very rarely even in the third decade of life. They suggest that there is variation between different individuals regarding the onset of closure as well as progress in suture closure over the years. Their study confirmed the previous theory that the suture begins to close earlier in the posterior parts a later in the anterior parts.

A reliable method of assessing skeletal maturity is radiography of the hand wrist, the method of cervical vertebral maturity and increase in stature. New approach in determining the maturity of the palatal suture was presented by Angelieri et al, based on evaluating the stages of midpalatal suture maturity on CBCT images. Five stages are described, stage A – straight sutural line with high density, B – high-density sutural line appearance, C – two parallel, highly-swept dense lines that lie next to each other, separated in some areas by small rooms with low density, D – fusion of the palatine bone, without evidence of a suture present and stage E – a complete fusion that also extends forward to the maxilla. In stage C it is expected less skeletal response than in stage A and B, because there are numerous bony bridges along the suture. For stage D and E patients, surgically assisted rapid maxillary is indicated.

Grünheid et al tested a new method called "midpalatal suture density ratio" (MSDR)[11]. The calculation uses gray levels, (substitutes for bone density levels) on CBCT images of defined regions of the palatum. MSDR values, chronological age and stage of maturation of the palatal suture are correlated with actual skeletal measurements and the results showed that only MSDR was significantly correlated to provide clinical value.

III. Indications, advantages and disadvantages for palatal expansion

Rapid palatal expansion (RPE) is indicated in cases where the transverse discrepancy is equal to or greater than 4 mm, where the maxillary molars are not buccally inclined to compensate the skeletal transverse discrepancy. Other clinical applications for RME are: space provision to relief of mild crowding[12]; interceptive treatment of palatally impacted canines[13,14], to facilitate maxillary protraction in the treatment of Class III malocclusion with disruption of the suture system that connects the maxilla to the cranial base, in growing patients; improvement of nasal airflow in patients suffering from nasal obstruction.

There are numerous advantages of forced palatal expansion. It works by separation of palatal bones across the median palatal suture due to a lateral force from the appliance[15]. Both sphenoid and zygomatic bones of the cranial base are met with resistence during expansion. Maxillary bones separation occurs in a triangular manner, with the apex toward the nasal cavity and the base at the same level as the palatine process[16] resulting in more opening anteriorly than posteriorly[17].

One of the indications for treatment with maxillary expansion is the problem with breathing. The problem is whether the expansion provides better breathing especially in people who have sleep apnea. There is evidence that nasal resistance usually decreases after expansion. In patients with sleep-disordered breathing but without adenotonsillar hypertrophy, rapid palatal expansion reduces Apnea-hypopnea index (AHI) which is maintained for the next 36 months. According to another study, in growing children RPE improves the conditions for nasal breathing and the results can be kept stable for at least 11 months after the therapy[18]. Anteroposterior cephalometric studies show evidence of an enlarged nasal cavity and decreased resistance to airflow[19].

It was belived that RPE primarily affect airway function through changes to nasal volume. Increased nasal width up to 4,5 mm for 4 weeks is reported by Hass[16] in his patient cohort. It was postulated that the alterations in nasal dimensions following RPE are related to the lateral movements of nasal walls[20], increase in the vertical dimension of nasal cavity secondary to downward rotation rotation of the palate[15].

Acoustic rhinometry measurements are used to assess the geometric changes of the nasal cavity in children undergoing this treatment protocol and the effect of this procedure on the size of the nasal airways. A satisfactory increase was observed in all patients and statistically significant increase corresponding to the decongestion on total nasal volumes and the width of the nasal cavity. 60% of childen switched from an oral to a nasal breathing pattern[21].

Baccetti and coworkers confirmed that the group treated before the pubertal peak showed significantly greater short-term increases in the width of the nasal cavities. In the long-term, maxillary skeletal and intermolar width, lateronasal and lateroorbitale width, were significantly greater in the early-treated group[22].

The effects of nonsurgical rapid maxillary expansion on deviated nasal septum are different in growing children and adolescents. In a study on 100 growing patients (ages 5-9 years), there is a significant straightening of the nasal septum in the middle and lower thirds of the nasal cavity after therapy with RPE[23]. In adolescents, no changes were observed in terms of improving the deviation of the nasal septum[24].

The secondary effects of this therapeutic protocol on tongue position and pharyngeal airways were assessed in the study using CBCT before and after palatal expansion. Autors concluded that in children with nasal obstruction, RPE does not only reduce nasal obstruction but improves the tonque position and increases the pharyngeal airways[25]. But it is worth mentioning that these changes refer only to the upper pharyngeal airways[26].

Phoenix et al[27] examine changes in hyoid bone position after upper jaw expansion, and concluded that RME produced higher hyoid bone position, and tongue length was unaffected.

Disregarding the genetic factors, environmental and somatic conditions, it is scientifically documented the connection between nocturnal polyuria and high threshold of night-time awakenings as well as upper jaw dimensions[28,29]. The advantageous impact of RPE on the results of treating respiratory disorders while sleeping was proven[30,31], and have beneficial impact also on reduction of NE[32,33].

RPE appears to have a positive effect also on middle ear disorders in both patients with cleft lip and palate[34] and non-cleft patients where significantly influences on voice quality[35]. Improvement of hearing in patients who suffer from conductive hearing loss as a result of Eustachian tube stenosis or middle ear problems, occur due to the functional normalization of the pharyngeal ostia of the Eustachian tube, secondary to the orthopaedic effects of the RPE treatment, which subsequently decreases the incidence of recurrent serous otitis media.

RPE is contraindicated in patients who have passed the growth peak, have recession on the buccal sides of the premolars and molars, anterior open bite, steep mandibular plane, faces with a convex profile and finally the persons who do not cooperate.

Disadvantages of using the RPE include discomfort due to the use of strong forces, traumatic separation of the palatal suture, the impossibility of correcting rotated molars, bite opening, dentoalveolar tipping, relapse, microtraumas of the TMJ, root resorption, tissue disruption, pain, the need for patient cooperation or parental activation of the device and labor-intensive procedure in the manufacture of the device. Devices may lead to harmful consequences on the teeth and surrounding tissues, especially in cases where the suture is ossified. Decrease in the thickness of the vestibular bone of the anchor teeth; alveolar bone height reduction; marginal bone loss, bone fenestration and buccal gingival recession of anchor teeth[36], especially on first premolars may also occur[37]. This is not only due to the ossification of the midpalatal suture but also due to the resistance form the circummaxillary bones and sutures, which provide the main resistance to expansion[38].

Primarily the theory was that with the application of rapid force, there would not be enough time for dental movement, the force would be transmitted to the suture and it would open and the teeth would moved only minimally. In other words, the rapid expansion was conceived as a way to maximize skeletal changes and minimize of dental changes. Opening the midpalatal suture has been shown to cause lower and posterior rotation of the mandible and increased lower facial height as a direct effect of the vertical displacement of the maxilla.

The limit of skeletal effect was around 4 mm since the transverse expansion of the maxilla would be inevitably compensated by dental tipping[39].

RPE with conventional appliances promotes the anterior and inferior displacement of the maxilla with a consequent posterior-inferior rotation of the mandible.

RPE devices promotes anterior and inferior displacement of the maxilla with consequent postero-inferior mandible rotation[40,41]. Several authors pointed out that this downward movement of the maxilla and premature dental contacts are responsible for the mandible backward rotation[42-44].

Many authors observe a significant change in cephalic position and craniocervical angulation after treatment to improve nasal ventilation. Rapid maxillary expansion therefore tends to normalize the posture in growing patients.

The magnitude of the forces required to separate the mid-palatal suture is approximately 900−4500 gr, which is very different from that required to move the teeth, about 10−150 gr. The theoretical principle behind substantial force application is to disarticulate the circummaxillary suture with resultant orthopaedic expansion before teeth respond[5,45].

Most of the children treated with RME report pain that generally occurs during the initial phase and disappears soon after. The highest level of pain was reported during the first 10 device activations, peaking on days 3 and 4. Twice-daily activation treatment protocols lead to higher pain levels than single-turn protocols.

The initial clinical changes noted with palatal expansion therapy are lateral tipping of the maxillary lateral teeth as the periodontal soft tissues are compressed and stretched in response to applied forces. This phase of orthodontic response ends in one week. Further orthodontic movements occur such as remodeling of the buccal alveolar plate due to continuous forces. Orthopedic separation and reposition of the maxillary segments occurs when applied transverse biomechanical forces exceed the bioelastic strength of the sutural elements. To maintain orthopedic separation of the maxilla, Storey noted that first, the applied force must be strong enough to overcome the tensile strength or induce changes in the sutural connective tissue so that they do not provide resistance to bone movement and secondly, forces must be present that exceed the strength of the extramaxillary musculature and the interdigital occlusal forces. When the activation of the device ends, the maxillary bones continue to move laterally until a new dynamic is achieved equilibrium when the applied force is reduced below the tensile strength of the bond suture tissue. Remodeling and reorganization of sutural and skeletal tissues continues in the retention period until the expanded maxillary bones are stabilized[46-48].

With expansion rate of 0.5 mm per day (two-quarter turn of the screw), 10 mm or more of expansion is achieved in 2-3 weeks, with 4-9 pounds of pressure along the suture. After expansion, space is created between the central incisors, because the suture opens wider and faster anteriorly while closure of the suture after expansion first begins in the posterior regions of the suture. The space created at the palatal suture is filled first with tissue fluids and hemorrage, at this point the expansion is very unstable. The expansive device must be stabilized to suture not closed again and the screw is left to stand for another 3- 4 months. Until then, new bone forms in the space created by expansion[5]. The medial diastema shrinks and disappears during this period. The diastema closes due to skeletal relapse and tooth movement due to stretched gingival fibers, not just pure tooth movement.

The main effect is skeletal, by separating the two maxillae in the medial palatal suture in the form of the letter V with a postero-superior tip and the anterior displacement of the maxilla with downward rotation. However, the literature suggests that most of the changes are still dentoalveolar[49]. The changes also affect other structures surrounding the maxilla. There is an increase in the interzygomatic, infraorbital and distance between the eyes. Morphological changes are also visible, such as an increase in the volume of the maxilla, reducing the adenoid appearance in children. The lingual bone rises, the intermolar, intercanine and interincisal distance increases in the maxilla, and changes are now occurring even in the mandible[50].

The relative amount of skeletal versus dental changes that can be expected with palatal expansion therapy, are related to the following variables: the patient's age, rate of expansion and magnitude of the applied transverse force, design of the orthodontic appliance and retention protocol.

A meta-analysis was performed in order to test the hypothesis that no change occurs in the soft tissues of the face after non-surgical rapid palatal expansion. In 13 articles that met the conditions for participation, it was concluded that there were changes in nasal width, lip width, upper philtrum width and distance between the lower lip and the E line after the retention phase. However, the clinical values of these results are questionable because the results are based on short-term observation of patients in the growth phase[51].

CBCT examination confirm increase in the interalar distance, as well as a significant increase in interzygomatic cutaneous distance, interorbital and infraorbital cutaneous distance, distance between eyes, and the average floor width of the face[52].

The statistically significant changes were reported also in the vertical plane. The lowering of the bispinal plane increases the upper and total anterior facial heights and creates a molar rotational hub, resulting in a mandibular post-rotation and the growth of the anterior facial height. Baratieri et al[53] showed a forward movement of the jaw, with an increase of SNB and a reduction of ANB that led to a spontaneous improvement of dental II classes in 75% of the sample in retention period. But this is not in accordance with Habeeb[54] and Sfondrini[55].

Age at the time of RPE is an important factor in the effect of maxillary opening, so each age has its own response pattern[56]. Expansion treatment before the peak in skeletal growth velocity is able to induce more pronounced transverse craniofacial changes at the skeletal level.

IV. Surgical- and mini implant-assisted rapid palatinal expansion

RPE can produce unwanted effects when it is used on skeletally mature patients, including inability to open midpalatal suture, microfractures, palatal tissue necrosis, pain, alveolar bone bending, lateral tipping of posterior teeth, buccal cortex fenestration, PDL compression, buccal root resorption and teeth extrusion. Main reasons for these are changes with increasing age in the osseous articulations of the maxilla with the adjacent bones[6].

Palatal expansion used in adolescents is not feasible in adults, because of the increased resistance of the interdigitated palatal suture and lateral maxillary sutures, although according to recent studies there are exceptions, when a skeletally supported expander is used. Surgically assisted rapid palatal expansion (SARPE) which uses bone incisions to reduce resistance, followed by screw expansion to separate the maxillary halves is another possible treatment approach for adult patients with narrow maxilla.

The concept was introduced by Brown in 1938, and since then SARPE procedure has gradually become the main treatment modality for skeletally mature patients with maxillary transverse deficiency[57]. In this technique, the expansion procedure is based on distraction osteogenesis of palatal bones after surgical operation[58]. Three types of expansion appliances have been described with SARPE: purely tooth borne (most commonly used), purely bone borne and tooth-bone borne appliances. SARPE is often a first stage surgery to correct transverse maxillary deficiency and sometimes further surgery is required after levelling and aligning in order to correct vertical and/or anteroposterior skeletal discrepancies[59].

The first step in the case selection protocol is determination of transversal deficiency, arch form and symmetry, occlusion, crowding, shape of palatal vault, buccal corridors width on smiling, predominant mode of breathing, soft-tissue thickness, mandibular shift on closure, accompanied sagital discrepancies.

The patient's age has been considered as the fundamental basis for distinguishing for the surgically assisted maxillary expansion. Epker and Wolford[60] recommended in patients over 16 years of age, Timms and Vero[61] gives a 25 years as upper limit, Mozzas[62] et all proposed "after second decade of live". Alpern[63] suggested 25 years for men and 20 for women as criterion.

Various combinations of midmaxillary, pterygopalatine, lateral nasal, septal, and palatine osteotomies have been used based on different theories regarding the locations of resistance to expansion[64,65]. The major resistance of transverse palatal expansion is the zygomaticomaxillary buttresses[66,67].

Surgically assisted expansion is mainly carried out in 2 ways. In the first method, the incision is directed parasagittally along the median suture, and in the second, the lateral wall of the maxillary sinus is cut, vestibular in the area of the transition of the alveolar ridge to the basal bone of the maxilla, on both sides in the area of the premolars. In addition, an incision is made under the spine nasalis anterior, which weakens the maxilla bone and enables it to break along the median suture when the hyrax screw is activated.

According to some authors, a combination of the procedures Le Fort I with PD results in less stress and displacement in the maxilla[68], while others prefer to perform separation of PD due to the risk of injuring the pterygoid plexus[69].

Bortolotti[70] noted that SARPE is effective in obtaining a significant expansion, however, the immediate effect is mainly a molar expansion rather than a pure bone transverse widening of the maxilla.

The results of longitudinal study showed overall significant widening and complete anterior and inferior displacement of the nasal soft tissues. No correlation was found between the initial and final width of the nose or of the nostrils and the most obvious changes were at the lateral alar bases. The difference in the lateral displacement affects the perception of the nose as rounder, so patients with narrow and constricted nostrils may benefit from these changes[71].

However, SARPE is an invasive method, and the morbidity, risks and cost related to surgical treatment might discourage many adult patients. The use of Mini-implant Assisted Rapid Palatal Expansion (MARPE) appliance, which can potentially avoid surgical intervention, is gaining popularity in treatment of maxillary transverse deficiency in young adolescent patients. The role of this appliance is to optimize the potential skeletal expansion and to solve undesirable dentoalveolar effects in patients with advanced stages of skeletal maturation and was proposed by South Korean orthodontists Lee, Park and Hwang, in 2010[72]. The device is classified mainly as: bone-anchored maxillary expansion (BAME), which is a bone-borne type having no tooth attachment and hybrid design or tooth-bone-anchored maxillary expansion, which combines both bone and tooth support[73,74].

Wilmes et al[75] introduced mini-implants with abutments in 2008, which allow mini-implants to be used for skeletal support of expansion. By inserting in the anterior palate, the expansion vector is close to the center of resistance of the maxillary segments meaning more basal expansion of the maxilla and less buccal tipping of the molars and less resorption of buccal alveolar bone[76]. The insertion of the palatal mini-implants is minimally invasive with no flap procedures required. For maxillary expansion the insertion is trans-sagittal with the target area for safe placement being the T-Zone immediately posterior to the third palatal Rugae[77]. Predrilling of 2–3 mm is required in adults, due to dense cortical bone and 2 mm diameter and 9 mm long mini-implants are used. This placement insures the implants are in the area with the best bone quality while away from the roots of the incisors. The system allows easy coupling with a conventional Hyrax expansion screw through the various abutments available making the laboratory process simple[59].

The bone-anchored device consists of 4 temporary self-drilling mini-implants placed 6-8 mm from the gingival margin: 2 between the root of the canine and the first premolar (or first and second premolar) and 2 between the root of the second premolar and the first molar. A bone-anchored device causes greater transverse skeletal expansion (1.5-2.8 times) compared to a tooth-anchored device, the movement of the anchor teeth is prevented, there is a no loss of the vestibular bone ridge and no inclination of the premolars in the vestibular direction. Although the skeletal effect is increased, also the dentoalveolar effect occurs even though the device is not anchored to the teeth, which is explained by the effect of bending the alveolar bone.

The expansion screw transmits its force via the force transmission system (steel arms, suprastructures, and mini-implants) directly to the maxillary bone. The more central the screw, the more the force will be close to the center of resistance of the maxilla and alveolar torsion will be less important[78]. So, a very rigid structure of the force transmission system is necessary.

Some studies recommend activating the device only a few days after the installation of the screws, whereas others recommend waiting 4–6 weeks allowing for a more organized bone matrix around the mini-implants.

Wilmes, Drescher, and Nienkemper[79] recommend the use of mixed-support disjunctors in the case of weakened vestibular periodontium at the premolar level and case with extracted molars. MARPE as compliance-free alternative, create the parallel split pattern of the midpalatal suture[73,80,81] while RPE resulted in a greater degree of opening in the anterior than the posterior palate. Expansion pattern, in coronal perspective, is largest at the inferior level, and gradually decreased superiorly.

Comparing the palatal splitting by surgically- and miniimplant- assisting, MARPE presented a more parallel expansion in both a coronal and axial view, whereas SARPE led to a V-shaped opening. The greater buccal inclination of the alveolar process and supporting teeth was observed in the SARPE group[82]. Similar effectiveness but less complications with MARPE was reported by Jesus et al[83] compared with SARPE in late adolescents and adults.

Lin et al[84] compared between tooth-borne and bone-borne maxillary expanders and concluded that bone-borne expanders can produce bigger orthopedic effects in late adolescents and adult patients.

Miniscrew placement can stimulate the surrounding soft tissues and evoke tissue inflammation, small infections, tissue overgrowth and periimplantitis, especially when placed through the non-keratinized or mobile gingiva[85].

V. Conclusion

It can be concluded that rapid maxillary expansion as a treatment for posterior crossbite in children is well established. The maturity of maxillary sutures determine the approach and success rate of treatment. To improve the management of adult patients or those with weak tooth anchorage, new techniques have recently emerged.

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